Typha domingensis Pers. subject to interactions among water level and fire event in a tropical lagoon

Typha domingensis Pers. sujeitas à interação entre nível da água e um evento de queimada em uma lagoa tropical

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Abstract: This study evaluated the biomass, reproductive effort, net aboveground and underground primary production (NAPP and NUPP) of *Typha domingensis* in response to water level fluctuations and fire. Sampling was carried out every 2 weeks from September 2004 to September 2005 in the littoral zone of the Campelo (coastal) Lagoon (State of Rio de Janeiro), where four quadrats of 0.25 m^2 were harvested and separated in young leaves (≤1 m), adult leaves (>1 m), detritus, rhizomes, roots and inflorescences. In the laboratory, all parts were oven-dried to determine biomass. During the sampling period the water level fluctuated seasonally, with two periods: 1) decreasing from May to November when the water failed to cover the macrophyte stand - the end of spring (natural dry out) and, 2) increasing from December to April (in summer - period of rainfall). Moreover, the stand was submitted to fire on May 2005. Net aboveground primary production was affected by both increase of water level and fire, when higher values were observed. Net underground primary production of *T. domingensis* was not influenced by water level fluctuations, but lower values were observed after fire. NAPP varied from 0 to 380 and NUPP varied from 0 to 142 g $DW.m^{-2}$ per day, respectively.

Keywords: aquatic macrophyte, *Typha domingensis*, reproductive effort, primary production, plant strategies.

Resumo: Este estudo avaliou a biomassa, esforço reprodutivo e produção primária líquida aérea e subterrânea (NAPP e NUPP) de *Typha domingensis* em resposta às flutuações nível da água e um evento de queimada. A amostragem foi realizada a cada duas semanas a partir de setembro de 2004 a setembro de 2005, na região marginal da lagoa costeira do Campelo (Estado do Rio de Janeiro), onde quatro quadrados de 0,25 m^2 foram amostrados e separados em folhas jovens (≤1 m), e adultas (>1 m), detritos, rizomas, raízes e inflorescências. No laboratório, todas as partes foram secas em estufa para determinar a biomassa. Durante o período de amostragem, o nível da água flutuou sazonalmente com dois períodos: 1) diminuição de maio a novembro, quando a água não conseguiu cobrir o banco de macrófitas - final da primavera (naturalmente período seco) e, 2) aumenta a partir de dezembro a abril (no verão - período de chuvas). Além disso, o estande foi queimado em maio de 2005. A produção primária líquida aérea foi afetada pelo aumento tanto do nível de água quanto do fogo, quando foram observados valores mais elevados. A produção primária líquida subterrânea de *T. domingensis* não foi influenciada pelas flutuações no nível d'água, mas valores mais baixos foram observados após a queimada. Os valores NAPP variaram de 0 a 380 e os de NUPP variaram de 0 a 142 g peso $seco.m^{-2}$ por dia, respectivamente.

Palavras-chave: macrófita aquática, *Typha domingensis*, esforço reprodutivo, produção primária, estratégias da planta.

1. Introduction

Coastal lagoons are characterized by their extend vulnerability to winds, anthropic impacts and climatic fluctuations, especially, changes in water level (Santos and Esteves, 2002; Angeler et al., 2004; Chow-Fraser, 2005). Many surveys have demonstrated influence of changes in water level over biomass, development, primary production and distribution of emergent aquatic macrophytes that develop within this type of ecosystem in temperate and tropical regions (Froend and McComb, 1994; Blanch et al., 2000; Palma-Silva et al., 2000; Santos and Esteves, 2002; Deegan et al., 2006). However, these surveys have focused only in determining aerial primary production of these plants. Usually, these experiments do not consider underground parts production and loss of grit from emergent aquatic macrophytes, underestimating aquatic macrophytes primary production in coastal lagoons.

In Brazil, there are several emergent aquatic macrophytes, and *Typha domingensis* Pers is usually found. This species is characterized as perennial, well distributed and abundant in flood areas, located in aquatic environments boundaries (Furtado and Esteves, 1997). As it is a rhizomatous plant, it is capable of forming monospecific stands in many continental flood areas of Brazil and of the world (Palma-Siva et al., 2005). It is easily self fecundated, presenting extremely high rates, however, gathering young individuals by means of clonal expansion is more effective, limited only by environmental conditions (Kuehn et al., 1999; Palma-Silva et al., 2005). Development of this species bank depends mostly on expansion of rhizomes in sediment and of new ramets (Kuehn et al., 1999).

Carbon incorporation in vegetal biomass may be expressive in areas dominated by *Typha*, mainly in places submitted to seasonal mortality of these aquatic macrophytes, which result is a more frequent return to initial successional stages and higher productivity (Neue et al., 1997). The absence of intense temperature fall during winter, such as occurs in temperate areas, may favor carbon incorporation by aquatic macrophytes during all year round in tropical wetlands (Neue et al., 1997). This study aims to estimate biomass variation of *T. domingensis* aerial and underground parts. Concomitantly, both aerial and underground primary production were evaluated, as well as reproductive effort of this plant due to variations of water level and an event of occasional fire, caused by surrounding population. These data will make possible to better understand the life cycle of this aquatic macrophyte in tropical region, where hydrologic variation is predominant, even more than temperature.

1.1. Study area

The Campelo Lagoon is located in the Campos dos Goytacazes and São Francisco de Itabapoana municipalities between the latitude 21° 38' to 21° 42' S and longitude 41° 08' to 41° 12' W (Figure 1). This lagoon presents a surface area of approximately 10 km^2, representing one of the three biggest lagoons of the northern region of Rio de Janeiro State (SEMADS, 2002). This coastal lagoon is geologically founded upon quaternary fluvial marine sedimentary deposits, is attributed to the processes of formation of the delta of the Paraiba do Sul River. Besides, until mid 2001, it presented a connection with the sea by means of Antônio Rezende Channel. This lagoon suffered consequences from work made by DNOS (Departamento Nacional de Obras e Saneamento - National Department of Work and Sanitation) in the region. Construction and embankment of channels, dikes and dams in the first half of the XX century resulted in a drastic reduction of its water table and fishing, did not allow free water flow from Paraíba do Sul River during flood periods (Bernardes and Barroso, 1995). Further, reduction in the water column probably made possible the development of the aquatic macrophytes that present dense colonization all along its coastal region (*T. domingensis*) and over almost all bottom sediment extension, recovered by mixed stands of submerged macrophytes (genera *Egeria, Ceratophyllum* and *Najas*), turning fishing even harder. Currently Campelo Lagoon receives discharge of fresh water from Vigário and Taquaruçu lacustrine system (located in Campos dos Goytacazes urban area) and Paraíba do Sul River by means of Vigário Channel, especially in flood periods. Until mid 2001, it also received a discharge of brackish water through Antônio Rezende Channel, which interconnects the lagoon with Atlantic Ocean, especially during dry period. However, built of a dike in its initial portion, not only better confined water in Vigário-Campelo system, but also stopped brackish water inflow. Watershed is consisted mainly of sand, poor in nutrients (CIDE, 1997). High soil porosity promotes great water percolation and dragging of nutrients added, that pass to the water table and then to the aquatic systems, accelerating eutrophication.

2. Material and Methods

Sampling was carried out every 2 weeks from September 2004 to September 2005 in the littoral zone of the Campelo Lagoon. Four quadrats of 0.25 m^2 were collected during each visit to the lagoon. Data on rainfall from September 2004 to September 2005 were required to meteorological station of the UENF distant about 10 km from the lagoon. The values of variation of water level were measured at the same point of the study plots. Harvested samples of *Typha domingensis* were separated in adult (>1 m) and young (≤1 m) leaves, inflorescences, roots, rhizomes and detritus (senescent leaves) and obtained water level. At laboratory, macrophytes were washed under running water and dried in a stove at 80 °C for 96 hours. Considering this, biomass was estimated in g DW.m^{-2}. Values of net aerial primary production (NAPP) were obtained using the technique proposed by Smalley as described by Linthurst and Reimold (1978) and Shew et al. (1981). This method determines net aerial primary production (NAPP), considering the variation of the live and dead biomass in two consecutives samples, as follows:

$$\text{When } \Delta ALB > 0 \text{ and } \Delta ADB > 0;\ NAPP = \Delta ALB + \Delta ADB; \quad (1)$$

$$\text{When } \Delta ALB < 0 \text{ and } \Delta ADB < 0;\ NAPP = 0; \quad (2)$$

$$\text{When } \Delta ALB > 0 \text{ and } \Delta ADB < 0;\ NAPP = \Delta ALB; \quad (3)$$

where:

ΔALB: aerial live biomass variation in the interval;
ΔADB: aerial dead biomass variation in the interval.

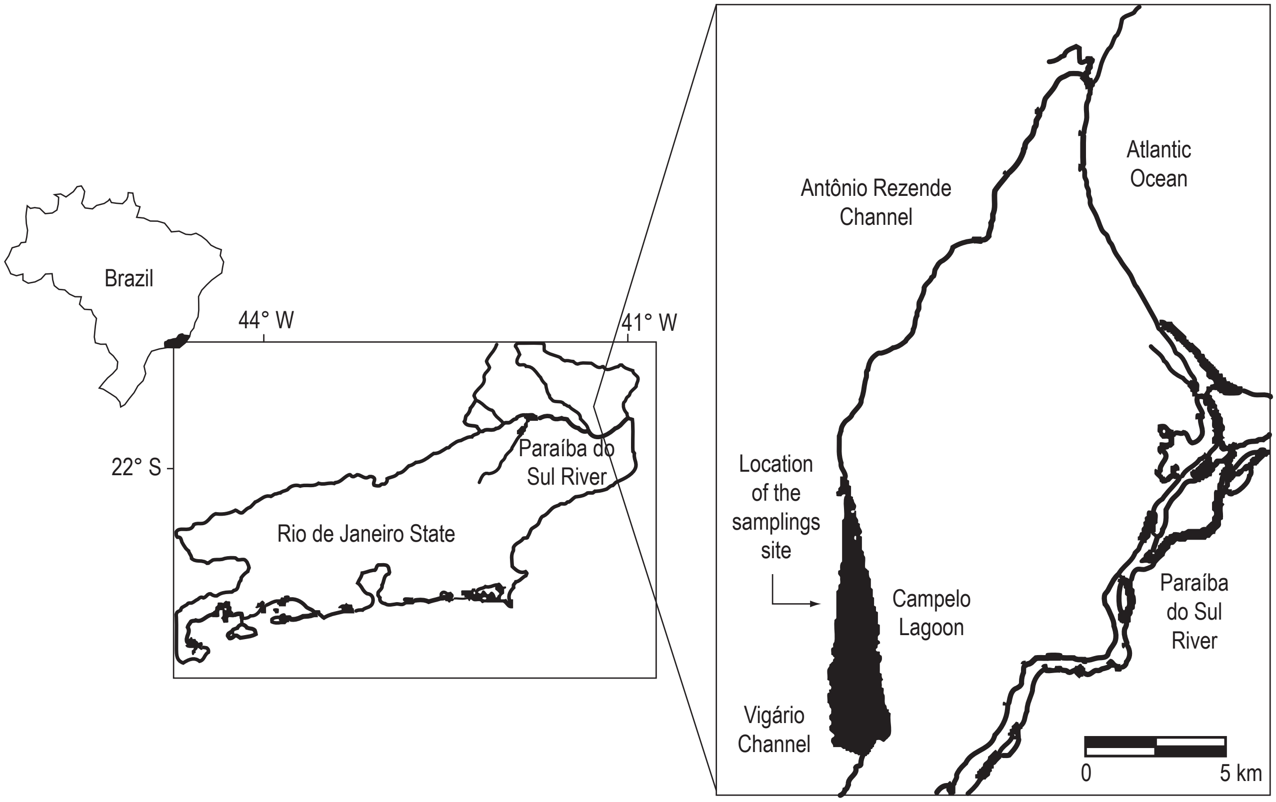

Figure 1. Study area and location of the sampling site in the Campelo Lagoon.

The underground biomass was not separated into dead and live categories. The estimates of the net underground primary production (NUPP) were calculated by dividing the biomass accumulated during the period by the time in days (Palma-Silva, et al. 2000). According to Palma-Silva et al. (2000) the reproductive effort (RE), for each month, was based on the relative percentage of the total of inflorescence throughout all the sampling period, as follows:

$$\%RE = (W_t / \Delta W_t) \times 100 \quad (4)$$

where:

W_t: total dry weight of inflorescence during one month;

ΔW_t: total dry weight of inflorescence during all study period.

The biomass was compared using Kruskal-Wallis statistic and Dunn's multiple comparison test at the 95% significance level. Pearson correlation test (r) analyses were performed to assess the relationships among water level, adult leaves, detritus, roots, rhizomes, young leaves, inflorescences, reproductive effort (% RE), NAPP and NUPP.

3. Results

The region of sampling presented decrease on deep since September, and reaching zero value in November/04. Water level higher values were observed during rainy period, which occurred between December/04 and March/05, when it peaked at 124 cm. Decrease of water level occurred after rainy period, from April on, when rains were dispersed (Figure 2).

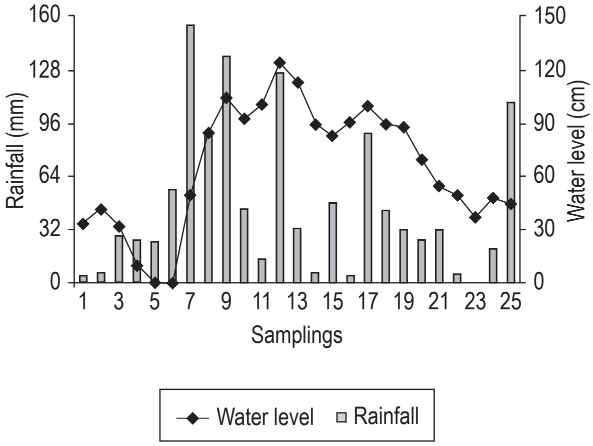

Figure 2. Water level fluctuation and rainfall during sampling periods (September 2004 to September 2005).

During sampling period, it was noted significant differences in biomass of different structures (Kruskal-Wallis; $p < 0.001$) (Figure 3). Adult leaves, detritus and rhizomes (8800, 8300 and 2870 $gDW.m^{-2}$, respective higher values) were the structures that contributed more to total biomass. Young leaves presented higher values associated to drought and after fire (235 and 505 $gDW.m^{-2}$, respectively). Roots did not present seasonal pattern, but did present tendency to biomass decline along studied period. Higher values of inflorescence biomass were associated to dryer periods. Rhizomes, as well as roots and detritus, presented decrease

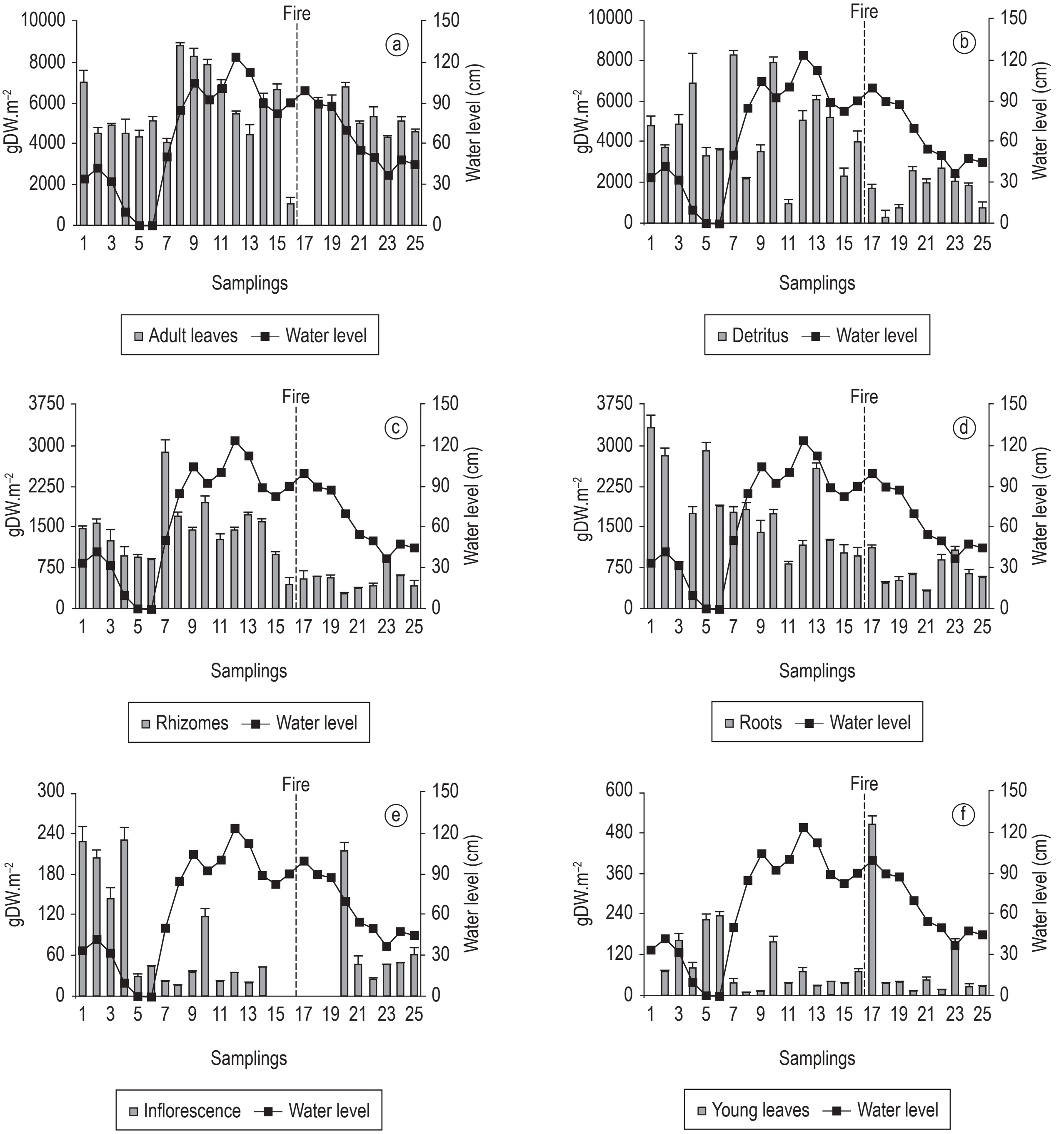

Figure 3. Water level fluctuation and biomass of *Typha domingensis;* a) adult leaves, b) detritus, c)rhizomes, d) roots, e) inflorescences and f) young leaves) during sampling periods (September 2004 to September 2005). The bar indicates standard deviation (n = 4).

in biomass values after fire event, reaching medium values around 532, 696 and 1650 $gDW.m^{-2}$, respectively, after fire, in counter position to medium values of 1409, 1747 and 4381 $gDWm^{-2}$ before fire.

Regarding primary production of different parts of the plant, aerial and underground primary production values reached 383 and 142 $gDW.m^{-2}.d^{-1}$, respectively (Figure 4). The highest development of aerial fraction of *T. domingensis* in Campelo Lagoon was noted right after rainy period started (313 $gDW.m^{-2}.d^{-1}$), when water level increase occurred (December-January) and right after fire (383 $gDW.m^{-2}.d^{-1}$). Underground primary production did not present any pattern related to the hydrologic cycle, but noted decrease after fire (medium value of 12 $gDW.m^{-2}.d^{-1}$, opposing to medium value of 31 $gDW.m^{-2}.d^{-1}$ noted before fire). Annual net aerial primary production was higher than underground's (1309 and 568 $gDW.m^{-2}.yr^{-1}$, respectively). Reproductive effort presented higher values in the beginning of sampling, in dry period (14%) and after fire episode (13%) (Figure 5).

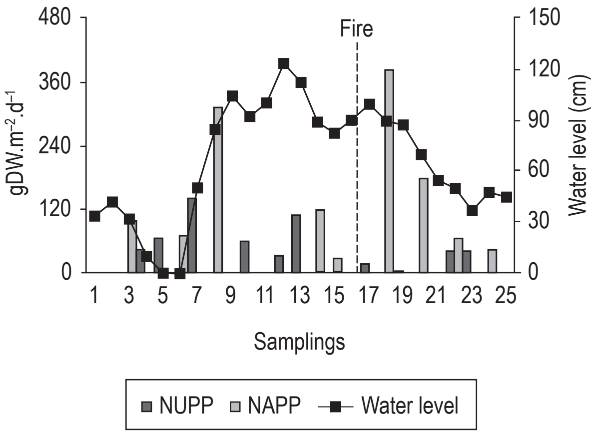

Figure 4. Water level fluctuation, NAPP (net aerial primary production) and NUPP (net underground primary production) during sampling periods (September 2004 to September 2005).

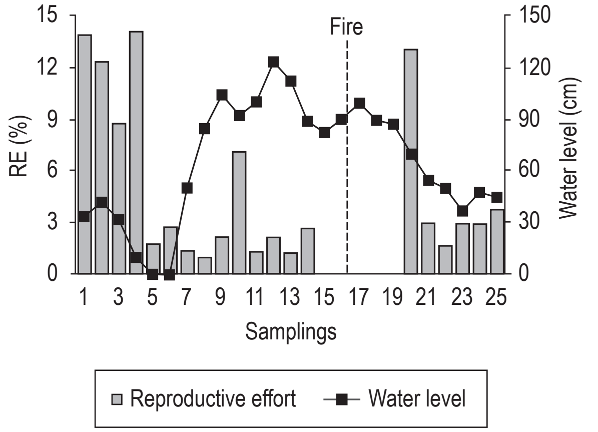

Figure 5. Water level fluctuation and reproductive effort during sampling periods (September 2004 to September 2005).

4. Discussion

4.1. Water level influence (September/04 until April/05)

Studies in flood areas in Brazil have pointed that water level presents preponderant function in determining emergent macrophytes biomass, and then, changing some local sceneries (Santos and Esteves, 2002; Palma-Silva et al., 2005). Throughout this study, reproductive effort ($r = -0.42$; $p < 0.05$), inflorescences ($r = -0.44$; $p < 0.05$) and young leaves ($r = -0.15$; $p > 0.05$) factors presented negative correlations with water level, showing possible stress caused by moments of hydric stress over this plant.

This study also shows increase of aerial parts biomass allocation (especially adult leaves) with water level increase. Medium increase of adults leaves biomass after water level increase (December/04-April/05 before fire) was 28% when compared to previous period (September - November/04) (average of 5070 to 6513 gDW.m^{-2}). Other researches show influence of the water level in biomass increasing and allocating by emergent aquatic macrophytes (Coops et al., 1996; Palma-Silva, 1998; Vretare et al., 2001; Deegan et al, 2006).

A few studies suggest that limitation by light and gases (O_2 and CO_2) forces macrophyte to develop more aerial part, supported by resources from underground parts (Miao, 2004). According to Vretare et al. (2001), as water column depth increases, roots and rhizomes would present equal importance, and allocation of nutrients from both structures would support photosynthetic areas. However, this study also pointed an increase in rhizome biomass after water level increase (around 5%), and decrease in roots biomass, suggesting that this period was favorable to compound storage in rhizome.

Although noting decrease in population biomass along study period until the fire, average aerial dry biomass was 5734 gPS.m^{-2}. This value is superior to the ones presented in other studies with *T. domingensis*, which obtained aerial biomass values relatively lower than the ones from Campelo Lagoon (Furtado and Esteves, 1997; Ennabili et al., 1998; Weisner and Miao, 2004, Asaeda and Siong, 2008, values between 70 and 3000 g.m^{-2}), which suggests that *T. domingensis* presents less limited growth in this lagoon. These values are also higher than the ones noted for other emergent aquatic macrophytes: *Phragmites australis*, *Vallisneria spiralis*, *Sparganium erectum*, *Cladium jamaicense*, *Juncus acutus* e *Zizania bonariensis* (Royle and King, 1991; Ennabili et al., 1998; Smith et al., 2000, values between 60 and 3000 g.m^{-2}).

Detritus biomass represented around 30% of total biomass, and 38% of aerial biomass, pointing importance of *T. domingensis* in cycling nutrients in Campelo Lagoon and as transporter of nutrients to sediment (Furtado and Esteves, 1997).

T. domingensis NAPP found here reached 380 gDW.m^{-2}.d^{-1}, values also found in other studies in the neighborhood (Furtado and Esteves, 1997; Palma-Silva, 1998). Constantly lacking NAPP suggests that *T. domingensis* stand analyzed was in aging and decline process. However, it could also have occurred translocation process for new ramets generation.

After decline of water level and exposition of substratum to the air in November/04, it occurred a fast response of issuing new leaves, when young leaves biomass reached values around 230 gDW.m^{-2}, suggesting this was a development strategy of the plant. With posterior increase of water level, leaves growth, in less than 15 days resulted in peak of production between December/04-January/05.

4.2. Influence of fire

Usually, marginal areas of Campelo Lagoon are used by local population as places to hunt small animals (e.g. guinea pigs and gallinules). In order to facilitate the hunt, fire is used, so to open clearings in macrophytes meadows.

Consequences of fire could be noted within studied area from May/05, when a fast increase in young leaves biomass was detected, and this portion's biomass peaked at 505 gDW.m^{-2}. Newman et al. (1998), studying *T. domingensis* development in the Everglades (Flórida, USA) after fire, also noted an intensive growth, suggesting that fire may change factors, like: remobilization of soil nutrients, surveying change and clearings opening in landscape. In Campelo Lagoon, fire was also a determinant factor. In this moment it was also noted intensive growth of leaves, in less than 15 days reached heights superior to 1 meter, resulting in another NAPP peak.

Impact caused by fire over *T. domingensis* meadow resulted in decrease of underground structures biomass. Part of this decrease is related to resources allocation for regeneration of leaves and recovery of photosynthetic activity (Coops et al., 1996; Vretare et al., 2001). Underground productivity within period after the fire presented lower values than the ones noted before the event, corroborating translocation of materials to aerial parts.

Underground biomass is an important factor for maintenance of the macrophytes meadow under unfavorable conditions. This portion represents fundamental source of energy for instantaneous response by the plant, mobilizing nutrients for the regeneration. Although dry underground biomass present similarities with those ones obtained by other studies (Ennabili et al., 1998; Asaeda et al., 2005; Asaeda and Siong, 2008, between 1600 and 3000 g.m^{-2}), literature usually reports that underground biomass represents more than half of plants total biomass (Westlake, 1965; Fiala, 1971). This pattern is not repeated in Campelo Lagoon, where underground portion represented an average of only 21% of total biomass. Content of the organic material and sediment compactness are factors that hinder in underground biomass content (Xie et al., 2005). According to some authors, places where present low nutrients availability, plants tend to present a more developed radicular system in order to increase its absorption (Xie and Yu, 2003; Xie et al., 2004), which increases underground biomass. Therefore, the relative small development of the underground portion may be explained by availability of nutrients in Campelo Lagoon sediment (unpublished data). Besides, that as rhizome is the structure responsible for species clonal expansion and perenization (Miao, 2004), constant production of new ramets may be responsible for low biomass of underground organs (Wetzel and Howe, 1999).

Rhizomes development in places with high nutrients availability increases ramets density, especially when sediment is exposed. This may generate competition by light and space, which explains young leaves decrease during the study, along with accelerated growth process of these leaves. Similar proportions to the ones found in this study between aerial and underground portions were reported by Furtado and Esteves (1997).

Miao and Sklar (1997) and Ennabili et al. (1998), working in subtropical and tropical areas, suggesting that such proportionality may also be related to geographical location of aquatic macrophytes meadows. In general, the biggest part of *T. domingensis* biomass is allocated in aerial part. However, detritus biomass presented considerable values, indicating that it may work as a storage compartment and transporter of nutrients for the water column and, specially, sediment of the lagoon.

Fast capacity of return to the pre-fire conditions by means of vegetative reproduction using resources stored in rhizomes, indicates high resilience of *T. domingensis* stand in Campelo Lagoon. Clonal expansion is an essential strategy for maintenance of aquatic macrophytes species in dynamic environments, such as coastal lagoons (Palma-Siva et al., 2005). High biomass production by vegetative expansion after disturb (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) was also registered by Palma-Silva (1998), who studied *T. domingensis* in Imboassica coastal lagoon, Rio de Janeiro State, Brazil.

Sexual reproductive effort was estimated by means of inflorescences quantification. Higher values of reproductive effort were noted during first samplings, correspondent to the period of low water levels and after fire event, suggesting that dryer periods would be propitious to a higher dispersion of species seeds within Campelo Lagoon areas.

For *T. domingensis*, it was already demonstrated that inflorescences production cycle happens when ramets reach 2-4 months (Krusi and Wein 1988). In this study, inflorescences presence in this plant was almost constant, absent only before the fire event. Inflorescences production was retaken around two months after fire, corroborating Krusi and Wein (1988) data and ramets constant production in studied stand. Development of meadows by sexual reproduction may be inhibited by several environmental conditions, growing preponderantly by clonal expansion (Djebrouni and Huon, 1988). Campelo Lagoon periodically suffers from flood, fire and dry events, increasing clonal expansion, which generates new ramets using nutrients and energy stored in rhizomes, therefore constituting an efficient perenization strategy of this species (Palma-Silva et al., 2005).

5. Conclusions

Changes in water level and fire caused effects over *T. domingensis* community in distinct forms: 1) sediment exposition to the air intensified growth of new leaves and posterior increase of water level stimulated mostly aerial production; and 2) fire stimulated aerial production in detriment of decrease of underground biomass. Detritus were another important structure, as demonstrated to be a biomass store compartment in Campelo Lagoon. This fact indicates that the detritus of this plant performs a nutrients transporter role to the sediment, being basic for this lagoon nutrients cycling.

Results reached in this study indicate that a possible intensification of fires may lead to a change in structure of emergent macrophytes community in the lagoon. This reduction of *T. domingensis* aerial biomass may take to a substitution by other vegetation in the littoral zones.

T. domingensis presented particular adaptative advantages of fast reproduction, sexual and clonal, at every new environmental stress (dry, flood and fire). This emergent macrophyte presented a fast growing with water column elevation and raise of NPP relative rates, mainly leaves and underground biomass.

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