Limnological parameters in the water accumulated in tropical bromeliads.

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ABSTRACT: Limnological parameters in the water accumulated in tropical bromeliads. The aim of this research was to study whether the phenological differences between Neoregeria cruenta (Graham) and Aechmea nudicaulis (L.) Griseb species, as well as their position in relation to the surrounding vegetation, have influence on the following parameters in the water accumulated in the tank from these species: volume, temperature, conductivity, pH and solids in suspension as well as dissolved oxygen concentrations, dissolved organic carbon, nitrate and ammonia. The oxygen and pH profiles in the water accumulated in 5 N. cruenta individuals were also studied during 24 hours. This study was carried out with bromeliads from Restinga de Jurubatiba National Park (Macaé- RJ). The results of this study show that: 1) limnological parameters in the accumulated water column are influenced by species phenological variations; 2) the bromeliad position in relation to the surrounding vegetation is an important and determinant factor on some physic-chemical parameters in the water accumulated in the bromeliads; 3) respiration ratios are higher than production (R:P›1), which characterizes the metabolism of the studied water bodies as heterotrophic and 4) the water column formed in the bromeliads showed a clinograde oxygen profile.
Key-words: Bromeliads, metabolism, oxygen, pH, Neoregeria cruenta, Aechmea nudicaulis.

RESUMO: Parâmetros limnológicos de água acumulada em bromélias tropicais. O objetivo desta pesquisa foi estudar se as diferenças fenólogicas entre as espécies Neoregeria cruenta (Graham) e Aechmea nudicaulis (L.) Griseb, bem como o posicionamento destas em relação a vegetação circundante, tem influência sobre os parâmetros: volume, temperatura, condutividade, pH e material em suspensão e as concentrações de oxigênio dissolvido, carbono orgânico dissolvido, nitrato e amônia da água acumulada nestas espécies. Também foram estudados os perfis de oxigênio e pH ao longo de 24 horas da água acumulada em 5 indivíduos de N. cruenta. Este estudo foi realizado com bromélias localizadas no Parque Nacional da Restinga de Jurubatiba (Macaé- RJ). Os resultados desta pesquisa indicam que: 1) os parâmetros limnológicos da coluna d'água acumulada são influenciados pelas variações fenológicas; 2) a posição da bromélia em relação à vegetação circundante é um importante fator determinante sobre alguns parâmetros físico-químicos da água acumulada nas bromélias; 3) as taxas de respiração são superiores às de produção (R:P›1), caracterizando o metabolismo dos corpos hídricos estudados como heterotrófico e 4) a coluna d'água formada nas bromélias apresentou um perfil de oxigênio clinogrado.
Palavras-chave: Bromélias, metabolismo, oxigênio, pH, Neoregeria cruenta, Aechmea nudicaulis.

Introduction

The Family Bromeliaceae, which belongs to the Bromeliales order, present approximately 2000 species in the American continent; most of them are found in the subtropical or tropical region. There are epiphytes and terrestrial bromeliads which occupy an area from sea level to 4000 m above, from Peruvian deserts to tropical forests (Frank, 1983). The bromeliads which are able to store water and detritus in their leaves are called bromeliad-tanks (Phytotelmata), and they can store up to 45 liters of water.

The water column formed by bromeliad-tanks is a relatively stable habitat to the aquatic biota, sheltering aquatic organisms such as phytoplankton, zooplankton and protozoan, which include primary producers, consumers and decomposers (Frank, 1983). These tanks are also useful food resources for preys and humidity for other animals, including small terrestrial vertebrates and amphibians, besides being a favorable spot for spawning and insect development (Laessle, 1961; Frank, 1983; Bermudes & Benzing, 1991; Lopez, 1997).

In the early 20th century, Picado (1912) referred to the micro-ecosystem formed by bromeliad-tanks as small lakes. Laessle (1961) was the first one to carry out research on bromeliad-tanks as if they were miniature lakes or marshes, realizing what he called "micro limnology". More recently, the bromeliad-tanks have been defined as a microcosm, a unique habitat with high diversity, where physical, chemical and biological parameters can be studied mainly due to its small size and definite limits (Richardson et al., 2000).

Several parameters can influence the bromeliad-tank metabolism. An aquatic ecosystem metabolism can be expressed, in a simplified way, by the balance between the autotrophic production and heterotrophic mineralization processes (Odum, 1956). Since the main regulator factors of the aquatic metabolism are nutrient availability, organic matter and light radiation (Hanson et al., 2003), the place where the bromeliad develops can influence the water column metabolism of its tank. The bromeliads that develop directly under the sunlight receive a higher incidence of light radiation as well as rain and a smaller input of organic matter (e.g. leaves), contrary to the bromeliads that develop in the shadow of plants (Scarano et al., 2002).

The aim of this research was to study whether the phenological differences between Neorogelia cruenta and Aechmea nudicaulis species, as well as their position in relation to the surrounding vegetation, have influence on some physic-chemical parameters in the water accumulated in these species. The oxygen profiles in the water accumulated in 5 N.cruenta individuals were also studied.

Material and methods

This current study was carried out in the coastal sandy plain adjacent to Cabiúnas lagoon, located in Restinga de Jurubatiba National Park, approximately 200 km north-westerly far from Rio de Janeiro city (Fig. 1).

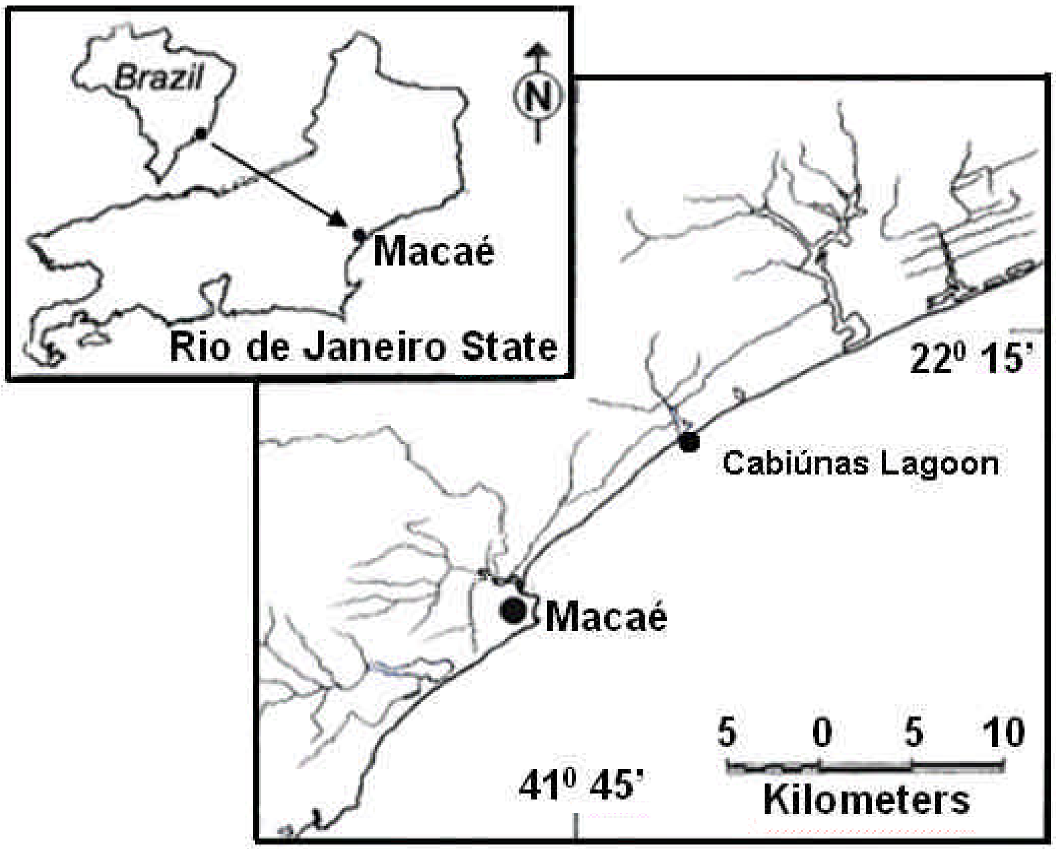

Figure 1: Study area

The regional climate is semi-humid and the mean annual rainfall is 1300 mm being the rainy period between November and March and the dry period between April and October. The mean annual relative humidity is 83% and annual temperature is approximately 22°C – 29.7° in January and 19°C in July (Panosso et al., 1998).

The sampling site vegetation is classified as open bushy of Clusia hilariana, which consists of dense bushes that vary from 1 to 1000m², with open sandy substrate and scattering vegetation between them. Neoregeria cruenta (Graham) and Aechmea nudicaulis (L.) Griseb bromeliads, used in this study, are among the main species of bromeliads found in the border and interior area of bushes together with Allagoptera arenaria and Pilosacereus arrabidae (Zaluar, 1997) species.

In Jurubatiba coastal sandy plain we find A. nudicaulis and N. cruenta side by side in the same environment, and N. cruenta under different environmental conditions. A. nudicaulis has a central tank with a narrow, long, tube-like opening and reduced lateral veins. N. cruenta individuals have a more open central tank, which enables a higher sunlight radiation incidence in the water column. A. nudicaulis and N. cruenta subjected to shading and input of organic matter from C. hilariana bushes, as well as individuals of N. cruenta exposed direct to the sunlight were chosen for comparison.

The limnological parameters studied in the water column formed in N. cruenta and A. nudicaulis were: volume, temperature, conductivity, pH and solids in suspension as well as dissolved oxygen concentrations (O_2), dissolved organic carbon (DOC), nitrate and ammonia. In July 2002 water samples were taken from central tanks of the following bromeliad groups: N. cruenta exposed to direct sunlight (N = 8) nominated as N. cruenta sun; N. cruenta in the shadow of C. hilariana bushes (N = 8) nominated as N. cruenta shadow and A. nudicaulis exposed to sunlight (N = 8) nominated as A. nudicaulis sun.

The water contained in the bromeliad-tanks was collected using a 5 mm-diameter tube coupled to a syringe. The samples were placed into polyethylene flasks. Temperature as well as O_2 concentrations were determined in the field at 11:00 hours on a clear sky day using of a portable oxygen meter TOA 11D. pH was measured with a pH meter Digimed and conductivity was determined by a conductive meter YSI. An aliquot of 20 mL of the collected water was filtered in the field, through a GF/C filter, which was later used to determine the amount of solids in suspension in the water by gravimetry. The filtered samples were frozen and DOC (TOC Shimadzu 5000), ammonia and nitrate (Mackereth et al., 1978) were later measured. Data that presented normal distribution were compared by ANOVA, followed by a paired Tukey post hoc test. The data of the three groups (N. cruenta sun, N. cruenta shadow and A. nudicaulis sun) were compared two by two among themselves. Data that did not present normal distribution were compared by Kruskal-Wallis test (significant, $p < 0.05$).

A daily variation on O_2 concentrations and pH values in the water column of 5 N. cruenta individuals was measured in January 2003, one day after a heavy summer rain that filled the bromeliad-tanks so that the water column presented its highest levels. These individuals were around a Clusia hilariana bush, subjected to the same light intensity and input of leaves from vegetation. The auto or heterotrophic state of the bromeliad water column was evaluated by the balance of oxygen concentrations during 24 h which were studied according to the interaction made by Profix Software (Berg et al., 1998). The effects of inaccurate corrections related to gaseous exchanges in water-atmosphere interface are reduced as the bromeliad leaves protect its water tank against wind action. Oxygen and pH profiles were measured at 6:00, 10:00, 14:00, 18:00 and 6:00 hours on the following day. Oxygen concentrations in daily variation were determined through a minieletrode Clark type (Unisense.co) and pH values were measured with pH meter Digimed. Due to pH electrode thickness, it was not possible to measure pH down to the bottom of the tank-bromeliads. The statistical treatment was performed with non-parametric tests, because even after the data transformation by logarithm (base 10), significant normality was not obtained. Statistical differentiation between initial and final processes was obtained by Kruskal- Wallis analysis (significative, $p < 0.05$).

Results and discussion

The results of this research clearly show that the limnological parameters in the accumulated water column are influenced by N. cruenta and A. nudicaulis phenological variations (Tab. I). Due to phenological differences of both bromeliad species, temperature and oxygen values in N. cruenta sun water column were significantly higher than those in A. nudicaulis sun individuals (Tukey-Kramer, $p < 0.05$). As N. cruenta sun presents a larger surface and lateral tanks with a good capacity of rain water storage, the accumulated water volume was significantly higher than that in A. nudicaulis sun (Tukey-Kramer, $p < 0.05$). Lopez et al. (1993) found significant differences among the organisms that inhabited A. nudicaulis and N. cruenta bromeliads under the same environmental conditions, suggesting that the morphology of the species can influence the microclimatic characteristics as well as the community of the tank of these plants.

N. cruenta individuals exposed to sunlight present significantly higher temperature and oxygen values than those in shadow (Tuckey-Kramer, $p < 0.05$; Tab. I), indicating that the bromeliad position in relation to the surrounding vegetation was also an important determinant factor on some physic-chemical parameters in the water accumulated in the bromeliads.

Table I: Mean ± SD (n=8) of the biotic factors in water column acumulated in the bromeliad-tanks Neoregeria cruenta and Aechmea nudicaulis exposed to sun and N. cruenta in the shadow of Clusia hilariana bushes. Different letters indicate significant differences between the same parameter (Tukey-Kramer, $p < 0.05$).

Parameter	**N. cruenta sun**	**N. cruenta shadow**	**A. nudicaulis sun**
Volume (ml)	392.8 ± 91.3^{a}	232.3 ± 96.6^{b}	179.7 ± 65.7^{b}
Oxygen (mg L^{-1})	123.4 ± 39.8^{a}	28.8 ± 6.9^{b}	45.6 ± 14.2^{b}
Temperature (^{o}C)	32.4 ± 1.8^{a}	28.7 ± 1.2^{b}	29.8 ± 0.8^{b}
Conductivity (mS cm^{-1})	0.04 ± 0.03^{a}	0.08 ± 0.06^{a}	0.04 ± 0.02^{a}
pH	4.57 ± 0.83^{a}	5.54 ± 0.37^{b}	5.59 ± 0.85^{b}
Solids in Suspension (mg L^{-1})	0.26 ± 0.15^{a}	0.53 ± 0.31^{a}	0.32 ± 0.14^{a}
Dissolved organic carbon (mmol L^{-1})	1.93 ± 0.31^{a}	4.13 ± 0.46^{b}	$3.55 \pm 0.22^{a.b}$
Nitrate (mmol L^{-1})	0.8 ± 0.3^{a}	1.0 ± 0.3^{a}	1.0 ± 0.3^{a}
Ammonium (mmol L^{-1})	3.9 ± 2.1^{a}	9.3 ± 3.0^{b}	4.2 ± 1.0^{a}

A higher incidence of photosynthetically active radiation promotes a rise in temperature and primary production in the water column, which promotes an increase in oxygen concentration. Despite the fact that the diameter of N. cruenta shadow bromeliads was bigger than that of N. cruenta sun (unpublished data), the water volume in N. cruenta sun was significantly higher than that in N. cruenta shadow individuals (Tuckey-Kramer, $p < 0.05$; Tab. I), what can be attributed to the interception of the rain by the Clusia bushes.

The highest organic matter input and the lowest solar radiation incidence in N. cruenta shadow probably promoted more favorable conditions to a more heterotrophic metabolic balance than in N. cruenta sun water column. The water column in individuals from N. cruenta shadow presented significantly lower oxygen concentrations and higher ammonia and dissolved organic carbon concentrations (Tuckey-Kramer, $p < 0.05$; Tab. I) than individuals from N. cruenta sun, highlighting a higher intensity of heterotrophic metabolism in the water column in individuals from N. cruenta shadow. Reduced oxygen concentrations and increased ammonium concentrations indicate the prevalence of heterotrophic in relation to the autotrophic processes (Fenchel, et al., 1998).

The absence of significant differences among the electric conductivity values, in the tanks of the three bromeliad groups, can be attributed to the fact that the plants are located from the same distance from the sea and are influenced by the same amount of salt water steam (Hay & Lacerda, 1984). The nitrate and solids in suspension concentrations did not differ significantly among the three bromeliad groups either (Tuckey-Kramer, $p < 0.05$; Tab. 1).

In the five N. cruenta sun individuals, in which daily variations of oxygen and pH were measured, a clinograde oxygen profile was recorded, with the presence of an anoxic water layer that varied from 1 to 6 centimeters. Oxygen and pH values were significantly higher on the surface of the tank water column (Kruskal-Wallis, $p < 0.05$; Figs. 2 and 3). This difference can be attributed to the organic matter decomposition accumulated at the bottom of the bromeliad water tank. Besides the oxygen consumption, the decomposition process also causes a release of organic acids and CO_2, which reduce water pH (Wetzel, 2001). The O_2 stratification was also favored by the form of the bromeliads as their leaves protects its water column from wind upwelling.

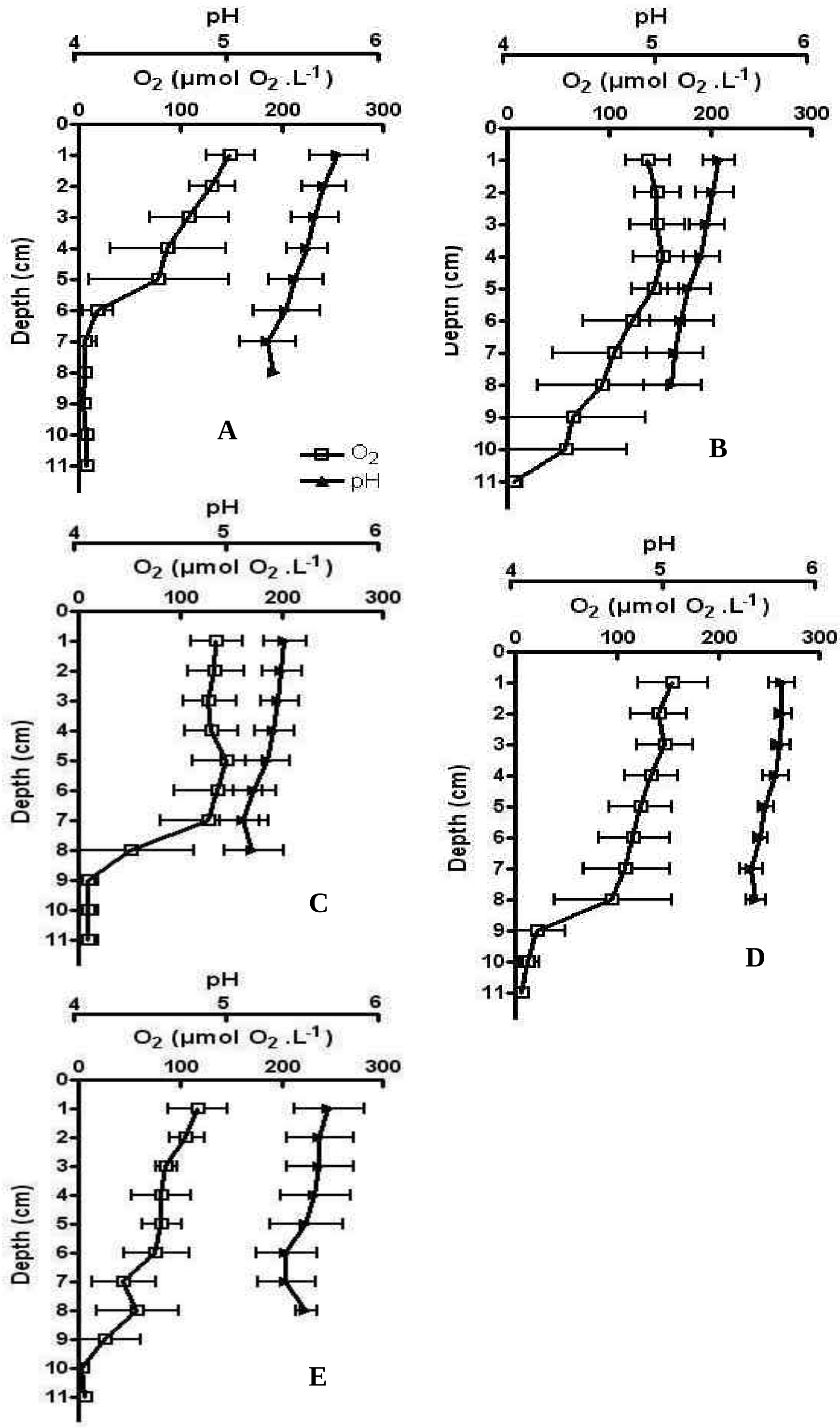

Figure 2: Oxygen and pH profiles in 5 different bromeliad-tanks (A, B, C D and E). Values represent the mean ± SD of the measurements obtained at 6:00, 10:00, 14:00 18:00 and 6:00 hours.

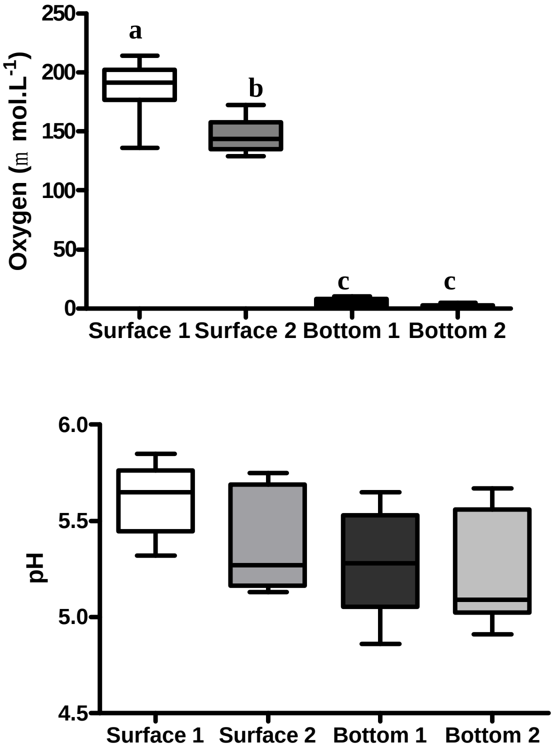

Figure 3: Comparison of oxygen concentrations (A) and pH values (B) at the surface and bottom at 6:00 hours from the first (1) and second (2) sampling days (Mann-Whitney, $p<0.05$). (Different letters represent significant differences).

The O_2 consumption or production rate was calculated from the average of the oxygen profiles in the N. cruenta sun water column (Fig. 2). In all bromeliads, the respiration rates were higher than the production (R:P >1), which characterizes the metabolism of these water bodies as heterotrophic. The respiration rates varied from 26 to 40 mmol O_2 $L^{-1}d^{-1}$ with an average of 34.5 ± 6 mmol O_2 $L^{-1}d^{-1}$ (mean ± SD). The prevalence of heterotrophic metabolism is usually found in continental aquatic environments (Cole & Caraco, 2001). The heterotrophic metabolism in N. cruenta water column was evident, due to significant reduction of O_2 values measured at 6:00 from the first to the second sampling days (Kruskal-Wallis, $p < 0.05$; Fig. 3A), a pattern that was also observed to pH values (Fig. 3B).

Conclusion

The results presented in this research led us to the conclusion that the phenological characteristics of the bromeliad species, as well as the place where it develops, influence the metabolism of accumulated water bodies in bromeliads-tanks. The water column formed in the bromeliads presented a clinograde oxygen profile, whose metabolism was classified as heterotrophic, since the respiration rate overcomes the primary production.

The aquatic microcosms formed in bromeliad-tanks can be used to study ecological processes, as they present great variability and a peculiar fauna, which can be use for the studies of trophic chains (Srivastava, 2004). Experiments that use the whole ecosystem (such as a whole lake) have the advantage of being more realistic, but they are difficult and expensive to be performed and they have been not easily replicated (Srivastava, 2004). The micro ecosystems formed in Phytotelmata allow the achievement of experiments which associate the whole ecosystem complexity with the reproducibility provided by its reduced size (Carpenter, 1996; Schindler, 1998).

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