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Effect of plant richness on the dynamics of coarse particulate organic matter in a Brazilian Savannah stream

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ABSTRACT

The high plant richness in riparian zones of tropical forest streams and the relationship with an input of organic matter in these streams are not well understood. In this study, we assessed (i) the annual dynamics of inputs of coarse particulate organic matter (CPOM) in a tropical stream; and (ii) the relationship of species richness on riparian vegetation biomass. The fluxes and stock of CPOM inputs (vertical-VI = 512, horizontal-HI = 1912, and terrestrial-TI = 383 g/m^2/year) and the benthic stock (BS = 67 g/m^2/month) were separated into reproductive parts, vegetative parts and unidentified material. Leaves that entered the stream were identified and found to constitute 64 morphospecies. A positive relationship between species richness and litterfall was detected. The dynamics of CPOM were strongly influenced by rainfall and seasonal events, such as strong winds at the end of the dry season. Leaves contributed most to CPOM dynamics; leaf input was more intense at the end of the dry season (hydric stress) and the start of the rainy season (mechanical removal). Our study show an increase of litter input of CPOM by plant diversity throughout the year. Each riparian plant species contributes uniquely to the availability of energy resources, thus highlighting the importance of plant conservation for maintaining tropical streams functioning.

1. Introduction

Headwater streams in forested areas are characterized by dense riparian vegetation that limits the penetration of light to the streambed, resulting in low stream autotrophic productivity (Vannote et al., 1980). Riparian vegetation also is the main source of energy for food web of these streams by coarse particulate organic matter (CPOM, material >1 mm; Webster and Meyer, 1997). CPOM derived from riparian vegetation includes various parts of plants (e.g. leaves, branches, flowers and fruits). Leaves comprise the largest fraction of CPOM, contributing more than 50% of the total organic matter (Gonçalves and Callisto, 2013; Molinero and Pozo, 2004; Webster and Meyer, 1997). The inputs and forms of CPOM that derive from riparian vegetation vary in quantity and quality and depend on the characteristics of the riparian vegetation and the season (Abelho, 2001; Bambi et al., 2016; Tank et al., 2010).

CPOM from riparian vegetation, in the form of litterfall goes into the stream by vertical (VI) and horizontal input (HI). VI was defined as CPOM entering a stream directly, manly by senescent leaves. HI was defined as CPOM entering a stream indirectly by organic matter runoff at the margins to stream water due to wind and animal transport. In addition, terrestrial input (TI), derived from the leaf litter and out of streams flood pulse (part decomposes in the soil), represents the potential stock that can be transported into the stream via HI. The variations in VI, HI and TI that occur at multiple spatial and temporal scales can influence the dynamics of CPOM inputs and stock (Benfield et al., 2001; Gonçalves and Callisto, 2013; Webster and Meyer, 1997). The CPOM inputs and stock also impact the remobilization of nutrients in the trophic chain of streams (Magana, 2001; Magana and Bretschko, 2003; Rezende et al., 2016).

Several studies have focused on elucidating organic matter dynamics in tropical streams (Afonso et al., 2000; Benson and Pearson, 1993; Carvalho and Uieda, 2010; França et al., 2009; Gonçalves et al., 2014; Larned, 2000; Londe et al., 2016; Magana and Bretschko, 2003; Rezende et al., 2016). The dynamics of organic

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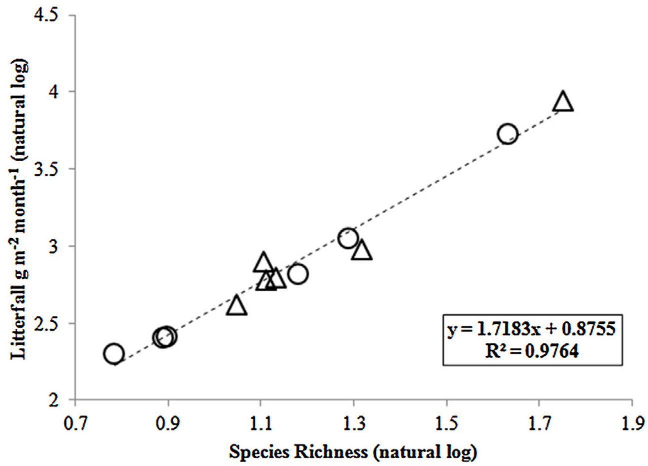

Fig. 1. Regression of the natural logarithm of the proportion of species richness and litterfall biomass over the sampling time period (circle = dry season; triangle = rainy season).

matter in tropical riparian vegetation is typically diver by phenological patterns (França et al., 2009; Gonçalves and Callisto, 2013) and the leaf senescence are often more pronounced during drier periods by hydrical stress (França et al., 2009). However, the relationship between dynamics of organic matter and plant species richness is largely unknown, and most studies consider only the dominant species (Afonso et al., 2000; Carvalho and Uieda, 2010; Magana, 2001). A review by Ives and Carpenter (2007), about stability and diversity in terrestrial systems show a temporal stability of biomass production due to increase of biological diversity, also supported by mathematics models (Valone and Barber, 2008). Therefore, identification of key species for ecosystem functioning and the quantification of plant species richness (and their contribution to ecosystems) in the riparian zone plus the phenological changes that occur throughout the year are important for tropical streams understanding (Rezende et al., 2016; Wantzen et al., 2008).

The amount of organic matter input can serve as an effective environmental indicator because of its efficiency and sensitivity in detecting changes in riparian plant species biomass (Gonçalves et al., 2014; Machado et al., 2008). This study may therefore help to resolve important ecological questions, such as (i) how is ecosystem function (e.g., CPOM input) altered by biodiversity change (e.g., plant species contributing to the CPOM input), and (ii) how important are less common species in the functioning of ecosystems? These questions were suggested to be two of the 100 fundamental questions in pure ecology with practical relevance for the conservation of biodiversity and ecosystem function (Sutherland et al., 2013). Therefore, we tested the following hypotheses: (i) the litterfall will be dominated by a small number of species (for more see also Gonçalves et al., 2014; Lisboa et al., 2014; Rezende et al., 2016), and an increase in species richness would not change the CPOM input of riparian vegetation (i.e., by low contribution of infrequent species); (ii) the hydric stress together with first rainfalls have positive effects in the CPOM inputs due the senescence stage of leaves and the removing physical by rain. Our goals were to (i) measure the quantity, (ii) describe species composition, and (iii) identify key species of the inputs and the stock of CPOM over 12 months in a Brazilian Savannah stream.

2. Methods

2.1. Study area

This study was conducted in a second-order stretch of the Boiadeiro stream (12°59′43.8″S, 41°19′35.6″W; elevation 900 m), which is located in Park City Mucugê (PCM) in Chapada Diamantina – Bahia, a transitional area between the Cerrado (Brazilian savannah) and Caatinga (Brazilian dry forest) biomes in northeastern Brazil. The surrounding landscape is composed of rocky fields and outcrops vegetated primarily with species associated with a physiognomy of herbaceous shrubs growing on quartzite soils (rupestrian fields). The climate is mesothermal, with a mean annual temperature of approximately 22 °C, low temperatures in the winter, and a rainy season (October to March) and a dry season (April to September). The rivers of this region are channeled through fractures within large rocks and consequently feature a regime of rapid flows during periods of rain (CPRM, 1994). The stretch of the Boiadeiro stream included in this study measured 50 m in length and has a width of approximately 10 m (horizontal distance of the water body between the boundaries of riparian vegetation), with dense bank vegetation and a closed canopy. Rainfall data were obtained from the National Agency of Waters of Brazil meteorological station in the city of Mucugê (station number 1241033; located at 13°1′37.1994″S, 41°13′16.32″W) from the National Agency of Waters of Brazil, available on the website hidroweb (http://hidroweb.ana.gov.br/).

2.2. Procedures

Litterfall was measured monthly from January to December 2011 (standardized as 30 d with an acceptable deviation of ± 2 d). The organic matter falling directly to the ground (TI) was estimated using 10 nets (1 m^2, 1-mm mesh size, located 10-m apart). CPOM entering directly into the river (VI) was measured using 90 buckets (0.53 m^2) that were suspended by ropes 2 m above the stream; they were transversely positioned in 5 rows (replicates in the stream), with 3 rows of 6 buckets per site (18 buckets in total) and 10 m between adjacent rows (buckets were the replicates). The bucket bottoms were perforated to allow rainwater to escape. At monthly intervals, the CPOM accumulated in the buckets was retrieved and weighed *in situ* (wet weight), and the bucket with the highest leaf-litter mass in each row was used for the humidity correction. The horizontal inputs (HI) were collected in nets with an opening of 0.1 m^2 (0.2 m in height, 0.5 m in width, 1 mm mesh size) that were installed along both banks of the stream (10 on each bank for a total of 20 samples). Two samples of benthic stocks (BS) were collected at each of 5 sampling points (April to December) using a Surber sampler (area of 0.45 m^2, 250 μm mesh size; total = 10 samples). The sample design was similar to that described by Sales et al. (2015) and Rezende et al. (2016).

The material collected from each compartment (VI, HI, TI and BS) were taken to the laboratory and dried in an oven at 60 °C for 72 h and weighed (precision = 0.005 g); then, the material was sorted into reproductive parts (flowers, fruits), vegetative parts (branches, leaves) and unidentified material (others). Leaves were identified to species according to the *Angiosperm Phylogeny Group* II system (APGII, 2003), and CPOM that could not be identified to species were sorted into morphospecies. Each leaf species was weighed to determine each species contribution to composition of the CPOM. We consider the most representative plant species in terms of the biomass of leaf material in the inputs and the stock as those species that contribute in excess of 5% of the total annual contribution. In Table 1, the literature search included personal literature databases and journal indices (in *Web of Science* -n = 15- and *Scopus* -n = 12-). The search terms used in online databases were “litterfall” and “tropical streams” and “riparian vegetation”. Studies were included if they satisfied the following criteria: (i) data of litterfall; (ii) performed in natural riparian zones of tropical and subtropical; (iii) data of number of plant species and/or leaf percentage in litterfall.