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Colonisation of leaf litter by aquatic invertebrates in an Atlantic Forest stream

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Abstract

Riparian vegetation along streams in the Atlantic Forest in Brazil contributes to the formation of a highly heterogeneous leaf litter in streambeds. To investigate the structure and composition of the aquatic invertebrate community during the process of leaf decomposition of two plant species present along the banks of the stream studied, 21 plastic mesh bags containing 2.5g (dry weight) of leaf matter from each species (*Alchornea glandulosa* (Vell) and *Cabralea canjerana* End. and Poeppig), for a total of 5.0g, were placed in the streambed. Three bags were removed after 3, 6, 9, 12, 24, 48 and 96 days. The taxonomic density was negatively correlated with the remaining weight. The high density of collector organisms, such as Chironomidae, Oligochaeta and Amphipoda, on the last day of incubation, probably occurred due to the increased amount of fine organic matter in the more advanced decomposition stages. The highest α diversity (Shannon-Wiener) values were observed for the 3rd and 96th days of the experiment, while the β diversity values showed that these days presented the highest variation in the taxonomic composition, thus presenting a different faunistic composition. This study showed that the trophic structure and composition of aquatic invertebrates changes during the decomposition of leaf litter. The faunistic abundance and diversity observed in this study indicate that the entrance of material from plants growing along streams provides favorable conditions for the colonisation and establishment of invertebrates in lower-order streams, and thus points to the need to preserve riparian vegetation.

Keywords: riparian vegetation, allochthonous materials, decomposition.

Colonização de folhiço por invertebrados aquáticos em um córrego de Mata Atlântica

Resumo

A vegetação ripária presente ao longo de córregos em áreas de Mata Atlântica contribui para a formação de serapilheira bastante heterogênea no leito de córregos. Com o objetivo de investigar a estrutura e composição da comunidade de invertebrados aquáticos durante o processo de degradação de detritos foliares de duas espécies vegetais presentes nas margens do córrego, 21 sacos de tela plástica contendo 2.5g de peso seco de cada espécie vegetal (*Alchornea glandulosa* (Vell) e *Cabralea canjerana* End. & Poeppig), totalizando 5.0g, foram colocados no leito do córrego. Três réplicas foram retiradas após 3, 6, 9, 12, 24, 48 e 96 dias. A densidade taxonômica esteve negativamente correlacionada com o peso remanescente. A elevada densidade de organismos coletores, como Chironomidae, Oligochaeta e Amphipoda, no último dia de incubação ocorreu provavelmente devido ao aumento de matéria orgânica particulada fina nas etapas mais avançadas da decomposição. Os maiores valores de diversidade α foram observados para o 3º e 96º dias de experimento, enquanto a diversidade β mostrou que esses dois dias apresentaram a maior variação na composição taxonômica, apresentando, portanto uma composição faunística diferente. Este estudo mostrou que ocorreu modificação na estrutura trófica e na composição de invertebrados aquáticos durante o processo degradativo dos detritos foliares. A abundância e diversidade faunística observada neste estudo indicam que a entrada de material vegetal de origem terrestre propiciam condições favoráveis para a colonização e estabelecimento dos invertebrados em córregos de baixa ordem e, portanto, reforça a necessidade de preservação da vegetação ripária.

Palavras-chave: vegetação ripária, material alóctone, decomposição.

1. Introduction

The riparian vegetation along streams in preserved areas of the Atlantic Forest in Brazil is composed of a great variety of species (Sanchez et al., 1999) that contribute to the formation of a highly heterogeneous leaf litter in the beds of these lotic environments (Swan and Palmer, 2004). Shallow and narrow streams with low water flow have retention features such as stones, trunks and branches (Wohl et al., 1995) that make them propitious environments for the accumulation of leaves falling mainly from riparian vegetation (Carvalho and Uieda, 2010). This detritus is normally used as a source of food and shelter by aquatic invertebrates.

The substrates present in streams, such as sand, stones and plant matter, have a considerable influence on the composition and structure of benthic fauna (Reice, 1980; Sanseverino and Nessimian, 2001), affecting the abundance and spatial distribution of organisms. Plant material of allochthonous origin accumulated in streambeds promotes spatial heterogeneity, increases the food availability for aquatic invertebrates (Francischetti et al., 2004), provides shelter against predators (Oberndorfer et al., 1984) and triggers environmental changes (Lancaster and Hildrew, 1993), making this material an important component in preserved lotic systems.

The plant material that falls into streams is colonised by microorganisms and aquatic invertebrates, either in series or simultaneously (Allan and Castillo, 2007). Shredding and borrowing invertebrates, together with decomposer microorganisms (fungi and bacteria) and physical abrasion, convert coarse organic matter (particles > 1 mm) into fine organic matter (< 1 mm and > 0.5 mm) (Graça, 2001; Kominoski et al., 2011). The structural and biochemical modification of leaf litter during the decomposition process alters the amount of available organic matter, the microbiota and the composition of the aquatic invertebrate community (Gonçalves Júnior et al., 2004; Moretti et al., 2007).

The colonisation of leaf litter by invertebrates in lotic environments has attracted a good deal of academic interest in recent years due to its importance in understanding the ecological succession in these environments (Abelho, 2001; Galizzi and Marchese, 2007; Swan and Palmer, 2006). However, there are few such studies in tropical streams (Benstead, 1996; Gonçalves Júnior et al., 2006; Mathuriau and Chauvet, 2002; Moretti et al., 2007).

The aim of the present work was to investigate the structure and composition of the aquatic invertebrate community during the decomposition of leaf litter made up of a mixture of two species of plants present along the banks of the stream studied.

2. Material and Methods

2.1. Study area

The study was carried out in the Poço D'Anta Municipal Biological Reserve. It is classified as a fully protected conservation unit and covers an area of about 277 hectares in the municipality of Juiz de Fora, Minas Gerais state, in southeastern Brazil (21°44'23"-21°45'51"S and 43°18'29"-43°19'9"W) at an altitude of about 850m. The Reserve is a fragment with typical Atlantic Forest vegetation in a secondary regeneration stage, partly inserted in an urban zone (Sousa, 2008).

The experiment was conducted along a five-metre stretch of a first-order stream located at the coordinates S 21°44'38" and W 48°18'50", with the physical characteristics presented in Table 1.

2.2. Collection and identification of leaves

The species A*lchornea glandulosa* Endl and Poeppig (Euphorbiaceae) and *Cabralea canjerana* (Vell) Mart (Meliaceae) were chosen for the colonisation experiment because they grow abundantly along the stream's banks, could be accessed easily and are listed among the main bush-tree species present in riparian vegetation in Brazil outside the Amazon region (Rodrigues and Nave, 2001).

Green leaves of the two species were gathered and dried in a drying chamber at 60 °C for 48 hours. Then a mixture of 2.5g (dry weight) of leaf matter of each species was placed in litter bags measuring 10cm in width and 15cm in length, with 1.0cm mesh. A total of 21 litter bags were placed in the streambed near the substrate and secured to PVC tubes partially buried along the banks, in three replicates. The bags were removed after 3, 6, 9, 12, 24, 48 and 96 days and were placed individually in plastic sacks containing 4% formaldehyde. The experiment was conducted between July and October 2008.

The samples were passed through a sieve with 0.21mm mesh and the organisms found were sorted under a stereoscopic microscope. The taxonomic identification followed McCafferty (1981), Merritt and Cummins (1984), Fernández and Domínguez (2001), Carvalho and Calil (2000) and Costa et al. (2006).

The remaining plant matter was dried in the same chamber at 60 °C until constant weight to calculate the weight loss of the leaves.

Each time the bags were removed from the stream the water temperature, depth, speed and flow rate were measured, along with the stream width. The speed was measured with a small float and the flow by calculating the cross-sectional area and multiplying it by the average speed in the section of the stream (Martinelli and Krusche, 2007).

Table 1. Physical characteristics of the stream segment where the experiment was conducted (between July and October 2008) in the Poço D'Anta Municipal Biological Reserve, Juiz de Fora – MG.

Physical characteristics	Values
Water depth (cm)	6.58 ± 2.37
Stream width (m)	1.80 ± 0.45
Water surface velocity (m/s)	0.29 ± 0.08
Water flow (m^3/s)	0.09 ± 0.01
Water temperature (°C)	17.94 ± 2.23

2.3. Analysis of the data

The dry weight loss rate of the leaf litter (k) was calculated by applying the formula $W_t = W_0.e^{-kt}$, where W_0 is the initial biomass at t_0 = 5g and W_t is the biomass at the removal times of t = 3, 6, 9, 12, 24, 48 and 96 days. According to Gonçalves Júnior et al. (2014), the weight loss in this type of experiment can be classified in Brazilian systems as slow ($k < 0.0041\ d^{-1}$), intermediate ($0.0041 < k < 0.0173\ d^{-1}$) or rapid ($k > 0.0173\ d^{-1}$). However, these values can range depending on the environment.

The aquatic invertebrate fauna was analysed by taxon density (number of individuals per gram of dry weight – average of three samples), relative density (%), taxonomic richness, Pielou evenness, α diversity (Shannon-Wiener), β diversity and percentage of functional feeding groups. Chironomidae (Diptera) and Hydroptilidae (Trichoptera) were not classified into functional feeding groups because they have diversified food habits, being removed from the analysis.

The α diversity was calculated for each day of bag removal according to the Shannon-Wiener diversity index. The β diversity measures the change or rate of substitution in the composition of taxa from one site to another along a space or time gradient (Magurran, 2004). In this work we used the Whittaker index to calculate the faunistic substitution rate between the bag removal days. This index regards the total richness between samples and the average richness.

The Kruskal-Wallis statistical test was employed to verify the variation of the mean invertebrate density, Shannon-Wiener diversity, Pielou evenness, taxonomic richness values and functional feeding groups among the bag removal days. The correlation between the remaining dry weight and average taxonomic density was measured by the Pearson correlation coefficient with logged data. All these analyses were carried out using the BIOESTAT. 5.0 program (Ayres et al., 2007).

3. Results

The bags containing the leaf litter lost weight rapidly during the experiment ($k > 0.01$). On the 96th day only 8% of the initial dry weight remained. The average invertebrate density increased progressively ($H = 22.06$; $p < 0.01$), reaching a maximum value on the 96th day (764.22 ind/g) (Figure 1). The taxonomic density was negatively correlated with the remaining dry weight of the leaf litter ($r = -0.93$; $p < 0.01$).

The indices of α diversity Shannon-Wiener ($H = 12.50$; $p = 0.05$) and Pielou evenness ($H = 15.90$; $p = 0.01$) were highest in the first and last day of the experiment. The taxonomic richness was higher on the 48th day ($S = 22$; $H = 3.97$; $p = 0.04$) and 96th day ($S = 23$; $H = 3.97$; $p = 0.04$) than on the 3rd day ($S = 15$) of the experiment (Table 2).

During the first 48 days of colonisation, the predominant organisms were Chironomidae larvae (> 50%), composing 84.21% of the total after 9 days of the experiment. On the 96th day, their participation had fallen to 15.35%, while there was an increase in the percentages of other orders: other Diptera (17%), Amphipoda (23.23%) and Oligochaeta (31.89%) (Figure 2).

The percentage of functional feeding groups changed during the days of bag removal (Figure 3). Scrapers were more representative at the start of colonisation period and decreased throughout the experiment ($H = 17.39$; $p < 0.01$). Collectors were above 38% during all the days ($H = 6.08$; $p = 0.41$) and shredders had higher percentages between 24 and 48 days the colonisation ($H = 16.44$; $p < 0.01$).

The β diversity (Table 3) showed higher variation in the taxonomic composition between the start (3 days) and end (96 days) of the colonisation period ($\beta_w = 0.63$) and indicated lower fauna substitution between consecutive days. It also showed lower values than 0.37 between each pair of consecutive days, as seen in Table 3.

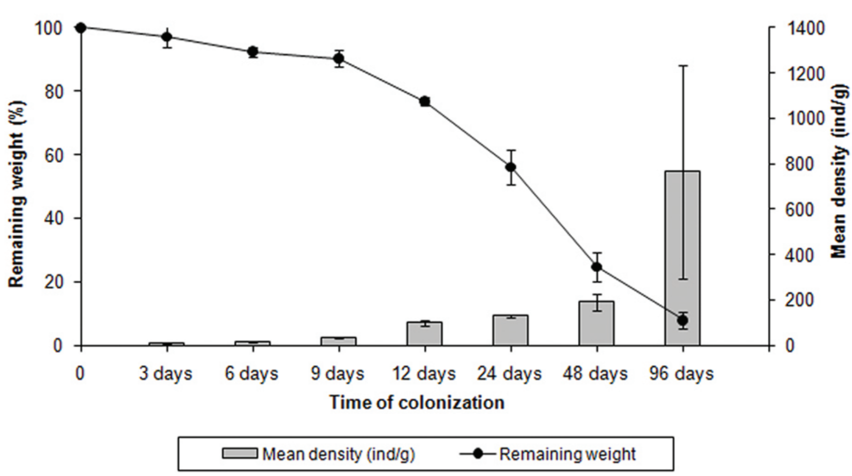

Figure 1. Percentage of remaining weight (mean ± SD) and mean invertebrate density during decomposition of the leaf litter in a first-order stream in the Poço D'Anta Municipal Biological Reserve, Juiz de Fora - MG, Brazil.

Table 2. Mean density ± standard deviation, abundance, taxonomic richness, Shannon-Wiener diversity and Pielou evenness of aquatic invertebrates during decomposition of leaf litter in a first-order stream in the Poço D'Anta Municipal Biological Reserve, Juiz de Fora – MG, Brazil.

	3 days	**6 days**	**9 days**	**12 days**	**24 days**	**48 days**	**96 days**
Plecoptera							
Perlidae	0.21±0.21	0.22±0.21	0.37±0.14	0.77±0.89	0.23±0.40	1.00±1.01	12.30±7.02
Gripopterygidae	0.07±0.11	0.29±0.12	0.29±0.25	1.29±0.67	1.83±0.90	13.91±3.18	0
Trichoptera							
Calamoceratidae	0	0.07±0.12	0.22±0.38	0.71±1.01	2.59±1.98	8.58±4.50	2.03±2.00
Hydrobiosidae	0	0	0	0	0	0	1.39±2.41
Helicopsychidae	0.21±0.21	0.21±0.37	0	0.17±0.30	0.27±0.46	0.28±0.48	0
Glossosomatidae	1.04±0.97	1.01±0.61	0.44±0.58	2.43±1.72	2.29±0.58	2.83±2.89	5.59±6.36
Polycentropodidae	0.28±0.49	0.14±0.12	0.08±0.13	0.35±0.61	0	0.33±0.57	0
Philopotamidae	0	0	0	0	0	0	1.40±1.22
Hydropsychidae	0	0.07±0.13	0	0	0.59±0.71	1.15±1.25	1.39±2.41
Leptoceridae	0.07±0.12	0.07±0.12	0.07±0.12	0	1.99±1.40	3.89±3.47	0
Odontoceridae	0	0	0	0	0	0.33±0.57	1.33±2.31
Hydroptilidae	0.07±0.12	0.50±0.49	0.37±0.12	8.01±2.57	8.88±5.00	1.23±1.08	0
Ephemeroptera							
Leptohyphidae	0	0.14±0.25	0.22±0.01	0.26±0.00	0.11±0.20	0.28±0.48	3.36±4.15
Leptophlebiidae	0.21±0.21	0.29±0.25	0.43±0.57	1.32±1.33	0.24±0.21	2.31±1.42	5.49±3.06
Baetidae	0.90+0.74	0.50±0.12	0.07±0.13	0.94±1.63	0.85±0.45	1.76±1.99	6.25±10.83
Melanemerellidae	0.13±0.23	0.07±0.12	0	0.09±0.15	0.11±0.20	0.45±0.78	0
Diptera							
Simuliidae	0	0	0	0	0.57±1.00	0	45.15±76.37
Chironomidae	4.18±2.89	12.92±4.02	28.29±3.62	78.05±9.99	101.33±17.87	115.90±27.89	117.31±34.09
Dixidae	0.07±0.12	0.07±0.12	0	0	0	0	0
Ceratopogonidae	0	0	0.30±0.34	0.17±0.15	0	0.55±0.50	82.07±88.60
Empididae	0	0	0	0	0.24±0.21	0.55±0.95	0
Tipulidae	0	0	0	0	0	0.45±0.78	2.75±2.39
Diptera NI*	0	0.07±0.12	0.08±0.13	0	0	0	0
Odonata							
Megapodagrionidae	0	0.07±0.12	0.07±0.13	0	0	0	1.33±2.31
Libellulidae	0	0	0.15±0.26	0	0.13±0.23	0	0
Calopterygidae	0.13±0.23	0.22±0.38	0	0.78±0.52	1.08±0.11	2.76±1.93	1.33±2.31
Gomphidae	0	0	0	0	0	0	0.71±1.23
Heteroptera							
Mesoveliidae	0.07±0.12	0	0	0	0	0.28±0.48	0
Veliidae	0	0	0	0.09±0.15	0	0	0
Coleoptera							
Hydrophilidae	0	0.07±0.12	0	0	0	0	0
Elmidae	0	0	0.15±0.13	0	0.23±0.40	0	5.53±2.43
Oligochaeta	0	0.07±0.13	0.67±0.46	0.35±0.16	0.34±0.34	0.73±0.68	243.74±227.67
Amphipoda	0.54±0.30	0.86±0.42	1.76±1.45	2.44±0.96	5.06±2.84	30.45±26.97	177.49±137.33
Bivalvia	0	0	0	0.09±0.15	0	0	26.92±36.14
Turbellaria	0	0	0	0	0	0	15.80±13.69
Hydrozoa	0	0	0	0	0	0	3.55±6.14
Abundance	120	249	462	1132	1086	691	802
Richness	15	21	18	18	20	22	23
Shannon-Wiener diversity	2.07	1.37	0.82	0.93	0.99	1.48	1.98
Pielou evenness	0.76	0.45	0.28	0.32	0.33	0.48	0.63

*NI = Not identified.

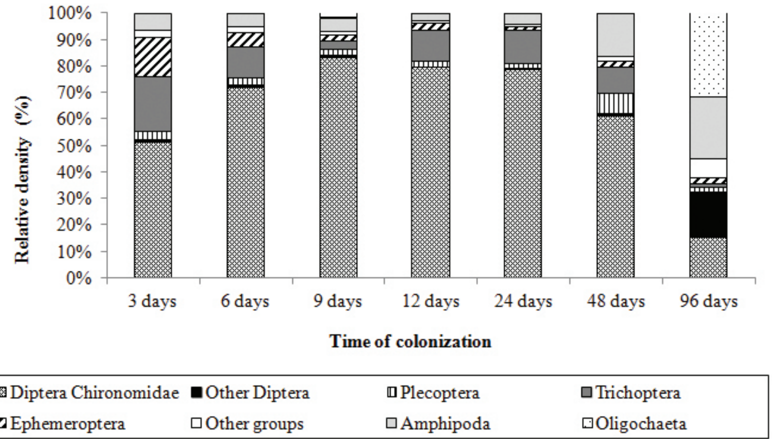

Figure 2. Relative density (%) of aquatic invertebrates during decomposition of leaf letter in a first-order stream in the Poço D'Anta Municipal Biological Reserve, Juiz de Fora - MG, Brazil.

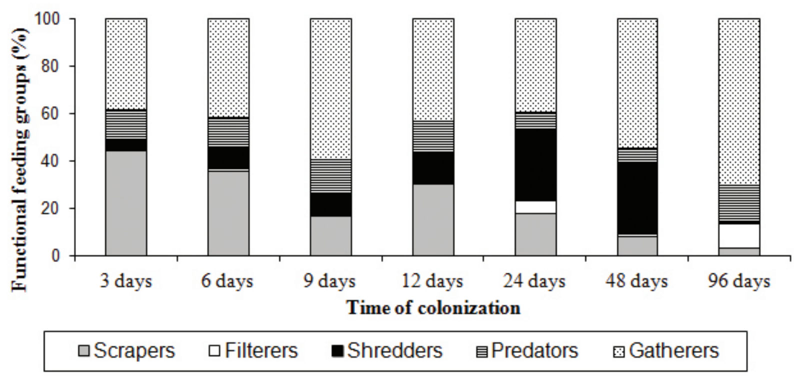

Figure 3. Functional feeding groups (%) of aquatic invertebrates during decomposition of leaf litter in a first-order stream in the Poço D'Anta Municipal Biological Reserve, Juiz de Fora - MG, Brazil.

4. Discussion

In this study the steady increase in the density of Chironomidae larvae with time and the increase of Oligochaeta and Amphipoda on the last experiment day culminated in the peak invertebrate density. According to Allan and Castillo (2007), plant matter undergoes structural and biochemical changes during decomposition that propitiate the high density of collector groups, such as Oligochaeta and Amphipoda, which efficiently use food resources of the detritivore chain, mainly in the more advanced decomposition stages, due to the increase in fine organic matter (Capello et al., 2004; Ligeiro et al, 2010).

The predominance of Chironomidae at the start of the experiment can be explained by the high colonisation capacity of these larvae (Batzer and Wissinger, 1996). The Chironomidae are present in high density during the colonisation of organic detritus (Benstead, 1996; Gonçalves Júnior et al., 2003; Moretti et al., 2007) and tend to have generalist and opportunistic feeding habits (Silva et al., 2008), enabling them to colonise leaf litter regardless of the quality and/or decomposition time (Gonçalves Júnior et al., 2006).

The decrease in the percentage of scrapers along the experiment may be related to their feeding habits, because these organisms feed on periphyton adhered to the surface of the mineral or organic substrates (Wallace and Webster, 1996) and according to Mormul et al. (2006), after some days of the experiment, there may be a decrease of the percentage of scrapers because part of the substrate used begins to be lost due the reduction of leaves and consequent drifting of these fragments. The shredders have an important role in the conversion of coarse particulate organic matter into fine particulate organic matter (Graça, 2001). However, these organisms use leaf detritus as a food resource only after structural and/or biochemical changes that make them more palatable (Cummins et al., 1989), which might explain the highest percentage of shredders between 24 and 48 days of the experiment.

The lowest invertebrate richness was observed on the 3rd day of colonisation, but the absence of dominant taxa contributed to one of the highest α diversity values obtained

Table 3. Matrix of bw diversity among the days of the experiment during decomposition of leaf litter in a first-order stream in the Poço D'Anta Municipal Biological Reserve, Juiz de Fora – MG, Brazil.

β_w	3 days	6 days	9 days	12 days	24 days	48 days	96 days
3 days	0						
6 days	0.22	0					
9 days	0.39	0.23	0				
12 days	0.27	0.23	0.27	0			
24 days	0.31	0.22	0.26	0.26	0		
48 days	0.24	0.21	0.30	0.20	0.19	0	
96 days	0.63	0.45	0.41	0.41	0.40	0.37	0

during the experiment. During the succession process the structural and/or biochemical modifications of the litter permits colonisation by other taxa (Gonçalves Júnior et al., 2003), leading to greater richness and consequently increased diversity, as observed on the 96th day of the experiment.

The highest β diversity on the 3rd and 96th days of the experiment showed that on these two days the greatest variation in taxonomic composition occurred, indicating the substitution of fauna between the start and end of the colonisation. The substitution of aquatic invertebrates is possibly related to the different degrees of leaf fragmentation, leading to a change in the composition of invertebrate species due to their different biological needs (Kikuchi and Uieda, 2005).

This study showed, as expected, that the structure and composition of aquatic invertebrates changes during the decomposition of the leaf litter. The faunistic abundance and diversity observed in this study shows the importance of the entrance of streamside plant matter as a source of energy for the invertebrates in first-order streams and the need to preserve forest areas, mainly riparian vegetation.

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