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Influence of Water Level Fluctuation on the Mortality and Aboveground Biomass of the Aquatic Macrophyte *Eleocharis interstincta* (VAHL) Roemer et Schults

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ABSTRACT

The goal of this study was to study the biometric alterations of Eleocharis interstincta in response to water level fluctuations in Cabiúnas Lagoon, located on the northern coast of the state of Rio de Janeiro, in the municipality of Macaé. Three quadrats of 0.0625 m^2 were harvested every two weeks from June/1997 to June/1998; samples were separated into stems, dead stems (detritus) and rhizome; lenghted, dried and weighted. The water level fluctuated seasonally in the macrophyte stand with two periods of drawdown. The first period occurred naturally at the end of winter and beginning of spring, when rainfall in the area was normally lowest. The second period of drawdown was the result of an artificial breaching of the sandbar that isolate the lagoon from the sea. The breach was made in the summer, at the time of highest rainfall, when the water level in the lagoon reached the maximum value recorded during the study (1.35 m). There was a strongly positive correlation of the water level with stems mean height and aboveground biomass, indicating that water level played an important role in the determination of these parameters. There was a significant difference between stem height (ANOVA; $p < 0.001$) and biomass (ANOVA; $p < 0.001$) in each sampling period, ranging from 143.9 cm and 338.8 g dry wt.m^{-2}, before the sandbar opening, to 16.3 cm and 20.2 g dry wt.m^{-2} respectively after the sandbar breaching. The drastic variation of the water level, leading mass mortality of the stems, together with the lowest mean biomass/stem (0.057 g dry wt.individual^{-1}), recorded after the sandbar breaching, did not represent a strong disturbance for E. interstincta, since the resilience time estimated for this population was about 30 days.

Keywords: Aquatic macrophytes, biomass, coastal lagoon, *Eleocharis interstincta*, water level fluctuation

INTRODUCTION

Coastal lagoons occur along the entire coast of Brazil, and are one of the most representative country's continental aquatic ecosystems (Esteves, 1998). Besides their widespread occurrence, coastal lagoons are known for their high productivity, exhibiting values comparable to those of estuaries and upwelling oceanic regions (Knoopers, 1994). This high productivity, reflected in high fishery productivity, led the establishment of early fishing villages, many of which later grew into cities.

Coastal lagoons usually have low maximum and relative depths, and are therefore, highly influenced by dynamic action of winds and other

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climate factors (Panosso et al., 1998). The shallow depths characteristic of these ecosystems result in an extensive littoral region, allowing colonization of large areas by aquatic macrophytes (Esteves, 1998). The seasonality of rainfall in tropical regions causes marked fluctuations in the water level of most continental aquatic ecosystems. Many studies have demonstrated the influence of water level fluctuations on biomass, growth, production, and distribution of aquatic macrophytes in both temperate (Linthurst and Reimold, 1978; Seischab et al.. 1985; Pip and Sutherland-Guy, 1987; Squires and Van Der Valk, 1992; Froend and McComb, 1994; Rea and Ganf, 1994) and tropical ecosystems (Junk and Piedade, 1993 a, b; Villar et al.. 1996). Some studies have been done in tropical coastal lagoons (Furtado, 1994; Brum and Esteves, 2001; Santos and Esteves, 2002). However, few investigators have examined the consequences of water level fluctuations in the biometry of aquatic macrophytes species. We intended to test the hypothesis that water level was an important driving force in coastal lagoons, like it has been in floodplains ecosystems (Junk and Piedade, 1993 a, b), which determine height and biomass of *Eleocharis interstincta*. This study had as its goal to measure the biometric changes in this emergent aquatic macrophyte, in response to water level fluctuations.

MATERIALS AND METHODS

Study Area

The Cabiúnas Lagoon has an area of 0.35 km^2, with a high perimeter/volume ratio and a maximum depth of 3.50 m (Fig. 1). It is located on the northern coast of Rio de Janeiro state, between the municipalities of Macaé and Carapebus (22^o to 22^o 30’ S and 41^{o}30’ to 42^o W). Its origin is associated with the formation of sandbars in the last oceanic regression (Esteves, 1998). Occasionally, the sandbar that separates the coastal lagoon from the ocean is opened, usually artificially with the aim of controlling the effect of floods by lowering the water level and/or allowing the entry of economically important fishes (Faria et al., 1994; Albertoni et al.,1999). The sandbar is about 20 m wide and is occasionally run over by the waves, which bring salt water into the lagoon. However, salinity in the lagoon is usually very low since the water level in the lagoon is above mean sea level. The climate of the region is subhumid/humid, with little or no water deficit, and mesothermal with the heat well-distributed throughout the year. Mean annual relative humidity is 83%. Mean annual temperature is about 22 ^{o}C, with the January (summer) mean being 25 ^{o}C, and the July (winter) mean being 19 ^{o}C. Mean annual precipitation is 1300 mm, concentrated in the spring and summer.

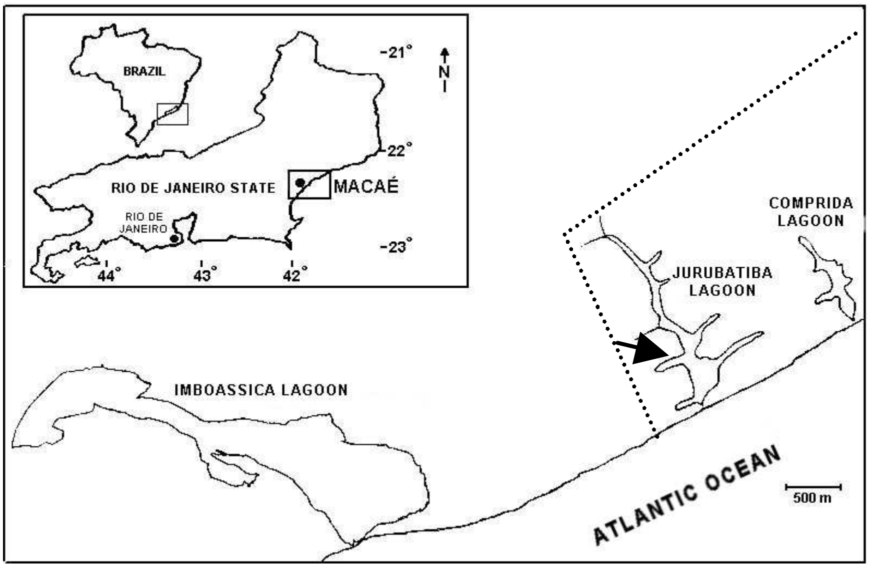

Figure 1 - Jurubatiba (Cabiúnas) lagoon in the National Park of Restinga de Jurubatiba, Macaé, RJ. The arrow indicates the sample area.

The period with the lowest rainfall is the winter, but there is no pronounced drought.

Winds are predominantly northeasterly throughout the year and to a lesser degree easterly, southeasterly, and southwesterly (Fiderj, 1977). Some littoral zone areas support dense stands of *Typha domingensis* and *Eleocharis interstincta*. In the deeper parts of the littoral zone, there are some aquatic macrophytes with floating leaves, such as *Nymphaea ampla* and *Nymphoides humboldtiana* (Henriques et al., 1988).

Biomass harvest

Sampling was performed every two weeks from June/1997 to June/1998 in the littoral region of Cabiúnas Lagoon. Three quadrats of 0.0625 m^2 were harvested, always in the middle part of *E. interstincta* stand, which was marked for further sampling. Twenty centimeters of sediment were removed to collect the aboveground (stems) and bellowground (roots-rhizome) parts of the plants. Water level was measured in each quadrat.

In the laboratory, the samples were washed with running water and separated into stems (more than 50 % of the stem height constituted by green tissue)cand dead stems (less than 50 % of the stem height constituted by green tissue). Stem length was measured, separated one by one and dried in a stove at 70 ^oC to constant weight.

Data analysis

The mean stems height and biomass in each sampling period were compared by one-way ANOVA and means compared using Tukey's HSD (honest significant difference) test. Density, dead stem, and aboveground biomass were compared by the non-parametric Friedman test, because data were not normally distributed. All analysis were performed using STATISTICA® 5.0 for windows.

RESULTS

Water level

The water level of Cabiúnas Lagoon changed seasonally, with two annual periods of drawdown. The first event occurred naturally in September/1997 (late winter - early spring), when rainfall in the region was lowest. During this, the water level gradually dropped until failed to cover the macrophyte stand in October/1997.

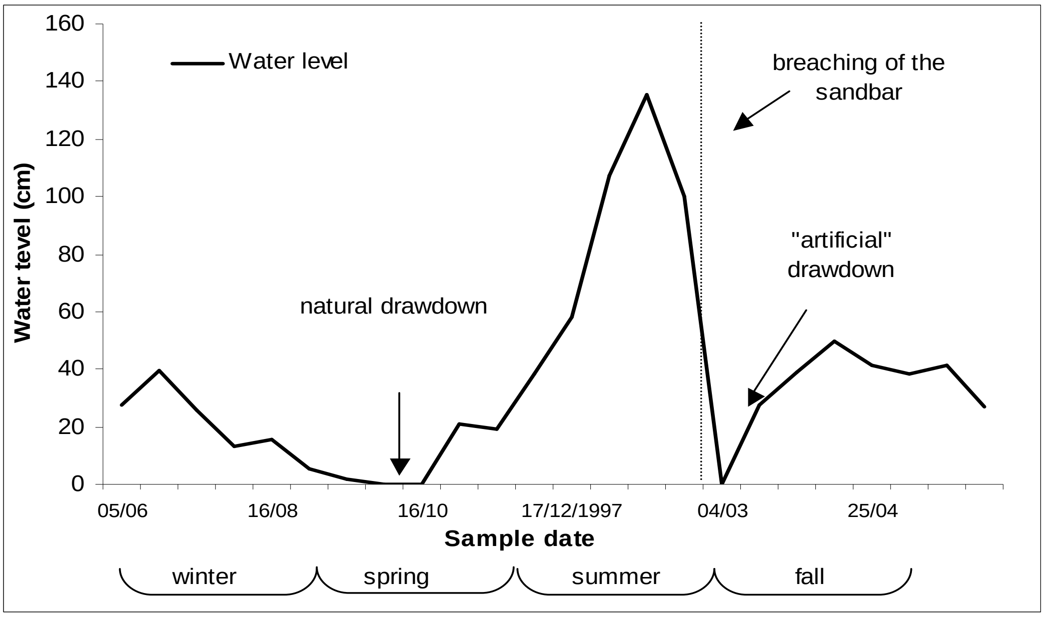

Figure 2 - Water level fluctuation in the Jurubatiba coastal lagoon between june/1997 to june/1998. The arrow indicates the artificial breaching of the sandbar (16/02/1998) and two periods of drawdown.

The second event occurred in February/1998 (summer), the season when rainfall was highest and at that time an uncommon increase in rainfall (398.8 mm) was recorded.
As a consequence, the sandbar, which separated the lagoon from the ocean was artificially breached by local people without government knowledge. Before the breaching, the water level in the stand was 1.35 m, the maximum value recorded during the study. The breaching of the sandbar drastically dropped the water level, which again failed to cover the stand. However, this reduction was abrupt, rather than gradual as in September/1997. After two weeks, the sandbar naturally re-formed and the water level began to rise gradually (Fig. 2).

Biometry
Fig. 3 shows the variation in stems height of *E. interstincta* during the study period. There was a significant difference between stems mean height (ANOVA; $p < 0.001$), ranging from 143.9 cm in February/1998, before the sandbar breaching, to 16.3 cm in the same month, after the sandbar breaching.
The sandbar breaching had a strong impact on this emergent aquatic macrophyte population, leading a sharp decrease in the stems aboveground biomass (Fig. 4), to the lowest value recorded during the study (Friedman, $p < 0.05$).
The values of aboveground biomass varied from 338.8 g dry wt.m^{-2}, when the water level reached its maximum, to 20.2 g dry wt.m^{-2}, after the sandbar breaching. Stems density (Fig. 5) did not exhibit a pattern similar to those found for height and aboveground biomass. The maximum value recorded occurred in the beginning of spring, when the water level aturally drewdown (Friedman, $p < 0.05$). The stem density was significantly lower, after the sandbar breaching, compared to the period when the water level was naturally drewdown.
The specific weight of the stems, i. e., the ratio between mean biomass and mean height (Fig. 6), varied from 5.38 mg dry wt.cm^{-1}, when the water level was naturally drewdown, to 2.42 mg dry wt.cm^{-1} after the sandbar breaching. The mean biomass/stem (Fig. 7) also was negatively influenced by the sandbar breaching, when it reached the lowest value recorded (ANOVA; $p < 0.001$) during the study (Tukey's test; $p < 0.05$).

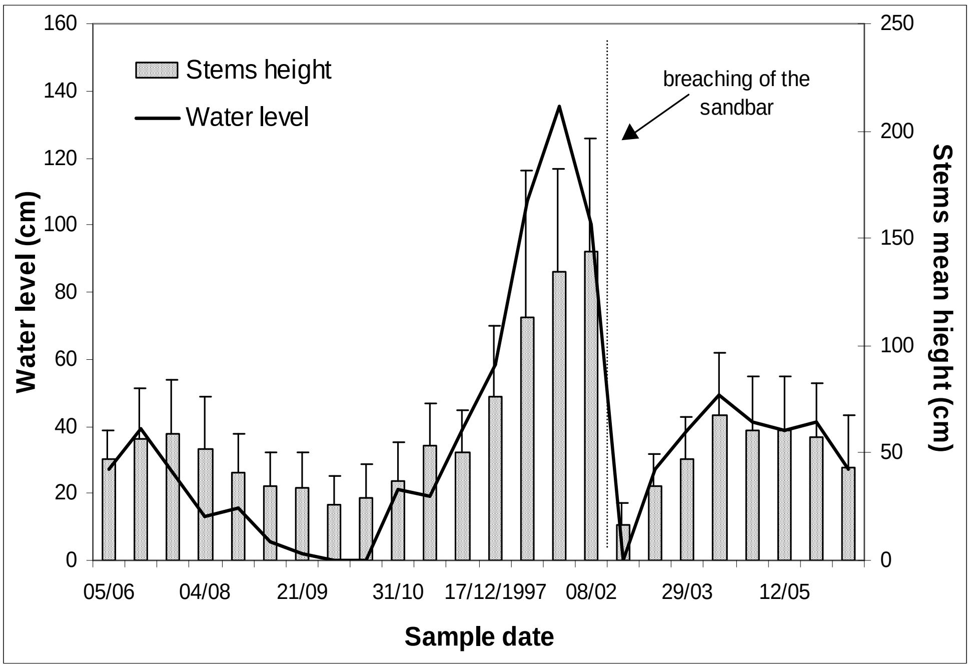

Figure 3 - Water level fluctuation and stems mean height of *E. interstincta* during sampling period. The error bar indicates standard deviation.

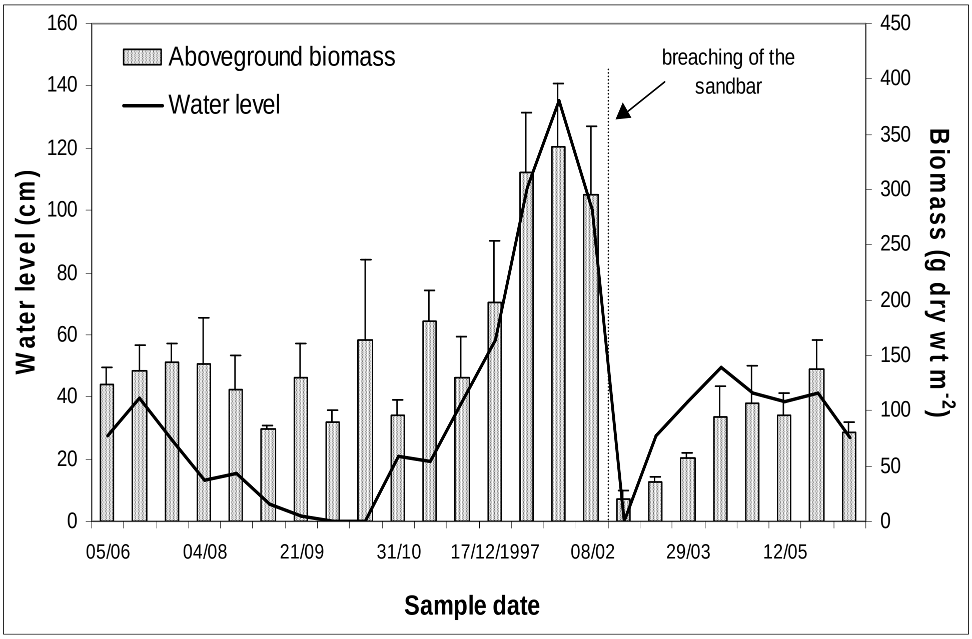

Figura 4 - Water level fluctuation and stems aboveground biomass of *E. interstincta* during sampling period. The error bar indicates standard deviation.

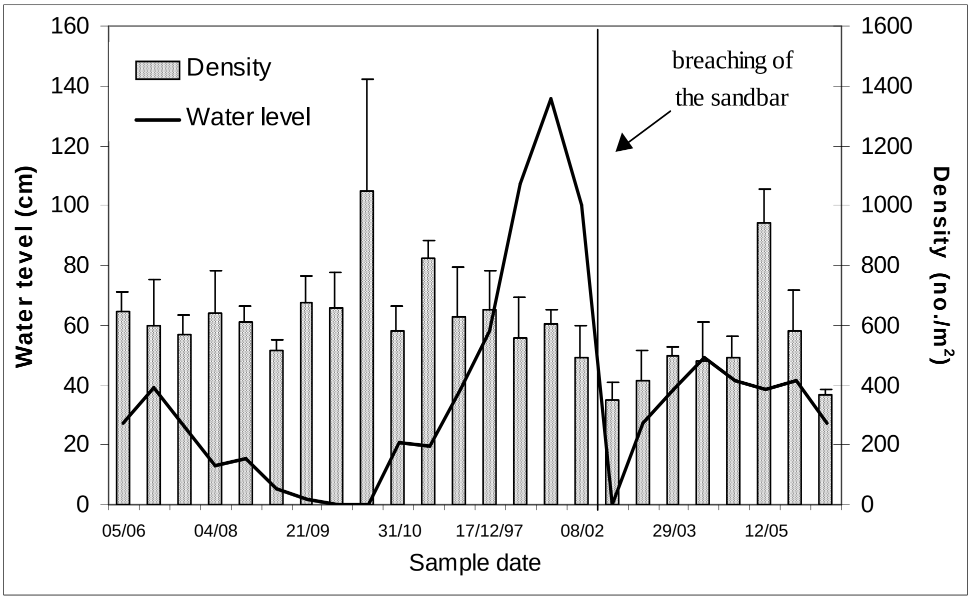

Figure 5 - Water level fluctuation and average stems density of *E. interstincta* during samplind period. The error bar indicates standard deviation.

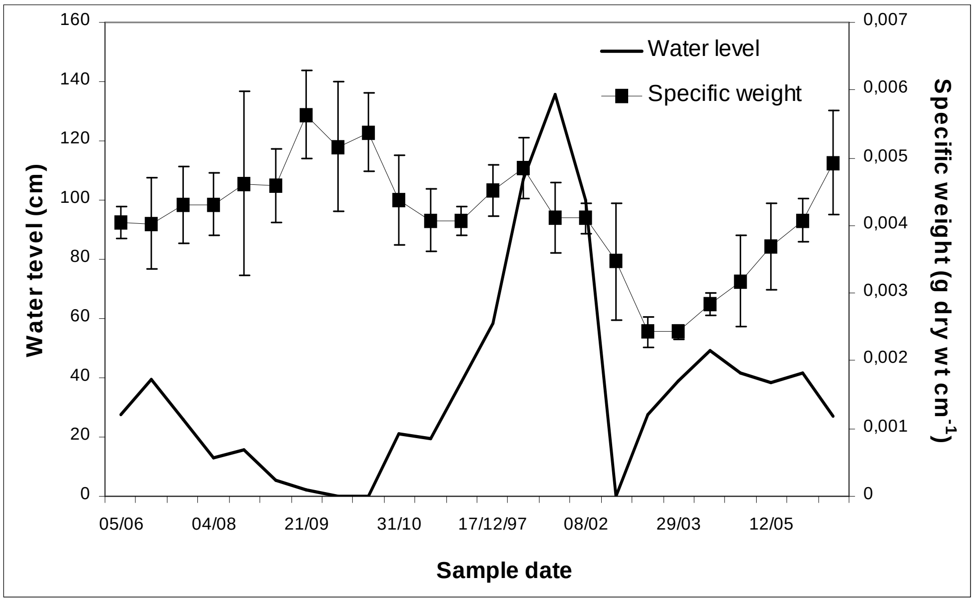

Figure 6 - Water level fluctuation and stems specific weight of *E. interstincta* during sampling period. The error bar indicates standard deviation.

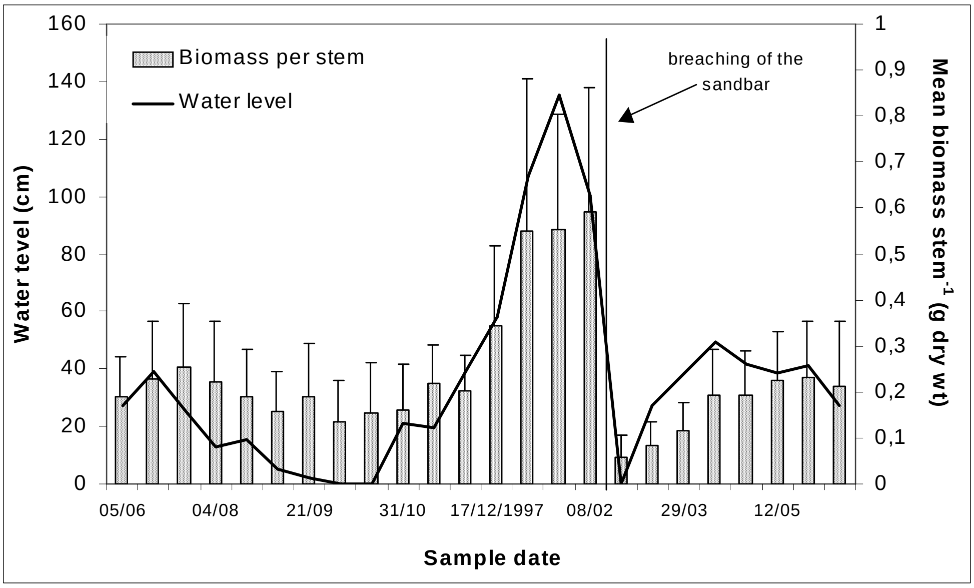

Figure 7 - Water level fluctuation and average biomass per stem of *E. interstincta* during sampling period. The error bar indicates standard deviation.

The variation of dead stem biomass (Fig. 8) was significantly different throughout the sampling period (Friedman, $p< 0.05$).
However, unlike the other variables, the dead stem biomass exhibited a different pattern, reaching the highest value (152.4 g dry wt.m^{-2}) when the water level was naturally drewdown. Water level was positively correlated with stem mean height and stem aboveground biomass (Fig. 9).

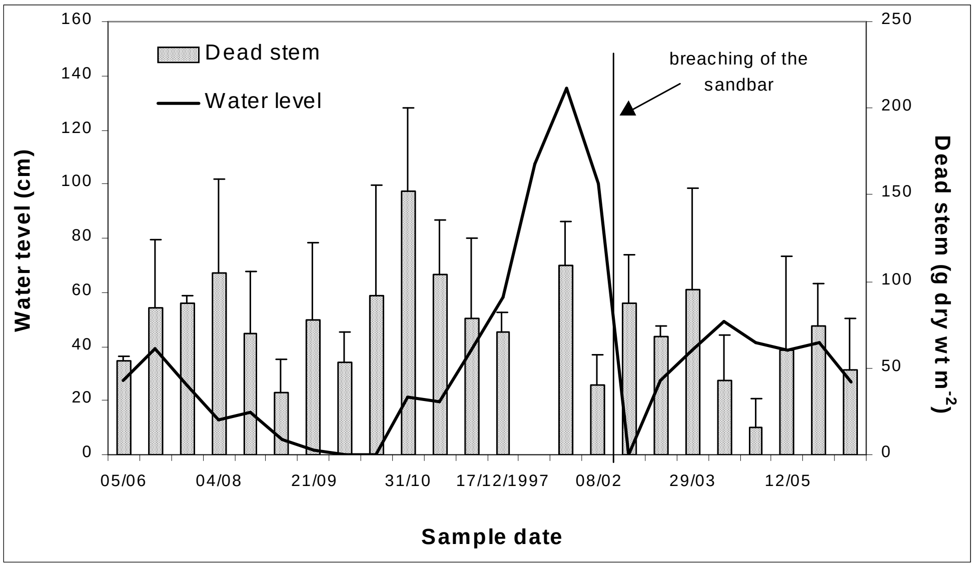

Figure 8 - Water level fluctuation and dead stem (detritus) biomass of *E. interstincta* during sampling period. The error bar indicates standard deviation.

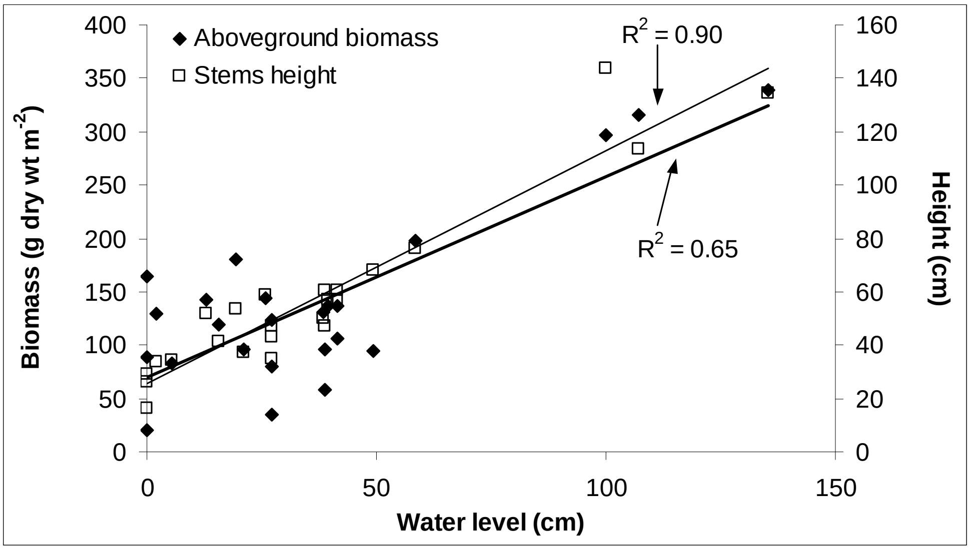

Figure 9 - Correlation of the water level with stems height ($p < 0,05$) and aboveground biomass ($p < 0,05$) of *E. interstincta.*

DISCUSSION

There is considerable evidence in many studies of wetlands water level fluctuations that growth and survival of emergent aquatic macrophytes are dependent on the water level (Neill, 1990; Squires AND Van Der Valk, 1992). The correlation between water level and the mean stem height and stem aboveground biomass suggested that water level has an important role in determining the size of the stems and, therefore, their aboveground biomass. Fluctuations in water level may induce changes in the productivity and biometry of aquatic macrophytes populations (Froend and McComb, 1994). Since water level was responsible for the stems height, as the water level decrease, the mean population height

E. interstincta decreased. This change in the mean stems height, by mortality (and subsequent growth of new shorter shoots), seemed to be an aspect of the plasticity, typical of emergent aquatic macrophytes, to insure their survival in extreme dynamic environments. The ability of emergent aquatic macrophytes populations to change their height was also reported for *Baumea articulata* and *Typha orientalis* by Froend and McComb (1994), and for submerged macrophytes by Brock (1991). A similar adaptation was observed in *Baumea arthrophylla,* an emergent aquatic macrophyte that exhibited smaller size classes when the water level was lowered from 50 to 0 centimeters (Rea and Ganf, 1994).

When one focuses on changes in the biometry of emergent aquatic macrophytes, the standing of the plant is of utmost importance. The supporting tissues of aquatic macrophytes were still present but highly reduced, since the aquatic environment provide adequate support (Sculthorpe, 1985). The adaptations found in *E. interstincta* for solving the support problem when their environment assumed terrestrial characteristics were: I) reduction of the mean size of the stems, and II) reduction of the space between each aeriferous lacunae, which was characteristic for this species. The smaller space between each aeriferous lacunae provide highest structural rigidity, and therefore, enhanced support. Although no specific test were done to verify the reduction of the space between aeriferous lacunae, this was observed in field. Data obtained in this study supporting these assertions were that the species had higher values of specific weight (more biomass per unit of height indicating more lacunae contributing to more weight) when the water level was naturally drewdown, although this was not recorded when the drawdown was a result of sandbar breaching. A reduction in plant size and in the proportion of specialized water-adapted tissues like aerenchyma, insuring the support of the plants in the terrestrial phase, was reported by Junk and Piedade (1993 a) in several species of the Amazonian region.

The biometric alteration observed in *E. interstincta* stems resulting in the reduction of the stems biomass values after the sandbar breaching, could be attributed to the combination of the following factors: I) the drastic variation of the water level of the lagoon (artificial breaching of the sandbar), leading mass mortality of the aboveground fraction of most stems (Palma-Silva, 1998). A similar response was observed in this study, where the stems density was the lowest (357.3 individuals.m^{-2}) after the sandbar artificial breaching; and II) the lowest value of mean biomass per stem (0.057 g of dry wt.individual^{-1}). This meant that after the sandbar artificial breaching, fewer and lighter stems were found (vegetative growth), despite the statistically similar stems mean height between the period in which the water level was naturally lowered (first drawdown) and this period (second drawdown) (Tukey's test; $p > 0.05$ - Figs. 3 and 4). Palma-Silva (1998) found that for *Typha domingensis* in Imboassica Lagoon, Macaé, Rio de Janeiro, the density, biomass, height, and mean weight of the stems were all lower after the sandbar breaching.

The disturbance caused by the sandbar artificial breaching in the *E. interstincta* population was reflected in the reduction of aboveground biomass, density, and specific weight of the stems. However, this aquatic macrophyte species seemed to be adapted to the rather dynamic environment found in coastal lagoons. The resilience time (here as time necessary for aboveground biomass recovery as when it was before drawdown) for this species was estimated at 30 days, since after this period, the aboveground biomass was statistically similar when compared with the period of natural drawdown.

During the period when the water level in the macrophyte stand was naturally drawdown, there was no loss of dead stem, since in the following period (31 October 1997), a significant increase in dead stem biomass due mortality of the aboveground fraction was recorded. In contrast, after the artificial breaching, dead stem biomass was considerably reduced, indicating the removal of autochthonous material from the stand. According to Palma-Silva (1998), sandbar breaching cause massive transport of dead material from aquatic macrophytes stands to the ocean, because of the strong water currents created.

Maye (1972) suggested that an increase in detritus biomass could result in an increase of nutrients for primary production. The removal of dead stem caused by the sandbar breaching probably reduced the amount of organic matter available for promoting the growth and development of the plants. This would explain the lower values of specific weight after the sandbar breaching, compared to the values found during the period when the water level was naturally drewdown, and higher specific weights were expected because of the plants' requirement for standing. Panosso et al.. (1998) reported that coastal lagoons were highly vulnerable to oscillations in climatic factors, as seen in the seasonal variation of the water level in Cabiúnas Lagoon. In the summer (February) of 1998, rainfall reached 398 mm in the region, which was an example of extreme conditions.

The observed pattern in stems height and aboveground biomass of *E. interstincta* showed the important role of water level in the determination of these parameters. Since both stem height and aboveground biomass were positively correlated with the water level, the hypothesis that they were regulated by the water level was corroborated.

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RESUMO

O objetivo deste trabalho foi verificar as alterações biométricas de *Eleocharis interstincta* em resposta às variações no nível da água da Lagoa de Cabiúnas, localizada na região norte do Estado do Rio de Janeiro, no município de Macaé (22^{o}00’ e 22^{o}30’ S, 41^{o}30’ e 42^{o}00’ O). Três quadrados de 0,0625 m^2 foram coletados quinzenalmente de junho/1997 a junho/1998; as amostras separadas em caules, detritos e rizoma; medidas, secas e pesadas. O nível da água variou sazonalmente no estande das macrófitas, apresentando dois períodos de seca. O primeiro período ocorreu naturalmente, no final do inverno e início da primavera, quando a precipitação na região é menor. O segundo período de seca foi resultado da abertura artificial da barra de areia, que separa a lagoa do mar. A abertura da barra foi feita no verão, período de maior precipitação, quando o nível da água registrou o máximo valor durante o período de estudo (1,35 m). Foi encontrada uma forte correlação positiva entre o nível da água com o tamanho médio dos caules e a biomassa aérea, indicando que o nível da água desempenha um importante papel na determinação destes parâmetros. Houve uma diferença significativa no tamanho (ANOVA; $p < 0.001$) e biomassa aérea dos caules (ANOVA; $p < 0.001$) entre os períodos amostrais, variando de 143,9 cm e 338,8 g peso seco.m^{-2}, antes da abertura, a 16,3 cm e 20.2 g peso seco.m^{-2} respectivamente depois da abertura da barra. A drástica variação no nível da água, ocasionando a mortalidade em massa dos caules, juntamente com a menor razão biomassa /caule (0.057 g de peso seco.individuo^{-1}), registrados depois da abertura de barra, não representou um grande distúrbio para *E. interstincta*, visto que o tempo de resiliência para esta população foi estimado em 30 dias

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