



# SEASONAL VARIATION OF WATER QUALITY IN A DEEP COASTAL LAGOON: THE CASE OF PERI LAGOON, FLORIANÓPOLIS, SOUTHERN BRAZIL

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## INTRODUCTION

The population of Santa Catarina Island has been increasing considerably in the last years: from 369,102 in 2003 to 402,346 inhabitants in 2008, which represents an increase of almost 10% in only five years (5). This considerable population growth requires attention not only because of the increasing water demand but also because it increases human activities that might potentially cause degradation of environmental and water quality in the region.

Coastal lagoons are considered ecologically and economically important environments due to their high productivity and intense use for aquaculture and recreational purposes and also because of their capability of acting as deposits of allochthonous materials (16). In spite of that, coastal lagoons are very vulnerable to inorganic and organic pollution (7), being severely exposed to impacts caused by human activities. The restoring of these environments is slow and problematic and reinforces the need of more intense knowledge and preservation of coastal lagoons of great importance.

Wetzel (2001) affirms that the comprehension about structure and functioning of freshwater ecosystems is essential to compensate the effects of human impacts and to achieve a better management of the aquatic resources.

The above mentioned emphasizes the importance of expanding the knowledge and conservation of Peri Lagoon, the largest freshwater body in Santa Catarina Island, which supplies potable water to almost 50% of the population of the island. Besides water supply, Peri Lagoon also offers beautiful landscapes and has great potential for recreational activities and environmental education initiatives.

Water quality studies that allow a better comprehension of the dynamics of aquatic ecosystems are of great importance for the preservation and conservation of these environments.

## OBJECTIVES

The purpose of this study was to understand the temporal dynamic of water quality in Peri Lagoon during one year (March/2008 - February/2009) and to compare the results with previous studies made ten and twelve years ago.

## MATERIAL AND METHODS

### Study Area

Peri Lagoon is located in the southeast portion of Santa Catarina Island ( $27^{\circ}42'59''$  -  $27^{\circ}46'45''$ S and  $48^{\circ}30'33''$  -  $48^{\circ}31'59''$ W). It has a surface area of 5.07 km<sup>2</sup> and it is surrounded by mountains covered by well preserved Atlantic Rain Forest and by sandy Restinga ecosystem. Previous studies observed that the lagoon presents absence of anoxia, a relative spatial homogeneity and is polymitic (9, 14, 15).

Peri Lagoon is classified as a coastal lagoon, but presents unique features when compared to other coastal lagoons in Brazil: its maximum depth is 11 meters and mean depth is 4.2 meters (most coastal lagoons are very shallow waterbodies, *e.g.* many coastal lagoons in Rio de Janeiro state - 8); it is located 3.0 meters above sea level, being composed by freshwater all over the year (many coastal lagoon receive seawater influence, *e.g.* coastal lagoons in Rio de Janeiro state - 8); it presents very low nutrient concentrations but an abundant phytoplankton community, dominated by the potentially toxic cyanobacteria *Cylindrospermopsis raciborskii* (coastal lagoons are usually nutrient rich environments).

### Sampling and Analysis

Monthly water column samplings were made in five locations of the lagoon between March 2008 and February 2009 at Secchi disk depth with a three liter Van Dorn bottle.

Temperature, conductivity, pH and dissolved oxygen were measured *in situ* with specific probes (WTW-Multi350i). Light penetration in the water column was estimated by a 0.2m white Secchi disk.

Nitrite (3), ammonium (6), soluble reactive phosphorus (17), total dissolved phosphorus (17) and total phosphorus and nitrogen (18) concentrations were determined in laboratory from filtered and unfiltered frozen water samples kept in polyethylene bottles at  $-20^{\circ}\text{C}$ .

Pigments concentrations (chlorophyll - a and phaeophytin) were obtained by filtering 500ml water samples through glass fiber filters Millipore AP40 using the method and equations described by Lorenzen (1967).

Since no transformation made the data present a normal and a homogeneous distribution, monthly variations were tested by Kruskal - Wallis test for non - parametric data (Statistica 7). Relations between sampling points, months and water quality parameters were tested by PCA-Principal Component Analysis (Statistica 7) and MDS-Multidimensional Scaling (Primer 6  $\beta$ ). No transformations were made on data to run the tests.

## RESULTS AND DISCUSSION

Since no significant differences were detected between the five sampled stations in Peri Lagoon by MDS, sampling stations were grouped in monthly means for all variables and compared by the non - parametric Kruskal - Wallis test. Laudares - Silva (1999) also measured water quality parameters in Peri Lagoon between March/1996 and February/1997 and did not detect spatial differences either. In a similar study conducted between March/1998 and February/1999, Simonassi (2001) also found no significant differences between his seven sampling stations.

MDS showed that the summer months of January and February and the winter month of June are different from the other sampled months, what can be attributed mainly to temperature and chlorophyll - a values. March, December and July also showed some differences in relation to spring and autumnal months.

PCA attributed the variance between months mainly to temperature, chlorophyll - a, nitrite and total phosphorus, but the percentage of the factors explaining the variance was low (31% for factor 1 and 19% for factor 2).

Water temperature showed seasonal variation with minimum mean value of  $18.2^{\circ}\text{C}$  in June/2008 and maximum of  $28.4^{\circ}\text{C}$  in February/2009. Mean annual water temperature was  $23.3^{\circ}\text{C}$ . Simonassi (2001) found similar temperatures. Laudares - Silva (1999) registered a lower minimum mean temperature of  $15.0^{\circ}\text{C}$  (June/1996) and higher maximum water temperature of  $30.0^{\circ}\text{C}$  (January/1997).

Mean Secchi disk depth was  $1.09 \pm 0.11\text{m}$  (mean  $\pm$  standard deviation). Minimum transparency was found in January/2009 (0.86m) and maximum in June/2008 (1.22m). All summer months presented lower Secchi depths which is probably associated to the more intense rainfall during this season of the year in the region. Simonassi (2001) found lower transparency values, ranging between 0.50m and 1.00m, while Laudares - Silva (1999) found higher Secchi disk depths that ranged from 0.90m to 1.50m. The differences between the three studies are probably associated with different rainfall volumes and wind speed intensities prior to sampling dates in each study.

Dissolved oxygen concentration ranged from 5.95mg/l (June/2008) to 9.11mg/l (September/2008) with a mean concentration of  $7.57 \pm 1.04\text{mg/l}$ . Significantly lower dissolved oxygen concentrations ( $p < 0.05$ ) were detected between June and July in relation to August and September which can be a result of lower primary productivity rates in the winter months and higher wind speeds in the days prior to sampling in August and September (mean wind speed: 25km/h). Similar dissolved oxygen concentrations were detected by Simonassi (2001) and Laudares - Silva (1999). Peri Lagoon can be considered a well oxygenated waterbody when compared to other Brazilian freshwater environments, which usually present periods of very low dissolved oxygen concentrations and lower mean concentrations (*e.g.* 1, 2).

Minimum pH value was found in July/2008 (5.5) and maximum in October/2008 (7.5). Mean pH value was  $6.8 \pm 0.7$ , which indicates a neutral environment, with periods of slightly acidity. Laudares - Silva (1999) also found waters slightly acid, but only a small variation in pH (6.0 - 6.7), while Simonassi (2001) observed pH values ranging between 6.6 and 8.1, which indicates neutral to slightly alkaline waters. Conductivity in this study ranged from  $69.6 \mu\text{S/cm}$  (February/2009) to  $85.8 \mu\text{S/cm}$  (March/2008) with a mean value of  $75.5 \pm 4.3 \mu\text{S/cm}$ . December and February had lower conductivity ( $p < 0.05$ ) than March, April and September, what is probably related to more intense rainfall in the days prior to sampling in the first two months and the absence or low rainfall in March, April and September. Laudares - Silva (1999) and Simonassi (2001) observed much higher maximum conductivities ( $205.0 \mu\text{S/cm}$  and  $150.0 \mu\text{S/cm}$ , respectively), but during most part of the year, their conductivity values were in accordance with the present study. Differences in pH and conductivity are probably associated to different weather conditions and to different marine influences (marine spray) during the three studies.

Chlorophyll - a maximum concentration was detected in March/2008 ( $27.8 \mu\text{g/l}$ ) with a mean concentration of  $18.5 \pm 5.2 \mu\text{g/l}$  and minimum of  $13.5 \mu\text{g/l}$  in July/2008. Significantly higher ( $p < 0.05$ ) chlorophyll - a concentrations were detected in summer months (January, February and March) in relation to the colder winter months (June and July). Simonassi (2001) found similar chlorophyll - a variations and concentrations, but Laudares - Silva (1999) observed lower mean, minimum and maximum values ( $13.9 \mu\text{g/l}$ ,  $7.4 \mu\text{g/l}$  and  $18.7 \mu\text{g/l}$ , respectively). Both studies also observed higher chlorophyll - a concentrations in summer months and lower concentration during winter. Phaeophytin concentrations were very low, ranging from non - detectable concentrations (February/2009) to  $1.0 \mu\text{g/l}$  (August/2008). Mean phaeophytin was  $0.5 \pm 0.3 \mu\text{g/l}$ .

Nutrients concentrations along the year in Peri Lagoon showed no clear pattern and can be considered low (oligotrophic) according to two different trophic indexes (11, 13). Laudares - Silva (1999) and Simonassi (2001) also observed low nutrient concentrations in their studies.

Nitrite concentrations were very low, with a mean value of  $0.54 \pm 0.20 \mu\text{g/l}$ . A minimum concentration of  $0.14 \mu\text{g/l}$  was detected in February/2009 and a maximum of  $0.79 \mu\text{g/l}$  in June/2008. Ammonium concentrations showed a very

wide range along the study period, from 3.3  $\mu\text{g/l}$  (February/2009) to 29.3  $\mu\text{g/l}$  (May/2008). Mean ammonium concentration was  $14.7 \pm 10.0 \mu\text{g/l}$ . Laudares - Silva (1999) and Simonassi (2001) researches found similar values for nitrite and ammonium concentrations in their researches.

The concentrations of total nitrogen also ranged widely from 283.5  $\mu\text{g/l}$  (September/2008) to 958.9  $\mu\text{g/l}$  (May/2008), with a mean concentration of  $633.3 \pm 197.0 \mu\text{g/l}$ , which is a little higher than the concentrations observed by Laudares - Silva (1999) (annual mean: 546.8  $\mu\text{g/l}$ ). Dissolved inorganic nutrients seem to be of little importance to the total nitrogen content in Peri Lagoon, what on the other hand point to organic and particulate matter as important sources of nitrogen to the system. Indeed, Simonassi (2001) and Laudares - Silva (1999) found that particulate organic matter was usually three times higher than the inorganic portion of the suspended particulate matter in the Lagoon.

Other freshwater lakes and lagoons subjected to low human impact in Brazil show similar total nitrogen concentrations (e.g. Amarela and Águas Claras lakes - 12; Batata Lake - 4), while waterbodies subjected to cultural eutrophication usually show higher average total nitrogen (e.g. Barra Lagoon - 4).

Soluble reactive phosphorus varied between 0.73  $\mu\text{g/l}$  (October/2008) and 6.75  $\mu\text{g/l}$  (June/2008) and showed a low mean concentration of  $2.38 \pm 1.86 \mu\text{g/l}$ . The highest concentration was observed in the month with the lowest dissolved oxygen concentration (June/2008). This probably occurred because high oxygen concentrations usually keep phosphorus attached to the sediment, while lower concentrations liberate it to the water column (19). Ortho - phosphate concentrations found by Laudares - Silva (1999) were slightly lower.

Total dissolved phosphorus mean annual concentration was  $5.15 \pm 1.49 \mu\text{g/l}$ , ranging from 2.72  $\mu\text{g/l}$  (January/2009) to 7.79  $\mu\text{g/l}$  (June/2008). It usually represented one third of the total phosphorus concentration, which ranged from 12.00  $\mu\text{g/l}$  to 22.14  $\mu\text{g/l}$  (June/2008 and December/2008, respectively) and showed a mean annual concentration of  $15.91 \pm 2.98 \mu\text{g/l}$ . Intense rainfall in the last days of November and high wind speeds prior to sampling may have caused the highest total phosphorus concentration in December. Total phosphorus mean, minimum and maximum values found by Laudares - Silva (1999) in 1996 - 97 were very similar to this study.

Total phosphorus in Peri Lagoon was similar to other oligotrophic waterbodies like Dom Helvécio and Claras lakes in Minas Gerais state (12) and Batata Lake in the Amazon region (4).

Total nitrogen to total phosphorus ratio was always higher than 30:1, except in September/2008 (17:1), which indicates that Peri Lagoon is limited by phosphorus. Most of the Brazilian waterbodies are phosphorus limited, like the four lakes studied by Petrucio & Barbosa (2004), Comprida Lagoon (1) and Batata Lake (4). Laudares - Silva (1999) also observed phosphorus limitation during most part of the year in her study and attributed the success and dominance of the cyanobacterium *Cylindrospermopsis raciborskii* in the Lagoon to this condition (along with others). There are two main factors that may contribute to this phosphorus

limitation: the permanent oxygenation of the water column due to the frequent wind action in the Lagoon, which keeps phosphorus attached to the sediment; and the reduced phosphorus loadings from allochthonous sources.

## CONCLUSION

The present study shows that there are no significant spatial differences in water quality parameters in Peri Lagoon and that seasonal differences in water quality are more clearly observed between summer (January - March) and winter months (June - August). As for water quality parameters that contribute more intensely to the variance of the data between sampling months, are temperature, chlorophyll - a, nitrite and total phosphorus. Comparing this study with previous researches developed in the 1990 decade, we could notice that the water quality parameters did not varied broadly in the last twelve years in Peri Lagoon, indicating that its surroundings have been properly preserved during the last few years in spite of the rapid urban growth that Florianópolis has been experiencing.

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