doi:10.12741/ebrasilis.v9i1.548
e-ISSN 1983-0572
Publicação do Projeto Entomologistas do Brasil
www.ebras.bio.br

Invertebrate Colonization During Leaf Decomposition of *Eichhornia azurea* (Swartz) Kunth (Commelinales: Pontoderiaceae) and *Salvinia auriculata* Aubl. (Salvinales: Salvinaceae) in a Neotropical Lentic System

Lidimara Souza da Silveira[1]✉, Renato Tavares Martins[2] & Roberto da Gama Alves[1]

1. Universidade Federal de Juiz de Fora, e-mail: lidimara@gmail.com (Autor para correspondência✉), gama.alves@ufjf.edu.br. 2. Instituto Nacional de Pesquisas da Amazônia, e-mail: martinsrt@gmail.com.

EntomoBrasilis 9 (1): 10-17 (2016)

Abstract. The decomposition of macrophytes is an essential process for cycling of carbon and nutrients, and it is source of organic matter for invertebrates in lakes. We evaluated the colonization by aquatic invertebrates in decomposing leaves of two species of macrophytes in a Neotropical lentic system. The experiment was conducted from November 2007 to February 2008, with the use of 54 litter bags (*Eichhornia azurea* (Swartz): n = 27 and *Salvinia auriculata* Aubl.: n= 27), each containing 10 g of dry leaves. Three bags of each species were retrieved after 2, 4, 8, 12, 24, 36, 48, 60 and 72 days of incubation. The remaining leaf mass of the two macrophytes species tended to decrease with time, although at different rates. The decomposition of *E. azurea* and *S. auriculata* leaves were classified as rapid and intermediate, respectively. In general, during the experiment carbon: nitrogen ratio declined in *E. azurea* and increased in *S. auriculata*, and presented difference among the days of the experiment and between the macrophyte species. In *E. azurea* mass loss was negatively correlated with carbon: nitrogen ratio of the leaves, but the same pattern was not observed for the *S. auriculata* leaves. The composition and richness of invertebrates differed among days, but not between macrophytes species. We concluded that the succession process along the detritus chain was more important in structuring the invertebrate community than the variation in the nutritional quality of the leaf litter for these two species of macrophytes.

Keywords: Aquatic insects; Carbon: nitrogen ratio; Leaf breakdown; Macrophytes; Oligochaetes.

Colonização por Invertebrados Durante a Decomposição foliar de *Eichhornia azurea* (Swartz) Kunth (Commelinales: Pontoderiaceae) e *Salvinia auriculata* Aubl. (Salvinales: Salvinaceae) em um Sistema Lêntico Neotropical

Resumo. A decomposição de macrófitas é um processo essencial para ciclagem de carbono e nutrientes, e é fonte de matéria orgânica para invertebrados em lagos. Avaliamos a colonização por invertebrados aquáticos em folhas em decomposição de duas espécies de macrófitas em um sistema lêntico Neotropical. O experimento foi conduzido entre novembro de 2007 e fevereiro de 2008, com a utilização de 54 sacos de detrito (*Eichhornia azurea* (Swartz): n = 27 e *Salvinia auriculata* Aubl.: n = 27), cada um contendo 10 g de folhas secas. Três sacos de cada espécie foram recuperados após 2, 4, 8, 12, 24, 36, 48, 60 e 72 dias de incubação. A massa remanescente de folha das duas espécies de macrófitas tendeu a diminuir com o tempo, embora a velocidades diferentes. A decomposição de folhas de *E. azurea* e *S. auriculata* foram classificadas como rápida e intermédia, respectivamente. Em geral, durante o experimento a razão carbono: nitrogênio diminuiu em *E. azurea* e aumentou em *S. auriculata*, e apresentou diferença entre os dias de experimento e entre as espécies de macrófitas. Em *E. azurea* perda de massa foi negativamente correlacionada com a razão de carbono: nitrogênio das folhas, mas o mesmo padrão não foi observado para as folhas de *S. auriculata*. A composição e riqueza de invertebrados diferiram entre os dias, mas não entre espécies de macrófitas. Concluímos que o processo de sucessão ao longo da cadeia de detritos foi mais importante na estruturação da comunidade de invertebrados do que a variação na qualidade nutricional do detrito de folha para estas duas espécies de macrófitas.

Palavras-chave: Insetos aquáticos; Decomposição foliar; Macrófitas; Oligoquetas; Razão carbono: nitrogênio.

Macrophytes are the main source of autochthonous organic matter in the littoral zone of lakes and their decomposition is an essential process for cycling of carbon and nutrients (Wetzel 2001; Li *et al*. 2012). The use of live macrophyte leaves as food is limited due to high concentration of cellulose and carbon: nitrogen (C:N) ratios, low digestibility of some proteins and presence of allelopathic substances that cannot be degraded by invertebrates (Suren & Lake 1989; Bruquetas de Zozaya & Neiff 1991). However, during the decomposition process litter of macrophyte is an important source of both food and refuge for invertebrates (Mormul *et al*. 2006).

The decomposition rate of aquatic plant species is influenced by interaction of environmental variables, intrinsic properties of the leaves and activity of microorganisms and invertebrates (Gimenes *et al*. 2010). Leaves intrinsic properties, such as size, morphological structure and initial chemical composition determine different decomposition rates for each plant species (Gimenes *et al*. 2010). Carbon (C) is the most recalcitrant of the structural components in macrophytes, and is often found in inverse proportion to the nitrogen (N) content in plant tissue (Chimney & Pietro 2006). Generally, higher leaf decomposition rates are associated with lower C:N ratios (Pagioro & Thomaz 1998; Chimney & Pietro 2006).

Invertebrates colonization on litter is influenced by leaf chemical composition, and by physical (i.e., reduced leaf size) and chemical (i.e., increase in nitrogen concentration) modification on the substrate due to activity of microorganisms (Gessner *et al*. 1999; Gulis & Suberkropp 2003; Capelo *et al*. 2004; Gonçalves Jr. *et al*. 2012), during the degradative ecological succession

Funding Agencies: CNPq and FAPEAM

(Gonçalves Jr. *et al.* 2003). Shredder invertebrates use detritus as food and increase its nutritional content by their excrement, contributing to accelerate the decomposition (Graça 2001). Despite the importance of shredders in leaf decomposition in temperate regions, the low abundance of these invertebrates in relation to microorganisms, indicates that these organisms have less influence on the decomposition of leaves in tropical streams (Mathuriau & Chauvet 2002; Moretti *et al.* 2007). In contrast, shredders were abundant in study in tropical Australian streams, comprising about 24% of the total macroinvertebrates biomass, not including the crayfish (Cheshire *et al.* 2005).

We aimed to analyze structure and composition of invertebrates community in decomposing leaves of *Eichhornia azurea* (Swartz) Kunth (Commelinales: Pontederiaceae) and *Salvinia auriculata* Aubl. (Salviniales: Salviniaceae) in a lentic system in southeastern Brazil, to verify if the chemical composition (C:N ratio) of the substrate has an influence on invertebrate colonization. We expected that higher decomposition rate and greater richness and abundance of invertebrates in macrophytes with a smaller carbon: nitrogen ratio (*E. azurea*). We also expected to observe differences in the colonization by invertebrates during the decomposition process due the improvement in nutritional quality of the substrate.

MATERIAL AND METHODS

Study Area. The experiment was conducted in Manacás Lake (21º 46' 68" S, 43º 22' 22" W), a reservoir with a surface area of 0.02 km² and a maximum depth of 5 m (Azevedo *et al.* 2003), located in southeastern Brazil. The lake's water is turbid (Secchi disk: 0.60 ± 0.12 m), with neutral pH (7.10 ± 0.25) and average levels (± S.D.) of dissolved oxygen, temperature and electrical conductivity of 5.55 ± 2.04 mgL^{-1}, 21.35 ± 2.25°C and 28.25 ± 12.82 µS cm^{-1}, respectively. The lake's marginal vegetation consists principally of *Merostachys* sp. Sprengel (Poales: Poaceae) and specimens of *Tibouchina granulose* Cogniaux (Myrtales: Melastomataceae). In the summer, blooms of *Salvinia* spp. usually occur in the lake. However, during the experiment, macrophytes were not observed (Martins *et al.* 2011).

Collection and data analysis. To perform the decomposition experiment we selected *E. azurea* and *S. auriculata*, two macrophyte species that are widely distributed in the Neotropical region (Barrett 1978; Alves dos Santos 1999; Santos *et al.* 2004; Prado 2006). Leaves of these two species were collected from a lake in the Poço D'Anta Municipal Biological Reserve (21°45'S, 43°20'W). The leaves were washed to remove the adhered material (Silva *et al.* 2011) and then were air dried in an oven at 60°C (24 h) to obtain initial dry mass (Ramseyer & Marchese 2009).

The experiment was conducted from November 2007 to February 2008, with the use of 54 litter bags (*E. azurea*: n= 27 and *S. auriculata*: n=27) measuring 15x15 cm and 2 mm mesh, each filled with 10 g of dry leaves. The litter bags were immersed near the bottom of Manacás Lake, about 3 m from the shoreline and 2.40 ± 0.41 m (± S.D.) deep. To keep the litter bags in contact with the sediment, small weights (150 g) were attached to them. Three litter bags of each species were retrieved after 2, 4, 8, 12, 24, 36, 48, 60 and 72 days of incubation.

The remaining material in each litter bag was fixed in 4% formaldehyde and washed on a sieve (mesh: 0.21 mm). The invertebrates were sorted under a stereoscopic microscope and identified to family level, using the identification keys for insects (McCafferty 1981; Merrit & Cummins 1984; Carvalho & Calil 2000; Fernández & Dominguez 2001; Pes *et al.* 2005; Costa *et al.* 2006) and for oligochaetes (Brinkhurst & Marchese 1989). Invertebrates were classified into functional feeding groups according to Merrit & Cummins (1984) and Schenková & Helesic (2006), respectively. The Chironomidae were not included in determination of the trophic functional groups because they have a wide variety of feeding habits and their trophic classification is still uncertain (Moretti *et al.* 2007).

The remaining plant material was dried in an oven at 60 ºC until reaching constant mass and then utilized to calculate the decomposition coefficient (k), according to a negative exponential equation (e.g., Petersen & Cummins 1974): k = [ln (initial mass / final mass)] / duration of the experiment; mass was expressed in grams and the duration time in days. The concentration of organic carbon in the *E. azurea* and *S. auriculata* leaves was estimated as being 46.5% of the organic matter content (Wetzel & Likens 1991). To calculate the organic matter content, we used subsamples of the remaining incubated leaves. This material was ashed in porcelain crucibles at 550 ºC in a muffle furnace for 4 h (Wetzel & Likens 1991). The organic matter content was calculated by the difference in the mass before and after ashing in the muffle furnace. The concentration of total nitrogen was determined by the digestion of subsamples of the remaining dry leaves with concentrated sulfuric acid in the presence of a catalyst (Allen *et al.* 1974).

We used analysis of variance (ANOVA two factors) to verify the existence of a significant difference of the leaf mass loss, leaf carbon: nitrogen ratio, abundance and richness (number of taxa) of invertebrates between macrophyte species and among the days of the experiment. Moreover, we used Pearson's correlation coefficient to analyze the relationship between mass loss and leaves carbon: nitrogen ratio, and between mass loss and invertebrates abundance. These analyzes was performed in R program (R Core Team 2013).

The similarity of the samples (macrophyte species and days) was analyzed by cluster analysis (UPGMA; Bray-Curtis distance coefficient), based on the invertebrate abundance (log x+1), with the NTSYS-PC version 2.10 program. To verify the variation in the composition of the community of invertebrates between the groups formed in the cluster analysis, we applied the nonparametric multiple response permutation procedure (MRPP) based on the Bray-Curtis distance coefficient, with the same data matrix used in the cluster analysis. This analysis was performed using the PC-ORD 5.15 program. Analysis of similarity (ANOSIM) was carried out to verify the variation in the composition of invertebrates between the two macrophyte species, using the R program (R Core Team 2013).

Indicator species analysis (Dufrêne & Legendre 1997) was used to verify which taxa were more closely related to a determined group of days established a priori in the cluster analysis. In this analysis, an indicator value is calculated for each species in each group and these are tested for statistical significance using a randomization technique. This analysis was performed in the PC-ORD version 5.15 program.

RESULTS

Leaf decomposition and C:N rate of the detritus. The decomposition coefficient was higher for *Eichhornia azurea* (k = 0.018 d^{-1}) than *Salvinia auriculata* (k = 0.008 d^{-1}). The mass loss for *S. auriculata* (30.2% of initial mass) were higher than those for *E. azurea* (24.1% of initial mass) in the initial period (day 2), but tended to reverse with experiment time duration, remaining 26.5% leaf masses for *E. azurea* and 51.0% for *S. auriculata* (Figure 1a). The remaining dry leaf mass of litter bags differ among days of the experiment ($F_{1, 53}$ = 12.53; p < 0.001), but not between species of macrophytes ($F_{1, 53}$ = 46.30; p = 1.000). There was no interaction between these factors ($F_{1, 53}$ = 12.53; p = 1.000).We recorded a negative correlation between mass loss and C:N ratio of the leaves only for *E. azurea* (r = -0.87; p = 0.001), but not for *S. auriculata* (r = 0.39; p = 0.270).

e-ISSN 1983-0572

The initial concentration of nitrogen in the *E. azurea* and *S. auriculata* leaves was 1.6% Dry Mass (DM) and 2.6% DM, respectively. During the experiment there was an increase in this nutrient in *E. azurea*, which reached 3.1% DM on day 72 (Figure 2b). In *S. auriculata*, the concentration of nitrogen on the last day (2.0% DM) was lower than at the start of the experiment (Figure 2b). The concentration of carbon in *E. azurea* (day 0= 43.3% DM, day 72= 38.8% DM) decreased during the experiment, unlike what occurred in the *S. auriculata* leaves (day 0 = 41.1% DM, day 72= 41.4% DM) (Figure 2c). We recorded a significant interaction effect between days of the experiment and macrophyte species on C:N ratio ($F_{1, 39}$ = 22.26, p = 0.001). In *S. auriculata* was observed increase in C:N ratio during the experiment (day 0 = 15.7%; day 72 = 20.6%), however, in *E. azurea* we recorded high values of C:N ratio on day 0 (27.1%) in relation to day 72 (12.4%).

Invertebrate communities. We recorded 8,093 individuals in *E. azurea* and 5,970 individuals in *S. auriculata*. The abundance of invertebrates ranged from 125 (day 2) to 1,553 (day 36) individuals in *E. azurea*, and from 59 (day 2) to 1,506 (day 36) individuals in *S. auriculata* (Table 1). The invertebrate abundance not differed among days of experiment ($F_{1, 53}$ = 3861.1; p = 0.424)

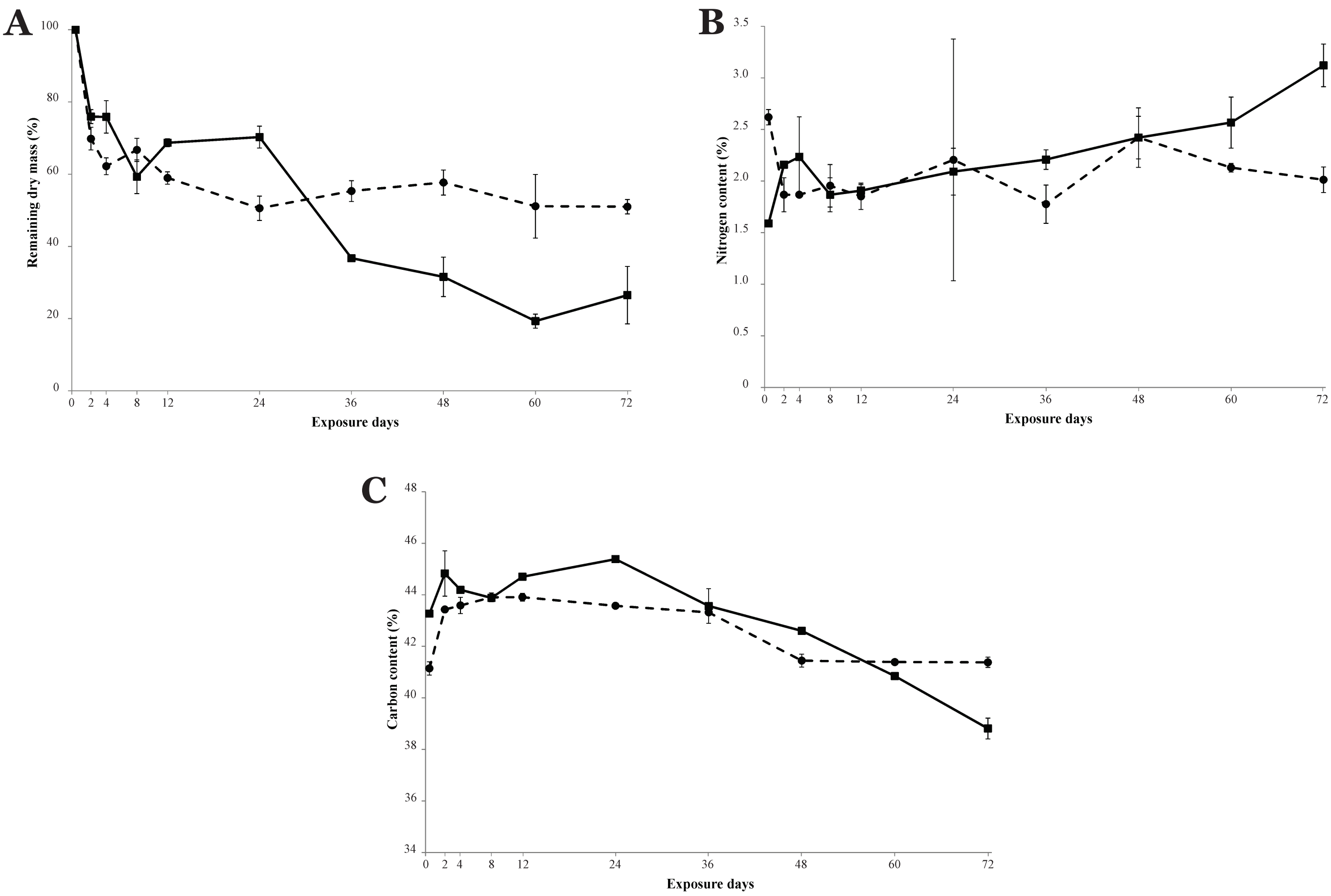

Figure 1. A. Remaining dry mass. B. nitrogen. C. carbon (means of three replicates ± S.D.) of *Eichhornia azurea* and *Salvinia auriculata* leaves during the decomposition experiment in Manacás Lake (southeastern Brazil). Full line: *E. azurea*; dashed line: *S. auriculata*.

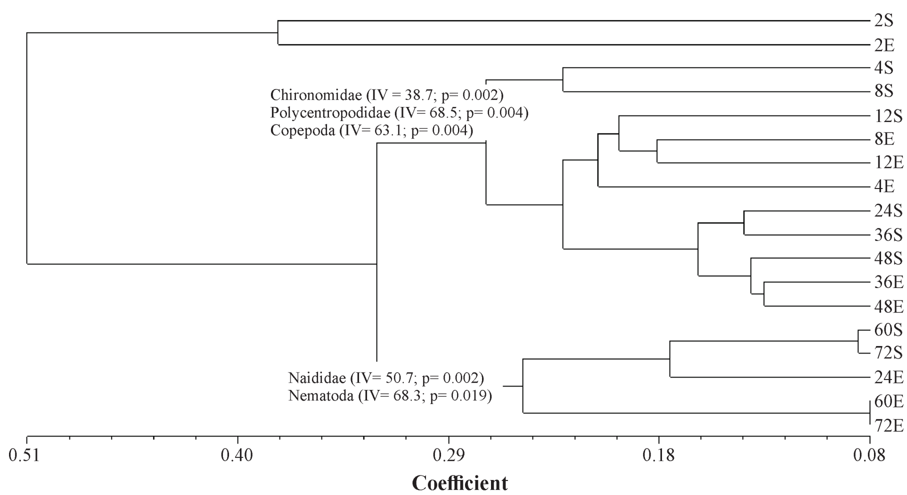

Figure 2. Cluster analysis (UPGMA, Bray-Curtis) based on the abundance of invertebrates during the decomposition experiment with Eichhornia azurea (E) and Salvinia auriculata (S) leaves in Manacás Lake (southeastern Brazil). The indicator species with their respective values (numbers between parentheses) are listed in the cluster.

and between species of macrophytes ($F_{1, 53} = 3910.3$; $p = 0.181$). Moreover, there was no interaction between these factors ($F_{1, 53} = 3858.4$, $p = 0.853$).There was no relationship between mass loss and invertebrate abundance for *E. azurea* ($r = 0.00$; $p = 0.944$) and *S. auriculata* ($r = 0.02$; $p = 0.549$).

We recorded 13 taxa of invertebrates in leaf litter of *E. azurea* and 17 taxa in *S. auriculata*. The richness ranged from four (day 24 and 72) to eight (days 4 and 8) taxa in *E. azurea*, and from three (day 60) to ten (day 8) taxa in *S. auriculata* (Table 1). The invertebrate richness differed among days of the experiment ($F_{1, 53} = 17.44$, $p = 0.034$), but not between species of macrophytes ($F_{1, 53} = 18.90$; $p = 0.629$). There was no interaction between these factors ($F_{1, 53} = 16.29$, $p = 0.061$).

In the cluster analysis (cophenetic correlation = 0.87), the samples were separated into three groups (Figure 2) according to the decomposition stage, independent of the macrophyte species. The first group was composed of day 2, on which no taxon was considered to be an indicator. The second group was composed of days 4, 8, 12, 24, 36 and 48 with Chironomidae, Polycentropodidae and Copepoda as indicator taxa. The last group was composed of days 60 and 72, with Naididae and Nematoda as indicators. The composition of the invertebrates community was different among the groups of days of the experiment ($T = -6.92$, $A = 0.25$, $p < 0.001$), but not differed between macrophytes species ($R = 0.02$, $p = 0.290$).

The invertebrates were distributed into two functional feeding groups (Figure 3a, b). The relative abundance of collector invertebrates ranged from 21.2% (day 12) to 100% (day 2) in *E. azurea*, and from 24.0% (day 24) to 93.7% (day 72) in *S. auriculata*. The relative abundance of predator invertebrates ranged from 0.0% (day 2) to 78.8% (day 12) in *E. azurea*, and from 6.3% (day 72) to 75.0% (day 2) in *S. auriculata*. The shredders invertebrates were absent in both macrophytes.

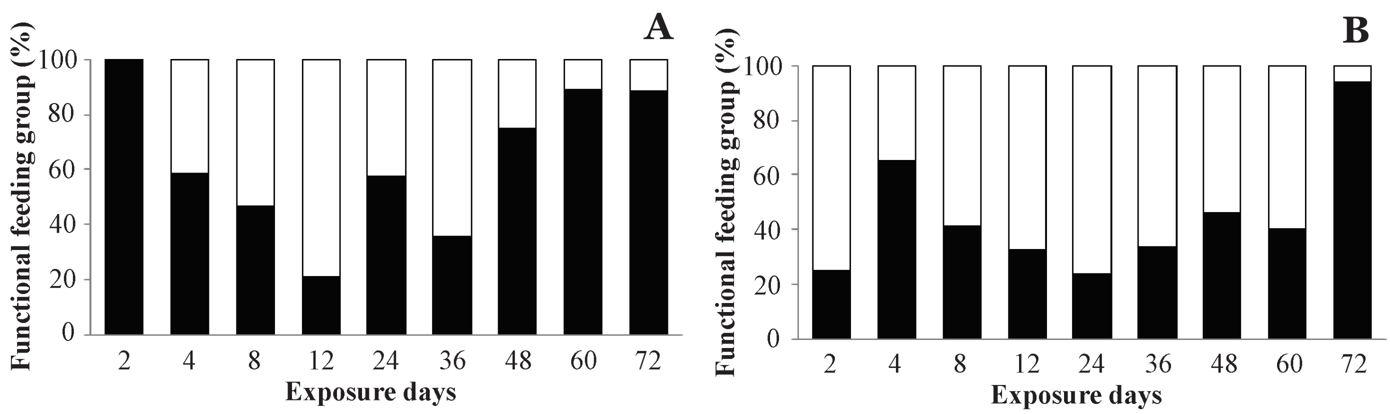

Figure 3. Relative abundance of functional feeding groups of invertebrates during the decomposition experiment with *Eichhornia* azurea (a) and Salvinia auriculata (b) leaves in Manacás Lake (southeastern Brazil). Black: collectors; white: predators.

Table 1. Abundance of invertebrates in *Eichhornia azurea* and *Salvinia auriculata* leaves ordered by exposure days in Manacás Lake (southeastern Brazil).

Taxa	*Eichhornia azurea*									*Salvinia auriculata*								
	2	4	8	12	24	36	48	60	72	2	4	8	12	24	36	48	60	72
OLIGOCHAETA																		
Aelosomatidae	0	1	12	0	2	3	19	36	70	0	2	7	2	4	3	2	0	0
Enchytraeidae	0	1	1	2	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Naididae	1	14	31	160	115	152	262	393	300	2	13	36	114	344	413	300	201	278
COLEOPTERA																		
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
DIPTERA																		
Chironomidae	120	529	1048	690	448	1369	824	549	494	43	279	269	513	727	1056	516	202	302
Ceratopogonidae	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0
Culicidae	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Simuliidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPHEMEROPTERA																		
Baetidae	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
HEMIPTERA																		
Hebridae	0	0	0	0	0	0	0	0	0	9	2	3	7	2	1	0	0	0
ODONATA																		
Libellulidae	0	0	1	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0
TRICHOPTERA																		
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

To be continue...

e-ISSN 1983-0572

Table 1. Continuation...

Taxa	*Eichhornia azurea*									*Salvinia auriculata*								
	2	**4**	**8**	**12**	**24**	**36**	**48**	**60**	**72**	**2**	**4**	**8**	**12**	**24**	**36**	**48**	**60**	**72**
Polycentropodidae	1	1	7	3	2	4	2	0	0	0	0	7	1	11	19	8	0	1
COPEPODA	2	76	103	172	0	22	11	2	0	3	41	41	85	59	12	5	0	0
HIRUDINAE	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
NEMATODA	0	3	0	0	0	2	6	12	10	1	0	0	0	1	0	1	2	2
NEMATOMORPHA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total abundance	**125**	**626**	**1204**	**1027**	**567**	**1553**	**1124**	**993**	**874**	**59**	**342**	**368**	**724**	**1150**	**1506**	**832**	**405**	**584**
Number of taxa	**5**	**8**	**8**	**5**	**4**	**7**	**6**	**6**	**4**	**6**	**8**	**10**	**8**	**8**	**8**	**6**	**3**	**5**

DISCUSSION

Leaf decomposition and C:N rate of the detritus. Based on the classification proposed by Gonçalves Jr. *et al.* (2014) for Brazilian aquatic environments, the decomposition rates of the *E. azurea* and *S. auriculata* leaves were classified as rapid and intermediate, respectively. The faster decomposition of *E. azurea* may be related to smaller C:N ratio in their detritus. There was a negative correlation between mass loss of *E. azurea* and detritus quality (C:N ratio). Chimney & Pietro (2006) found a negative correlation between decomposition rate and C:N ratio and a positive correlation between decomposition rate and nitrogen content of different macrophyte species –*Typha domingensis* Pers. and *T. latifolia* L. (Typhaceae), *E. crassipes* [Mart.] Solms. (Pontederiaceae), *Pistia stratiotes* L. (Araceae), *Najas guadalupensis* [Spreng.] Magnus (Hydrocharitaceae) and *Ceratophyllum demersum* L. (Ceratophyllaceae). Lan *et al.* (2006) showed that rhizomes of *Zizania latifolia* (Griseb.) Turcz. ex Stapf (Poaceae) with lower C:N ratio presented faster decomposition rates. These results corroborate the importance of the quality of leaf litter on decomposition rate.

On the first two days of decomposition, there was observed rapid mass loss in both macrophyte species. This high mass loss during the initial days is due to leaching of phenols and amino acids (Gessner *et al.* 1999). Martins *et al.* (2011) attributed the high mass loss in *E. azurea* leaves at the start of the experiment to method of drying the leaves in an oven before immersion in the lake, because this drying promoted rupture of the cell wall, accelerating the loss of soluble components. We used the same method, so it is likely the rapid mass loss observed at the start of experiment was related to this drying procedure.

The decrease in C:N ratio observed in *E. azurea* leaves was not observed in *S. auriculata*. Although we did not analyze the colonization by microorganisms, it is well established in the literature that these organisms immobilize nitrogen from the water to the detritus (Pagioro & Thomaz 1999; Padial & Thomaz 2006), which may have contributed to increase the concentration of this nutrient in the decomposing *E. azurea* leaves, while the decline in carbon found in this species during the study period can be attributed to carbon mineralization (Rejmánková & Houdková 2006). Sciessere *et al.* (2011) studied three species of macrophytes (*Salvinia* sp., *E. azurea* and *Cyperus giganteus* Vahl (Cyperaceae)) and found that the *Salvinia* sp. litter was more recalcitrant, with lower mass loss and enzyme activity than the other two species. Therefore, it is likely that the *S. auriculata* leaves in our study may have been less colonized by microorganisms, influencing the reduction of N during the experiment. Howard-Williams & Junk (1976) and Longhi *et al.* (2008) did not observe an increase in nitrogen concentration during decomposition of *S. auriculata* and *S. natans* (L.) All. (Salviniaceae) leaves, respectively.

Invertebrate communities. We did not observed significant differences in abundance, richness and composition of invertebrates between the two macrophytes species, probably because we did not observe significant differences in the mass loss and rate of carbon: nitrogen between macrophytes species. In contrast to Mathuriau & Chauvet (2002) found that in *Croton gossypifolius* Vahl (Euphorbiaceae) leaves, with a faster decomposition rate, colonization by fungi and the accumulation of N support faster and more highest colonization by invertebrates, while *Clidemia* sp. (Melastomataceae) leaves, which degrade more slowly, provide a substrate more durable to fauna and support a more diversified invertebrate community.

We recorded a significant increase of richness along the experiment, which may be related to observation of greater uniformity of organic matter particles size these stages of the experiment. According to Capello *et al.* (2004), the least heterogeneity at the beginning of the experiment is due the leaves to be a new substrate to be colonized. Similarly, at the end of the experiment the action of decomposer organisms leads to greater physical homogeneity of the detritus (Capello *et al.* 2004). Additionally, the increase in the proportion of support material (cellulose and lignin) (Begon *et al.* 1995) because of the consumption of softer parts leads to reduction in the richness of invertebrates.

The better quality of detritus at the end of experiment provides a more plentiful food supply (Smock & Stoneburner 1980), in turn allowing greater density of fauna (Gonçalves Jr. *et al.* 2003, 2004; Moretti *et al.* 2007). However, even for *E. azurea* in which has an increase in the concentration of nitrogen and reducing in the concentration of carbon at the end of our experiment, no correlation was observed between the abundance of invertebrates and weight loss. Mathuriau & Chauvet (2002) also observed the N increase in both leaf species studied (*C. gossypifolius* and *Clidemia* sp.), and a decrease after the peak in early colonization of leaves by invertebrates.

The composition of invertebrates was dissimilar among the days in the cluster analysis and MRPP, probably due the fauna respond differently to physical and chemical modification on the leaf litter during the experiment as a consequence of the different survival strategies. A study in a pond in the tropical region with *Typha domingensis* Pers. (Typhaceae) and *Nymphaea ampla* (Salisb.) DC. (Nympheaceae) was observed formation of three groups, according to the stage of decomposition (initial, intermediate and advanced), in the cluster analysis and thus it can be concluded that the invertebrate community is structured mainly by degradative ecological successional (Gonçalves Jr. *et al.* 2004).

In our study, Chironomidae larvae have been recorded since the beginning of the experiment. Nevertheless was considered indicator, with higher abundance and frequency in intermediate days of our experiment of decomposition. This family is considered early colonizers (r-strategists), inhabiting various substrates (Takeda *et al.* 2003), and Gonçalves Jr *et al.* (2004), for example, show that the family Chironomidae was indicator in all stages of decomposition. Among the families of oligochaetes, Naididae occurred in greatest abundance in both macrophytes and was considered indicator of the final days of decomposition. Smock & Stoneburner (1980) showed that species of Naididae exhibited positive responses to presumably increasing levels of food as leaf decomposition progressed, and they become abundant after the leaves visually show signs of decomposition.

In respect to the functional feeding groups, the predators were represented mainly by *Chaetogaster* that feed on small invertebrates as rotifers and protozoa (Martins *et al.* 2011) and probably its abundance was not determined by collectors. Furthermore, we did not observe the presence of shredders. The same result was reported by Rezende *et al.* (2010) in two other lakes in southeastern Brazil. In the absence of this functional feeding group, invertebrates such as the Tubificinae, Gastropoda and Chironomidae can assume a similar role (Chauvet *et al.* 1993; Capello *et al.* 2004; Casas *et al.* 2011). Nevertheless, we did not observe the presence of the first two taxa. Low abundance and richness of Tubificinae also were reported by Martins *et al.* (2011) in decomposing *E. azurea* leaves in Manacás Lake and these authors observed that this subfamily was not important to macrophyte decomposition. Although the Chironomidae were not included in the functional feeding group in this study, Silveira *et al.* (2013) shows the importance of larvae of this family in decomposition, since the main food item observed in stomach content of the majority of genera analyzed at the start and end of the experiments was leaf detritus.

In conclusion, we believe that decomposing *E. azurea* and *S. auriculata* leaves are important substrates for colonization by invertebrates, principally the Chironomidae and Oligochaetes, given high abundance of these groups in the two macrophytes. Changes in chemical composition and structure of the leaf litter during decomposition were more important to determine the structure of invertebrate community than quality (C:N ratio) of the two types of leaf litter.

ACKNOWLEDGEMENTS

We thank the Aquatic Ecology Laboratory of Juiz de Fora Federal University (LEA/UFJF) for providing the lake water data and for conducting the analysis of the carbon and nitrogen content of the leaf litter. RTM and LSS received a scholarship from CNPq and UFJF, respectively. RTM received Programa de apoio à fixação de Doutores no Amazonas – FIXAM/AM fellowship (FAPEAM). RGA was supported by a research fellowship (proc. 303156/2012-0).

REFERENCES

Allen, S.E., H.M. Grimshaw, J.A. Parkinson & C. Quarby, 1974. Chemical analysis of ecological material. Oxford, Blackwell Scientifc Publications, 565 p.

Alves dos Santos, I., 1999. Polinização de macrófitas aquáticas da família Pontederiaceae, p. 121-129. *In*: Pompêo, M.L.M. (Ed.). Perspectiva da Limnologia no Brasil. São Luís, Gráfica e Editora União, 198 p.

Azevedo, M.T.P., C.A. Souza, T. Rosado, V. Huszar & F. Roland, 2003. *Limnothrix bicudoi*, a new species of Cyanophyceae/ Cyanobacteria from Southeast of Brazil. Archiv für Hydrobiologie–Algological Studies, 109: 93-102. DOI: http://dx.doi.org/10.1127/1864-1318/2003/0109-0093.

Barrett, S.C.H., 1978. Floral biology of *Eichhornia azurea* (Swartz) Kunth (Pontederiaceae). Aquatic Botany, 5: 217-228.

Begon, M., J.L. Harper & C.R. Towsend, 1995. Ecologia: indivíduos, poblaciones y comunidades. Barcelona, Editora Omega, 3rd ed., 1172 p.

Brinkhurst, R.O. & M. R. Marchese, 1989. Guia para la indentificación de oligoquetos acuáticos continentales de Sud y Centroamérica. Santa Fé, Clímax, 2nd, 207 p.

Bruquetas de Zozaya, I.Y. & J.J. Neiff, 1991. Decomposition and colonization by invertebrates of *Typha latifolia* L. litter in Chaco cattail swamp (Argentina). Aquatic Botany, 40: 185-193. DOI: http://dx.doi.org/10.1016/0304-3770(91)90096-N.

Capello, S., M. Marchese & I. Ezcurra de Drago, 2004. Descomposición y colonización por invertebrados de hojas de *Salix humboldtiana* en la llanura aluvial Del río Paraná Medio. Amazoniana, 18: 125-143.

Carvalho, A.L. & E.R. Calil, 2000. Chaves de identificação para as famílias de Odonata (Insecta) ocorrentes no Brasil, adultos e larvas. Papeis Avulsos de Zoologia, 41: 223-241.

Casas, J.J., M.O. Gessner, D. López & E. Descals, 2011. Leaf-litter colonization and breakdown in relation to stream typology: insights from Mediterranean low-order Streams. Freshwater Biology, 56: 2594-2608. DOI: http://dx.doi.org/10.1111/j.1365-2427.2011.02686.x.

Chauvet, E., N. Giani & M.O. Gessner, 1993. Breakdown and invertebrate colonization of leaf litter in two contrasting streams: significance of Oligochaetes in a large river. Canadian Journal of Fisheries and Aquatic Sciences, 50: 488-495. DOI: http://dx.doi.org/10.1139/f93-057.

Cheshire, K., L. Boyero & R.G. Pearson, 2005. Food webs in tropical Australian streams: shredders are not scarce. Freshwater Biology 50: 748–769. DOI: http://dx.doi.org/10.1111/j.1365-2427.2005.01355.x.

Chimney, M.J. & K.C. Pietro, 2006. Decomposition of macrophyte litter in a subtropical constructed wetland in south Florida (USA). Ecological Engineering, 27: 301-321. DOI: http://dx.doi.org/10.1016/j.ecoleng.2006.05.016.

Costa, C., S. Ide & C.E. Simonka, 2006. Insetos Imaturos: Metamorfose e Identificação. Ribeirão Preto, Holos Editora, 249 p.

Dufrêne, M. & P. Legendre, 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs, 67: 345-366. DOI: http://dx.doi.org/10.2307/2963459.

Fernández, H.R. & E. Domínguez. 2001. Guía para la determinación de los artrópodos bentónicos sudamericanos. San Miguel de Tucumán, Editorial Universitária de Tucumán, 219 p.

Gessner, M.O., E. Chauvet & M. Dobson, 1999. A perspective on leaf litter breakdown in streams. Oikos, 85: 377-384. DOI: http://dx.doi.org/10.2307/3546505.

Gimenes, K.Z., M.B. Cunha-Santino & I. Bianchini Jr., 2010. Decomposição de matéria orgânica alóctone e autóctone em ecossistemas aquáticos. Oecologia Australis, 14: 1036-1073. DOI: http://dx.doi.org/10.4257/oeco.2010.1404.13.

Gonçalves Jr., J.F., A.M. Santos & F.A. Esteves, 2004. The influence of the chemical composition of *Typha domingensis* and *Nymphaea ampla* detritus on invertebrate colonization during decomposition in a Brazilian coastal lagoon. Hydrobiologia, 527: 125-137. DOI: http://dx.doi.org/10.1023/B:HYDR.0000043190.49651.dc.

Gonçalves Jr., J.F., F.A. Esteves & M. Callisto, 2003. Chironomids colonization on *Nymphaea ampla* L. detritus during a degradative ecological succession experiment in a Brazilian coastal lagoon. Acta Limnologica Brasiliensia, 15: 21-27.

Gonçalves Jr., J.F., R.S. Rezende, J. França. & M. Callisto, 2012. Invertebrate colonization during leaf processing of native, exotic and artificial detritus in a tropical stream. Marine & Freshwater Research, 63: 428-439. DOI: http://dx.doi.org/10.1071/MF11172.

Gonçalves Jr., J.F., R.T. Martins, B.M.P. Ottoni & S.R.M. Couceiro, 2014. Uma visão sobre a decomposição foliar em sistemas aquáticos brasileiros, p. 89-116. *In*: Hamada, N., J.L. Nessimian & R.B. Querino. Insetos aquáticos na Amazônia brasileira: taxonomia, biologia e ecologia. Manaus, Editora do INPA, 724 p.

Graça, M.A.S., 2001. The role of invertebrates on leaf litter decomposition in streams - a review. International Review of Hydrobiology, 86: 383-393. DOI: http://dx.doi.org/10.1002/1522-2632(200107)86:4/5<383::AID-IROH383>3.0.CO;2-D.

Gulis, V. & K. Suberkropp, 2003. Leaf litter decomposition and microbial activity in nutrient-enriched and unaltered reaches of a headwater stream. Freshwater Biology, 48: 123-134. DOI: http://dx.doi.org/ 10.1046/j.1365-2427.2003.00985.x.

Howard-Williams, C. & W.J. Junk, 1976. The decomposition of aquatic macrophytes in the floating meadows of a central Amazonian várzea lake. Biogeographica, 7: 115-123.

Lan, N.K., T. Asaeda & J. Manatunge, 2006. Decomposition of aboveground and belowground organs of wild rice (*Zizania latifolia*): mass loss and nutrient changes. Aquatic Ecology, 40: 13-21. DOI: http://dx.doi.org/10.1007/s10452-005-9020-4.

Li, X., B. Cui, Q. Yang, H. Tian, Y. Lan, T. Wang & Z. Han, 2012. Detritus quality controls macrophyte decomposition under different nutrient concentrations in a eutrophic shallow lake, North China. Plos One, 7: e42042. DOI: http://dx.doi.org/10.1371/journal.pone.0042042.

Longhi, D., M. Bartoli & P. Viaroli, 2008. Decomposition of four macrophytes in wetland sediments: Organic matter and nutrient decay and associated benthic processes. Aquatic Botany, 89: 303-310. DOI: http://dx.doi.org/10.1016/j.aquabot.2008.03.004.

Martins, R.T., L.S. Silveira & R.G. Alves, 2011. Colonization by oligochaetes (Annelida: Clitellata) in decomposing leaves of *Eichhornia azurea* (SW.) Kunth (Pontederiaceae) in a Neotropical lentic system. Annales de Limnologie - International Journal of Limnology, 47: 339-346. DOI: http://dx.doi.org/10.1051/limn/2011053.

Mathuriau, C. & E. Chauvet, 2002. Breakdown of litter in a Neotropical stream. Journal of the North American Benthological Society, 21: 384-396.

McCafferty, W.P., 1981. Aquatic Entomology. Boston, Jones and Bartlett Publishers, 448 p.

Merritt, R.W. & K.W. Cummins, 1984. An introduction to the Aquatic Insects of North America. Dubuque, Kendall /Hunt publishing Co, 2nd ed, 722 p.

Moretti, M.S., J.F. Gonçalves Jr., R. Ligeiro, R. & M. Callisto, 2007. Invertebrates colonization on native tree leaves in a Neotropical stream (Brazil). International Review of Hydrobiology, 92: 199-210. DOI: http://dx.doi.org/10.1002/iroh.200510957.

Mormul, R.P., L.A. Vieira, S. Pressinatte Jr., A. Monkolski & A.M. Santos, 2006. Sucessão de invertebrados durante o processo de decomposição duas plantas aquáticas (*Eichhornia azurea* e *Polygonum ferrugineum*). Acta Scientiarum. Biological Sciences, 28: 109-115. DOI: http://dx.doi.org/10.4025/actascibiolsci.v28i2.1017.

Padial, A.A. & S.M. Thomaz, 2006. Effects of flooding regime upon the decomposition of *Eichhornia azurea* (SW.) Kunth measured on a tropical, flow-regulated floodplain (Paraná River, Brazil). River Research and Applications, 22: 791-801. DOI: http://dx.doi.org/10.1002/rra.936.

Pagioro, T.A. & S.M. Thomaz, 1998. Loss of weight and concentration of carbon nitrogen and phosphorus during decomposition of *Eichhornia azurea* in the floodplain of the upper Paraná River, Brazil. Revista Brasileira de Biologia, 58: 603-608. DOI: http://dx.doi.org/10.1590/S0034-71081998000400007.

Pagioro, T.A. & S.M. Thomaz, 1999. Decomposition of *Eichhornia azurea* from limnologically different environments of the Upper Paraná River floodplain. Hydrobiologia, 411: 45-51. DOI: http://dx.doi.org/ 10.1023/A:1003839704084.

Pes, A.M.O, N. Hamada & J.L. Nessimian, 2005. Chaves de identificação de larvas para famílias e gêneros de Trichoptera. Revista Brasileira de Entomologia, 49: 181-204.

Petersen, R.C. & K.W. Cummins, 1974. Leaf processing in a woodland stream. Freshwater Biology, 4: 343-368. DOI: http://dx.doi.org/10.1111/j.1365-2427.1974.tb00103.x.

Prado, J., 2006. Criptógamos do Parque Estadual das Fontes do Ipiranga, São Paulo, SP. Pteridophyta: 18. Salviniaceae. Hoehnea, 33: 107-110.

R Core Team, 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Avaiable: <http://www.R-project.org/> [Accessible in: 04.21.2014].

Ramseyer, U. & M. Marchese, 2009. Leaf litter of *Erythrina crista-galli* L. (ceibo): trophic and substratum resources for benthic invertebrates in a secondary channel of the Middle Parana River. Limnetica, 28: 1-10.

Rejmánková, E. & K. Houdková, 2006. Wetland plant decomposition under different nutrient conditions: what is more important, litter quality or site quality? Biogeochemistry, 80: 245-262. DOI: http://dx.doi.org/10.1007/s10533-006-9021-y.

Rezende, R.S., J.F. Gonçalves Jr. & M.M. Petrucio, 2010. Leaf breakdown and invertebrate colonization of *Eucalyptus grandis* (Myrtaceae) and *Hirtella glandulosa* (Chrysobalanaceae) in two Neotropical lakes. Acta Limnologica Brasiliensia, 22: 23-34. DOI: http://dx.doi.org/10.4322/actalb.02201004.

Santos, M.G., L.S. Sylvestre & D.S.D. Araujo, 2004. Análise florística das pteridófitas do Parque Nacional da Restinga de Jurubatiba, Rio de Janeiro, Brasil. Acta Botanica Brasilica, 18: 271-280. DOI: http://dx.doi.org/10.1590/S0102-33062004000200007.

Schenková, J. & J. Helesic, 2006. Habitat preferences of aquatic Oligochaeta (Annelida) in the Rokytná River, Czech Republic – a small highland stream. Hydrobiologia, 564: 117-126. DOI: http://dx.doi.org/10.1007/1-4020-5368-1_12.

Sciessere, L, M.B. Cunha-Santino & I. Bianchini Jr., 2011. Cellulase and xylanase activity during the decomposition of three aquatic macrophytes in a tropical oxbow lagoon. Brazilian Journal of Microbiology, 42: 909-918. DOI: http://dx.doi.org/10.1590/S1517-83822011000300009.

Silva, D.S., M.B. Cunha-Santino, E.E. Marques & I. Bianchini Jr., 2011. The decomposition of aquatic macrophytes: bioassays versus in situ experiments. Hydrobiologia, 665: 219-227. DOI: http://dx.doi.org/10.1007/s10750-011-0625-4.

Silveira, L.S., R.T. Martins, G.A. Silveira, R.M. Grazul, D.P. Lobo & R.G. Alves, 2013. Colonization by Chironomidae larvae in decomposition leaves of *Eichhornia azurea* in a lentic system in southeastern Brazil. Journal of Insect Science, 13: 1-13. DOI: http://dx.doi.org/10.1673/031.013.2001.

Smock, L.A & D.L. Stoneburner, 1980. The response of macroinvertebrate to aquatic macrophyte decomposition. Oikos, 35: 397-403. DOI: http://dx.doi.org/10.2307/3544656.

Suren, A.M. & P.L. Lake, 1989. Edibility of fresh and decomposing macrophytes to three species of freshwater invertebrates herbivores. Hydrobiologia, 178: 165-178. DOI: http://dx.doi.org/10.1007/BF00011667.

Takeda, A.M., G.J. Souza-Franco, S.M. Melo & A. Monkolski, 2003. Invertebrados associados às macrófitas aquáticas da planície de inundação do alto rio Paraná (Brasil), p. 243-260. *In*: Thomaz, S.M. & L.M. Bini. Ecologia e manejo de macrófitas aquáticas. Maringá, EDUEM, 341 p.

Wetzel, R.G. & G.E. Likens, 1991. Limnological analyses. New York, Springer-Verlag, 2nd ed., 391 p.

Wetzel, R.G., 2001. Limnology, Lake and River Ecosystems. San Diego, Academic Press, 3rd ed., 1006 p.

Received in: 04.ix.2016
Accepted in: 25.ii.2016

****

Suggestion citation:

Silveira, L.S. da, R.T. Martins & R. da G. Alves, 2016. Invertebrate Colonization During Leaf Decomposition of *Eichhornia azurea* (Swartz) Kunth (Commelinales: Pontoderiaceae) and *Salvinia auriculata* Aubl. (Salvinales: Salvinaceae) in a Neotropical Lentic System. EntomoBrasilis, 9 (1): 10-17.

Available in: doi:10.12741/ebrasilis.v9i1.548