LOSS OF WEIGHT AND CONCENTRATION OF CARBON, NITROGEN, AND PHOSPHORUS DURING DECOMPOSITION OF *EICHHORNIA AZUREA* IN THE FLOODPLAIN OF THE UPPER PARANÁ RIVER, BRAZIL

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(With 2 figures)

ABSTRACT

Leaf packs of the aquatic macrophyte *Eichhornia azurea* were used to experimentally evaluate changes in mass, carbon, nitrogen, and phosphorus concentrations, and C:N ratios during initial stages of decomposition in two different environments, the Paraná River and Garças Lake. Analysis of weight loss showed relatively slow decomposition rates in both environments (0.0047 d^{-1} and 0.0048 d^{-1} respectively). Over a 45-day period we observed significant changes ($p < 0.05$) in concentrations of carbon, nitrogen, and phosphorus, but only carbon differed between the environments ($F = 10.479$; $p = 0.03$). Therefore we concluded that detritus behaved similarly during decomposition, since intrinsic characteristics of the environments affected only the carbon concentrations.

Key words: Eichhornia azurea, decomposition, floodplain, Paraná river.

RESUMO

Perda de peso e concentrações de carbono, nitrogênio e fósforo durante a decomposição de *Eichhornia azurea* na planície de inundação do Alto Rio Paraná, Brasil

Maços de folhas da macrófita aquática *Eichhornia azurea* foram utilizados para avaliar experimentalmente as alterações na massa, concentrações de carbono, nitrogênio e fósforo, bem como a relação C:N, durante os estágios iniciais de decomposição em ambientes distintos (rio Paraná e lagoa das Garças). A perda de peso revelou uma taxa de decomposição relativamente lenta para ambos os ambientes (0,0047 d^{-1} e 0,0048 d^{-1}, respectivamente). Durante o período de 45 dias, observaram-se alterações significativas ($p < 0,05$) nas concentrações de carbono, nitrogênio e fósforo, sendo que apenas as concentrações de carbono diferiram entre os ambientes ($F = 10,479$; $p = 0,03$). Portanto, pode-se concluir que os detritos comportam-se de maneira semelhante durante o processo de decomposição, sendo que as características intrínsecas dos ambientes afetam apenas as concentrações de carbono.

Palavras-chave: Eichhornia azurea, decomposição, planície de inundação, rio Paraná.

INTRODUCTION

Many species of aquatic macrophytes contribute substantially to detritus input in continental aquatic ecosystems (Wetzel, 1975, 1990). In most investigations of the decomposition process of macrophytes, the plant material is enclosed in litter bags. This technique has been criticized because the detritus is isolated (Boulton & Boon, 1991), leading some investigators to use senescent material still attached to the plant (Roland *et al.*, 1990), or naturally dried material (Newell, 1993; Thomaz & Esteves, 1998; Pagioro, 1996).

The floodplain of the Upper Paraná River contains many species of aquatic macrophytes, some with relatively high biomass (Bini, 1996). One of the main species is *Eichhornia azurea*, which develops in the floodplain lakes and the side channels. Studies of this species by Pagioro (1996) showed that during the decomposition changes in concentrations of phosphorus, nitrogen, and carbon are observed in plant material. Although that study was performed with plant material from lentic and lotic environments of the Upper Paraná River floodplain, the experiments were done in microcosms. The objectives of the present study were to estimate the in situ loss of weight and nitrogen, carbon, and phosphorus concentration during the initial decompositional phase of *E. azurea* leaves and to compare the decomposition in two different environments.

MATERIAL AND METHODS

Samples of *E. azurea* were collected in Garças Lake, located near Cortado Channel, a side channel of the Paraná River, within the municipality of Porto Rico, State of Paraná (22°40' – 22°50'S and 53°10' – 53°40'W). The study area is within the floodplain of the Upper Paraná River.

Garças Lake is on the right bank of the Paraná River, to which it is connected intermittently by a channel about 50 meters long. Its littoral zone is colonized mainly by *E. azurea*, though other species of macrophytes such as *Polygonum* spp., *Pistia stratiotes*, *Salvinia* sp., and *Cabomba* sp. are also present.

Cortado Channel, on the left bank of the Paraná River, is a lotic environment and is surrounded by well-developed gallery forest. *Eichhornia azurea* is also the dominant species here, but *Salvinia* sp. is also present.

The following data were provided by Rodrigues (1998), who studied these environments, during the period of low water (July and August 1994):

- Cortado Channel: temperatures between 18.6 and 20.1ºC, pH between 7.42 and 7.60, and electrical conductivity between 58 and 62 µS cm^{-1}.
- Garças Lake: temperatures between 16.2 and 19.3 ºC, pH between 6.67 and 6.83, and electrical conductivity between 46 and 53 µS cm^{-1}.

A study by Paes da Silva & Thomaz (1997) in these environments established that phosphate concentrations are low (< 11 µg l^{-1}) in both systems, but nitrate concentrations in the Paraná River (83-212 µg l^{-1}) are higher than in the lake (6-107 µg l^{-1}).

The experiments were done with the aerial part (stem and petiole) of *E. azurea*, collected when already dead or senescent (75 to 100% of the leaves yellowed or dried).

The plant material was washed in running water to remove excess matter adhering to it, and then oven-dried at 70ºC to constant weight. After being dried and weighed, the leaves were arranged in leaf packs.

The leaves were numbered and the leaf packs were left to decompose in the littoral zones of the lake and channel, in the same locations where the material originated, from 21 July to 4 September 1995.

After periods of 1, 2, 3, 5, 9, 15, 30, and 45 days, the leaves were collected in triplicate and again oven-dried to constant weight at 70ºC. The coefficient for decrease of the detritus mass (weight loss) was estimated by the negative exponential equation of Olson (1963), based on the initial dry weight and the weight after 45 days of decomposition.

The plant material was pulverized, in order to determine nitrogen and phosphorus in an injection-flow spectrophotometer (Zagatto *et al.*, 1981), and organic matter by incineration in a muffle furnace at 550ºC for 4 hours. The values for organic matter were multiplied by 0.465 to obtain the carbon concentrations (Wetzel & Likens, 1991).

Differences between treatments, the effects of time, and the time x treatment interaction were analyzed by analysis of variance with repeated measurements (ANOVA Repeated). This method of analysis was chosen to account for temporal measurements and the correlation between dates (Ende, 1993). The

C:N ratio was not statistically analyzed, since it was derived from the other analyses already tested.

RESULTS

Concentrations of carbon, nitrogen, and phosphate varied over time in the initial stages of decomposition, which is shown by the significant effect of time on these variables (Table 1). Weight loss showed an irregular pattern in both lentic and lotic environments, and was relatively slow. Approximately 80% of the dry mass still remained after 45 days of decomposition (Fig. 1a). For the entire period, the coefficients for decrease of the detritus mass were 0.0047 d^{-1} and 0.0048 d^{-1} for Cortado Channel and Garças Lake, respectively.

Environment (lentic and lotic) significantly affected carbon concentrations during decomposition (Table 1). Carbon content remained relatively constant when decomposition occurred in Garças Lake (between 41.783% and 46.287% of dry weight), but in detritus that decomposed in Cortado Channel, carbon declined steeply by day 30 (Fig. 1b). The interaction of location x time was also significant (Table 1).

Nitrogen concentrations fell during the first days of decomposition. Values near the initial levels (1.43% in channel and 0.99% of dry weight in lake) were again reached by day 45 (Fig. 2a). For this variable, no significant effect of environment, nor of environment x time interaction was observed (Table 1).

The C:N ratio, which was 29.6 in detritus from Cortado Channel and 42.5 in detritus from Garças Lake, rose to values above 45 during the first days, but fell again by the end of the experiment (34.7 for the channel and 39.4 for the lake; Fig. 2b).

In both environments there was a constant decline in phosphorus concentrations, which decreased from 0.179% and 0.196% of dry weight to 0.067% and 0.062% of dry weight in Cortado Channel and Garças Lake respectively (Fig. 2c). The effect of environment was not significant for phosphorus concentrations in the detritus, nor for the interaction of locality x time (Table 1).

DISCUSSION

Weight loss, expressed as a percentage of material remaining, has been used by many authors as a measurement of the decomposition of plant material (Odum & De La Cruz, 1963; Kulshreshtha & Gopal, 1982). In the present work, the detritus was arranged in leaf packs in the littoral zone. The detritus was not confined in litter bags, which are usually used in this kind of study, and which interfere with the decomposition process (Boulton & Boon, 1991). Thus, the rates of weight loss obtained ought to be closer to those for leaves of *E. azurea* decomposing naturally.

The values for the coefficient of decrease obtained for the first 45 days of decomposition (0.0047 and 0.0048) are considerably lower than

TABLE 1

F values and levels of significance obtained by the ANOVA Repeated to verify the influence of environment, time, and the location x time interaction on the decomposition rates and quality of decomposing detritus.

	Environment	Time	Interaction environment x time
Mass lost	F = 5.401	F = 5.681	F = 2.803
	p = 0.081	p < 0.001	p = 0.024
Carbon	F = 10.479	F = 11.941	F = 5.832
	p = 0.032	p < 0.001	p < 0.001
Nitrogen	F < 0.001	F = 2.989	F = 1.359
	p = 0.994	p = 0.018	p = 0.261
Phosphorus	F = 1.321	F = 3.037	F = 0.197
	p = 0.315	p = 0.017	p = 0.989

those recorded for *E. azurea* decomposing in other tropical environments (Roland *et al.*, 1990; Camargo, 1991; Pagioro, 1996). The rate of decrease and loss of initial weight, which can be attributed to leaching (<15% in the first week), is also considerably lower than observed for *E. crassipes* by other investigators (Hammerly *et al.*, 1989; Poi de Neiff & Neiff, 1989). This first phase of decomposition is characterized by rapid liberation of the soluble fraction, and is caused basically by the action of physical processes (Olah, 1972; Kulshreshtha & Gopal, 1982).

The low rate of weight loss during the decomposition may be related to two different causes. First, in the leaching phase, we found a

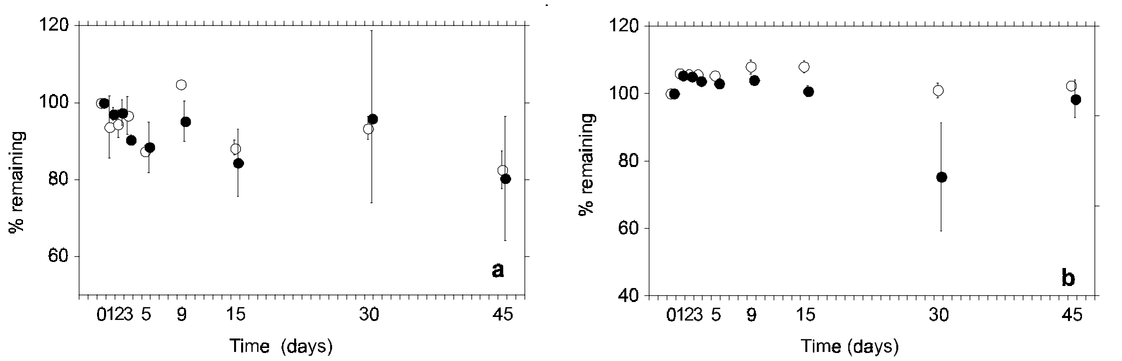

Fig. 1 — Ash free mass (a) and carbon remaining (b) (in % of original amount) during the decomposition of de *E. azurea* from Cortado channel (filled cycles) and Garças lake (blank cycles). Bars = standard deviation; N = 3.

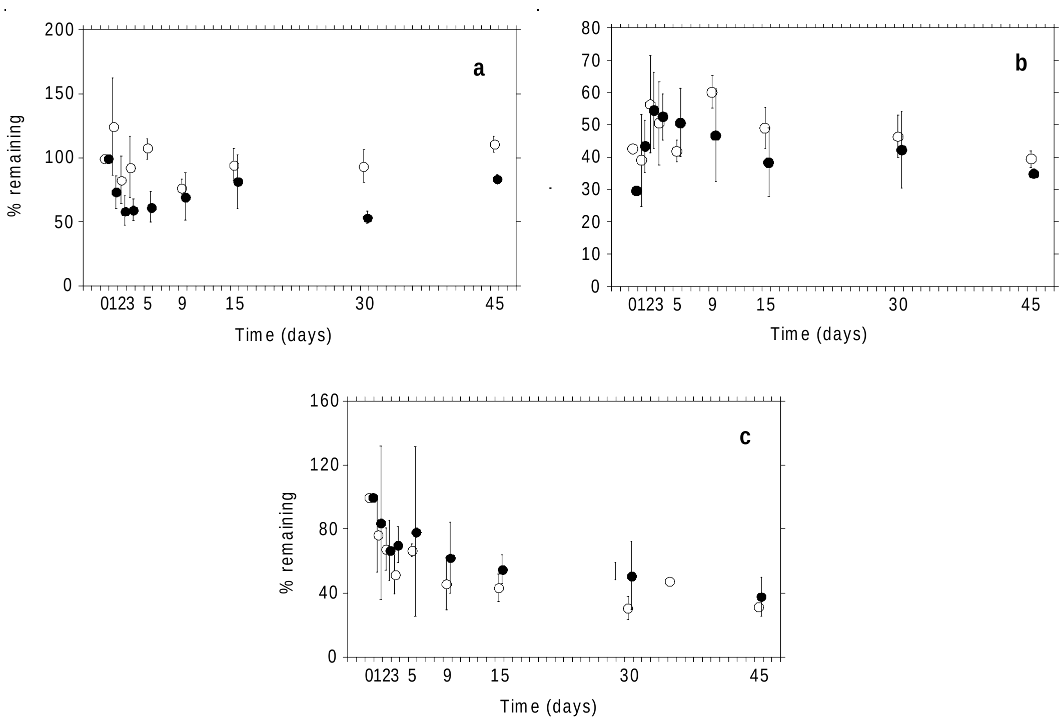

Fig. 2 — Concentration of nitrogen (a), C:N relationship (b) and phosphorus (c) (in % of original amount) during the decomposition of de *E. azurea* from Cortado channel (filled cycles) and Garças lake (blank cycles). Bars = standard deviation; N = 3.

methodological reason that can be attributed to the use of already dead or senescent leaves of *E. azurea*. Consequently, part of the organic and inorganic compounds in the protoplasm of the leaf cells probably had already been lost by translocation and passive cell loss to the environment (Newell, 1993), before the detritus was immersed to begin the process of sub-aquatic decomposition. Second, the low decomposition rate can be also attributed to the high detritus C:N ratio (mean values between 43.6 and 47.3). These results indicate that *E. azurea* detritus can be considered relatively refractory during the first 45 days of decomposition. Together with the fiber fraction, the C:N ratio has been considered an important factor affecting decomposition (Esteves & Barbieri, 1983; De Busk & Dieberg, 1984; Poi de Neiff & Neiff, 1989). According to Anderson (1973), decomposition proceeds faster when this ratio attains values lower than 25.

The temporal sequence of the nitrogen concentrations, which decreased during the experiment, is contrary to that observed by most investigators studying decomposition (Odum & De La Cruz, 1963; Kulshreshtha & Gopal, 1982; Poi de Neiff & Neiff, 1988, among others). However, the C:N ratio of *E. azurea* detritus must decrease in more advanced stages of decomposition, as shown by Pagioro (1996) who studied this process over a longer period.

The decline in phosphorus concentrations during decomposition accords with results obtained in other investigations (Esteves & Barbieri, 1983; Poi de Neiff & Neiff, 1988), may also have contributed to impoverishing the nutrient value of the detritus.

However, this element also must be found in higher concentrations during more advanced stages of decomposition, when it is assimilated by the microbiota associated with the detritus (Kulshreshtha & Gopal, 1982; Esteves & Barbieri, 1983).

The lack of effect of environment (channel x lake) on weight and nitrogen and phosphorus concentrations indicates that detritus behaves similarly with respect to these characteristics at the beginning of decomposition, independently of the environment where it is decomposing. This similarity was not expected, because these environments differ in concentrations of nutrients (Thomaz *et al.*, 1997; Paes da Silva & Thomaz, 1997) and in current velocity, which has been considered one of the main physical variables related to rates of weight loss (Hammerly *et al.*, 1989). However, the effect of current in Cortado Channel must have been attenuated by the location of the experimental site within the stands of *E. azurea*.

Even though there were no differences between localities with respect to nitrogen and phosphorus concentrations and rates of weight loss, locality significantly affected the carbon content of the detritus.

Higher inputs of inorganic suspended matter carried by the Paraná River were enough to cause such differences. Consequently, the greater accumulation of inorganic matter in the detritus may indicate that the nutritional value of this plant matter is reduced when decomposition occurs in the river channel.

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