Biota and water quality in the Riacho Grande reservoir, Billings Complex (São Paulo, Brazil).

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ABSTRACT: Biota and water quality in the Riacho Grande reservoir, Billings Complex (São Paulo, Brazil). The Billings reservoir catchment area is located in São Paulo Metropolitan Region, Brazil, and, nowadays, has multiple uses, even though eutrophication is one of its most serious problems. The aim of this work was to verify similarities concerning physical and chemical variables from three sampling stations located in the reservoir's central body, and assess water quality through Secchi Disc depth (SD), pH, dissolved oxygen (DO), electric conductivity (EC), nitrate, soluble reactive phosphorus (SRP), chlorophyll a (Chl a), and qualitative analysis of phytoplankton, zooplankton and zoobenthos. We used Carlson's Trophic State Index (TSI) calculated from SD and Chl a data. We observed water column desestratification in all three stations. TSI values, both for Chl a and for SD, have magnitudes corresponding to a hypereutrophic environment. Presence of Chlorophyceae and cyanobacteria (in phytoplankton), Bosmina and a great number of Rotifera (in zooplankton) corroborates the indication of an eutrophic environment. In zoobenthos, the presence of Tubificidae indicates an environment rich in organic matter and poor in DO. Therefore, all parameters analyzed here indicate an eutrophic environment. Concerning the Brazilian Resolution CONAMA n° 357/2005, for Class of use II, the Riacho Grande region is in accordance with what is required for DO and nitrate. Chl a measurements were not in conformity with the legislation. Hence, the Riacho Grande is in need for remedial actions to improve its water quality in order to comply with the regulation.
Key-words: eutrophication, trophic state index, Billings Complex, reservoir, bioindicator organism.

RESUMO: Biota and water quality in the Riacho Grande reservoir, Billings Complex (São Paulo, Brazil). A bacia hidrográfica da represa Billings está localizada na grande São Paulo (São Paulo, Brasil), e atualmente é aproveitada para usos múltiplos, apesar de a eutrofização ser um de seus maiores problemas. O objetivo deste trabalho foi analisar variáveis físicas e químicas de três estações de coleta localizadas no corpo central do reservatório e avaliar a qualidade da água com base no disco de Secchi (DS), pH, oxigênio dissolvido (OD), condutividade elétrica (CE), fósforo solúvel reativo (FSR), nitrato, clorofila a (cla) e da análise qualitativa de fitoplâncton, zooplâncton e zoobentos. Foi calculado o Índice de Estado Trófico de Carlson (IET) para DS e cla. A coluna d'água apresentou-se desestratificada nas três estações. O IET revelou ser o ambiente hipereutrófico tanto para DS como cla. A presença de clorofíceas e cianobactérias (no fitoplâncton), Bosmina e grande número de Rotifera (no zooplâncton) confirmam a indicação de eutrofização do ambiente. No zoobentos, a presença de Tubificidae indica ambiente rico em matéria orgânica e com pouco OD. Portanto, todos os parâmetros analisados indicam eutrofização do ambiente. Quanto ao cumprimento dos padrões estabelecidos pela Resolução CONAMA n° 357/2005, para Classe II, a região do Riacho Grande está em conformidade quanto ao oxigênio e ao nitrato. Cla está em concentrações não conformes com a legislação, o que exige medidas de remediação visando adequar a qualidade da água aos usos previstos.
Palavras-chave: eutrofização; Índice de Estado Trófico; Complexo Billings; reservatório; bioindicadores.

Introduction

Reservoirs have social and economical importance for human societies, as they bring industrial, agricultural and urban development, contributing with electric power and supplying water for human consumption and irrigation (Baxter, 1977; Tundisi, 2003). In Brazil, the constructions of large reservoirs began around 1950. Since then, a large number of such artificial lacustrine ecosystems have been created (Esteves, 1998).

The social and economical improvements that result from damming the river are accompanied by ecological problems: these water bodies also serve as waste and sewage receptors for cities located nearby (Odum, 1988). This causes the phosphorus and nitrogen levels to increase, leading to artificial eutrophication processes (Esteves, 1998; Carpenter, 2005). As a primary consequence of eutrophication, there is a breakdown in homeostasis. In aquatic ecosystems, homeostasis is characterized by the equilibrium among organic matter production, consumption and decomposition. Such ecological imbalance is coupled with metabolic changes in the ecosystem as a whole, and alters the lacustrine community (i.e. modifications in species dominance and abundance) (McLachlan, 1974; Tundisi, 2003).

Since organic load is a key factor for the distribution and abundance of organisms, one can use organisms as indicators of the degree of physical and chemical alteration in the ecosystem. Such parameter yield better information than physical and chemical alone, regarding the ecosystem, because the latter can only provide information about the environment at the moment they are sampled, while the former represent the full amount of changes in the environment, at least during one life cycle. Nonetheless, physical and chemical parameters must not be disregarded. The precise assessment of the ecosystem must rely on as much information as possible, combining data from chemical, physical and biological variables (Stein & Denison, 1967).

Therefore, the present study is a characterization of the Billings Reservoir's central area (Riacho Grande), based on plankton and benthic composition and on the trophic state of the system.

Study area

Billings reservoir was built in 1927 in order to stabilize the water level of Rio das Pedras reservoir and assure a continuous water flow to the Henry Borden hydropower plant (in the city of Cubatão). The catchment area is 582.8 km², and the area of the water surface is 108.1 km². The basin is integrally located in the municipality of Rio Grande and partially within the municipalities of Diadema, Ribeirão Pires, Santo André, São Bernardo do Campo and São Paulo, in the state of São Paulo, Brazil. The so-called Billings Complex is composed of a central body to where a number of branches converge, resulting in a reservoir with dendritical morphology. The residence time of the water in Billings reservoir is about 600 days (Cetesb, 2005), time considered long by Straskraba & Tundisi (2000). At the moment, the reservoir is of multiple uses, including water supply for 4.9 million people (Rio Grande and Guarapiranga systems together), recreation, nautical sports and fishing, in spite of its critical eutrophication situation (Cetesb, 2005; Sabesp, 2005).

Regarding the rainy regime, historical annual mean for the São Paulo Metropolitan Region is 1,506 mm, with two characteristic seasons: the dry (from April to September) and the rainy one (from October to March) (Cetesb, 2005). The annual pluviosity for 2004 was below historical mean, even though, the total capacity of the reservoir increased 6%, being 56% in January and 62% in December (Cetesb, 2005). Köppen climate classification for São Paulo Metropolitan Region is Cwa, which means an altitude tropical climate with rainy season during summer and dry season during winter, mean temperature of the warmest month higher than 22°C (Miranda et al., 2006).

The Riacho Grande region, which composes the study area described here, is located between Anchieta dam and Imigrantes highway (Fig. 1). It comprises a 5 km wide region inside the Pedreira compartment. Adjacent to the Imigrantes highway, it has linkages with the Rio Pequeno and Rio Capivari branches. Its margins are occupied by nautical clubs, hotels and public beaches. According to the state law n° 10.755 (São Paulo, 1977), this water body is for class II use purposes, including water supply for humans (after conventional treatment), aquatic community protection, recreation of primary contact (like swimming, water skiing and diving), vegetable irrigation and aquatic community protection for water bodies inside Indian lands (Brasil, 2005).

Although the Riacho Grande is part of the Billings Complex, and is a strategical fresh water resource for the São Paulo metropolitan region, few scientific papers have been published on this region of Billings Complex, and the majority is technical reports, which have not been well-distributed to the scientific community.

Material and methods

The present study was conducted on May 19th 2004, in three sampling stations located in the central body of the Billings's reservoir. The mean distance from one station to another was 800 m (non-differential GPS, Datum SAD 69, reference meridian 49 º W and metric coordinates UTM) (Fig. 1).

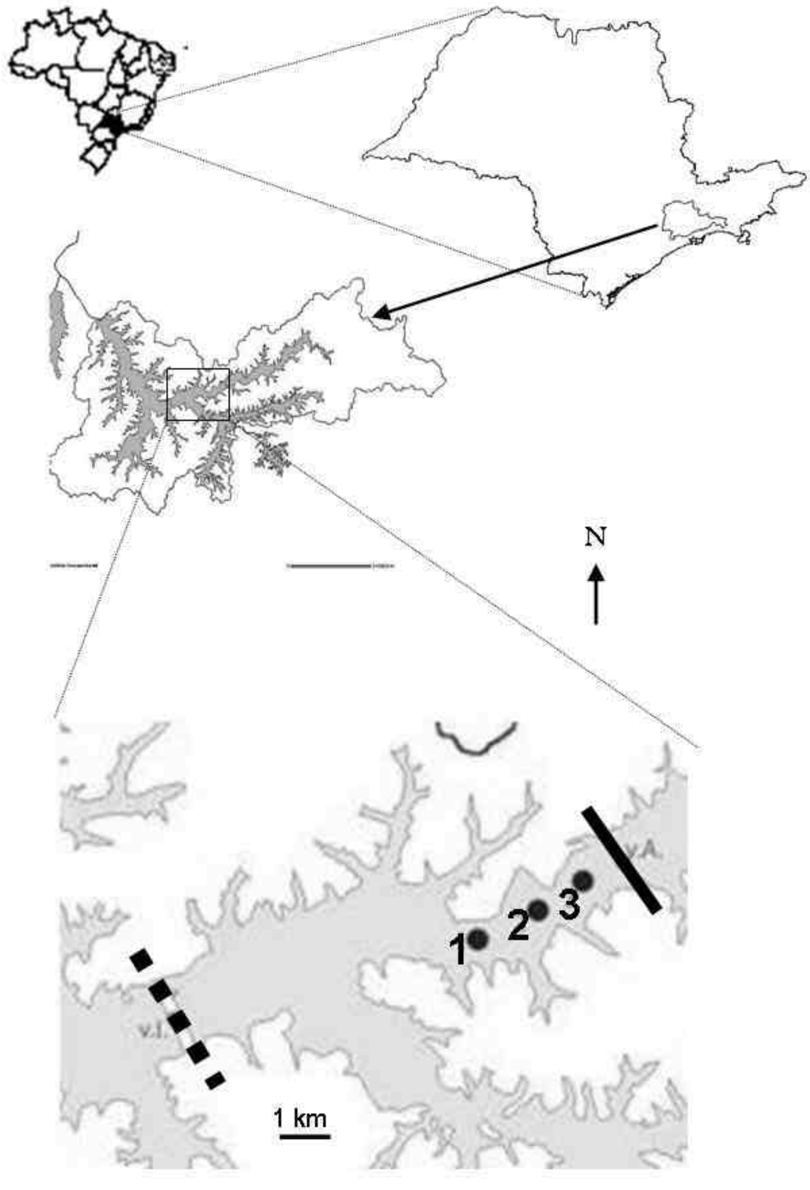

Figure 1: Central body of the Billings Complex, Riacho Grande region, between the Imigrantes (v.I. dotted line) and Anchieta (v.A. continuous line) highways. (● sampling station).

Measures were taken of water transparency (Secchi Disc disappearance depth), temperature (°C), pH and electrical conductivity ($mS.cm^{-1}$) along the vertical profiles (Multiparameter probe YSI 63). We used Van Dorn bottles to collect deep water samples. Water bottles were kept inside thermal bags, protected them from light. At the laboratory, we filtered the water (Whatman GF/C filters) in order to estimate dissolved nutrient, chlorophyll a and phaeophytin concentrations. The variables analyzed and the methodology used are presented in Tab. I.

Table I: Limnological variables, unit, methodology, equipment and references.

Variable	Unit	Methodology	Equipment	Reference
Dissolved oxygen	mg L^{-1}	Winkler method		Golterman et al. (1978)
pH		Multiparameter probe	YSI 63	
Electrical conductivity	mS cm^{-1}	Multiparameter probe	YSI 63	
Temperature	^{o}C	Multiparameter probe	YSI 63	
Secchi Disc	m	Secchi Disc		Wetzel & Likens (1991)
Chlorophyll a and Phaeophytin	mg L^{-1}	Espectrophotometric	Micronal B572	Lorenzen (1967) Wetzel & Likens (1991)
Nitrate	mg L^{-1}	Espectrophotometric	Micronal B572	Mackereth et al. (1978)
Soluble reactive phosphorus	mg L^{-1}	Espectrophotometric	Micronal B572	Strickland & Parsons (1965)
Total solids	mg L^{-1}	Gravimetric		Wetzel & Likens (1991)

We collected phytoplankton with a 25 mm mesh net, and preserved it using 4% formol. In the laboratory, we carried out qualitative analysis under an optical microscope, using a qualitative analysis under an optical microscope in the laboratory using a Sedgwick-Rafter counting cell. For zooplankton, a 44 mm mesh net was used. We preserved the samples with 4% formol, and carried out qualitative analyses under an optical microscope using the keys of Pennak (Smith, 2001).

We collected benthic organisms by means of an Ambühl & Bührer sediment collector (Ambhül & Bührer, 1975), with a 7.2 cm diameter acrylic tube. We considered only the top 10 cm of the sediment column. We transferred the sediment to plastic bags and used concentrated formol for pre-fixation of the organisms. For each sample station, we obtained 3 sample units. In the laboratory, we rinsed the samples with running water in a 250 mm mesh. After washing, the samples were preserved in 4% formol and Rose Bengal until sorting and identification under stereomicroscope, classified to the family taxonomic level, according the keys of Courtney et al. (1996) and Brinkhurst and Marchese (1989).

The Trophic State Index was calculated according to Carlson modified by Toledo et al. (1983).

Results

In relation to the thermal structure, the variation range was from 19.9 to 20.3 ^{o}C. The lowest values registered were at the surface (Fig. 2a).

Secchi Disc depths were 0.98, 0.85 and 0.83 m for stations 1, 2 and 3, respectively. The calculated euphotic zone was 2.94, 2.55 and 2.49 m, for stations 1, 2 and 3, respectively.

Dissolved oxygen (DO) contents were greater at the surface for stations 1 and 2 (6.75 mg L^{-1} in both stations). Mean DO concentrations at stations were 6.58 mg L^{-1} (station 1) and 6.55 mg L^{-1} (station 2). At station 3, there was a greater variation between surface and bottom depths (6.55 mg L^{-1} and 5.02 mg L^{-1}, respectively) and the mean value was 5.73 mg L^{-1} (Fig. 2b).

At station 1, pH varied from 7.75 (surface) to 5.86 (bottom). At stations 2 and 3, pH varied from 7.69 and 7.83 (respectively) at the surface to 7.34 at the bottom at both stations (Fig. 2c). Mean pH values were 6.92, 7.50 and 7.53 at stations 1, 2 and 3, respectively.

The minimum value registered for electrical conductivity (EC) was 164.5 mS,cm^{-1} (station 2 at the surface) and the maximum value 184.2 mS cm^{-1} (station 2 at 1.5 m) (Fig. 2d). Mean values were 181.2, 181.2 and 182.3 for stations 1, 2 and 3, respectively.

Chlorophyll a concentrations varied from 33 mg L^{-1} (station 3 at 9 m) to 39 mg L^{-1} (station 2 at 0 m). Station 3 showed the lowest mean value (mean of 33 mg L^{-1}) and showed the lowest variation along the profile. Station 1 and 2 had similar mean values (35 mg L^{-1}), but they showed different profile pattern: at station 1, the greatest value was at the bottom (36 mg L^{-1}) while at station 2 the greatest value was at the surface (39 mg L^{-1}). Phaeophytin concentration had the inverse profile pattern as chlorophyll a. It ranged from 5 mg L^{-1} (station 1 at 10.5 m) to 11 mg L^{-1} (station 3 at 9 m). The lowest mean value was at station 1 (6.7 mg L^{-1}). Stations 1 and 2 had mean values of approximately 10 mg L^{-1}. Both pigments showed a higher range of variation between surface and bottom at station 2 (Fig. 2).

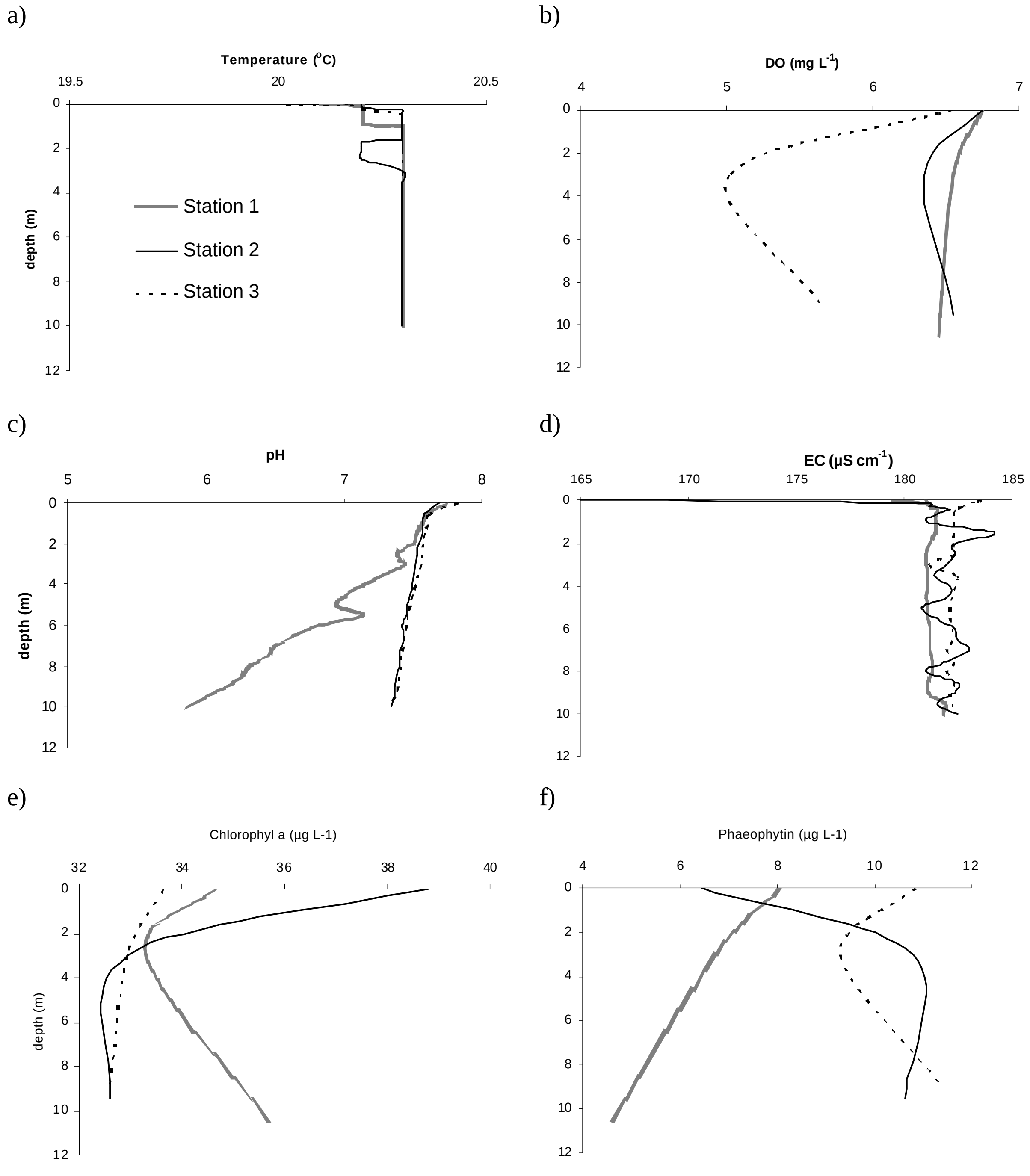

Figure 2: Temperature (a), dissolved oxygen – DO (b), pH (c) and electrical conductivity – EC (d), Chlorophyll a (e) and phaeophytin (f) profiles in the Riacho Grande region.

All Soluble reactive phosphorus measures were below detection limit (10 mg L^{-1}).

Nitrate content ranged from 58 mg L^{-1} (station 3 at 9 m) to 93 mg L^{1} (station 2 at 0 m). Nitrate concentrations showed the same vertical pattern at stations 2 and 3: an increase from surface to medium depths followed by a decrease towards the bottom. Station 1 had the exact opposite pattern from stations 2 and 3. Mean values at each station were 71.8, 86.7 and 66.2 mg L^{-1} for station 1, 2 and 3, respectively (Fig. 3).

Total suspended solids showed little variation. The lowest value was 1.05 mg L^{-1} (station 3 at 9 m) and the greatest was 1.25 mg L^{-1} (station 1 at the surface) (Tab. II). Total suspended solids did not show any trend with respect to the water profile.

Trophic State Index (calculated using chlorophyll a and Secchi Disc) varied from 86 to 93 (Tab. II). These values are characteristic of eutrophic environments.

We identified a total of 52 phytoplankton taxa. These taxa were distributed among 7 Classes: Chlorophyceae (18 taxa), Cyanophyceae (11 taxa), Zygnemaphyceae (8 taxa), Euglenophyceae (7 taxa), Bacillariophyceae (5 taxa), Dinophyceae (2 taxa) and Chrysophyceae (1 taxon) (Tab. III). Only samples from stations 1 and 2 were analyzed with respect to zooplankton (Tab. IV).

The benthic taxa are presented in Tab. V. The organisms were distributed among 4 taxa.

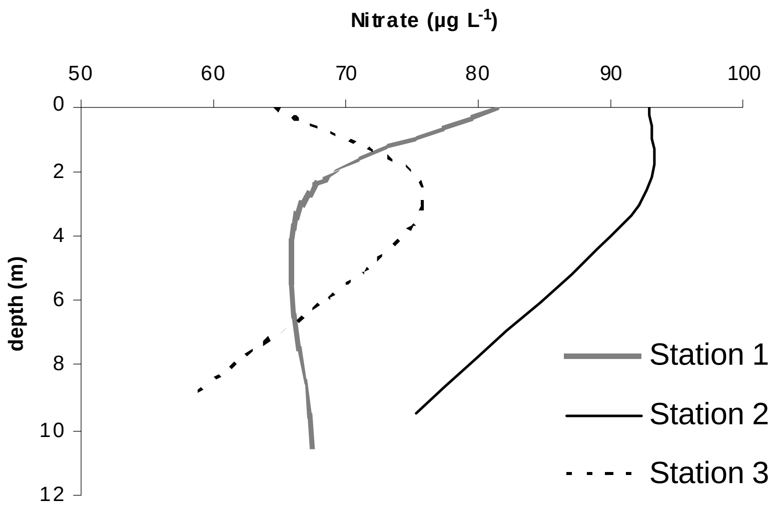

Figure 3: Nitrate profiles in the Riacho Grande region.

Table II: Total solids (mg.L^{-1}) profiles in the Riacho Grande region, Tropic State Index (TSI) for Secchi Disc (SD) and chlorophyll a (Chl a).

Station	Depth (m)	Total Solids (mg L^{-1})	TSI (SD)	TSI (chl a)
1	0.0	1.25	87	92
	3.0	1.08		
	10.5	1.13		
2	0.0	1.13	89	93
	3.0	1.11		
	9.5	1.12		
3	0.0	1.12	89	91
	3.0	1.14		
	9.0	1.05		

Table III: Phytoplankton taxa observed in the Rio Grande region. (X = present).

Class	Station 1	Station 2	Station 3
Cyanophyceae			
Anabaena sp	X	X	
Anabaena spiroides			X
Anabaena circinalis			X
Cylindropermopsis raciborskii	X	X	X
Merismopedia tenuissima		X	X
Merismopedia punctata		X	
Microcystis sp	X	X	X
Planktothrix agardhii	X	X	X
Pseudoanabaena sp	X		
Pseudoanabaena catenata	X	X	X
Pseudoanabaena mucicola		X	
Chlorophyceae			
Actinastrum aciculare		X	X
Ankistrodesmus falcatus			X
Botryococcus braunii		X	X
Coleastrum microporum	X	X	X
Coleastrum reticulatum			X
Coleastrum pulchellum			X
Dictyosphaerium pulchellum		X	
Golenkia radiata			X
Kirchneriella lunaris	X	X	X
Micratinium pusillum		X	X
Monoraphidium contortum			X
Pediastrum duplex	X	X	X
Pediastrum tetras		X	X
Scenedesmus acuminatus			X
Scenedesmus quadricauda		X	X
Scenedesmus denticulatus		X	
Scenedesmus javanensis		X	X
Tetraedrum cruciatum	X	X	X
Zygnemaphyceae			
Closterium gracile	X	X	X
Mougeotia sp	X	X	X
Scenedesmus quadricauda	X		
Scenedesmus javanensis	X		X
Scenedesmus obtusus			X
Staurastrum sp	X	X	X
Staurastrum leptocladum	X	X	X
Staurodesmus sp	X	X	
Euglenophyceae			
Euglena variabilis		X	X
Phacus longicauda	X	X	X
Phacus tortus	X	X	X
Trachelomonas sp	X		X
Trachelomonas armata	X	X	X
Trachelomonas hispida	X		
Trachelomonas volvocina	X	X	X
Bacillariophyceae			
Aulacoseira granulata	X	X	X
Aulacoseira distans	X	X	X
Cyclotella meneghiniana	X	X	X
Pinnularia sp		X	
Synedra sp	X	X	X
Dinophyceae			
Peridinium sp	X	X	
Peridinium umbonatum	X	X	X
Chrysophyceae			
Mallomonas sp		X	

Table IV: Zooplankton taxa observed in the Riacho Grande region. (X = present).

Zooplankton	Station 1	Station 2
Phylum **Protozoa** Thecamoeba	X	X
Phylum **Rotifera** Asplanchna		X
Brachionus		X
Kellicotia	X	X
Trichocerca	X	X
Lecane		X
Polyarthra	X	X
Keratella	X	X
Phylum **Arthropoda** Subphylum Crustacea Bosmina	X	
Genus not identified		X
Order Cyclopoida (nauplius + copepodite + adult)	X	X

Table V: Benthic organisms observed in the Riacho Grande region. (X = present).

Benthic macrofauna	Station 1	Station 2	Station 3
Phylum **Annelida**			
Class Oligochaeta			
Family Tubificidae	X	X	X
Phylum **Arthropoda**			
Class Insecta			
Order Diptera			
Family Chaoboridae	X	X	X
Family Chironomidae		X	X
Subphylum Crustacea			
Class Copepoda			
Order Cyclopoida			
Family Cyclopidae	X	X	X

Discussion

Small variations in surface temperatures during the morning may lead to micro-stratifications of the water column due to heating caused by solar radiation (Deberdt, 1999). In this study, a thermal homogeneity was recorded along the water column.

A great heat loss at the surface was observed by Moschini-Carlos et al. (1998) in a marginal lagoon of the Paranapanema River, near the mouth of the Jurumirim reservoir. Esteves (1998) and Henry et al. (1995) found the same pattern during the night and at noon in tropical lakes and in the Jurumirim reservoir, respectively. According to Simonato (1986, apud Deberdt, 1999), in a study carried out in the Lobo reservoir, strong winds and consequent wave formation caused turbulence and mixture of the water column within a 24 hour period. In the present study, the lowest temperatures were recorded at the surface, which may be associated with air temperature and local wind intensity. In fact, air temperature at the beginning of the sampling procedure was 18.8 °C. This explains the heat loss by the water mass, since surface water temperature was 20.1 °C. At the time of sampling at station 3 (the last to be sampled), surface water temperature was 19.9 °C, lower than at station 1. This fact supports the hypothesis that water mass was losing heat at that time.

Climatic and hydrological factors are external components that interfere in physical, chemical and biological processes occurring within a reservoir. This is particularly important for tropical regions, and is true for the Billings Complex (Maier et al., 1997). In a broad study at the Billings Complex, the thermal homogeneity of the water column could be observed at different stations in the reservoir (Pompêo, 2006), in particular during November and December. According to Cetesb (2005), stratification of the water column occurs specially during summer. Water mass may circulate within a 24 h period, due to wind action (Maier et al., 1997). Therefore, the reservoir should be classified as polymictic with respect to the water mass circulation.

Among the chemical variables, DO is the one that best reflects alterations occurring during a day cycle, in particular, in tropical and subtropical regions. This happens because oxygen concentration is a result of all physical, chemical and biological processes together (Deberdt, 1999); the oxygen content and its distribution in the water mass is a consequence of atmospheric exchanges, physical circulation, water temperature and organic matter decomposition (Wetzel & Likens, 1991). DO is also an important water quality indicator in limnic systems. In the present study, we found lower DO content at medium depth (approximately 3 m deep). This is especially important when DO profiles are compared to Chlorophyll a and to nitrate. Oxygen is released in the water by algae photosynthetic activity. Therefore, when chlorophyll decreases, photosynthesis and DO also decrease. This can be noticed comparing chlorophyll a and DO profiles, which have the same profile pattern. Nitrate profiles resembles DO one, as well. This can be explained by ammonification process that consumes both oxygen and nitrate. The decreasing tendency from surface to bottom is also observed for pH values.

According to Brazilian water quality regulation CONAMA n º 357 (Brasil, 2005) this water body complies with the oxygen content for its class of uses.

The pH values were homogeneous along the water column, except at station 1, where the pH decreased gradually from surface to bottom until it reached 5.86 at 10 m deep. This pH value is the only measurement below 6.00, the pH indicated by the Brazilian legislation CONAMA 357 (Brasil, 2005), and it was taken near sediment. Bottom water may reach low pH, due to organic matter chemical oxidation of anaerobic bacteria. This happens specially when organic matter load is high and water column is kept stratified for a long period, what enables dissolved oxygen to reach deep waters. Hence, this low pH value reinforces the need for environmental monitoration in order to guarantee water quality for the uses foresaw by the regulation CONAMA 357/2005.

Vertical homogeneity in EC was recorded at all three stations, and also showed similar spatial values. Bicudo et al. (2002) found, in Lago das Garças (SP, Brazil), a variation in EC of 138.3 to 172.1 mS cm^{-1}. Such values are considered typical of eutrophic lentic environments. Calijuri et al. (1999) recorded values around 159 mS cm^{-1} for the Salto Grande (Americana, SP, Brazil) reservoir and classified that system as hypereutrophic. The values recorded in the present study are higher than those found in other reservoirs, what reflects the eutrophic state of the environment.

The chlorophyll a contents at the three stations show the same pattern found for eutrophic environments: greater concentration at the surface, and gradual decrease towards the bottom (Andrade, 1988; Wetzel, 2001). The zones of the water column where the greater chlorophyll a values were recorded (0 until 4 m deep) correspond to the calculated euphotic zone. Also, chlorophyll a and phaeophytin profiles are opposite from one another. Therefore, photosynthesis is occurring on the top 4 m of the water column and, deeper than that, phytoplankton tendency is to die and decompose.

Chlorophyll a profile at station 2 closely resembles what is expected to happen in eutrophic environments: high surface values and abrupt decrease at the end of the euphotic zone. Comparing the chlorophyll a content in the Riacho Grande with the Salto Grande reservoir (Calijuri et al., 1999), the eutrophic state of the former is reinforced. Those authors found a chlorophyll a content varying between 10.9 and 73.2 mg L^{-1} in the Salto Grande reservoir, and classified it as hypereutrophic. According to CONAMA 357 (Brasil, 2005), this body of water is not in conformity regarding chlorophyll a content, since the legislation foresees a values bellow 30 mg L^{-1}.

Stations 2 and 3 showed the same pattern of nitrate distribution along the water profile. Nitrate concentration increased at subsurface and than decreased towards the bottom. Deberdt (1999) found a similar result in the Salto Grande reservoir (SP, Brazil). At station 1, nitrate showed an inverse pattern from those found at stations 2 and 3. The same was true of the pH. Also, the nitrate pattern in station 1 was the opposite from the DO one. Therefore, nitrate may be going through an ammonification process.

According to Brazilin regulation CONAMA 357 (Brasil, 2005), maximum nitrate content for class II should be 10.0 mg L^{-1}. All stations showed values below that figure. Hence, with respect to nitrate content, the Riacho Grande is in accordance with its class of use.

Soluble reactive phosphorus (SRP) measures were bellow minimum detectable levels. The filtration step holds particles with diameter greater than 1.2 mm, what means phyto and zooplankton. Therefore, all phosphorus at that moment at the three stations was component of living organisms. This is a common observation in tropical lakes, since the high temperatures allow fast metabolism of organisms and, consequently, fast dissolved phosphate up take (Esteves, 1998). The turnover time of the SRP pool, estimated from the gross uptake of radioactive phosphorus (^{32}P), may be less than 10 minutes under P-limited conditions (Lampert & Sommer, 1997). This fact also can explain the low SRP determined.

One consequence of eutrophication is algae blooms. Such blooms may reduce the water body potential for multiple uses, because some cyanobacteria produce hepatic and neurotoxins. For example, Branco & Senna (1991) reported a bloom of Cylindrospermopsis raciborskii in the Paranoá reservoir (Brasilia, DF, Brazil). These cyanobacteria can survive in nutrient-deficient environments and high pH and water temperature conditions. Their predation rate is low, and their residence time in the reservoir is high. In the present study, although we have no quantitative data, we observed a large number of C. raciborskii and Planktothrix agardhii individuals at the three stations, both potentially toxic cyanobacteria.

We also identified the cyanobacteria Microcystis at all three stations. Microcystis is a common alga in eutrophic tropical reservoir, and blooms frequently in Brazilian reservoirs. A bloom of such algae was responsible for the decrease of water quality for leisure purposes in the Paranoá reservoir, and, possibly, for the death of a large number of fish observed at the same place (Branco & Senna, 1994). Cetesb (2004) pointed to the predominance of cyanobacteria as an indicator of decreased water quality in the Billings Complex.

Chlorophyceae was the best-represented group, with the greatest number of taxa. According to Cetesb (1996), the Chlorophyceae group was the most representative in the Billings reservoir. Its predominance in eutrophic tropical lakes is not rare. Chlorophyceae are ecologically characterized by their growth under a wide spectrum of environmental conditions. Falco & Calijuri (2002) observed a greater contribution of Chlorophyceae at the rainy season in the Americana reservoir (SP), considered eutrophic. In the Barra Bonita reservoir, Chlorophyceae was the greatest contributing group for species richness (Calijuri, 1999).

Bacillariophyceae is a class that, in tropical deep lakes, develops better under low luminosity and high nutrient content, as in the central body of the Billings Complex, an indication of a eutrophic environment. Marins (1981) observed in the Lobo reservoir that this species remains attached to the bottom sediment, and that the wind action brings individuals up to the surface. The presence of that species in the water column of Billings Complex at the three stations suggests a recent water mixture and thermal destratification.

Among Dinoflagelate, only the genus Peridinium was detected at all stations. This genus is considered extremely tolerant to changes in chemical variables and to high organic matter content (Wetzel, 2001). The presence of individuals of the Peridinium genus indicates the eutrophic state of the environment.

Concerning zooplankton, the only Protista detected were from the genus Thecamoeba, for all sampling stations. The presence of Thecamoeba individuals is usually associated with high organic matter availability in the environment.

Rotifera was the best-represented zooplankton group. At station 2, seven genus were found, among which only four (Kellicotia, Trichocerca, Keratella and Polyarthra) were identified at station 1 as well.

Rotifera show a wide environmental distribution, due to the great variety of morphology and accessory structures present in the group, characteristics that allow this group to dominate zooplankton in terms of number of individuals in both lotic and lentic environments (Paggi & Paggi, 1990). This dominance is also associated with the "r" reproductive strategy, which is favored in unstable environments (Matsumura-Tundisi, 1999), such as the Billings Complex.

We also detected Cladocera individuals in the samples analyzed: genus Bosmina at station 1 and an unidentified genus at station 2. Cladocera are extensively used for biomonitoring, since some species are sensitive indicators of environmental conditions. Among them, the genus Bosmina, found at station 1, is an indicator of very eutrophic environments, especially individuals of Bosmina longirostris (Rocha & Günztel, 1999).

Among Copepoda, the Cyclopoida order was present in both samples analyzed, in different development stages: nauplius, copepodit and adult. Cyclopoida are, usually, abundant in lentic environments, and are preferentially carnivorous when adults. In the larvae stages, they are usually either detritivorous or herbivorous (Paggi & Paggi, 1990). Although we did not carry out a quantitative analysis of the zooplankton, we were able to notice a predominance of nauplius and copepodits in relation to the adults. This may be due to the seasonal life cycle stage and/or to the greater food availability for the early stages: phytoplankton, measured indirectly by chlorophyll a content.

The benthic fauna composition was very similar at the three stations. Three taxa were present at all stations: Chaoboridae, Tubificidae and Cyclopidae. Chironomidae was found at 2 of the stations, and was not detected at station 1.

The fauna of lacustrine bottom sediments may be poor in species number due to physical and chemical instabilities, especially oxygen depletion (Brinkhurst, 1974). Therefore, the Riacho Grande is expected to possess a low taxa variety, as observed by Kuhlmann et al. (2005) in reservoirs of the metropolitan region of São Paulo (São Paulo State, Brazil), despite the tendency for great species diversity in tropical regions. In fact, the benthic fauna identified in Riacho Grande is typical of the deep zone, and was composed of species considered resistant to environmental stress.

The physical, chemical and biological water quality parameters indicate that the Riacho Grande is a eutrophic environment. This is confirmed by the TSI that classifies the water body as hypereutrophic. In such hypereutrophic environments, the organic matter may be decomposed along the water column, what consumes oxygen and causes the bottom to have low DO content. The thermal homogeneity of the water profile found in this study, and the high DO concentration in deep water, suggest a recent water mass circulation. This raises the possibility of a previous water column stratification and explains the exclusive presence of low oxygen tolerant species in zoobenthos, at the time of sampling, specially Tubificidae, Chironimidae e Chaoboridae.

In nutrient-enriched conditions, wherein lake sediments become rich in organic matter and low oxygen due to intense microbial ativities, an oligochaete-dominated benthic community is expected (Havens et al., 1996). The Riacho Grande sediment had a strong smell, brown to black colors, and a predominantly fine grain, as observed, in situ, with the naked eye. Other studies carried out in the Billings Complex showed high organic matter content and the predominance of fine grain (Da Silva et al., 2002; Cetesb, 2005; IPT, 2005). Such conditions explain the presence of Tubificidae in Riacho Grande.

Several species of Chironomidae are also tolerant to low DO stress and are successful in organic sediments (Pinder, 1986). However, they are less tolerant compared to Tubificidae, and as DO diminishes they may migrate to other sites, while Tubificidae remain a little longer. The sampler is another important factor because multiple corer may underestimate

Chironomidae (Flannagan, 1970). Although the Ambühl & Büher sampler possesses many characteristics of an ideal sampler, as stated by Brandimarte et al. (2003), one may not overcome the problem of benthos underestimation, due to the small sample size brought up by the sampler.The presence of Chaoboridae in deep zones is related to the fact that they are tolerant to low DO content (Arcifa, 1997; Cleto Filho, 2005).

Although Cyclopoida taxa have some species that inhabit bottom sediments, the species found in these sediment samples seem to be planktonic. Their presence in sediment samples may be due to these animals' habits: they bury themselves for short periods of time, and they migrate in search of food.

In conclusion, vertical stratification of the water column was not noticed at any station. Probable recent water mass mixing may explain the DO distribution, which showed no trend with respect to depth, just like EC.

Presence of Bosmina (Cladocera) together with the dominance of individuals from Phylum Rotifera reinforces the eutrophic state of the Riacho Grande region, Billings Complex. The presence of benthic fauna also points out to this trophic state, since the presence of Tubificidae in zoobenthos is indicative of an organic matter rich and low DO content environment. Therefore, its relative dominance in an oxygen rich environment suggests a recent water mass mixing, putting in evidence polymictic characteristics of the Riacho Grande. TSI results also corroborate the eutrophic state of the studied region.

According to state regulation n° 10.755 (São Paulo, 1977), the uses for the Riacho Grande water body correspond to class II. The parameters from CONAMA 357 (Brasil, 2005) analyzed here are in accordance with the regulation regarding dissolved oxygen and nitrate. Chlorophyll a content from the Riacho Grande are higher than what is stated by the regulation, and pH is below. Therefore, this water body must be the target of remediation and water quality improvement, since some parameters are not in accordance with Federal and State legislation, what compromises its water uses.

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