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Relationship between dynamics of litterfall and riparian plant species in a tropical stream

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ABSTRACT

We investigated the dynamics of organic matter and type of detritus in a riparian zone of the Atlantic Rain Forest domain, and specifically determined the inputs and stock of detritus contributed by plant species, and their relationship to temperature and precipitation. Our hypotheses tested were: (1) the species composition of riparian vegetation influences the amount and type of detritus delivered to a stream in an Atlantic Rain Forest, and (2) the dynamics of litterfall in the riparian zone is influenced by climate factors. The plant community was formed principally by pioneer and early successional species such as *Apuleia leiocarpa*, *Erytrina velutina*, *Erytrina verna*, *Eucalyptus torelliana*, *Ficus glabra*, *Ficus insipida*, *Guarea guidonea*, *Guarea guidonia*, *Maprounea guianensis* and *Psidium guajava*. There was a large number of *G. guidonea* (318 individuals/ha), followed by *Cupania oblongifolia* (91), *Trichilia pallida* (52), *Piptadenia gonoacantha* (26) and *E. torelliana* (14). *G. guidonea* contributed >50% of the total litterfall; however, some species which were present in high density in the plant community and did not yield significant biomass, indicating that detritus production was based on the contribution of a few species. We found 697, 856 and 804 g/m^2/year from vertical, terrestrial, and lateral inputs, respectively, whereas to the annual benthic standing stock was 3257 g/m^2. Detritus was formed by leaves (60%), branches (32%), reproductive parts (3%), and unidentifiable fragments of organic-matter (5%). Inputs and benthic stock were markedly seasonal, with an increase of leaf litter during the dry season. Our results indicate that litterfall dynamics is basically composed of a few species that contribute with higher values of biomass. Moreover, ecological characteristics together with environmental factors can be viewed as the principal factors determining the energy balance of riparian ecosystems. The biological implications of the dynamics of organic matter have high importance for the maintenance and restoration of riparian zones. However, the amount of litterfall required to maintain the balance of the riparian community remains unclear in the tropical zone.

Introduction

Riparian forests along the banks of waterbodies provide important environmental services including control of nutrient input, maintenance of water quality, reduction of erosion, temperature control, maintaining the integrity of the watershed, and maintaining the stability of biological communities under their influence (Karr and Schlosser, 1978; Lima, 1989). These forests constitute the interface between terrestrial and aquatic ecosystems, and as transition areas affect the composition of plant species, particularly through the soil properties and moisture gradient (Wantzen and Junk, 2000; Wantzen et al., 2008). Riparian forests serve as important longitudinal and transversal corridors for exchange of material and dispersal of biota (Naiman et al., 2005). Several studies have demonstrated the significance of riparian zones for stream organic-matter budgets, solute balance, and the structure of benthic invertebrate assemblages (Wantzen and Junk, 2000; McClain and Elsenbeer, 2001; Wantzen et al., 2008).

Riparian forests are much more than a buffer strip filtering sediment and pollutants, but act as an ecotone in relation to floristic composition, biodiversity and ecological processes controlling the energy balance of lotic systems (Rodrigues and Nave, 2000). Studying the dynamics of allochthonous plant litter is especially important in order to understand energy flows and the maintenance of stream metabolism (Rodrigues and Nave, 2000; Naiman et al., 2005). The available energy in lotic ecosystems can be derived from autochthonous sources, resulting from photosynthetic production of the system itself by periphyton and microbial

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production; and allochthonous terrestrial material originating from riverbanks (Naiman et al., 2005). The presence of riparian forests along waterbodies controls the supply of energy to aquatic ecosystems (Nakano and Murakami, 2001; Wantzen et al., 2008). In forested streams primary productivity is low because of shading by canopy vegetation, and the ecosystem uses allochthonous organic matter in the food web, so that heterotrophic processes prevail over autotrophic (Hill et al., 1995). Thus, allochthonous organic matter-MO (formed by coarse particulate organic matter – CPOM; fine particulate organic matter – FPOM, and dissolved organic matter – DOM) is the main source of energy for the aquatic communities of these ecosystems (Gregory et al., 1992; Esteves and Gonçalves, 2011).

This allochthonous organic matter (basically formed by CPOM) is composed of litterfall, mainly leaves and secondarily twigs and reproductive parts, regardless of vegetation type or geographic area (Benfield, 1997; Abelho, 2001). The amount of litterfall depends on the riparian species (composition, phenology and abundance), and the environmental conditions (temperature, precipitation, humidity, and wind) (Hernandez et al., 1992; Alencar, 1994). The organic-matter dynamics can be considered as the inputs to stream and soil in the riparian zone (Webster and Meyer, 1997). Horizontal input is the organic matter carried from the soil to the stream, and the benthic stock is the remaining part retained in the streambed (Benfield, 1997). For instance, studies have recommended that planting buffer zones of native trees reduces the degradation of streamside habitat (Wantzen et al., 2008) and because of the large number of native flora and fauna species that they support, studies have proposed that riparian zones be treated as 'keystone habitats' for conservation (Dudgeon, 2000; Wantzen et al., 2008).

Many studies have examined the relationship between riparian zones and streams in temperate regions (e.g., Wallace et al., 1997; Pozo et al., 1997; Molinero and Pozo, 2004). However, little information is available on the relationship between organic-matter dynamics, plant communities and environmental variables in tropical riparian ecosystems (Afonso et al., 2000; Gonçalves et al., 2006; Wantzen et al., 2008; França et al., 2009). Most tropical forests have been converted into secondary growth by human activities (e.g., agriculture, uncontrolled occupation, and silviculture), supplying a wealth of plant species and leading to changes in riparian community structure and energy input by litterfall. In this study we investigated the dynamics of organic matter and type of detritus in a riparian zone undergoing a process of ecological regeneration of the Atlantic Rain Forest domain, and specifically determined the inputs and stocking by plant species and their relationship to temperature and precipitation. This study was based on the premise that the dynamics of allochthonous organic matter in streams is mainly associated with environmental factors (e.g., availability of water and light) and phenology aspects. Our hypotheses tested were: (1) the species composition of riparian vegetation influences the amount and type of detritus delivered to a stream in the Atlantic Rain Forest, and (2) the dynamics of litterfall in the riparian zone is influenced by climate factors.

Materials and methods

Study area

The present study was conducted from December 2006 to November 2007, through monthly samples taken in the riparian zone of a stretch of the second-order Zé Adão stream (19°34′28″ S, 42°37′50″ W; elevation 440 m). During the 12 sampling sessions, we measured the stream channel (~2 m), water temperature (annual mean 20.2 ± 1.1 °C SD), pH (7.0 ± 0.2), dissolved oxygen (8.0 ± 0.4 mg/L), and electrical conductivity (77.8 ± 7.7 μS/cm). The stream is poor in nutrients, with total nitrogen 0.07 mg/L and total phosphorus 0.018 mg/L, measured monthly during the period of the experiment. The site is a 989-ha fragment of successional Atlantic Forest, previously occupied by eucalyptus plantations of Aperam Inox South America S/A, and is currently in the process of ecological regeneration and has been recovering for 30 years. The site is part of the Doce River watershed complex, an 83,400 km^2 drainage basin in eastern Brazil, which forms an ecological corridor for the Parque Estadual do Rio Doce, the largest continuous expanse of Atlantic Forest in the state of Minas Gerais, with 36,974 ha. The climate is humid tropical with a defined dry season from April to October (Köppen Aw). The highest rainfall periods occurred in December (482.2 mm) and January (278.8 mm) and the lowest in July (2.6 mm) and August (1.2 mm). The annual mean wind speed is 1.25 m/s, mean air temperature 23.2 °C and mean relative humidity 68%. The climate parameters were obtained from the weather station of the Environmental Education Center of Aperam Inox South America S/A, located 5 km from the study site.

Plant community

A floristic survey was carried out monthly from October 2007 through August 2008, using the plot method (Mueller-Dombois and Ellenberg, 1974). We allocated 50 plots of 10 m × 20 m, with 25 plots on the right bank and 25 on the left bank along the stream, totaling 1 ha. All tree species with a circumference at chest height (CCH) equal to or greater than 15.0 cm were sampled. Two of the plots were established in the same area where we collected the input samples, where we could identify the individual plants that contributed allochthonous organic matter. Voucher specimens were deposited in the herbarium of the Botany Department of the Universidade Federal de Viçosa (Vic) and the herbarium of the Centro Universitário do Leste de Minas Gerais (HUNL/Unileste). The species list was compiled following the Angiosperm Phylogeny Group II (APG II 2003).

The terrestrial input (TI) of organic matter that falls directly on the soil surface of the riparian zone was quantified by the use of six nets (n = 6; total area = 6 m^2; 5 mm mesh). The vertical input (VI) that enters directly into the stream was evaluated by means of 20 buckets (n = 20; total area = 1.06 m^2) placed 2 m above the water surface. The buckets were arranged in four rows of five buckets each, spaced along a nylon rope attached to the streambank, with an approximate distance between each row of 12.5 m. The base of each bucket was completely drilled to prevent water from accumulating. The lateral input (LI) that passes laterally from the soil to the stream was assessed by means of ten nets (n = 10; area total = 2.5 m^2; 5-mm mesh), five on each streambank, to estimate the potential biomass that can be carried by rain or wind to the streambed. The stock of benthic litterfall (SB) was estimated by means of a Surber sampler (n = 5; total area = 0.45 m^2) deployed randomly in a 50-m stretch of the stream. The litter accumulated in traps (buckets and nets) was removed monthly and stored in plastic bags. The samples were washed on a 1-mm sieve to separate the coarse particulate organic-matter fraction, and then sorted into leaves, twigs, reproductive parts and miscellaneous (unidentifiable fragments of organic matter), and dried in an oven at 60 °C for 72 h before weighing.

Data analysis

To evaluate the diversity of the plant community, the Shannon–Weaver diversity index was estimated for the study area. To analyze the overall effects of variation in different types (leaves, reproductive parts, branches and miscellaneous) of plant detritus (dependent variable), sampling times (continuous variable) and interaction between the two factors in the compartment (vertical,