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Caloric Density of Aquatic Macrophytes in Different Environments of the Baía River Subsystem, Upper Paraná River Floodplain, Brazil

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ABSTRACT

The aim of *this work* was *to determine the caloric density of leaves, stems and roots of aquatic macrophytes in different environments of the Baía subsystem (Baía river and Fechada and Guaraná lagoons) on the Upper Paraná river floodplain, in addition to identify the variability between ecological groups. Samplings of* ***Eichhornia crassipes****,* ***Salvinia*** spp, ***Pistia stratiotes****,* ***Eichhornia azurea****,* ***Polygonum*** sp*, Cyperaceae and Poaceae were carried out in February 2003. Spatial differences in the caloric densities were not observed for these plants. Caloric density values varied from 1906.9 cal/g dry weight (root) to 4675.0 cal/g dry weight (leaf). However, significant differences between the caloric content averages of the vegetative structures were observed only for* ***Polygonum*** sp and ***Salvinia*** spp. *In relation to the ecological groups, the highest average value was verified for the emergent macrophytes (3529.7 ± 722.5), which were significantly different from the floating ones (3056.5 ± 571.0). There was no difference between the sites included in the subsystem when the caloric densities were compared.*

Key words: Paraná river, floodplain, aquatic macrophytes, calorimetry

INTRODUCTION

Tropical and subtropical floodplains possess an abundance of aquatic macrophytes of different species and ecological groups (Bini, 1996; Bini et al., 2001). The presence of these plants generally represents high primary production, biomass (Esteves, 1998; Pedralli, 2000), nutrient cycling and stock capacity for the ecosystem (Henry-Silva et al., 2001). For animals, they contribute to the feeding of herbivores and detritivores (Maine et al., 1999; Pompêo et al., 1999), in addition of serving as food substrate for algivores and invertivores (Casatti et al., 2003).

In recent years, biomass production rates and the chemical composition of aquatic macrophytes have been analyzed by various researchers (Esteves, 1982; Esteves and Thomaz, 1990; Camargo and Esteves, 1996; Henry-Silva et al., 2001). On the other hand, the accumulated energy in the plant tissues of these primary producers (made available to the system) has undergone little investigation (Golley, 1961; Thomaz and Esteves, 1984).

Differences in the caloric density between species are caused by exogenous and endogenous factors (Caspers, 1977), trophic and climatic conditions (Dykyjova and Pribil, 1975), in addition to the

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physiology of each species. The average caloric value of aquatic vascular plants varies little, but there are some differences between the ages, as well as between organs of the same plant (Dykyjova and Pribil, 1975; Caspers, 1975).

As for botany, especially for superior plants, there is a distinct dependence of caloric values on climatic conditions, the availability of water and the concentration of dissolved salts in the soil (Caspers, 1975).

These differences can also depend on the ecological group (emergent, submerged and floating). Bianchini Junior (2003) affirms that each group responds to the abiotic and biotic factors in a different way, in accordance with adopted survival strategies.

In the preparation of energy flow models that explain food webs, energy data from Upper Paraná river floodplain macrophytes had not yet been obtained, considering that studies had only been made with animal groups (Benedito-Cecilio and Morimoto, 2002; Benedito-Cecilio, et al., 2004; Vismara et al., 2004). So, this work had as its aim the analysis of the caloric density of the leaves, stems and roots of aquatic macrophytes collected in the Baía river and in two lagoons of its subsystem. It was hypothesized that the caloric content of aquatic macrophytes could be associated: (1) with the plant organ (leaf, stem and root); (2) with the ecological group (emergent and floating); or (3) with the environment (lagoon with or without a link to the river).

MATERIALS AND METHODS

Study Area

This study was performed in the Baía river and in two lagoons of its environment (Fechada and Guaraná) (Fig. 1).

The Baía river (moderately lotic) presents a varied width and an average depth of 3.2m, with narrow stretches having high embankments and occupied by riparian vegetation or cultivated fields. In the wide stretches, the embankments are low and the vegetation consists of flooded fields (Manetta et al., 2003).

Fechada lagoon has an elongated shape, a length of 624.4m and an average depth of 2.5m. It does not present a direct connection with the Baía river, which is 100m away. The margin consists of a few trees (1%) and high macrophyte abundance (Manetta et al., 2003). Guaraná lagoon has a rounded shape, a length of 386.5m and an average depth of 2.1m. It presents a macrophyte-laden connection with the Baía river that is 70m long and 18m wide. The marginal embankment presents a height of 0.4m and its margins are laden with grasses (95%) and bushes (5%) (Manetta et al., 2003).

Methodology

Samplings were obtained in February 2003. The aquatic macrophytes were collected for caloric analysis of the leaf, stem and root, and divided into emergent (Cyperaceae, Poaceae, *Eichhornia azurea* (Sw.) Kunth and *Polygonum* sp.) and floating (*Eichhornia crassipes* (Mart) Solm., *Salvinia* spp and *Pistia stratiotes* (L.)) ecological groups.

Different aquatic macrophyte individuals (n = 5) belonging to the same family and species were randomly sampled. The plants were put in plastic bags and labeled with the site name and collection date. Later, the samples were washed in running distilled water, and the vegetative organs (leaf, stem and root) separated and dried in a greenhouse at 60^{o}C. Next, they were softened in a ball mill and submitted to combustion in a Parr calorimetric bomb.

The data of temperature from water, dissolved oxygen, eletric conductivity, pH, transparency and alkalinit were taken daily and supplied by the Limnology Laboratory.

Caloric differences were investigated using a null model ANOVA and the program ECOSIM (Gotelli and Entsminger, 2003). Graphic inspections were carried out using the program STATISTICA.

RESULTS

It was verified that the three environments studied present similarities as regards average water temperature, pH and transparency. The concentration of O_2 was higher in the Baía river (2.0mg/L), while the conductivity of Fechada Lagoon reached about 32µs/cm. Alkalinity was higher in Guaraná lagoon (190.4 µM), while the lowest value was recorded in Fechada lagoon (134.5) (Table 1).

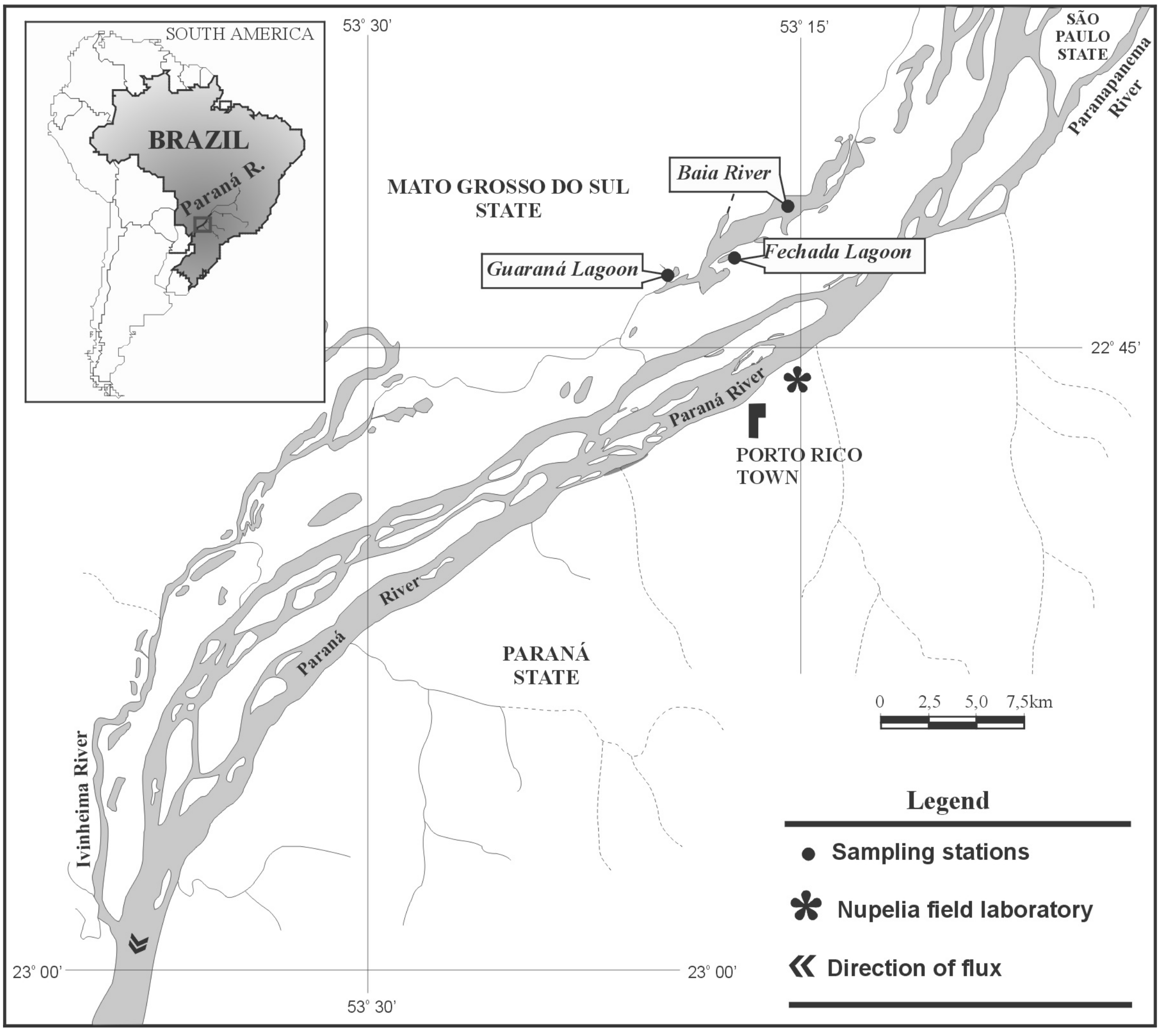

Figure 1 - Site of sampling in the Paraná river floodplain.

Table 1 - Physic and chemical variables in different environments of the Baía river.

Site	Water temperature (º C)	Dissolved oxygen (mg/L)	Electric Conductivity (µs/cm)	pH	Transparency (m)	Alkalinity (µM)
Baía river	29.5	2.07	23.9	5.61	0.75	168.8
Guaraná lagoon	29.5	0.56	26.2	5.40	0.60	190.4
Fechada lagoon	29.1	0.66	31.9	5.75	0.55	134.5

Source: UEM/NUPÉLIA/PELD/CNPq (2003).

Caloric density values varied from 1906.9 cal/g dry weight (root) to 4075.5 cal/g dry weight (leaf) for Cyperaceae specimens; from 2767.4 cal/g dry weight (root) to 3316.0 cal/g dry weight (root) for *E. azurea*; from 2196.4 cal/g dry weight (leaf) to 3798.3 cal/g dry weight (leaf) for *E. crassipes*; 3114.3 cal/g dry weight (stem) to 4613.1 cal/g dry weight (leaf) for Poaceae; from 2547.7 cal/g dry weight (root) to 4675.0 cal/g dry weight (leaf) for *Polygonum* sp; from 2332.4 cal/g dry weight (root) to 3470.2 cal/g dry weight (root) for *P. stratiotes*; from 2200.8 cal/g dry weight (root) to 3933.8 cal/g dry weight (leaf) for *Salvinia* spp. (Fig. 2)

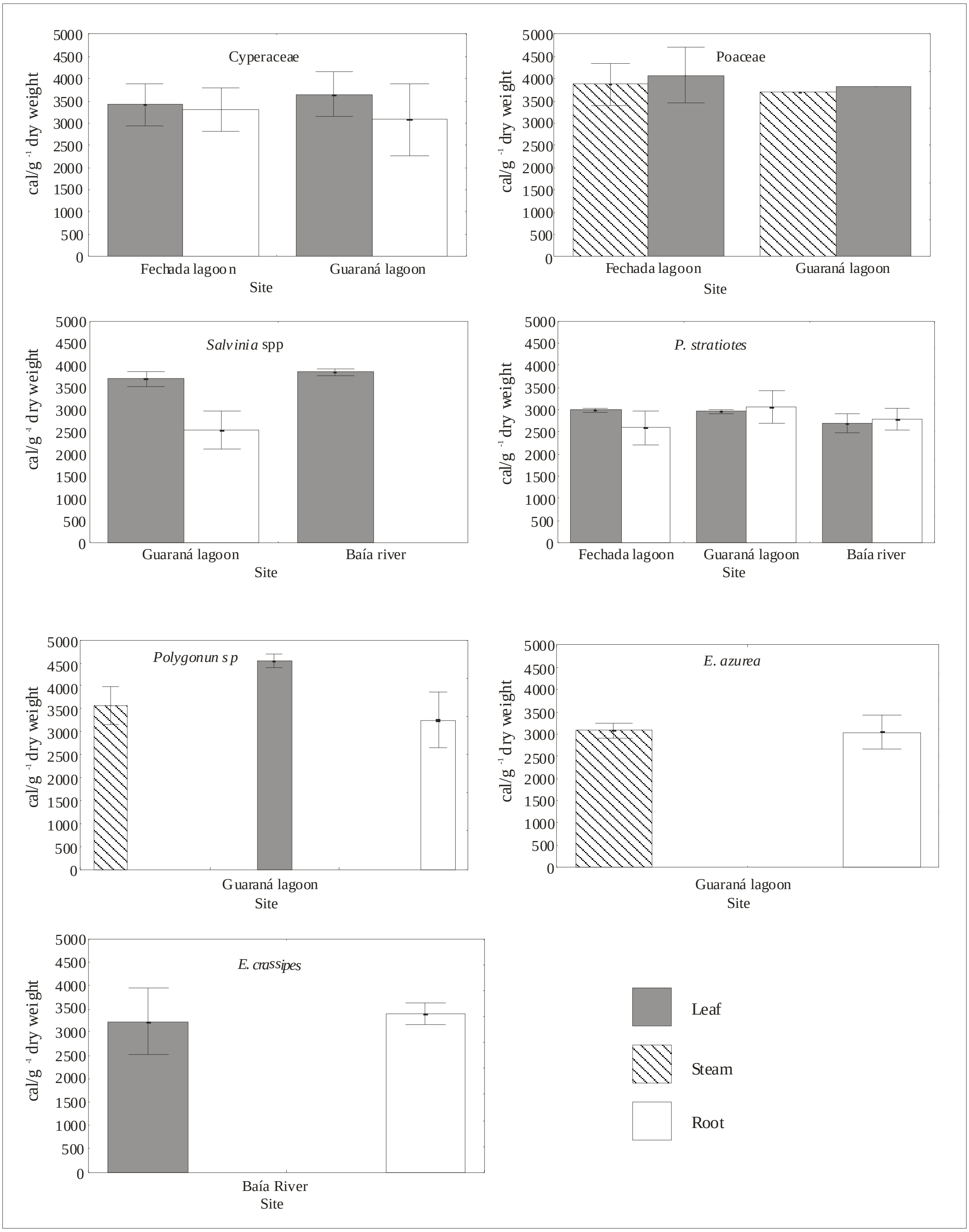

Figure 2 - Caloric density of vegetative organs of aquatic macrophytes in different environments of the Baía subsystem.

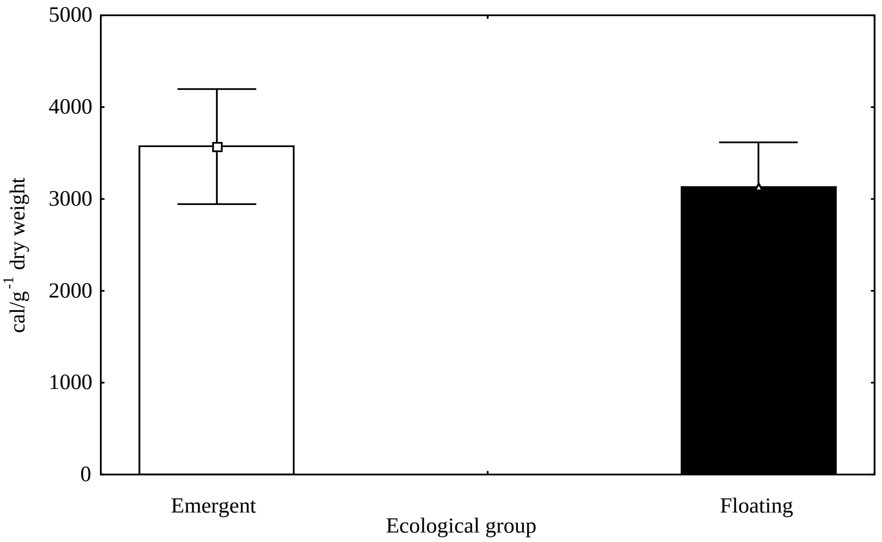

Figure 3 - Caloric density of ecological groups of analysed aquatic macrophytes.

The highest average caloric densities were observed for aquatic macrophyte leaves, with the exception of the *E. crassipes* specimens collected in the Baía river and the *P. stratiotes* specimens taken from Guaraná lagoon and the Baía river.

In addition, the values obtained for the roots presented the greatest variations, except for *E. crassipes*. However, significant differences between the vegetative structure averages were observed between leaves and roots from *Salvinia* spp. (OI = 50.2, $p < 0.05$) while for *Polygonum* sp all the vegetable organs had different caloric values different (OI = 6.97, $p < 0.05$). For both plants, the leaves had the highest average of caloric densities (cal/g dry weight) when compared to the roots (*Polygonum* sp: root = 3249.28, leaf = 4540.79; *Salvini*a spp: root = 2535.32; leaf = 3698.01).

Spatial differences in the caloric densities were not observed for the studied plants (Cyperaceae: OI = 0.018, p = 0.90; Poaceae: OI = 0.26, p = 0.66; *P. stratiotes*: OI = 2.43, p = 0.12; *Salvinia* spp: OI = 1.29, p = 0.20).

In relation to the ecological groups, the highest average value was verified for the emergent macrophytes (3529.7 ± 722.5), which were significantly different from the floating ones (3056.5 ± 571.0) (Fig. 3).

DISCUSSION

The physical and chemical variable values did not present marked differences between the analyzed environments. This similarity may be responsible for the absence of caloric variation between the macrophytes of the river, open lagoon and closed lagoon. Abiotic factors such as pH, ionic concentration, nutrients, light, dissolved oxygen, water level and temperature (Ikusima and Gentil, 1985; Pompêo et al., 1999) and biotic factors such as herbivory, competition and parasitism (Neill, 1989; Esteves, 1998; Duarte, 1992) influence the spatial variations in the physical, chemical and biological characteristics of the macrophytes. Spatial variation was not verified inside the Baía river subsystem (main channel and lagoons). But, it is necessary to analyse this variation between other subsystems from the Paraná river floodplain because these plants also influence the dynamics of the environment, resulting in differences in their caloric values. Dourado et al. (2004) identified spatial variability for macrophytes in fluvial, transition and lacustrine zones from reservoirs. The caloric values of these plants affect the entire food chain since they represent one of the most productive communities in aquatic ecosystems (Camargo et al., 1983; 2003).

In general, the macrophytes presented the highest average values of energy in the leaves in relation to the stems and roots, except for *P. stratiotes* and *E. crassipes*. In Lobo Dam in São Paulo State, Esteves and Thomaz (1990) also verified this relationship for two macrophytes (*Nymphoides indica* (L) and *Pontederia cordata* (L)). These results may be due to the high content of nutrients such as soluble carbohydrates, lipids and polyphenols (Esteves and Nogueira, 1991; Esteves, 1998) and high leaf metabolism, the result of the great enzymatic activity of photosynthetically active structures (Henry-Silva and Camargo, 2002). However, for other plants this organ was not more caloric and differences were not verified. According to Sieghardt (1973), the translocation of organic compounds between vegetative organs can also cause calorimetric differences, and he also emphasizes that in temperate regions the processes of energy distribution between the plant organs are more evident than in tropical regions, mainly because of conspicuous seasonality. So this question needs more investigation in neotropical regions.

The efficiency of vegetative reproduction and high nutrient absorption (area/volume) are among the possible factors that confer high productivity on floating and emergent aquatic macrophytes in aquatic ecosystems (Esteves, 1998). Both groups possess high absorption and vegetative growth. However, differences exist in the chemical composition of these groups, since they presented different values in the energy content. These results can be related to a larger amount of cell wall fraction tissues in emerging macrophytes, which need larger sustentability. Therefore energy content increases along with a larger content of carbon, consequently, it is high among woody plants (Larcher, 2000).

Although studies have shown relevant differences between vegetative organs (Dykyjova and Pribil, 1975; Caspers, 1975), it may be inferred, based on the results obtained, that energy investigations of the Baía river subsystem may be carried out on the vegetative organs as a whole, with the exception of only *Polygonum* sp and *Salvinia* spp, in which significant differences were verified. It is worth emphasizing the possibility of investigation in one of the environments of the subsystem and/or all of them, mainly for *P. stratiotes*. However, generalizations between ecological groups should be avoided. The caloric values were not influenced by the kind of environment (with or without communication) but suffered effect from the ecological group. In this way, the first hypothesis was accepted for *Polygonum* sp and *Salvinia* spp. In relation to the second hypothesis, the specimens were rejected in the local studies and the third hypothesis was accepted and showed a difference between the ecological groups.

In addition, considering that macrophytes represent a stock of nutrients for aquatic consumers (Casatti et al., 2003) exercising a relevant role in system cycling, these results make it possible to prepare models representing the potential energy that could be transferred to upper links. However, allied to caloric density, future researches on the chemical composition and digestibility of aquatic plants are important complements because these plants can present the same caloric density, but different chemical constitutions (Esteves, 1982) and high energy values. So, it is important to note the low efficiency of using the energy due to the high cell wall fraction.

The Upper Paraná river floodplain presents high spatial heterogeneity (Thomaz et al., 1997) and, therefore, the results presented here for the Baía river may not be valid for other environments of the floodplain, for example Ivinheima and Paraná subsystems. Complementary studies about the floodplain may clarify this question, as well as the energy flow in the food chains. The acquisition of information of this nature is urged as anthropogenic impacts occur at a velocity and intensity superior to the current acquisition of ecological data, making the implementation of adequate management and conservation measures impossible.

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RESUMO

O presente trabalho teve por objetivo determinar a densidade calórica de folhas, caules e raízes de macrófitas aquáticas, em diferentes ambientes do subsistema Baía (Rio Baía e lagoas Fechada e do

Guaraná) na planície de inundação do alto rio Paraná, além de identificar a variabilidade entre grupos ecológicos. As amostragens foram realizadas em fevereiro de 2003, sendo coletadas amostras de diferentes macrófitas, *Eichhornia crassipes*, *Salvinia* spp, *Pistia stratiotes*, *Eichhornia azurea*, *Polygonum* sp, Cyperaceae e Poaceae. Diferenças espaciais nas densidades calóricas não foram observadas para as plantas estudadas. Os valores de densidade calórica variaram de 1906,9 cal/g de peso seco (raiz) a 4675,0 cal/g de peso seco (folha). Entretanto, diferenças significativas entre as médias dos conteúdos calóricos das estruturas vegetativas foram observadas somente para *Polygonum* sp e *Salvinia* spp. Em relação aos grupos ecológicos, o maior valor médio foi verificado para as macrófitas emergentes (3529,7 ± 722,5) as quais foram significativamente diferentes das flutuantes (3056,5 ± 571,0). Considerando que não houve diferença entre os ambientes, conclui-se que os fatores inerentes aos ambientes analisados não foram preponderantes na determinação da densidade calórica.

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