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Chapter 3 – Natural Wetlands Systems.

THE ROLE OF A NATURAL WETLAND SYSTEM IN IMPROVING THE QUALITY OF THE ATIBAIA RIVER'S WATER (STATE OF SÃO PAULO, BRAZIL)

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ABSTRACT

The effectiveness of a wetland system at the upstream end of Salto Grande Reservoir (São Paulo, State, Brazil) in reducing fecal coliforms and nutrient inputs from the Atibaia river was evaluated. Samples of water were taken from ten sampling stations along the two edges with vegetation of the river in three periods of different water level. A significant reduction was observed in fecal coliforms present in the Atibaia river after the water's passage through the wetland system throughout the periods studied. However, the wetland's performance in reducing nutrient loads from the Atibaia river varied considerably, depending on the nitrogen and phosphorus form considered and on the different hydrological conditions. The critical period for retention of nutrients was the flood period, when the wetland system appeared to be a donor of soluble reactive phosphorus and total phosphorus. The results to date indicate that the wetland system of the Atibaia river must be manipulated to increase its ability to entrap nutrients to improve the quality of the reservoir's water. This should be implemented as part of an overall catchment approach to treat both diffuse and point source pollution.

KEYWORDS: fecal coliforms, nitrogen, phosphorus, reservoir water quality, river cleanup, sedimentation rate, wetland manipulation.

1. INTRODUCTION

The Salto Grande reservoir on the Atibaia River is located in the central eastern part of the São Paulo State, Brazil (Figure 1). It was built in 1949 to supply electricity but it later also became an important water source for irrigation, stock, domestic supply and recreation, such as fishing and sailing.

The Atibaia River drains a heavily urbanized watershed (2,950km^2) encompassing the third largest economic region in Brazil. Despite its economic development, under 5% of the domestic sewage receive some kind of treatment. As a result, the Atibaia river receives these untreated domestic effluents as well as those from the Campinas-Paulínia industrial complex, including waste from the area's chemical, petrochemical, textile, cellulose, and food industries. Moreover, agricultural practices within the basin include the use of high amounts of fertilizers and pesticides.

Measurements of non-point contaminants for the Atibaia are not available, but there is no doubt that these contaminants contribute to enhance its pollution.

Violations of the state's water quality standards for domestic supply were detected for cadmium, lead and fecal coliforms. Other water quality problems of the river are associated with turbidity. With a mean concentration of 55.71mg/L, over 100,000tons of suspended solids enter the Salto Grande reservoir per year via the Atibaia. Approximately eighty percent of these solids are inorganic.

There is also a significant nutrient load, as evidenced by the 5,753ton/year of total nitrogen and 212ton/year of total phosphorus (Leite, 1998).

For the above stated reasons, the reservoir has had a continuing history of water quality problems. Over the past ten years, the surface area near the dam has been covered with dense stands of floating and emergent aquatic macrophytes. The development of blue-green algal blooms is also common all over the year. The problems associated to the potential toxic products of these blooms and to macrophytic spread can render the entire reservoir's uses enviable.

A water quality management plan must be developed immediately for the catchment, outlining a strategy to reduce nutrients loads to acceptable levels. Considering that there is a natural wetland system at the upstream end of Salto Grande reservoir, one option is to manage this system, primarily as an interim measure to intercept phosphorus and nitrogen before they enter the reservoir.

As the first step in this direction, this study was carried out to evaluate the effectiveness of the natural wetland system in reducing nutrient inputs from the Atibaia river.

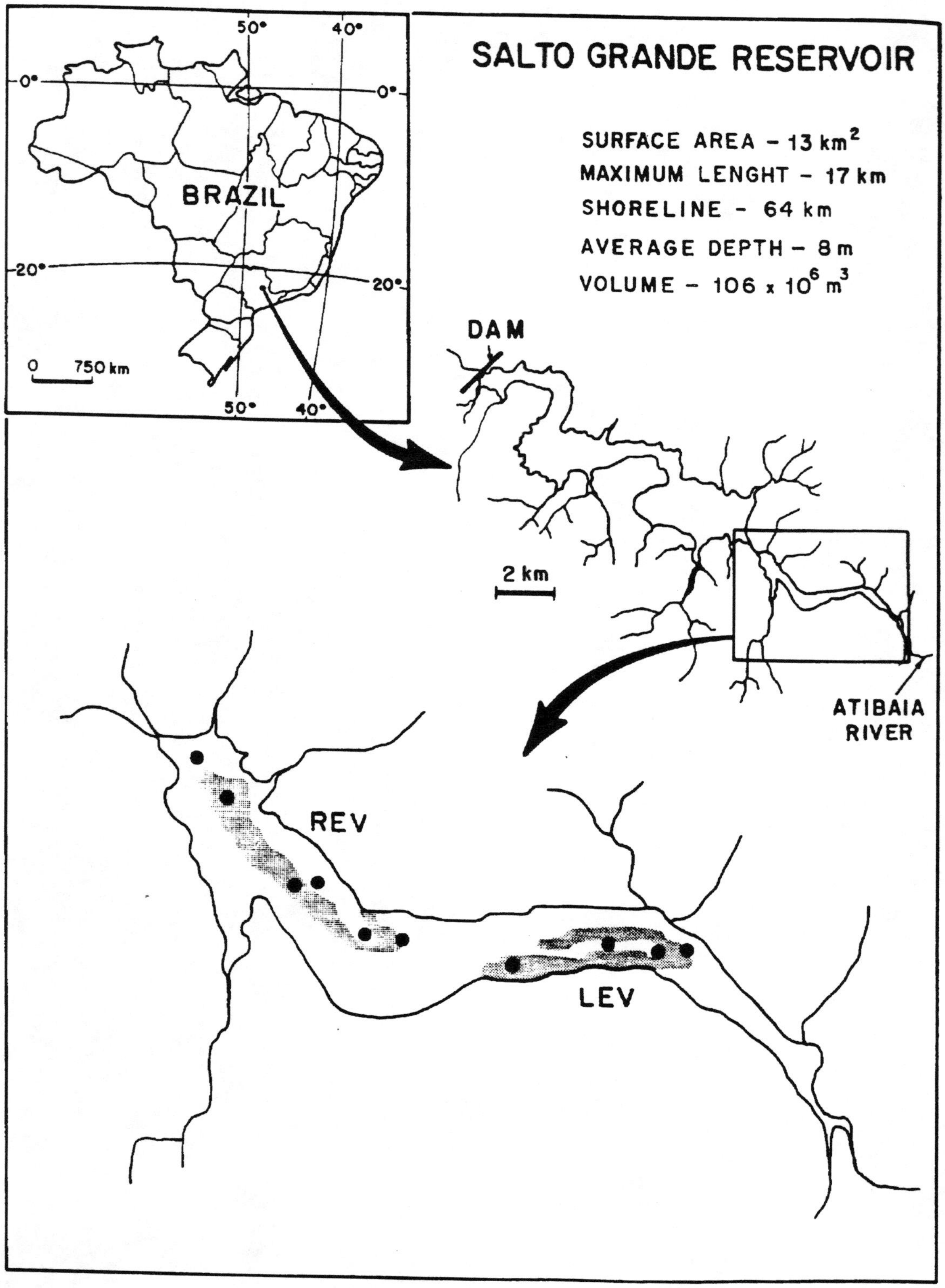

Fig. 1 - Location of the Salto Grande reservoir, focusing on the wetland system at its upstream end, with the ten sampling stations.
LVE, RVE = Left and Right Edge with Vegetation

2. MATERIAL AND METHODS

Establishment of field sites and periodicity

The wetland system at the upstream end of the Salto Grande reservoir consists of two edges covered with vegetation on the Atibaia river (Figure 1). On the left edge (LEV), the dominant aquatic macrophyte is *Pistia stratiotes,* whereas *Brachiaria decumbens* is dominant on the right (REV). Each edge with vegetation is approximately 2.5ha in size.

Ten sampling stations were established in this system: two on the river and one at the inlet of each edge (inlet), two in the left edge (LEV), three on the right edge (REV) and lastly, one on the river downstream from the wetland system (outlet) (Figure 1).

Water samples were collected during three periods. This procedure was adopted because the wetland's features change over the year according to variations in the water level of the reservoir, which is regulated by the dam, i.e. high water level (HWL- September/97), low water level (LWL-January/98) and intermediate water level (IWL-May/98). The HWL period occurs during the dry season, when the Atibaia river receives its lowest inflow (9,816m^3/s) and the dam is kept closed to hold water in the reservoir.

The wetlands' average depth at this time is 1.0m. On the other hand; the LWL period is in the rainy season, when the river inflow reaches its maximum value (54,194m^3/s) and the wetlands' average depth is 0.4m.

Water quality

Nutrients were determined by standard methods (APHA, 1995). Total phosphorus (TP) and total Kjeldahl nitrogen (TKN) measurements were taken from unfiltered samples after acid digestion. Samples were kept cold after collection and filtered to determine soluble reactive phosphate (SRP), ammonium nitrogen (NH_4-N) and nitrate (NO_3-N).

Fecal coliforms and sedimentation rate were measured only at the inlet and outlet of the wetlands.

Fecal coliforms were detected and confirmed using the Colilert Test Kit based on IDEXX's patented Defined Substrate Technology (DST ™). This product utilizes nutrient indicators that produce color and fluorescence when its metabolizes total and fecal coliforms after incubation for 24h at 35 ± 0.5°C.

Cylindrical sediment traps with a 10cm diameter and a 3:1 aspect ratio were filled with distilled water and placed at 30% of the total depth (Henry & Maricato, 1996). After 24h the traps were retrieved and a known volume of water was filtered through dry, pre-weighed 0.45μm Whatman GF/C filters. Total solids were determined gravimetrically after drying the filters at 60°C during 24h.

3. RESULTS AND DISCUSSION

Fecal coliforms

There was a significant reduction in fecal coliforms present in the Atibaia river after the water's passage through the wetland system in all the periods studied (Figure 2). The highest efficiency of this area was achieved in the LWL period, when the density of coliforms in the wetland's outlet was only 10% of that found at the inlet.

Except for the HWL period, the densities detected at the wetland's outlet were reduced to the standard values allowed for recreational water. This probably occurs because, during the HWL period, the river's volume is reduced, causing a reduction in the dilution factor and a higher concentration of incoming fecal coliforms. Moreover, because this period coincides with winter when temperatures are lower, the metabolism of the vegetable system is also reduced and its capacity to remove fecal coliforms is, therefore, correspondingly lower.

Wetlands are known to offer a suitable combination of physical, chemical and biological factors for the removal of bacteria (Vincent, 1994). Physical factors include mechanical filtration and sedimentation. Chemical factors include oxidation, exposure to biocide excreted by some plants and absorption to organic matter. Biological removal mechanisms include antibiosis, ingestion by nematodes and ciliates and natural die-off (Gersberg *et al.*, 1986, 1987). All these factors are present in the Atibaia wetlands and may be involved in the observed removal.

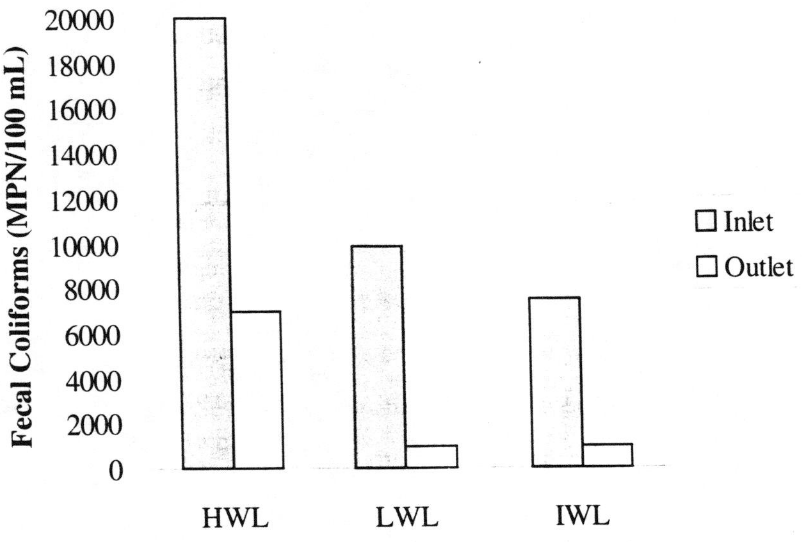

Fig. 2 - Fecal coliforms densities in the Atibaia river before (inlet) and after (outlet) the water's passage through the wetland system. HWL, LWL, IWL = High, Low, Intermediate Water Level

Nitrogen and Phosphorus

The data shown in Table 1 indicate that wetland performance in reducing nutrient loads from the Atibaia river varies considerably, depending on the nitrogen and phosphorus form considered and on the different hydrological conditions.

The most elevated concentrations were found in the HWL period but, as the river inflow is higher in the LWL period, the nutrient loads were bigger at this time.

Considering the nitrogen forms, the maximum values of reduction were found for N-NO_3. No significant decrease or increase was observed for N-NH_4 and TKN in the river after passing through the wetland system. Peterjohn & Correl (1984) obtained similar results. The riparian forest studied retained about 90 % of the nitrate in two successive hydrological years, whereas it was a net exporter of total Kjeldahl nitrogen. According to Holland *et al.* (1990), denitrification in riparian forests is responsible for the loss of nitrates occurring in the narrow zone (no wider than 20 m) at the edge between arable land and riparian forests or close to the banks of streams. The same process probably occurs in the Atibaia wetlands.

Table 1 - Changes in concentration of NO_3-N, NH_4-N, TKN, SRP and TP along the Atibaia river, with the percentage of reduction after passage through the wetland system

	Inlet		LEV	REV	Outlet		Reduction
	mg/L	ton/month	Mg/L	mg/L	mg/L	ton/month	%
N-NO_3							
HWL	2.21	78.04	0.30	0.64	0.96	33.97	56.47
LWL	1.60	313.11	0.94	0.84	0.97	189.7	39.41
IWL	0.74	34.5	0.55	0.45	0.53	24.6	28.7
N-NH_4							
HWL	1.88	66.73	0.98	2.15	2.01	71.15	-6.96
LWL	0.83	161.9	0.87	0.73	0.70	137.12	15.30
IWL	1.54	71.3	1.53	0.15	1.55	72.0	-1.0
TKN							
HWL	14.00	494.62	12.13	16.32	16.63	587.36	-18.82
LWL	4.79	935.21	4.60	3.66	4.24	826.44	11.63
IWL	8.70	403.1	8.89	8.84	9.29	427.4	-6.8
SRP							
HWL	0.14	4.98	0.05	0.26	0.23	7.95	-59.66
LWL	0.10	19.01	0.05	0.06	0.04	7.91	58.42
IWL	0.18	8.14	0.08	0.12	0.08	3.74	54.03
TP							
HWL	0.27	9.54	0.26	0.42	0.38	13.38	-40.19
LWL	0.23	45.55	0.22	0.21	0.15	28.84	36.68
IWL	0.25	11.41	0.26	0.26	0.21	9.95	12.87

LVE = Left Edge with Vegetation RVE = Right Edge with Vegetation

HWL, LWL, IWL =High, Low and Intermediate Water Level

As regards phosphorus, the wetland system appeared to be a donor of both analyzed forms during the HWL period. However, particular in the case of SRP, a sharp decrease in concentration was observed at this time on the left edge. As the opposite was found to be true on the right edge, it may be releasing this compound into the river, thus enhancing the concentration at the outlet. This situation is completely different during the LWL period, when SRP and TP concentrations are lower on both edges and the highest efficiency in reducing SRP was found. Because the right edge is covered primarily by grass, it is probable that most of this area is submerged during the

HWL period, increasing decomposition and releasing phosphorus into the system. The floating macrophytes on left edge, on the other hand, are not subject to this process.

It is clear that the yearly retention of phosphorus is strongly dependent on the frequency and duration of water table fluctuations and the relative thickness of the soil's or sediments aerobic layer. Since phosphorus is precipitated and stored in sediment particles (mainly bound to iron and aluminum) under aerobic conditions during the period of low water table, it is quickly released and desorbed under anaerobic conditions after the sediment or soil surface is flooded. Hossner & Backer (1988) found that the phosphates are released into the water two to three weeks after the sandy loam sediments are flooded. In clay-dominated sediments, like those found in the Atibaia river, this process is significantly delayed and the release rate is much lower. It seems that fine particles of clay are the best immobilize for phosphorus in watersheds: deposition of total phosphorus was very closely related to the deposition of clay.

This agrees with the results obtained here. The highest values of the sedimentation rate (Figure 3) were found in the LWL and IWL periods, when the best retention of inorganic and total phosphorus was observed. It must also be noted that the LWL coincides with the summer, when vegetable metabolism is higher and more SRP is probably being absorbed by aquatic macrophytes.

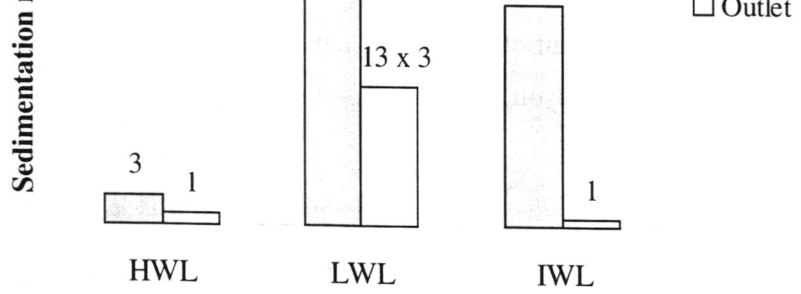

Fig. 3 - Sedimentation rate in the Atibaia river before (inlet) and after (outlet) the water's passage through the wetland system. HWL, LWL, IWL = High, Low, Intermediate Water Level

A good example of year-round values and their seasonally as observed in this work, is given by Stachurski & Zimka (1994) appud Hillbricht-Ilkowska (1995) in their studies on the transformation of nitrogen and phosphorus forms in the load passing through a patch of wetland (20ha reed belt and wet meadow). No decrease in the load of total or dissolved nitrogen and organic phosphorus was detected.

The significant decrease of nitrates and phosphates was found to effectively remove close to 73% of $N\text{-}NO_3$ and 42% of SRP. The authors also verified that the critical period for retention of inorganic forms of nutrients is the flood period during the spring, when a wetland patch releases phosphates in larger amounts than it receives and simultaneously retains the inorganic nitrogen very effectively. A close relation between iron and phosphorus was found and the authors stated that the presence of phosphates during the spring was caused by the release of iron compounds in wetland soils under anaerobic, waterlogged conditions. The same conditions are responsible for the effective removal of inorganic nitrogen due to denitrification.

The results to date indicate that the wetland system of Atibaia river must be manipulated to increase its ability to entrap nutrients to improve the quality of the reservoir's water. Managing these wetlands by regulating the water flow, enhancing vegetable absorption of nutrients, growing highly nutrient-absorbing plants, and diverting the river flow into the wetlands could be as successful as the Des Plaines River Wetlands Demonstration Project (Kadlec & Hey, 1994), the Lake Jackson (Landers & Kruth, 1991, Oberts & Osgood, 1991) in the United States, and the Kis-Balaton in Hungary (Pomogyi,1993).

A very similar case of reservoir water quality problems, where a large riparian wetland at the upstream end of the dam was constructed to treat river nutrient pollution in a reasonable and cost-effective manner, is the Carcoar Wetland in Australia (White *et al.*, 1994).

The Carcoar Wetland was implemented as part of an overall catchment approach to treat both diffuse and point source pollution. The same approach should be taken in the case of the Atibaia river and Salto Grande reservoir.

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