Influence of limnological characteristics of water in the occurrence of Salvinia molesta and Pistia stratiotes in rivers from the Itanhaém River basin (SP, Brazil).

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ABSTRACT: Influence of limnological characteristics of water in the occurrence of Salvinia molesta and Pistia stratiotes in rivers from the Itanhaém River basin (SP, Brazil). Itanhaém River basin is located in the South Coastal Plain of São Paulo State (Brazil) and is formed by many small rivers and streams with low water flow and meandered beds. Pistia stratiotes and Salvinia molesta are the most abundant species of floating aquatic macrophytes that occur in different rivers of the basin. Although the water flux can transport these species for different rivers, these two species do not coexist in the same stand. In this work we measure some physical and chemical characteristics of the water from four stands (2 of P. stratiotes located in rivers Guaú and Aguapeú and 2 of S. molesta located in rivers Preto and Branco) with the objective to identify favourable conditions for occurrence of these species and understand why the two species do not coexist in the same stand. The Principal Component Analysis (PCA) showed that the stands located in rivers Branco and Guaú have very distinct limnological characteristics while the stands located in rivers Aguapeú and Preto have similar limnological characteristics. Between stands located in rivers Aguapeú and Preto, only phosphorus concentrations were significantly ($p<0.05$) higher in Aguapeú River. Mean concentrations of total P in water from stand of P. stratiotes in Aguapeú River (111.2 $mg.L^{-1}$) was similar to water from stand of P. stratiotes in Guaú River (110.9 $mg.L^{-1}$) and significantly ($p<0.05$) higher than in water from stands of S. molesta in Preto River (53.5 $mg.L^{-1}$) and Branco River (63.3 $mg.L^{-1}$). We concluded that the concentration of phosphorus, probably, is an important factor that determines the distribution of these two species of floating aquatic macrophytes in rivers from the Itanhaém River basin.

Key-words: Limnological characteristics, phosphorus, Pistia stratiotes, Salvinia molesta.

RESUMO: Influência das características limnológicas da água na ocorrência de Salvinia molesta e Pistia stratiotes em rios da bacia do rio Itanhaém (SP, Brasil). A bacia hidrográfica do Rio Itanhaém está localizada no sul da Planície Costeira do Estado de São Paulo e é formada por pequenos rios e canais com baixas velocidades de corrente e leitos meândricos. Pistia stratiotes e Salvinia molesta são as espécies de macrófitas aquáticas flutuantes mais abundantes nos rios da bacia. Embora o fluxo de água possa transportar estas espécies para diferentes rios, estas duas espécies não coexistem no mesmo estande. Neste trabalho nós medimos algumas características físicas e químicas da água de quatro estandes (2 de P. stratiotes localizados nos rios Guaú e Aguapeú e 2 de S. molesta localizados nos rios Preto e Branco) com o objetivo de identificar condições favoráveis a ocorrência das duas espécies e compreender porque não coexistem no mesmo estande. A Análise de Componentes Principais (ACP) mostrou que as características limnológicas da água dos estandes localizados nos rios Branco e Guaú são muito distintas, enquanto as características limnológicas da água dos estandes localizados nos rios Aguapeú e Preto são semelhantes. Entre a água dos estandes localizados nos rios Aguapeú e Preto, somente as concentrações de fósforo foram significativamente ($p<0.05$) maiores no rio Aguapeú. A concentração média de P-total na água do estande de P. stratiotes no rio Aguapeú (111,2 $mg.L^{-1}$) foi similar à da água do estande de P. stratiotes no rio Guaú (110,9 $mg.L^{-1}$) e significativamente ($p<0.05$) maior que na água dos estandes de S. molesta nos rios Preto (53,5 $mg.L^{-1}$) e Branco (63,3 $mg.L^{-1}$). Concluímos que a disponibilidade de P, provavelmente, é um importante fator que determina a distribuição de S. molesta e P. stratiotes em rios da bacia hidrográfica do rio Itanhaém.

Palavras-chave: Características limnológicas, fósforo, Pistia stratiotes, Salvinia molesta.

Introduction

There is a large coastal plain in the Centre-South of the State of São Paulo, with approximately 50 Km length and 15 Km width. Several small rivers and streams run through this plain starting in a mountain range area and draining into the Atlantic Ocean. Most of these water bodies are located in the Itanhaém River basin. The flat terrain originates lotic ecosystems with meandered beds that present slow flow and stagnant waters. Great part of the region is well preserved because there is a large conservation area (Parque Estadual da Serra do Mar) in the mountain range. The urban areas are restrict to coastal line (Camargo et al., 1996; Camargo et al., 2002). The rivers are well preserved and show a large diversity of water types: black, white, clear and brackish (Camargo et al., 1997).

In areas with stagnant water, aquatic macrophytes from different ecological types are abundant, and among the floating species, Pistia stratiotes and Salvinia molesta predominate. Although the stands of the two species are closely located and the flow of the water is enough for the transport of the floating species to different areas of the coastal plain, these species do not coexist in the same stand. Considering that (i) the distribution of aquatic macrophytes is controlled by many factors like temperature, light intensity, speed of the water flow and nutrients availability (Payne, 1986; Thomaz et al., 2003) and (ii) that those two macrophyte species are noxious in many regions of the planet (Pieterse & Murphy, 1990); the study of the physical and chemical characteristics of the water from the stands of these species can indicate favourable growth conditions.

In this work we measure some physical and chemical characteristics of the water from stands of P. stratiotes and S. molesta, in order to identify favourable conditions for occurrence of these species and contribute to understand why the two species do not coexist in the same stand in rivers from the Itanhaém River basin.

Study Area

The present study was carried out in stagnant water areas of four different rivers from the Itanhaém River basin (23˚50', 24˚15'S and 46˚35', 47˚00' W). The areas are isolated from each other by ca. 10 Km and are located in the rivers Preto, Branco, Aguapeú and Guaú (Fig. 1).

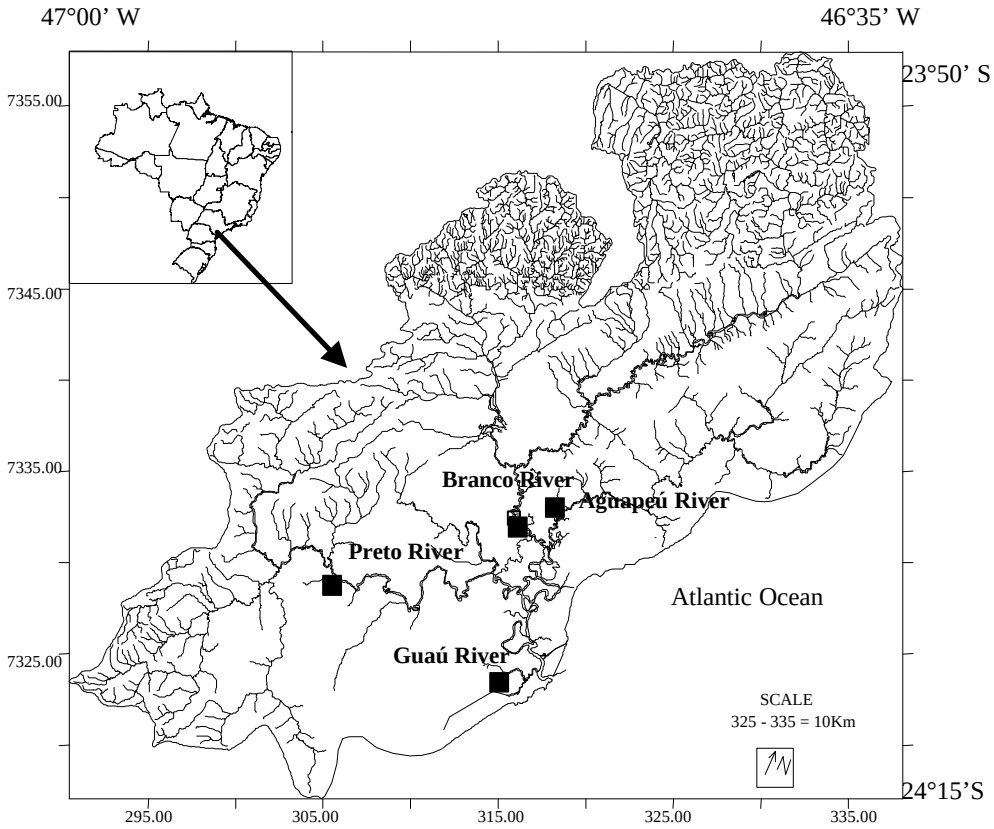

Figure 1: Itanhaém River basin map. The symbol ■ indicate studied areas from the rivers Guaú, Aguapeú, Preto and Branco.

The rivers Aguapeú, Guaú and Preto presented black waters and the Branco River clear waters (Camargo et al., 1997). The studied areas from the two first rivers are only colonised by monospecific stands of P. stratiotes while the areas from the two last ones are colonised by stands of S. molesta associated with Eichhornia azurea. According to Köppen classification, the climate of the region is Cfa humid subtropical. According to Lamparelli & Moura (1998), the meteorological conditions present little variation due to its latitude and proximity to the Atlantic Ocean. Rain is abundant (annual mean of 2183 mm), with more rainfall in March (279.9 mm) and less in August (84.7 mm). The annual mean minimum temperature is 19.0 °C (July) and the annual mean maximum temperature is 26.2 °C (February).

Material and methods

Four replicate samples of water and two macrophytes species were collected in October 2002 and February, May and July 2003. P. stratiotes was collected in monospecific stands from the rivers Aguapeú (24°05'37" S and 46°45'33" W) and Guaú (24°11'27" S and 46°47'00" W); meanwhile S. molesta was collected in stands from the rivers Preto (24°08'07" S and 46°52'15" W) and Branco (24°06'15" S and 46°46'27" W). The wide occurrence of free floating aquatic macrophytes P. stratiotes (studied areas from the rivers Guaú and Aguapeú) and S. molesta (studied areas from the rivers Branco and Preto) was the criterion to select the studied areas. Samples from the two species of macrophytes were randomly obtained within a square of 0.25m^2. The plants were cleaned through successive washes in order to remove the periphyton, organic matter and associated inorganic particles. Thereafter, the plants were dried at 60°C and weighted in order to determine values of biomass in grams of dry mass by square meter (g DM.m^{-2}).

Water samples were collected from the subsurface (10 cm) close to the stands (ca. 1.0 m from stand external limit). Water temperature, pH, electrical conductivity and salinity were measured with a Water Quality Checker Horiba, model U-10. Photosynthetic active radiation (PAR) was measured, at 0.0m and 0.2m, with the Light Meter LiCor (model 189) and the coefficient of the vertical attenuation (K_x) was calculated using the following equation: $K_x = (\ln.Io - \ln.I)/z$, where ln is the natural logarithm, I is the PAR at a determined depth (m), Io is the PAR at the surface and z is the depth (m) (Wetzel, 1983). Dissolved oxygen concentrations were determined by Winkler method (Golterman et al., 1978) and total alkalinity was measured by titration (Mackereth et al., 1978). Approximately 0.5 litters of water were filtered (Whatman GFC) in the laboratory of the Centre of Research of Itanhaém River some hours after the sample. The filtered and non-filtered samples were conditioned in polyethylene bottles and immediately frozen at -20°C. Concentrations of ammoniacal nitrogen (Ammoniacal-N) (Koroleff, 1976), nitrate (NO_3-N), nitrite (NO_2-N) and total dissolved nitrogen (Dissolved-N) (Mackereth et al., 1978), orthophosphates (PO_4-P) and total dissolved phosphorus (Dissolvded-P) (Golterman et al., 1978) were measured in the Laboratory of Aquatic Ecology (Ecology Department/ UNESP/Rio Claro). Total suspended material was determined by the method described in APHA (1989). Samples of non-filtered water were used to determine total nitrogen (Total-N) (Mackereth et al., 1978) and total phosphorus (Total-P) (Golterman et al., 1978).

A Principal Components Analysis (PCA) (Ludwig & Reynolds, 1988), based on the all water variables obtained, was used to ordinate the four studied areas and months. Prior to ANOVA (one way), we checked the homogeneity of variances in water, P. stratiotes and S. molesta data, using Bartllet's Test. When significant differences ($p \leq 0.05$) occurred, we used the Tukey's HSD test (Zar, 1996). The Statistica program (version 5.5) was used for the statistical analysis (Statistica, 2000).

Results

Tab. I shows the mean values and the standard deviation of the physical and chemical variables measured in the four studied areas. The mean temperature (24°C), pH (5.8), conductivity (296.6 mSm^{-1}), salinity (126.2 ppm), K_x (11.9), total alkalinity (0.30 meq.L^{-1}), suspend matter (75.2 mg.L^{-1}) are

higher in studied area from the Guaú River; the mean pH (4.7), conductivity (30.6 mS.cm^{-1}), dissolved O_2 (2.6 mg.L^{-1}), salinity (15.0 ppm), total alkalinity (0.02 meq.L^{-1}) and suspend matter (23.0 mg.L^{-1}) are smaller in studied area from the Branco River. The standard deviation values also show that there are great variations in the variables analysed between the four sampling months in the same area. With the aim to establish a general view of the differences and similarities of the characteristics of the water in the four areas under study in the four seasons of the year, a Principal Component Analysis was applied to the data. Tab. II shows the values of the components loadings for each variable, the explained variance and the percentage of the total variance by the components 1 and 2. Tab. II shows that with the exception of the NO_3-N the other forms of N and P are highly correlated to the Principal Component 1. In the same way, the variables conductivity, K_x and total alkalinity are also correlated with

Table I: Annual mean and standard deviation of the physical and chemical variables measured in the four studied areas.

Rivers	**Guaú**		**Aguapeú**		**Branco**		**Preto**	
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
T (^oC)	24.0	3.7	21.0	3.3	21.0	3.5	21.3	3.4
pH	5.8	0.6	5.4	0.4	4.7	0.4	5.5	0.6
Conductivity (mS.cm^{-1})	296.6	427.0	43.3	4.5	30.6	5.9	140.4	199.8
Dissolved oxygen (mg.L^{-1})	3.4	1.65	3.8	1.32	2.6	1.14	7.8	1.50
Salinity (ppm)	126.2	19.82	18.7	6.19	15.0	4.47	66.3	101.45
K_x	11.9	2.81	4.8	1.74	6.8	5.21	2.5	1.29
Total alkalinity (meq.L^{-1})	0.30	0.11	0.10	0.03	0.02	0.02	0.09	0.02
Suspended matter (mg.L^{-1})	75.2	47.40	61.4	37.49	23.0	13.71	42.4	29.61
Ammoniacal-N (mg.L^{-1})	15.9	17.70	6.7	4.61	4.0	0.17	5.0	2.29
NO_3-N (mg.L^{-1})	18.6	18.92	31.4	17.00	30.9	20.69	71.7	17.95
NO_2 -N (mg.L^{-1})	7.7	4.91	5.3	1.35	7.5	3.61	5.2	0.97
Dissolved-N (mg.L^{-1})	0.57	0.17	0.38	0.04	0.36	0.06	0.34	0.05
Total-N (mg.L^{-1})	0.91	0.19	0.57	0.09	0.56	0.10	0.49	0.08
PO_4 -P(mg.L^{-1})	31.7	14.12	28.8	14.66	16.5	11.86	7.2	4.15
Dissolved-P (mg.L^{-1})	78.2	29.25	63.6	13.54	40.4	19.80	20.6	8.27
Total-P (mg.L^{-1})	110.9	48.04	111.2	35.33	63.6	31.84	53.5	61.48

Table II: Correlations of the variables with Principal Components 1 and 2.

Component loadings	**1**	**2**
Temperature	0.043	-0.634
pH	0.525	0.746
Conductivity	0.613	0.593
Dissolved O_2	-0.342	0.846
Salinity	-0.042	0.563
K	0.696	-0.562
Total alkalinity	0.815	0.254
Suspended matter	0.360	0.256
Ammoniacal-N	0.763	0.206
NO_3-N	-0.636	0.154
NO_2-N	0.253	-0.438
Dissolved-N	0.864	0.035
Total- N	0.953	0.059
PO_4-P	0.748	-0.438
Dissolved-P	0.912	-0.142
Total-P	0.730	0.137
variance explained by components	6.677	3.282
percent of total variance explained	41.733	20.514

this Component 1. The variables water temperature, pH and percentage of oxygen saturation are correlated to Principal Component 2. The two first Principal Components explain 62.2% of the total variance.

Fig. 2 shows the ordination by principal components (1 and 2) of the studied areas. It is clear that studied area from the Branco River is located in the upper left quadrant during the four seasons while studied area from the Preto River is in the lower left quadrant. The studied area from the Guaú River is located in the right side of the figure being in the upper quadrant in winter and autumn and in the lower quadrant in summer and spring. The studied area from the Aguapeú River is always located in the central part of the figure. The Principal Component Analysis showed that studied areas from the rivers Branco and Guaú have very distinct limnological characteristics while studied areas from the rivers Aguapeú and Preto have similar limnological characteristics.

Fig. 3 shows that the mean annual values of ammoniacal nitrogen, dissolved N and total N are significantly ($p<0.05$) higher in studied area from the Guaú River than in studied areas from rivers Aguapeú, Preto and Branco. In these 3 rivers that variables do not present significantly differences. In relation to P availability, the mean annual values of orthophosphate, dissolved P and total P are significantly higher ($p<0.05$) in studied areas from the rivers Guaú and Aguapeú than in studied areas from the rivers Branco and Preto.

Fig. 4 shows the mean annual values and standard error of biomass (g $DM.m^{-2}$) for the two studied species. It was noticed higher mean values for the biomass of P. stratiotes in studied area from the Aguapeú River, values a little lower for this species in studied area from the Guaú River and even lower values of S. molesta in studied areas from the rivers Preto and Branco.

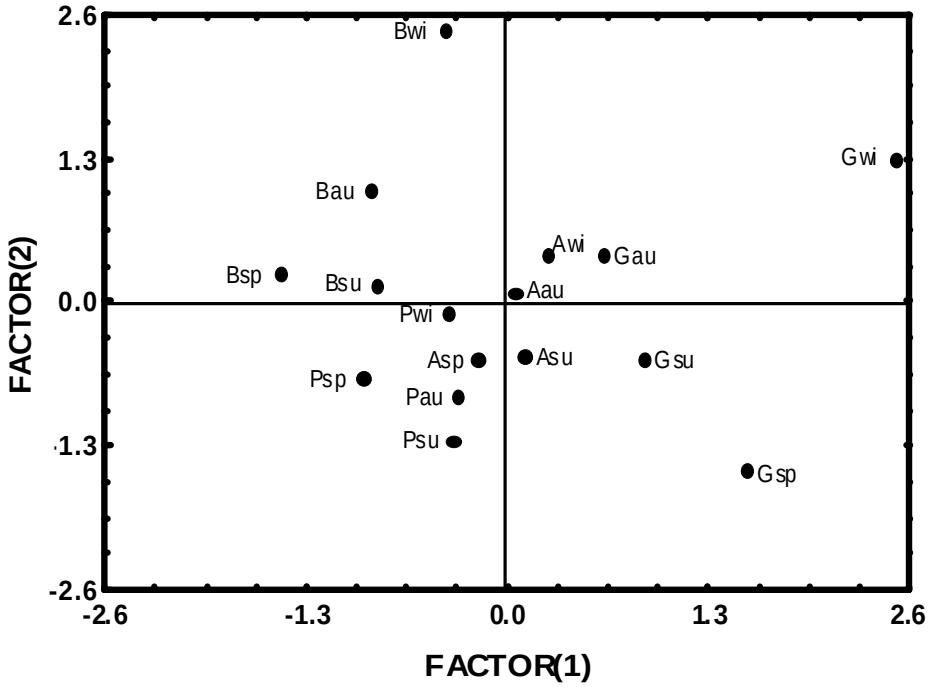

Figure 2: Principal Components Ordination (factors 1 and 2) of the studied areas based upon limnological variables analysed. (G = Guaú, A =Aguapeú, P = Preto, B = Branco. Su = summer, au = autumn, wi = winter, sp = spring).

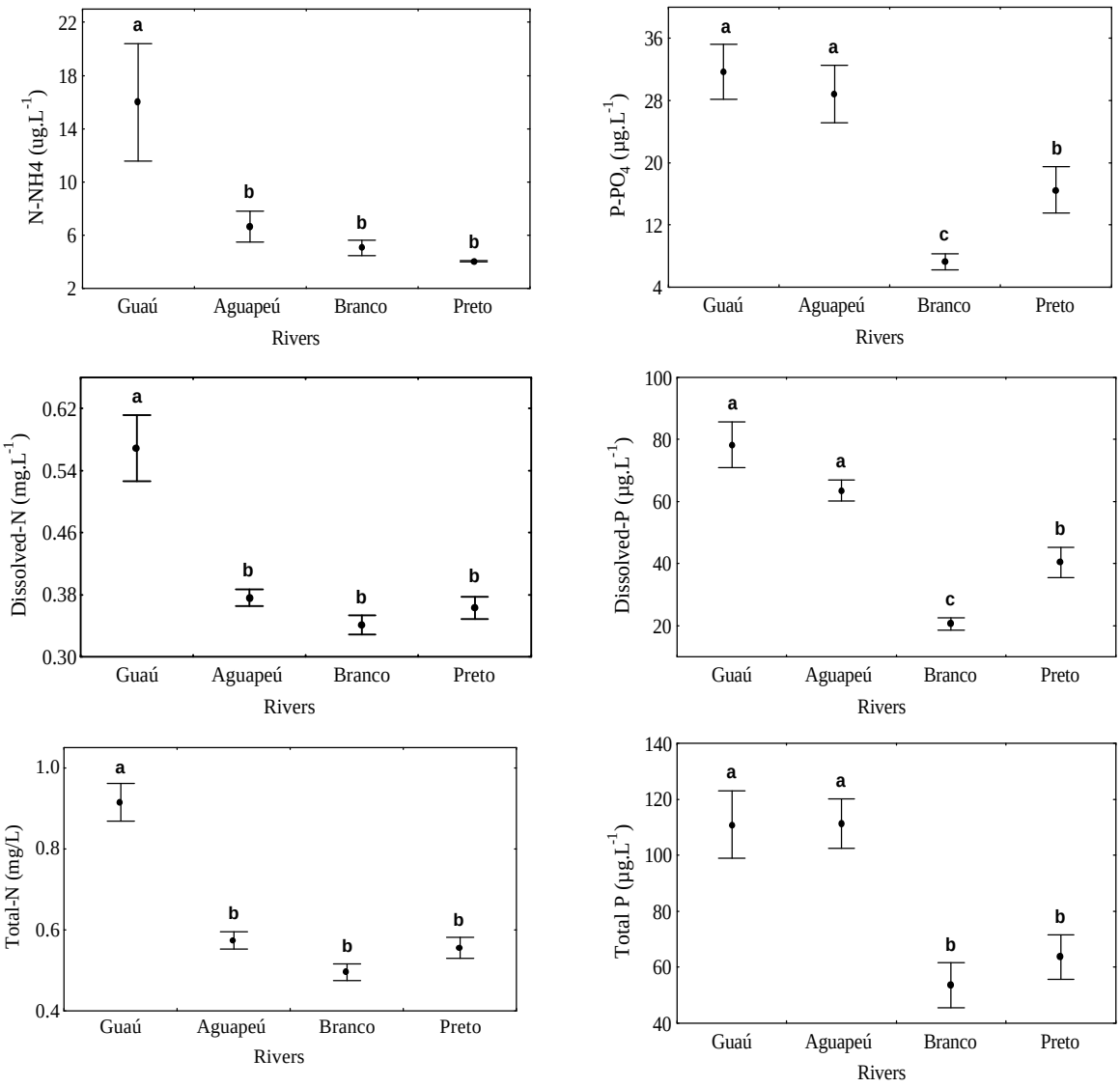

Figure 3: Mean annual concentrations and standard error of orthophosphate (PO_4-P), dissolved phosphorus (Dissolved-P), total phosphorus (Total-P), ammoniacal nitrogen (Ammoniacal-N), dissolved nitrogen (Dissolved-N) and total nitrogen (Total-N) in water from the studied areas of the rivers Guaú, Aguapeú, Branco and Preto. Different letters indicate significant differences ($p \leq 0.05$).

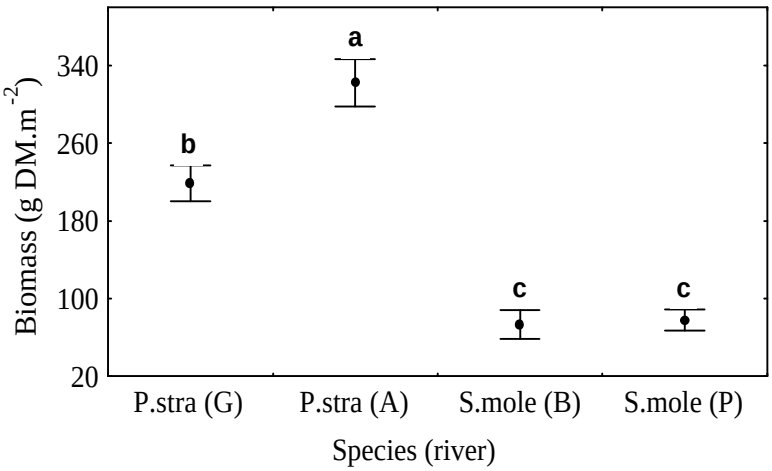

Figure 4: Annual mean and standard error of the biomass (g DM.m^{-2}) of P. stratiotes (P. stra) and S. molesta (S. mole) in studied areas from the rivers Guaú (G), Aguapeú (A), Branco (B) and Preto (P). Different letters indicate significant differences ($p \leq 0.05$).

Discussion

Physical and chemical variables of the waters in studied areas from the rivers Guaú and Branco are very distinct and, probably these differences are responsible for the occurrence of P. stratiotes in the first and S. molesta in the second river. In fact, many studies focusing distribution of aquatic macrophytes asseverate that macrophytes occurrence is determined by many factors like temperature, light intensity, current flow speed and nutrients availability (Bini, et al., 1999; Thomaz et al., 1999). These studies of distribution emphasize that free floating macrophytes occur in general in eutrophic or hypereutrophic environments. However, the abiotic limnological characteristics in studied areas from the rivers Aguapeú and Preto are similar according to Principal Components Analysis and the studied area from the Aguapeú River is colonized by P. stratiotes and of Preto River by S. molesta. Only phosphorus concentrations in water column are different between these two rivers. In addition, phosphorus concentrations in studied area from the Aguapeú River are similar to Guaú River and phosphorus concentrations in studied area from the Preto River are similar to Branco River. According to total P concentration in water, the studied areas from the rivers Aguapeú and Guaú are classified like hypereutrophic and studied areas from the rivers Branco and Preto like eutrophic (Wetzel, 1983). Probably, phosphorus concentration in water column is an important factor that influences the distribution of P. stratiotes and S. molesta in rivers from the Itanhaém River basin. Other studies showed that P. stratiotes have higher growth rate in waters with higher concentrations of phosphorus. Henry-Silva et al. (2002) observed higher growth rate of this species (0.031 day^{-1}) in water with 77 $mg.L^{-1}$ of total P and lower growth rate (0.016 day^{-1}) in water with 15 $mg.L^{-1}$ of total P. In waters colonised by Salvinia sp., Camargo & Esteves (1995) found orthophosphates concentrations ‹ 5.0 $mg.L^{-1}$ during nine months of the year and only during the summer (December, January and February) the concentrations increase to 14 $mg.L^{-1}$. In addition, Henry-Silva et al. (2002) observed high growth rate (0.029 day^{-1}) of S. molesta in water with 15 $mg.L^{-1}$ of total P. Although the two species occur in environments with higher levels of phosphorus, probably, P. stratiotes is a species that requires highest concentration of phosphorus than S. molesta that grows in areas with lower total P concentration in water.

The non-coexistence of the two species in the same stand is, probably, due to the limiting phosphorus concentration for the growth of P. stratiotes in the regions were S. molesta grows. Benassi & Camargo (2000) studying the competition of these two species in water with low concentrations of nutrients verifies that S. molesta increase the biomass while P. stratiotes decrease. On the other hand, in regions were the concentration of this nutrient is higher P. stratiotes grows abundantly and, probably, the competition for space prevents the development of S. molesta. P. stratiotes presents a higher size with more developed leaves growing over and shading S. molesta. This is supported by the fact that the mean values of biomass of P. stratiotes are higher than 200 g $DM.m^{-2}$ while the ones for S. molesta are lower than 80 g $DM.m^{-2}$.

We conclude that the concentration of phosphorus in water, probably, is an important factor for the distribution of P. stratiotes and S. molesta in rivers from the Itanhaém River basin.

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