Chemical composition of five species of aquatic macrophytes from lotic ecosystems of the southern coast of the state of São Paulo (Brazil)

HENRY-SILVA, G. G.[1]; PEZZATO, M. M. [1]; BENASSI, R. F. [1] & CAMARGO, A. F. M. [2]

[1] Programa de Pós-Graduação em Aqüicultura, CAUNESP, SP - Brasil, e-mail: ghgs@rc.unesp.br;

[2] Departamento de Ecologia, Instituto de Biociências - Universidade Estadual Paulista - Avenida 24A, 1515 Rio Claro, (SP), CEP: 13506-900.

ABSTRACT: Chemical composition of five species of aquatic macrophytes from lotic ecosystems of the southern coast of the state of São Paulo (Brazil). The objective of this paper is to infer on the fate of the biomass of five species of aquatic macrophytes (*Pistia stratiotes* (L), *Salvinia molesta* (Mitchell), *Eichhornia azurea* (Swatz) Kunth, *Utricularia foliosa* (L) and *Egeria densa* (Planch)), by determining the concentration of total phosphorus, protein, polyphenols, lipids, cell wall fraction and stocks of nitrogen and phosphorus. *E. densa*, *U. foliosa* e *P. stratiotes* presented greater concentration of protein (21.8; 11.9; 11.6 % dry mass, respectively) and low levels of cell wall fraction (53.4; 39.4; 41.6 % dry mass, respectively) when compared with *S. molesta* and especially with *E. azurea*. According to the results of this study it is possible to infer that the biomass of *E. azurea*, probably, contributes more to the detritus food chain, while the biomass of *E. densa* contributes more to the grazing food chain. *S. molesta*, *P. stratiotes* and *U. foliosa*, probably, contribute to both trophic chains.

Key-words: aquatic macrophytes, chemical composition, lotic ecosystem.

RESUMO: Composição química de cinco espécies de macrófitas aquáticas de ecossistemas lóticos do litoral sul paulista (Brasil). O objetivo deste trabalho é inferir sobre o destino da biomassa de cinco espécies de macrófitas aquáticas, através da análise da composição química desses vegetais. Foram determinadas as concentrações de fósforo total, proteína, polifenóis, lipídeos, fração de parede celular e os estoques de nitrogênio e fósforo na biomassa de *Pistia stratiotes* (L), *Salvinia molesta* (Mitchell), *Eichhornia azurea* (Kunth), *Utricularia foliosa* (L) e *Egeria densa* (Planch). As espécies *E. densa*, *U. foliosa* e *P. stratiotes* apresentaram maiores concentrações de proteína (21,8; 11,9; 11,6 % massa seca, respectivamente) e baixos valores de fração de parede celular (53,4; 39,4; 41,6 % massa seca, respectivamente), quando comparadas com *S. molesta* e principalmente com *E. azurea*. A partir dos resultados obtidos pode-se inferir que a biomassa de *E. azurea* deve contribuir principalmente para a cadeia de detritos, enquanto que a biomassa de *E. densa*, provavelmente, contribui mais para a cadeia de herbivoria. *S. molesta*, *P. stratiotes* e *U. foliosa* devem contribuir para ambas as cadeias tróficas.

Palavras-chave: Macrófitas aquáticas, composição química, ecossistemas lóticos.

Introduction

Aquatic macrophytes constitute important communities in many continental aquatic ecosystems, due to high levels of primary production, large biomass and high capacity for stocking nutrients. They also participate in the nutrient cycle and contribute to the food supply of herbivores and detritivorous (Cattaneo & Kalff, 1980; Esteves, 1998; Maine *et al.*, 1999 e Pompêo *et al.*, 1999).

For a better understanding of the contribution of these plants in the food chains and the dynamic of their biomass in aquatic ecosystems, the determination of the sum

of their protein concentrations, total phosphorus, lipids, polyphenols and cell wall fraction, is important (Thomaz & Esteves, 1984). Chifamba (1990) found that the aquatic macrophytes with high energy and protein content were consumed preferentially by herbivorous fishes. But, species with high content of structural polyphenolic compounds and calcareous material are avoided (Horn *et al.*, 1982).

In the Itanhaém River basin (coastal region of the state of São Paulo), the rivers are colonized by aquatic macrophytes of different life forms, being the most abundant *Pistia stratiotes* (L), *Salvinia molesta* (Mitchell) (free floating), *Eichhornia azurea* (Kunth) (emergent), *Utricularia foliosa* (L) (free submersed) and *Egeria densa* (Planch) (submerged). However, little is known about the importance of this community in the metabolism of these ecosystems (Henry-Silva, 1998; Camargo & Florentino, 2000).

The objective of this paper is to infer on the fate of the biomass of these aquatic macrophytes in the trophic chains of different lotic ecosystems, by analyzing the chemical composition of each species.

Material and methods

The Itanhaém River basin is located in the southern coastal region of the State of São Paulo-Brazil (23° 50' and 24° 15' S; 46° 35' and 47° 00' W) (Suguiu & Martin, 1978). The basin drains a considerable area of the coastal plain and the rivers presents low turbulence as a result of the little relief declivity. As a consequence, there is a large development of aquatic macrophytes of different life forms in these lotic environments.

Aquatic macrophytes were collected at quarterly intervals during a year, using quadrants of 0.25 m^2 in area. Samples of *S. molesta* and *E. azurea* were collected in the Preto and Branco Rivers, *P. stratiotes* in the Aguapeú and Guaú Rivers, *U. foliosa* in the Preto River and *E. densa* in the Aguapeú and Mambu Rivers. The plant material was cleaned through successive washes in order to remove the periphyton, organic matter and associated inorganic particles. Plants were dried at 60 °C and weighted, after which the samples were grounded in a mill, to determine their chemical composition.

Percentage of cell wall fraction was determined according Van Soest & Wine (1967). Polyphenols were determined by the method described in King & Heait (1967). The lipids were obtained through the method of Folch *et al.* (1957). Crude protein was calculated by multiplying the results of total nitrogen by 6.25 (Boyd, 1970). Total nitrogen was determined by the method of Kjeldahl, according to Allen *et al.* (1974). Total phosphorus was determined by the method described by Esteves (1980). Stocks of nitrogen and phosphorus were estimated by total nitrogen and the total phosphorus together with the biomass values of each species.

The Newman-Keuls test was applied to chemical composition data, in order to check for significant differences ($p \leq 0.05$) between the species of aquatic macrophytes.

Results

The protein values (21.7 % dry mass) and phosphorus (0.61 % dry mass) were significantly higher in *E. densa* and the average values of polyphenols (0.18 % dry mass) were lower. On the other hand in the biomass of *E. azurea* the protein levels (6.6 % dry mass) were significantly lower and the polyphenols (4.05 UDO/g dry mass) and cell wall fraction (61.7 % dry mass) levels were higher. In *U. foliosa* low levels of phosphorus (0.22 % dry mass), polyphenols (0.55 UDO/g dry mass) and cell wall fraction (39.4 % dry mass) concentrations were found. *P. stratiotes* and *E. densa* showed the lowest values of lipids (4.36 and 4.38 % dry mass, respectively). The phosphorus values in *S. molesta* (0.15% dry mass) were significantly lower when compared to the other species (Fig.1 and 2).

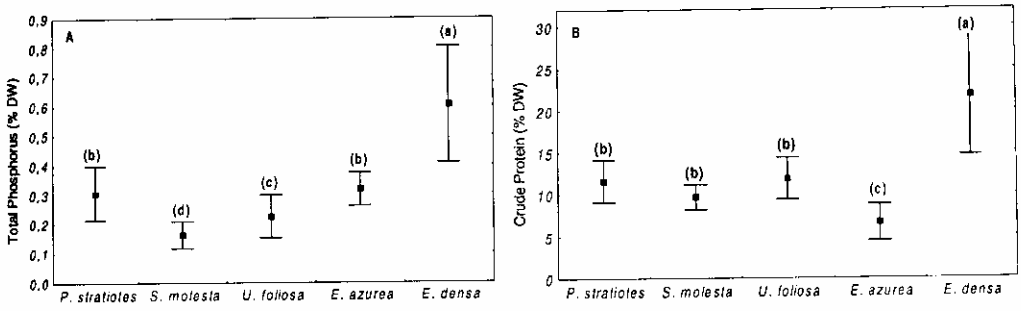

Figure 1: Means and standart deviations of the phosphorus (A) and crude protein (B) in the aquatic macrophytes *P. stratiotes*, *S. molesta*, *U. foliosa*, *E. azurea* and *E. densa*.

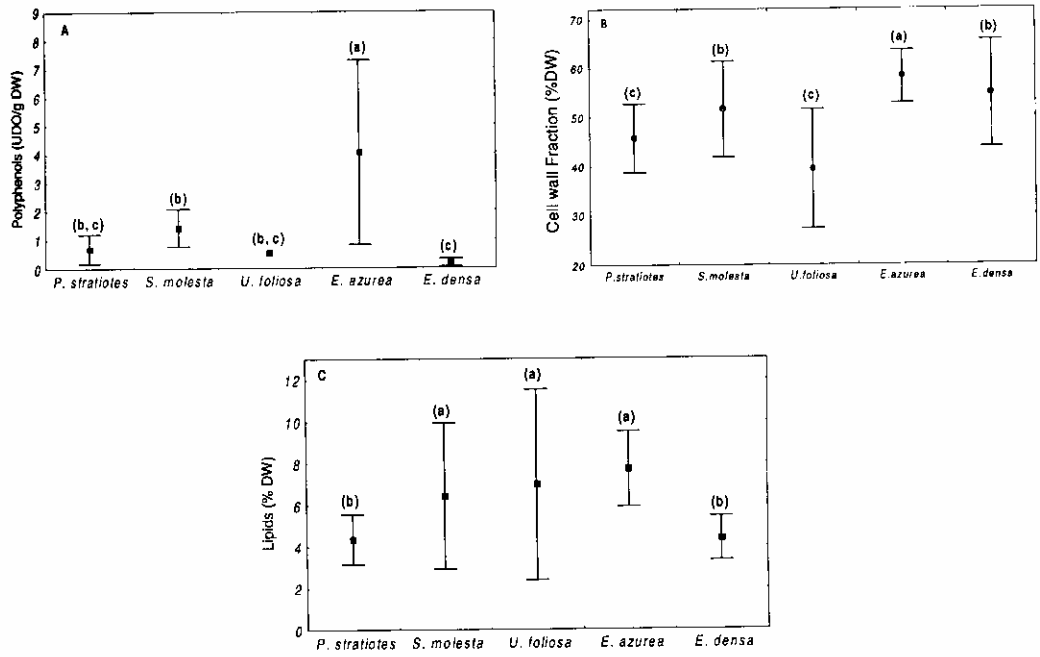

Figure 2: Means and standart deviations of the polyphenols (A), cell wall fraction (B) and lipids (C) in the aquatic macrophyte *P. stratiotes*, *S. molesta*, *U. foliosa*, *E. azurea* and *E. densa*.

The stocks of nitrogen and phosphorus (0.9 gN/m² and 0.1 gP/m², respectively) and total biomass (48.7 g dry mass/m²) in *U. foliosa* were significantly lower when compared to *P. stratiotes*, *S. molesta* and *E. azurea*. The largest average stocks of nitrogen were observed in the biomass of *E. densa*, *P. stratiotes* and *S. molesta* (6.2, 4.9 and 4.5 gN/m², respectively), presenting no significant differences. The average stock values of phosphorus in the biomass of *E. azurea* and *E. densa* (1.2 gP/m² for both) were higher than those of *P. stratiotes*, *S. molesta* and *U. foliosa* (0.7, 0.5 and 0.1 gP/m², respectively). *E. densa* showed high stocks of nitrogen and phosphorus due to the larger concentration of these nutrients in its biomass, however the average values of the total biomass were lower than those in *E. azurea*, *S. molesta* and *P. stratiotes* (Fig. 3).

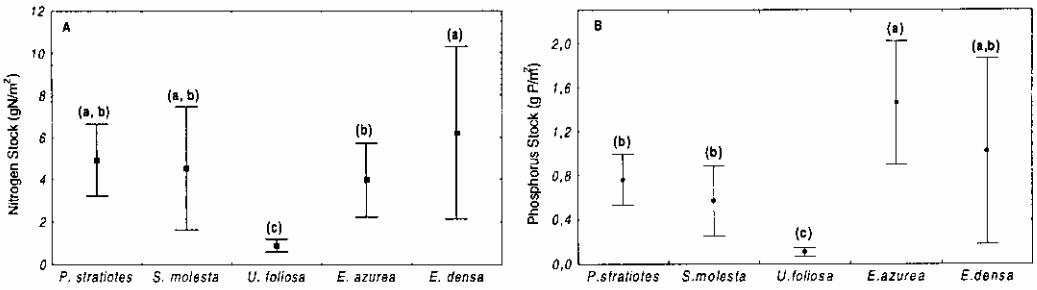

Figure 3: Means and standart deviations of the stocks of total nitrogen (A) and stocks of phosphorus in the aquatic macrophytes *P. stratiotes*, *S. molesta*, *U. foliosa*, *E. azurea* and *E. densa*.

Discussion

Differences in the chemical composition of the five species are probably related to the life forms of the macrophytes and to the limnological characteristics of the rivers. According to Gopal (1991) the submersed and the floating macrophytes are richer in nitrogen and phosphorus. The results showed that *E. densa* (submersed) and *P. stratiotes* (floating) have the highest concentrations of these nutrients in their biomass. However, *S. molesta* showed low concentrations of phosphorus and protein. These low levels could be related to the low nutrient concentrations in the Branco and Preto Rivers (Camargo *et al.*, 1997).

Total phosphorus in the biomass of *E. azurea* in Branco and Preto rivers was higher than that reported by Da Silva *et al.* (1994), for the same species in water bodies in the Pantanal. The values of total phosphorus in the biomass of *P. stratiotes*, measure in this work, was higher than that reported by Piedade *et al.* (1997) and Howard-Williams & Junk (1977) in the Amazon region (Tab. 1). Probably, the different trophic states of these ecosystems and the distinct climatic conditions, may have contributed to these differences, because the chemical composition of the aquatic macrophytes are also related to the availability of nutrients in the environment (Fernández-Aláez *et al.*, 1999).

According to Boyd (1970), plants that present values with less than 12 % of protein in their biomass are considered protein poor. Van Soest & Wine (1967) report a sharp drop in the ingestion of aquatic macrophytes when the concentration of cell wall fraction attained values higher than 60 % dry mass. In the biomass of *E. azurea* the mean content of protein was less than 12 %, while the cell wall fraction was higher than 60% dry mass, showing that this species, in the rivers studied, have low nutritional value. Additionally, high levels of polyphenols and lipids reduce the action of herbivorous. This suggests that this species participates more intensively in the detritus food chain than the other aquatic macrophytes studied. Moreover, this species, probably, has a slower decomposition rate. In general, submersed and floating-leaved macrophytes are more quickly decomposed, while floating and emergent species have slower decomposition (Kulshreshtha & Gopal, 1982; Sharma & Goel, 1987).

The highest protein and phosphorus levels, reduced values of polyphenols and lipids, apart from the intermediate values of cell wall fraction in the biomass of *E. densa*, show that this species possess a high nutritional value. It should thus have an important role in the grazing food chain. In relation to the stocks of nitrogen and phosphorous, *U. foliosa* have low capacity of stock, when compared to the other species studied and, probably, have smallest importance in the nutrient cycling.

According to the results of this study it is possible to infer that the biomass of *E. azurea*, probably, contributes more to the detritus food chain, while the biomass of *E. densa* contributes more to the grazing food chain. *S. molesta*, *P. stratiotes* and *U. foliosa*, probably, contribute to both trophic chains.

Table I: Values of chemical composition of some species of the aquatic macrophytes.

Species	Nitrogen	Phosphorus	Lipids	Cell Wall Fract.	Polyphenols	author
	% Dry Mass				UDO/g DM	
Eichhornia azurea aerial	1.20	0.10	8.40	5.80	6.40	Da Silva et al. (199
Submersed	3.60	0.20	3.50	70.80	1.30	Da Silva et al. (199
Eichhornia azurea all plant	1.05	0.32	7.70	61.78	4.05	This Work
Utricularia breviscapa all plant	2.67	0.22	6.68	40.23	-	Barbieri (1984)
Utricularia foliosa all plant	1.90	0.22	6.97	39.44	0.55	This Work
Salvinia auriculata all plant	1.28	0.08	-	-	-	Piedade et al. (199
Salvinia molesta all plant	1.55	0.15	6.42	52.20	1.40	This work
Pistia stratiotes all plant	1.85	0.19	-	-	-	Horward-Williams & Junk
Pistia stratiotes all plant	1.47	0.13	-	-	-	Piedade et al. (199
Pistia stratiotes all plant	1.85	0.30	4.36	41.64	0.69	This work
Egeria densa all plant	3.49	0.61	4.38	53.30	0.18	This work

Acknowledgements

We would like to acknowledge the assistance of Carlos Fernando Sanches, of the Laboratory of the Aquatic Ecology of the Department of Ecology (UNESP-Rio Claro) and to FAPESP for financial support (Process: 95/2573-8).

References

Allen, S. E., Grimshaw, H. M., Parkinson, J. A. & Quarmby, C. 1974. Chemical Analysis of Ecological Materials. Blackwell, Oxford. 565 p.

Barbieri, R. 1984. Estudos da composição química de algumas espécies de macrófitas aquáticas e suas implicações no metabolismo da represa do Lobo (Broa). São Carlos. Universidade Federal de São Carlos. 225p. (Dissertação)

Boyd, C. E. 1970. Aminoacids protein and caloric content of aquatic macrophytes. Ecology, 51: 902-6.

Camargo, A. F. M., Nucci, P. R., Bini, L. M. & Silva J. R. 1997. The influence of the geology on the limnological characteristics of some lotic ecosystems of the Itanhaém River Basin SP-Brazil. Verh. Int. Verein. Limnol., 26: 860-4.

Camargo, A.F.M. & Florentino, E.R. 2000. Population dynamics and net primary production of the aquatic macrophyte *Nymphaea rudgeana* C.F. may in a lotic environment of the Itanhaém River basin (SP, Brazil). Rev. Bras. Biol., 60: 83-92.

Cattaneo, A. & Kalff, J. 1980. The relative contribution of aquatic macrophytes and their epiphytes to the production of macrophytes beds. Limnol. Oceanogr., 25: 280-289.

Chifamba, P. C. 1990. Preference of *Tilapia rendalli* (Boulenger) for some species of aquatic plants. J. Fish Biol., 36: 701-705.

Da Silva, C. J., Nogueira, F. & Esteves F.A. 1994. Composição química das principais espécies de macrófitas aquáticas do Lago Recreio Pantanal Matogrossense (MT). Rev. Bras. Biol., 54: 617-622.

Esteves, F. A. 1980. Die bedeutung der quatischem makrophyten fur den stoffhus haalt des schohsses. III. Die anorganischen hauptbestanatteile der a quatischen makcrophyten. Gewasser und Abwasser, 66/67: 29-94.

Esteves, F.A. 1998. Fundamentos de Limnologia. 2.ed. Interciência - FINEP, Rio de Janeiro. 602p.

Fernández-Aláez, M., Fernández-Aláez, C. & Bécares, E. 1999. Nutrient content in macrophytes in Spanish shallow lakes. Hidrobiologia, 408/409: 317-326.

Folch, J., Less, M. & Sloanestanley, G. H. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biochem., 26: 497-509.

Gopal, B. 1991. Nutrient dynamics of aquatic plant communities In: Gopal, B. (ed.). Ecology and management of aquatic vegetation in the Indian subcontinent. Kluwer Academic Publisher, Dordrecht. p. 177-197.

Henry-Silva, G.G. 1998. Comparação da composição química da biomassa de *Eichhornia azurea* Kunth. encontrada em ecossistemas lóticos (Rio Preto e Rio Branco) da Bacia Hidrográfica do Rio Itanhaém no litoral sul paulista. Rio Claro. Universidade Estadual Paulista., 76p (Monografia).

Horn, M. H., Murray, S. N. & Edwuards, T. W. 1982. Dietary selectivity in the field and food preferences in the laboratory for two herbivorous fishes (*Cebidichthys violaceus* and *Xiphister mucosus*) from a temperate interdital zone. Mar. Biol., 67: 237-246.

Howard-Williams, C. & Junk, W. 1977. The chemical composition of central Amazonian aquatic macrophytes with special reference to their role in the ecosystem. Arch. Hydrobiol., 79: 446-464.

King, H. C. & Health, G. W. 1967. The chemical analysis of small sample of leaf material and the relationship between the disappearance and composition of leaves. Pedobiologia, 7:192-7.

Kulshreshtha, M. & Gopal, B. 1982. Decomposition of freshwater wetland vegetation. II. Aboveground organs of emergent macrophytes. In: Gopal, B., Turner, R. E., Wetzel, R.G. & Whigham, D. F. (ed.) Wetlands: Ecology and managements. Nat. Inst. Ecol./ Int. Sci. Publs., Jaipur. p. 281-296.

Maine, A., Suñe, N. L., Panigatti, M. C., Pizarro, M. J. & Emiliani, F. 1999. Relationships between water chemistry and macrophyte chemistry in lotic and lentic environments. Arch. Hydrobiol., 145:129-145.

Piedade, M. T. F., Junk, W. J. & Long, S. P. 1997. Nutrient dynamics of the highly productive C4 macrophyte *Echinochloa polystacha* on the Amazon floodplain. Funct. Ecology., 1: 299-316.

Pompêo, M. L. M., Henry, R. & Moschini-Carlos, V. 1999. Chemical composition of tropical macrophyte *Echinochloa polystachya* (H.B.K.) Hitchcock in Jurumirim Reservoir (São Paulo, Brazil). Hydrobiologia, 411:1-11.

Sharma, K. P. & Gocl, P. K. 1987. Decomposition of water hyacinth, *Eichhornia crassipes* (Mart.) Solms. Int. J. Ecol. Environ. Sci., 13:13-18.

Suguiu, K. & Martin, L. 1978. Carta Geológica de Itanhaém, São Paulo, FAPESP.

Thomaz, S. M., Esteves, F. A. 1984. Estudos da biomassa de algumas espécies de macrófitas aquáticas quanto ao seu valor nutritivo. In: Anais do 4° Seminário Regional De Ecologia.UFSCAR, São Carlos. p. 439-67.

Van Soest, P. J., Wine, R. H. 1967. Use of detergents in the analysis of fibrous feeals. IV. Determination of plant cell-wall constituents. J. Assoc. Off. Anal. Chem., 50:50-1.

Recebido em: 02 / 10 / 2000
Aprovado em: 23 / 07 / 2001