Colonization of leaf litter by aquatic macroinvertebrates: a study in a low order tropical stream.

JANKE[1], H. & TRIVINHO-STRIXINO[1], S.

[1] Laboratório de Entomologia Aquática, Departamento de Hidrobiologia,
Universidade Federal de São Carlos, CP 676, CEP 13.565-905, São Carlos, São Paulo, Brasil / helenajanke@uol.com.br; strixino@power.ufscar.br

ABSTRACT: Colonization of leaf litter by aquatic macroinvertebrates: a study in a low order tropical stream. The streambed of low order tropical streams is composed mainly by dead leaves and tree branches originated from riparian forest. This substratum is decomposed by physical, chemical and biological factors, and can be colonized by a characteristic fauna. The colonization dynamics of these substrates by macroinvertebrates can reflect how they use the multidimensional space of the environment. This work aimed to investigate if the colonization of leaf litter by macroinvertebrates depends of the composition of leaf litter. Three representative species of the riparian forest of the Fazzari stream, in São Carlos, SP, were chosen: Cecropia pachystachya, Calophyllum brasiliensis, and Talauma ovata. Four treatments were used, with leaf litter bags containing leaves of each isolated species and a fourth treatment with a mixture of the species. Replicated bags were placed into the stream, and recovered after 7, 21 and 35 days. The colonizing fauna was analyzed in relation to the taxonomic structure, relative taxon abundance, and functional structure (feeding guilds). Only C. brasiliensis presented differences of faunal colonization in relation to the other treatments, with fewer taxa (12) and functional feeding groups, and the lowest abundance of colonizing individuals (80). T. ovata and the mixed substratum were mainly colonized by macroinvertebrate shredders (e.g., Endotribelos spp. and Phylloicus sp.), presenting the greatest number of taxa (23 and 21), and abundances (357 and 271). These patterns suggest that leaf litter colonization was strongly influenced by the quality of the resources represented by leaves from different tree species.
Key-words: Macroinvertebrates, colonization, leaf litter, functional feeding groups.

RESUMO: Colonização de detritos foliares por macroinvertebrados aquáticos: um estudo em córrego tropical de baixa ordem. O fundo de córregos de baixa ordem é composto em sua grande parte por folhas e galhos provenientes da mata ripícola. Este substrato é decomposto por fatores físicos, químicos e biológicos diversos e pode ser colonizado por uma fauna característica. A dinâmica de colonização desses substratos por macroinvertebrados pode refletir a forma como estes utilizam o espaço multidimencional do ambiente. O presente trabalho teve como objetivo responder se a colonização de detritos foliares por macroinvertebrados aquáticos depende da composição do detrito. Para isso foram escolhidas 3 espécies de plantas (Cecropia pachystachya, Calophyllum brasiliensis, Talauma ovata) representativas da mata ripícola do Córrego do Fazzari, São Carlos, SP, local onde se desenvolveu o experimento. Sacos de detritos, contendo folhas de cada espécie de planta isolada e misturadas, foram mergulhados no córrego onde permaneceram por 7, 21 e 35 dias. A fauna colonizadora foi analisada segundo a estrutura taxonômica, participação relativa dos táxons e estrutura funcional (guildas de alimentação). Apenas C. brasiliensis apresentou diferença de colonização em relação aos demais substratos, com menor representação de táxons (12) e de grupos funcionais, além de menor número de indivíduos colonizadores (80). T. ovata e o substrato misto (detritos das 3 espécies) foram fortemente colonizados por macroinvertebrados fragmentadores (por ex., Endotribelos spp. e Phylloicus sp.) apresentando maior número de táxons (23 e 21) e de indivíduos (357, 271). Os resultados obtidos sugerem que para as condições estabelecidas experimentalmente a colonização foi influenciada pela qualidade do recurso.
Palavras-chave: Macroinvertebrados, colonização, detritos foliares, grupos funcionais.

Introduction

Streams with dense vegetation coverage have their energy dynamics strongly subsidized by allochtonous material that comes from the riparian forest (Vannote et al., 1980, Wallace et al. 1997); due to the reduction of the solar radiation

on the waterbody, the primary production is strongly reduced (Petersen & Cummins, 1974; Gregory et al. 1991).

The substrate on these streambeds is composed mostly by leaves and tree branches, which are decomposed by the association of physical, chemical and biological factors. Decomposition thus depends on the intrinsic characteristics of the stream, such as the nature of stream bed, water flow, pH, water temperature, chemical composition of litter (Wallace et al., 1997; Wright & Covich, 2005; Leroy & Marks, 2006), and composition of aquatic invertebrates fauna (Cummins et al. 1989; Graça, 2001).

In this context, the role of the aquatic macroinvertebrates has received special attention, particularly in temperate regions (Cherguei & Patee, 1988; Leroy & Mark, 2006) and recently in tropical streams (Wright & Covich, 2005; Gonçalves Jr. et al, 2006.; Watzen & Wagner, 2006). The association of this fauna to the process of leaf litter decomposition is not completely clear, but it is known that leaves can provide food, shelter or both (Dudgeon & Wu, 1999; Graça, 2001).

Previous studies have shown that detritus of different plant species have a different faunal association (Leroy & Mark, 2006; Moretti, 2005). The selection of different species can be related to leaf chemical properties (Wright & Covich, 2005; Graça, 2001) or to nutrient concentration (Graça, 2001). However, Dudgeon & Wu (1999) demonstrated that macroinvertebrates also colonize artificial leaves, suggesting that the accumulation of algae and fine particulate organic material (FPOM) on their surface could be the main source of food. Apart from these deterministic elements, the colonization of detritus by macroinvertebrates can still occur at random like the drift, when the organisms are transported down by the river flow (Rosenberg & Resh, 1982).

Thus, in the present study we evaluated if the colonization of leaf litter in a first order tropical stream by aquatic macroinvertebrates depends on the specific composition of litter debris.

Study area

The experiment was carried out in a first order stream (Córrego Fazzari) located in a preserved area of Cerrado vegetation in the Reserva Legal da Universidade Federal de São Carlos (21°59'S – 47°54'W) São Carlos, SP, Brasil.

The stream is characterized exuberant riparian vegetation preserved in both margins, with tree canopies covering 70% of the channel, high levels of dissolved oxygen (72.40 mg l^{-1}), thermal amplitude varying from 15ºC to 23ºC, sandy bed and predominance of leaves and branches on the main bed (Siqueira, 2006).

Materials and methods

The colonization experiment was carried out during the dry season (April to June 2006). The plants species of the arboreal component of the study area were selected for the analyses of colonization by macroinvertebrates according to their representativity in the riparian zone (Roque et al., 2003), and belonged to different successional stages: Cecropia pachystachya (Cecropiaceae), a pioneer plant; Calophyllum brasiliensis (Clusiaceae), present in several stages of secondary succession; T. ovata (Magnoliaceae), a late secondary or climax plant (Lorenzi, 2002). Leaves that have recently fallen or the oldest ones on the trees were collected. To standardize the samples, leaves which had signals of herbivory and visible stains caused by fungus were discarded (Wright & Covich, 2005).

We used litter-bags measuring 15 x 20 cm (Cherguei & Patee, 1988; Moretti, 2005) and 0.8 cm of mesh, each one containing 6.0 g of whole leaves. There were four treatments, each isolated species and a mixture of all species (2.0 g of each one). Fifteen bags of each treatment (60 samples) were randomly placed in the stream, where they remained for 7, 21 and 35 days. At each sampling date, five litter-bags of each treatment were randomly collected. The contents of each bag was washed through a 0.21 mm mesh screen to extract the macroinvertebrates, which were fixed in ethanol 70% and identified with the aid of a stereomicroscope.

Data analysis

The invertebrate community was characterized according to the following variables: total number of individuals and relative abundance of each taxon in each type of substrate and period, and functional feeding groups, according to Merritt & Cummins (1996) classification. We evaluated faunal composition according to the time of colonization and type of substrate with multidimensional scaling (MDS) ordination

(2-dimensional MDS plot; stress = 0.10). The significance of differences among observable groups in the MDS ordination were tested by the analysis of similarity (one-way ANOSIM test), and the contribution of each taxon for the dissimilarity between the first and last period of colonization and between the less colonized substrate and the others were determined through Similarity Percentages (SIMPER), using the PRIMER software (Clarke & Warwick, 1994). The species richness of the community in C. pachystachya, C. brasiliensis, T. ovata and mixed leaves were compared by the rarefaction method (Krebs, 1998) that valued the expected species number ($P<0.05$) using the smaller size of the samples (80 individuals in C. brasiliensis), using Analytic Rarefaction 1.3 software (UGA, 2005).

Results

During the study period 912 individuals were collected, belonging to 29 taxa of macroinvertebrates. The litter bag with less colonization both in richness of taxa and number of individuals was C. brasiliensis, with 12 taxa and 80 individuals, followed by C. pachystachya, with 17 taxa and 204 individuals, the mixed substrate, with 21 taxa and 271 individuals and T. ovata, with 23 taxa and 357 individuals (Tab. 1).

Table 1: Macroinvertebrate taxa (total number and relative participation) after 7, 21, and 35 days of colonization on each substrate.

			Cecropia pachystachya				**Colophyllum brasiliensis**				**Talauma ovata**				**Mixed Substrate**			
Familia	Taxa	FG	7	21	35	%	7	21	35	%	7	21	35	%	7	21	35	%
Chironomidae	Ablabesmyia (Karelia) sp.	Pre	24	18	11	25,98	5	7	2	17,50	30	26	12	19,05	30	19	12	22,51
	Labrundinia sp.	Pre	14	-	1	7,35	4	-	1	6,25	5	2	-	1,96	8	7	-	5,54
	Pentaneura sp.	Pre	3	7	1	5,39	15	1	3	23,75	12	13	7	8,96	11	25	1	13,65
	Djalmabatista sp.2	Pre	-	-	-		-	-	-		-	-	-		-	1	-	0,37
	Fittkauimyia sp.	Pre	-	-	-		-	-	-		-	-	1	0,28	-	-	-	
	Corynoneura sp.	Col	3	4	6	6,37	-	-	-		3	11	4	5,04	-	9	5	5,17
	Cricotopus sp.4	Col	-	-	-		-	1	-	1,25	-	-	-		-	-	-	
	Nanocladius sp.	Col	-	6	3	4,41	-	-	-		2	-	-	0,56	-	6	1	2,58
	Chironomus sp.4	Col	-	-	-		-	-	-		1	-	-	0,28	-	-	-	
	Endrotibelos sp.1	Shr	-	-	-		-	-	-		22	19	13	20,17	6	15	2	8,49
	Endrotibelos sp.2	Shr	-	-	-		-	-	-		7	12	11	8,40	-	3	-	1,11
	Endrotibelos sp.3	Shr	-	-	-		-	-	-		2	1	-	0,84	2	2	-	1,48
	Polypedilum (Pol.) sp.	Col	-	-	-		-	-	-		2	2	2	1,68	1	1	-	0,74
	Beardius sp.	Scr	-	-	1	0,49	-	-	-		-	-	-		-	-	-	
	Tanitarsus sp.1	Col	-	1	2	1,47	-	1	1	2,50	1	-	2	0,84	2	3	-	1,85
	Tanitarsus sp.2	Col	-	3	-	1,47	-	-	-		-	-	2	0,56	1	2	1	1,48
Leptophlebiidae	Miroculis sp.	Col	41	18	4	30,88	7	13	2	27,50	40	28	9	21,57	28	28	10	24,35
Hydrophilidae	Tropistemus sp.	Scr	-	-	-		-	-	-		-	-	-		1	-	-	0,37

Table I: Cont.

			Cecropia pachystachya				Colophyllum brasiliensis				Talauma ovata				Mixed Substrate			
Familia	Taxa	FG	7	21	35	%	7	21	35	%	7	21	35	%	7	21	35	%
Naucoridae	Limnocoris sp.	Pré	-	-	2	0,98	-	-	-		-	-	2	0,56	2	1	-	1,11
Libellulidae	Anatya sp.	Pre	1	-	-	0,49	-	1	-	1,25	1	-	-	0,28	-	1	-	0,37
Megapodagrionidae	Oxystigma sp.	Pre	-	2	3	2,45	2	1	1	5,00	2	3	5	2,80	1	5	5	4,06
Calamoceratidae	Phylloicus sp.	Shr	-	1	-	0,49	-	-	1	1,25	3	-	-	0,84	-	3	-	1,11
Helicopsychidae	Helicopsyche sp.	Col	-	-	-		-	-	-		-	-	-		-	1	-	0,37
Hydropsychidae	Macronema sp.	Col	-	-	-		-	-	-		-	-	1	0,28	-	-	-	
Leptoceridae	Oecetis sp.	Pre	-	1	1	0,98	-	1	-	1,25	-	-	1	0,28	-	-	-	
Odontoceridae	Marilia sp.	Scr	-	8	12	9,80	2	4	2	10,00	-	2	4	1,68	-	6	2	2,95
	Barypenthus sp.	Scr	-	-	1	0,49	-	-	-		-	-	-		-	-	-	
Glossiphoniidae	Helodella sp.	Pre	-	-	1	0,49	-	-	2	2,50	-	1	9	2,80	-	1	-	0,37
Naididae	Alonais paraguaiensis	Col	-	-	-		-	-	-		-	1	-	0,28	-	-	-	

The analysis of abundance, in relation to the time of colonization, showed that leaf litter from individual species presented the greatest number of individuals with 7 days of colonization, decaying afterwards. In the mixed substrate, however, the greatest number of individuals was found after 21 days, decaying at the end of the experiment.

The detritus of C. pachystachya presented an increase in taxon richness along the experiment (days of colonization). The detritus of C. brasiliensis also showed an increase in taxon richness, but it occurred from 7 to 21 days after exposure. T. ovata presented a reduction of taxa after 21 days of the colonization and an increase after 35 days.

The predominance of predators (mainly Ablabesmyia (Karelia) sp., Labrundinia sp. and Pentaneura sp.) and high participation of collectors (mainly Miroculis sp.) were observed in all substrates and periods. Shredders were more abundant on leaf litter of T. ovata and mixed ones. Scrapers were present only in few numbers in all substrates (Fig. 1).

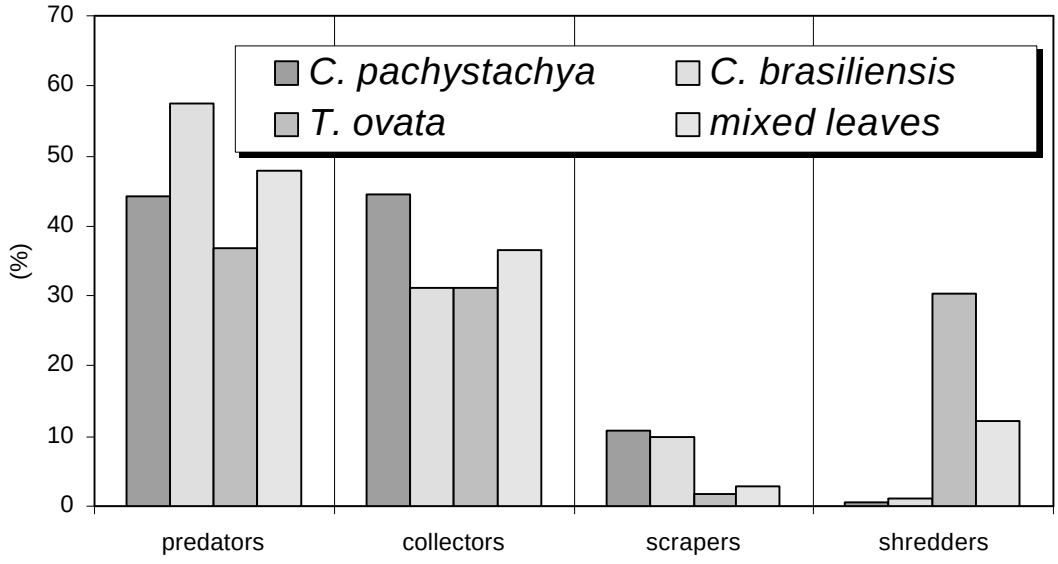

Figure1: Functional feeding groups (relative abundance) on each type of leaf litter.

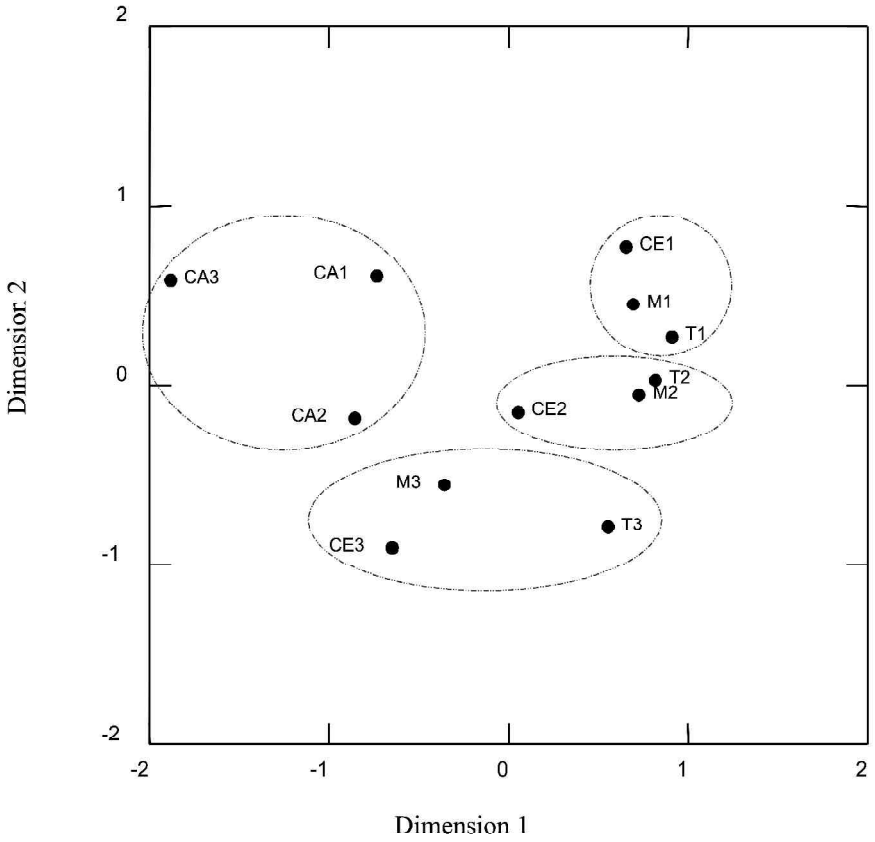

Figure 2: Ordination of macroinvertebrate assemblages composition after diferents periods of colonization, according to MDS using the Bray-Curtis index. CE= Cecropia pachystachya, CA= Calophyllum brasiliensis, T= Talauma ovata e M= Mixed leaves. The numbers 1, 2 and 3 represent 7, 21 and 35 days of colonization, respectively. Stress = 0.10.

The MDS ordination separated leaf litter of C. brasiliensis as a distinct group from the other substrates (ANOSIM: R= 0.342, P = 0.017) (Fig. 2). The time of colonization (days) was also a determinant factor for the colonization. Thus, the substratum of C. pachystachya, T. ovata and mixed ones appeared next to each other in every sampling date, confirmed by ANOSIM analysis (R= 0.494, P= 0.018).

The SIMPER analysis showed that the average dissimilarity between the periods 1 (7 days) and 3 (35 days) was 63.10%. The taxa with a stronger influence in the first sampling date of the experiment were Miroculis sp., Ablabesmyia (Karelia) sp., Endotribelos sp.1, Labrundinia sp., and Pentaneura sp., whereas Marilia sp. was more expressive after 21 days of colonization.

The average dissimilarity of C. brasiliensis leaf litter to other substrates was 65.8%. The absence of Endotribelos sp.1, Endotribelos sp.2, Corynoneura sp. and Nanocladius sp., and the low abundance of Miroculis sp., Ablabesmyia (Karelia) sp., Pentaneura sp. on C. brasiliensis contributed to this low similarity.

The rarefaction method showed that there is a superposition of the reliable interval. The values of species (using a sample of 80 individuals) was 12 to C. pachystachya, 12.7 ± 2.74 to C. brasiliensis, 14.4 ± 3.31 to T. ovata and 15.1 ±3.06 to mixed leaves.

Discussion

According to the conditions established in the experiment, the colonization of leaf litter by aquatic macroinvertebrates was differentiated by the quality of the available resources in the mesh bags. This was also demonstrated in other studies, like Graça et al. (2001), Graça (2001) and Dudgon & Wu (1999). Resource quality has special importance for the attraction of shredder macroinvertebrates (Graça, 2001; Dobson 1991, Richardson 1992), and representatives

of this guild were present, in the present study, only in the litter of T. ovata and in the mixed substrate.

Although there is no comparison of leaf decomposition rates between the plant species used in the present study, another study on the decomposition dynamics of native plant species of several forest ecosystems in the region, that used C. brasiliensis as one of the plant species studied, found that C. brasiliensis presented a very low decomposition rate, which was justified in part by high lignin concentration (Castanho, 2005). As the decomposition of leaf litter is frequently related to macroinvertebrates (Dangles et al., 2001), the presence of secondary compounds and high concentration of lignin in the leaves can influence the processing rate for colonization, although this relation is not well clarified to tropical streams. Therefore, the apparent low resource quality formed by the detritus of C. brasiliensis can have resulted in low colonization by macroinvertebrates.

The observed difference in the time of colonization is justified by the reduction in numbers of individuals between the first and last periods of the study (7 and 35 days, respectively) which was followed by considerable reduction of predators and collectors. However, the increase in abundance after 21 and 35 days of the shredder Endotribelos sp.2 (a great contributor to the dissimilarity between periods of colonization), mainly on T. ovata and mixed substratum, and of scrapers like Marilia sp. on C. pachystachya, can indicate preference for these resources.

Shredders seem to prefer more susceptible substrates to microbial colonization and thus partly degraded (Cherguei & Patee, 1991; Graça, 2001). Further, they can differentiate more palatable leaf substrate in relation to its chemical composition (Rincón & Martinez, 2006). In this particular, the larvae of Endotribelos (miner of plant substrate) were exclusive to T. ovata leaf debris, the occurrence of these larvae living inside fallen-fruits of T. ovata, C. brasiliensis and other plants of riparian Atlantic Forest streams already had been reported by Roque et al. (2005).

Since tropical plants present a great variety of secondary compounds (Coley & Aide, 1991) which can maintain themselves even after leaf abscision, it would be necessary more time for leaching of these compounds and microbial colonization to result in a more palatable substrate for macroinvertebrate shredders. Probably, the others plant detritus used in this study need more time to become available for the shredders.

Although the rarefaction had shown a superposition number of species in the different substrates, the low quality of the detritus of C. brasiliensis for the macroinvertebrate fauna of was demonstrated by the absence the shredders feeding group in this plant.

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