Variability in the caloric content of vascular plants in two *Paraná* State reservoirs

Elãine Christine dos Santos Dourado*, Danielle Peretti and Evanilde Benedito-Cecilio

*Núcleo de Pesquisa em Limnologia, Ictiologia e Aqüicultura, Universidade Estadual de Maringá, Avenida Colombo, 5790, 87020-900, Maringá, Paraná, Brasil. *Author for correspondence. e-mail: ecsdourado@yahoo.com.br*

ABSTRACT. The present research aimed to quantify the vascular plants caloric content in two reservoirs in *Paraná*, as well as the spatial and ecological group variabilities. The sampling was done in December 2002, in the fluvial, transition and lacustrine zones in *Rosana* and *Mourão* reservoirs. Aquatic macrophytes and riparian vegetation mature leaves, from different individuals (n=5), belonging to the same species, were randomly sampled. In order to obtain the caloric content, in $cal.g^{-1}$ dry weight, the samples were pulverized in a ball mill and subjected to combustion in a PARR calorimetric bomb. The data were treated with a null model ANOVA (EcoSim 7.44 program). A wide caloric variability was verified in the vascular plants analysed. Besides, the spatial and ecological group variabilities were significant, so it is not recommended, being use of only one caloric value to these primary producers in energy flow models, necessary a preliminary inspection of the breadth and of the factors that determine such variation.

Key words: reservoirs, vascular plants, caloric content.

RESUMO. Variabilidade no conteúdo calórico de plantas vasculares em dois reservatórios do Estado do Paraná. Com o intuito de quantificar o conteúdo calórico das plantas vasculares de dois reservatórios do Estado do Paraná, bem como sua variabilidade espacial e entre grupos ecológicos, foram realizadas amostragens em dezembro de 2002, nas zonas fluvial, de transição e lacustre dos reservatórios *Mourão* e *Rosana*. Foram amostradas, ao acaso, folhas maduras de plantas aquáticas e da vegetação ripária de diferentes indivíduos (n=5), pertencentes à mesma espécie. Para obtenção do conteúdo calórico, em $cal.g^{-1}$ de peso seco, as amostras foram maceradas em moinho de bola e submetidas à combustão em bomba calorimétrica PARR. Os dados foram submetidos a uma ANOVA modelo nulo, utilizando-se o programa EcoSim versão 7.44. Foi constatado que as plantas vasculares analisadas apresentaram ampla variabilidade calórica. Além disso, foram significativas as variabilidades espacial e entre os grupos ecológicos, não sendo recomendável o uso de um único valor calórico para estes produtores primários em modelos de fluxo de energia, sendo necessária, uma inspeção preliminar da amplitude e dos fatores que são determinantes de tal variação.

Palavras-chave: reservatórios, plantas vasculares, conteúdo calórico.

Introduction

Endogenous and exogenous factors are responsible for caloric variability of many species from different taxonomic groups (Caspers, 1977). Climatic conditions, availability of water and the concentrations of dissolved salts seem to be related with energy values of higher plants, although some authors ignore such variability.

The formation of artificial lakes, through dam construction alters the hydric dynamics which, consequently, has effects on the aquatic communities. Plants under environmental stress condition have their metabolic products altered (Verduin, 1972). On the other hand, it is verified that most of these environments have morphometric characteristics that propitiate the development of extensive aquatic macrophyte communities in the littoral regions, which play important role in the ecosystem metabolism (Esteves and Camargo, 1986).

According to Camargo *et al.* (1983), an important aspect of the presence of aquatic plants in these environments concerns to the role performed in the nutrients accumulation and cycling, besides they act in the organic detritus formation, constituting the largest energy source for detritivorous animals. The riparian vegetation also exerts a considerable effect on the aquatic communities through available matter and energy.

Thus the aim of this research was to quantify the caloric content of the vascular plants as well as spatial and ecological groups variability in two reservoirs of *Paraná* State. Such information will subsidize models of energy flow for these reservoirs, necessary to understand the dynamic and functioning of these ecosystems.

Material and methods

Sampling Site

The samples were taken in two mesotrophic reservoirs of *Paraná* State (Roberto *et al.*, in press) (Figure 1), located in different basins. The *Mourão* reservoir (24º02'S and 52º22'W) is located in *Mourão* River, a tributary of *Ivaí* River, close to *Campo Mourão* town. It is a headwater reservoir and the main local antropogenic actions are agriculture and the sugar-cane cultivation.

The *Rosana* reservoir (22º36'S and 52º50'W) is located in *Paranapanema* River between *Rosana* and *Diamante do Norte* towns (*Relatório para Licenciamento Ambiental*, 2001). It is located 25km from the confluence with *Paraná* River, integrating the energetic complex of the *Pontal do Paranapanema*. The diagnosis about the natural vegetation, under the area of influence of this dam, indicated almost an inexistence of riparian vegetation and continuous process of deforestation in the margin of *São Paulo* State, while in the *Paraná* State side it is verified a larger quantity of forest fragments. It is also observed a larger agricultural use of the soils and larger concern about soil conservation in pasture areas.

Analysis

The samples were collected in December 2002, in the fluvial, transition and lacustrine zones in *Mourão* and *Rosana* reservoirs. Mature leaves of aquatic plants and of the riparian vegetation were sampled from different individuals (n = 5), belonging to the same species. The samples were accomplished at random, with aleatory choice. Some plants were completly collected for subsequent identification. Thus they were pressed and the exsiccates analysed by specialists, being identified, as possible, at the lowest taxonomic level.

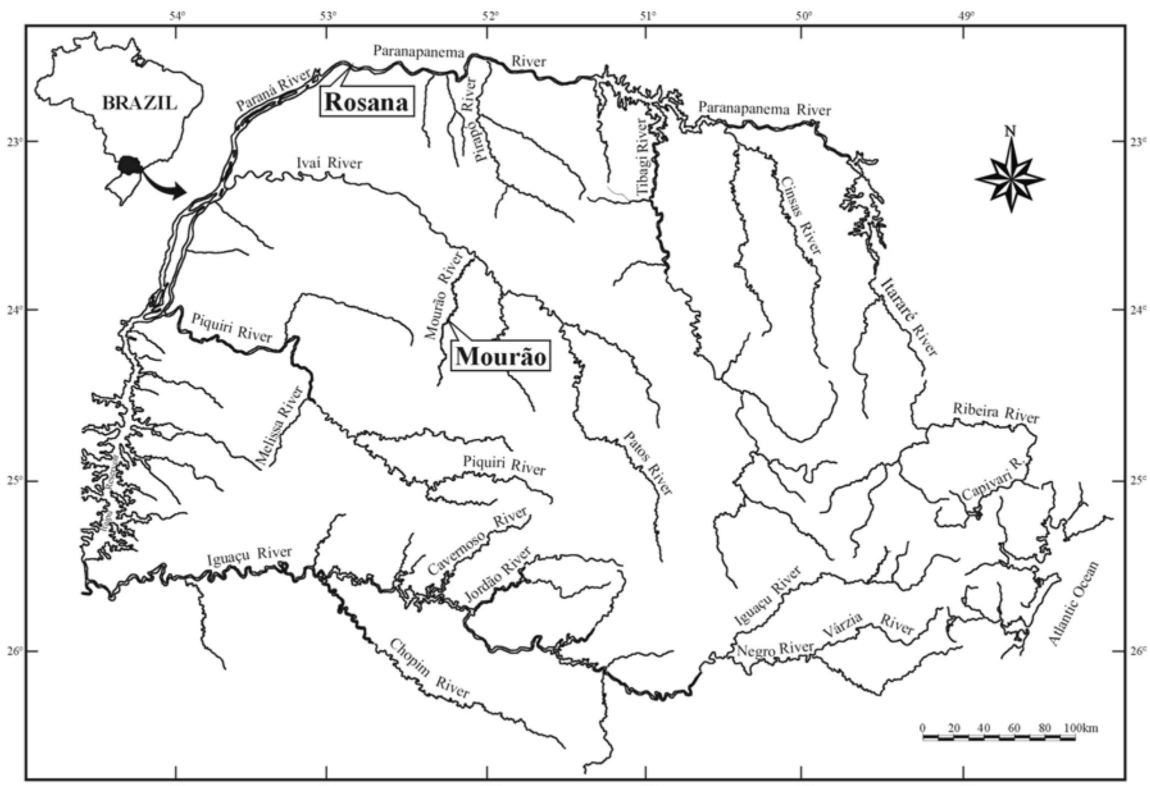

Figure 1. Geographic location of *Rosana* and *Mourão* reservoirs.

After sampling, the material was transported in plastic bags to the laboratory where it was washed with distilled water to remove the adhered material (sediments and periphyton), and oven-dried at 60ºC, until constant weight. To obtain the caloric content, in cal.g^{-1} of dry weight, the samples were pulverized in a ball mill and submitted to combustion in a Parr Model 1261 oxygen bomb calorimeter.

Differences in the caloric content between ecological groups as well as spatial variability were verified, after graphic analysis, through a null model ANOVA in the EcoSim program version 7.44 (Gotelli and Entsminger, 2001), because the normality and homocedasticity assumptions of parametric ANOVA could not be reached.

Results

Both reservoirs edge present several species of aquatic macrophytes and riparian vegetation. For the ecological groups analysis the plants were considered as terrestrial, emergent, floating rooted and floating (Table 1).

Table 1. Vascular plants present in *Mourão* and *Rosana* reservoirs and their respective ecological groups.

Vascular plants	Ecological groups	*Mourão*	*Rosana*
Alchornea sp.	Terrestrial		X
Asteraceae	Terrestrial	X	
Cecropia pachystachya Trec.	Terrestrial		X
Eichhornia azurea (Sw.) Kunth	Emergent		X
Eichhornia crassipes (Mart.) Solms	Floating		X
Eriochloa punctata (L.) Desv.	Emergent	X	X
Eupatorium sp.	Terrestrial	X	
Euphorbiaceae	Terrestrial	X	
Ludwigia sp.	Terrestrial		X
Nymphaea sp.	Floating rooted		X
Pera glabrata Baill.	Terrestrial	X	
Pistia stratiotes L.	Floating		X
Poaceae 1	Emergent	X	X
Poaceae 2	Emergent	X	
Poaceae 3	Emergent	X	X
Polygonum ferrugineum Wedd.	Emergent	X	X
Polygonum sp.	Emergent	X	X
Salvinia auriculata Aubl.	Floating		X

Among the species from *Rosana* reservoir the lowest caloric value was found to *Pistia stratiotes* (2789.2 cal.g^{-1}) and the highest to *Alchornea* sp. (4607.6 cal.g^{-1}). In *Mourão* reservoir, the lowest and the highest values were registered to riparian vegetation species (Euphorbiaceae and *Pera glabrata*, with 3823.7 and 5273 cal.g^{-1}, respectively) (Figure 2).

Considering the medium caloric contents of different ecological groups, riparian vegetation plants presented higher values in both reservoirs. In *Mourão* reservoir, significant differences between emergent aquatic macrophytes and plants of the terrestrial vegetation were observed (null model ANOVA; $F_{(1, 95)} = 39.38$; $p < 0.05$). In *Rosana* reservoir, these two groups presented very close medium values, differing from floating and floating rooted, which had medium values of, approximately, 3400 cal.g^{-1} ± 385.98. Furthermore, it could be observed a great variability in the caloric values in the floating group (Figure 3).

Significant differences were observed in caloric contents of the *Polygonum* species, associated to fluvial, transition and lacustrine zones for both reservoirs standing out the fluvial zone, which presented higher variabilities, mainly in *Mourão* reservoir (Figure 4).

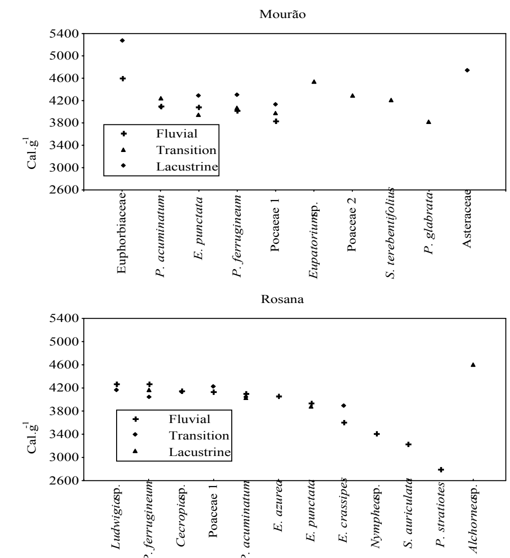

Figure 2. Medium caloric values (cal.g^{-1} of dry weight) for species of the vascular plants collected in fluvial, transition and lacustrine zones of *Rosana* and *Mourão* reservoirs.

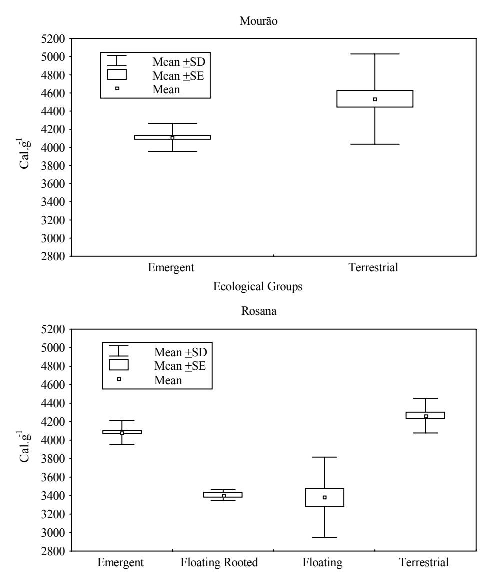

Figure 3. Medium caloric values (cal.g^{-1} of dry weight), standard deviation and standard error for ecological groups of vascular plants collected in *Rosana* and *Mourão* reservoirs.

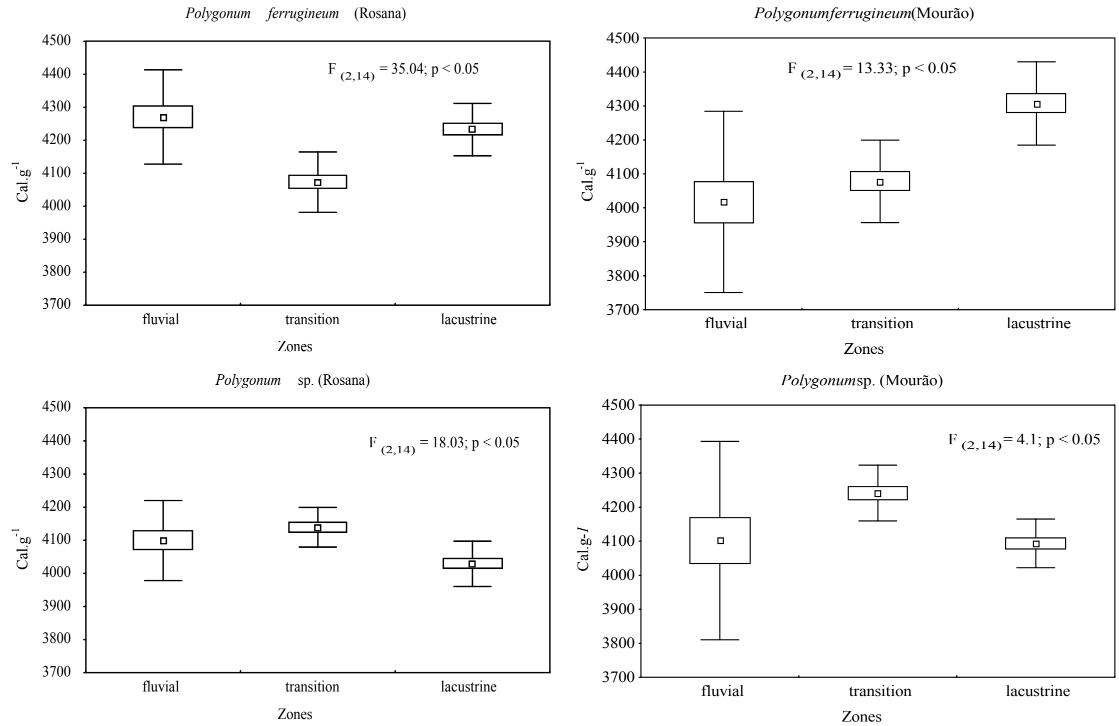

Figure 4. Medium caloric values (cal.g^{-1} of dry weight), standard deviation and standard error for *Polygonum* species collected in fluvial, transition and lacustrine zones of the *Rosana* and *Mourão* reservoirs.

Discussion

The vascular plants analysed in this research presented great variation in their caloric contents, differently from the values registered for vascular plants of temperate zones, which were relatively constant (Boyd, 1968; Grabowsky, 1973; Dykyjová and Pribil, 1975). Considering the different ecological groups of vascular plants, the highest caloric values were presented by terrestrial plants, followed by emergent, floating rooted and floating plants. Verduin (1972) also verified this fact for terrestrial plants in temperate environments. The evolutionary level, the life form and chemical characteristics genetically fixed are the main factors that determine the dry plant material energetic content (Larcher, 2000).

According to the same author Thallopphytes and coniferous are, generally, richer in energy than the Angiosperms arboreal forms, and the Monocotyledones plants are poorer in energetic content than Dicotyledones ligneous plants. These comparisons indicate an evolutionary development toward more economic energetic investiments, or, the energetic content of the plants type is shorter than the energetic content of the primitive types. However, Golley (1961), Hunt (1966) and Caspers (1977) obtained similar caloric contents between aquatic macrophytes and terrestrial vegetation. Thus, we can assume that environmental factors, as temperature, moisture, CO_2, atmospherical pollutants, besides the influence of the development phase and the plant activity level on the respiration and photosynthesis, can interfere in this pattern and influence the plant productivity and, consequently, in plants caloric content. The respiratory activity and the photosynthetical capacity are conspicuous characteristics for each plant species, but they are not constant values (Larcher, 2000).

The energetic content increases with a higher carbon content, consequently with higher productivity. So, to aquatic plants, the environment (water or atmosphere) that involve the plant is the determinant factor in the concentration gradient between CO_2 and O_2. It is expected that the way to obtain the CO_2, directly from the atmosphere or from the aquatic environment, can influence the macrophyte ecological groups caloric contents, as verified in this study. The dissolved CO_2 is described as the preferential carbon form assimilated by plants, however, many species are able to assimilate the HCO_3, as some submerged plants, or as in the emergent plants, the atmospherical CO_2 (Keeley and Sandquist, 1992).

For *Polygonum* species, in spite of significant differences in the caloric contents associated to fluvial, transition and lacustrine zones, for *Mourão* and *Rosana* reservoirs, a specific area with great concentration of energetic values was not observed. The lacustrine area presented the highest values to *Polygonum ferrugineum*, while to *Polygonum* sp. it was the intermediate area. Larger caloric variabilities were registered for the fluvial area in both reservoirs; however, it was larger to *Mourão* reservoir. This fact can be justified by the lotic influence of the river which originated the reservoir, constituting a transitional area of the reservoir, with fluvial and lentic characteristics. Lopes and Benedito-Cecilio (2002) admit that the water turbulence degree can influence on the enzimatic discrimination processes and consequently on the photosynthetical CO_2 acquisition. In general, the lentic waters allow shorter enzimatic discrimination than the lotic ones. The difusional resistence in waters that have faster flowing, is essentially shorter, facilitating the enzim RuBP – carboxilase action, primary CO_2 receptor in C_3 plants.

The aquatic macrophytes distribute themselves among the C_3, C_4 and CAM photosynthetical ways. The complexity of macrophytes photosynthetical behaviour makes it dificult to distinguish the photosynthetical ways in aquatic environments (Lopes abd Benedito-Cecilio, 2002). Family Poaceae species, for example, can present submerged leaves with CAM photosynthetical activity, while the floating leaves fix CO_2 through C_4 way (Keeley and Sandquist, 1992). For the aquatic plants presented in this paper, the isotopic values are still being investigated. The results will allow the detailed elucidation about the caloric variability exhibited by this plant group.

The studies which aimed the understanding of the ecosystem functioning have been intensified since Lindeman (1942) proposed the energy flow concept related with the lacustrine ecosystem trophodinamics (Acot, 1990). Data about caloric equivalent have been obtained for some groups, however, quantitative analyses of energy are still far from being understood for many trophic groups. Golley (1961) stated that the ecologists interest in energy flow studies in the ecosystem can not be limited to certain methodologies, and one of them is the biomass conversion in energy using the caloric equivalent obtained from the literature. As confirmed in this article, the caloric variations do exist and, depending on the research object, these variations should be spatial and seasonally considered. So, the caloric value of plant or animal is a function of genetic constitution, nutritional condition and life history, and since these factors can vary among species, seasons, and environmental conditions, the ecologists need to do intensive measures of energy flow through natural systems and they can not depend on constant caloric or equivalent.

Thus, due to significant variability existence among the groups of vascular plants analysed, it is not recommended the use of a single caloric value for those primary producers in models of energy flow. In the same way, spatial variations should be considered, and they are dependent on the plant species analysed and also on the environment. Seasonal variations, although not investigated in this study, should also have effects on the plants caloric content, once the concentration of nutrients and light intensity alter remarkably with the seasonal period.

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