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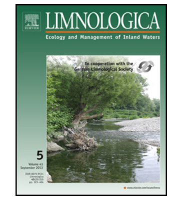

Shading effects on community composition and food web structure of a deforested pasture stream: Evidences from a field experiment in Brazil

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ABSTRACT

Experimental manipulations in the field can evidence cause–effect relations from the manipulated variables. In this context, the aim of the present study was to investigate the effects of shading on stream community composition and food web structure. The experiment was conducted in two reaches of a pasture stream: one that remained open (control) and another that was covered with 75% factor shading cloth (treatment), sampled before and after 21 months. At each sampling, algae, macrophytes, plankton, meiofauna, macroinvertebrates, and fish were collected. All heterotrophic organisms were submitted to diet analysis and dietary data was used to calculate food web parameters. Community composition was evaluated through cluster analysis. A total of 7556 individuals of 148 taxa were identified. The control reach presented lower richness, abundance, and food web parameter values than the treated reach before shading cloth installation, whereas after the experiment the opposite was observed. Despite these differences, both reaches had changed over the experimental period for being under increased siltation as a result of long term land use effects, which resulted in higher similarity of community composition between periods than between treatments. This observation was corroborated by higher food web complexity before the experiment, with decreases in all food web parameters (except connectance) after 21 months, especially in the treated reach. Hence, decreases in community attributes and food web parameters after the experiment evidenced the effects of siltation, while the strongest decreases observed at the treated reach evidenced the effects of shading. Finally, we stress that the artificial shading itself does not promote allochthonous materials inputs (which add up to food web basis and promote habitat heterogeneity), so full-canopy riparian forest restoration is of fundamental importance for low-order streams.

Introduction

Field experimentation can elucidate specific community attributes, such as the effect of shading and nutrient manipulation on periphytic communities (Mosisch et al. 1999), the effect of shading on temperature of small streams (Johnson 2004), or the effect of species addition or removal on food web structure (Motta and Uieda 2008). Regardless of the context, such experimental manipulations can reveal the role of species interactions and colonization process in stream community organization (Townsend 1989; Raffaelli 2005) by evidencing cause–effect relations from the manipulated variables (Motta and Uieda 2002).

When the whole community is studied in a food web context, cause–effect relations can become more evident, since each trophic level is related to those above and below it (Brett and Goldman 1996), direct or indirectly (Winemiller 2007), so the repercussion of a given effect through different trophic levels characterizes a 'trophic cascade'. This theory had been evolved in the controversy regarding the main forces that determine aquatic trophic structure (whether they are bottom-up or top-down) (Brett and Goldman 1996). In true trophic cascades, both top-down and bottom-up processes interact simultaneously, and thus produce a distinct interlace of processes of populations, communities, and ecosystems (Power 1992; Strong 1992). In unshaded small streams, resources that are made available by primary productivity form the autochthonous food web basis, whereas in shaded streams (as headwaters with abundant riparian canopy) gross primary production is reduced, leading to community dependence on allochthonous material inputs for consumption (Nakano and Murakami 2001).

In general, many authors emphasize the importance of the riparian forest to stream communities (Gregory 1992; Pusey and Arthington 2003; Sweeney et al. 2004; Kikuchi and Uieda 2005) and the harmful results of its removal to the aquatic biota (Resh

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et al. 1988; Belsky et al. 1999; Harding 2003). On the other hand, in deforested streams the producers proliferate due to the increase of radiation and nutrients, yielding greater algae and macrophyte abundance and consequently higher primary production (Esteves 1998; Raven et al. 2001; Pusey and Arthington 2003; Amaral et al. 2008). In this context, riparian forest removal can affect stream communities through the shift of the main energy source from allochthonous to autochthonous (Stone and Wallace 1998), and the kind of force that determines local trophic structure can also shift form top-down to bottom-up.

In São Paulo State, the original vegetation coverage is reduced to 13.94% of the former original area (Nalon et al. 2008), and most deforestation actions have resulted from land use for livestock grazing, especially in the Northwestern region, where stream physical integrity is highly divergent from reference conditions (Casatti et al. 2006). Practically half of these streams are characterized by an extensive grass proliferation over stream margins to the stream channel (Casatti et al. 2009) what indicates possible effects through bottom-up mechanisms. Given the recurrence of this anthropogenic alteration, understanding how riparian forest removal influences the structure and dynamics of stream environments is of critical importance (Moore and Palmer 2005). The present study was conducted under the hypothesis that bottom-up mechanisms are influenced by radiation (Allan and Castillo 2007). In this sense, natural shading must interfere in these mechanisms and alter the local community composition and trophic interactions through the decrease of primary production. Hence, our aim was to investigate, using an experimental shading cloth, the influence of shading on stream communities and food web structure.

Methods

Study area

The stream is a tributary of São José dos Dourados River and it is located at northwestern São Paulo State, southeastern Brazil (20°46′45.7″ S, 49°34′52.2″ W). This area is part of the 'Planalto Ocidental Paulista', a flat or smoothly rolling region (Silva et al. 2007b) with sedimentary origin of unconsolidated silt and clay, which confers this soil its high erosive potential (IPT 2000). The regional climate is hot tropical (Nimer 1989), with a rainy season from October to March and a dry season from April to September (IPT 2000). Average temperature during the experimental period was 26 °C, with maximum mean temperature (32 °C) in December and minimum mean temperature (14 °C) on June (CIIAGRO 2013). The annual average precipitation is around 1.250 mm (Silva et al. 2007b), with a monthly average precipitation of 213 mm at the rainy season and 36 mm at the dry season, when the samples were taken. Remnants of native vegetation (seasonal semideciduous forest) comprise less than 4% (Nalon et al. 2008), and livestock grazing represents 78% of total region land-cover, including 30 m riparian buffer zone (Silva et al. 2007a). Consequently, high sunlight incidence across the entire stream channel is typical.

The studied stream was selected for representing a typical pasture stream, characterized by a narrow cross-section, low depth, predominantly sandy substrate, and grass proliferation within the channel. It was also characterized by the complete clearance of riparian forest, which is one of the most common ecological impacts in the studied region. Monthly visits to the sampling reaches were carried out in order to check shading cloth integrity and overall stream structure. During this period, no storm events were observed.

Samplings and experimental design

Samplings were conducted in two 30 m long reaches of the stream, one that remained open (control), located upstream, and another that was covered with 75% factor shading cloth (treatment), located downstream, reproducing an average shading intensity of the riparian forests of the region. The two treatments were placed 20 m apart from each other. Each reach was divided in seven equidistant transects (5 m) for standardization of the sampling procedure employed for habitat variables, channel internal structure, fauna, and flora. Sampling was directed upstream in order to minimize disturbance, and began with plankton, algae, and environmental features, followed by macroinvertebrates, meiofauna, and fish.

Both reaches were sampled in August 2007, before the shading cloth was installed. After the sampling, the shading cloth was spread over the channel and tightly fixed to a wire frame that had been suspended between posts (2.2 m in length and 10 cm in diameter) driven into the ground of both bank tops at intervals of 3 m. Border effects were minimized by 5 m additional shading upstream and downstream of the 30 m test reach. Finally, the two reaches were sampled again 21 months after shading cloth installation, being the time expected for the community as a whole to have adjusted to the new condition.

At each sampling, physical and chemical water variables (conductivity, pH, turbidity, dissolved oxygen, and temperature) were measured *in situ* with a portable multimeter instrument (Horiba U-10). Light measurements were taken with a digital lux meter in both control and treatment reaches, as well as in a preserved forested stream, only to evaluate whether the shading intensity used for the experiment corresponds to natural conditions. Physical and structural variables as width, depth, and water velocity were measured, the latter with three replicates over 30 s each (taken along each transect, right and left margins and mid channel) using a flow meter, held in the upper third of the water column. Percent composition of substrate types (i.e. sand, silt, and pebbles, among others) and percent of substrate occupied by primary producers (algae and macrophytes) were both visually estimated for the whole reach using underwater observations (with a diving mask) when needed.

Before initiating the biota samplings, reaches were firstly blocked upstream and downstream with nets (0.3 mm mesh), and overall disturbances within stream channel were kept minimal. Planktonic organisms were sampled at all transects (total of seven samples) with a 45 μm mesh plankton net (according to Pinto-Coelho 2004), toward upstream for 4 min. Benthic macroalgae and macrophytes were sampled before and behind each odd-numbered transect (at left and right sides, in a total of six samples) within the reach using a combination of the square method and the line transection method (adapted from Necchi 2004). Benthic macroinvertebrates were sampled at the odd transects (mid channel, four samples) with a 250 μm Surber net, by substrate washing over 1 min and along the whole reach with a 250 μm D-shaped hand net (over 6 min). Meiofauna was sampled at the even-numbered transects from sediment cores, 20 cm in length, using a PVC core sampler (a total of three samples). Fish were sampled with two electrofishing passes along the entire reach (20 min each). Invertebrates caught during electrofishing were also included into further analysis. Qualitative samplings of periphyton (epiphyton, epipelon, and epilithon) and other organisms found out of the specified sampling points within the reach were also included. All sampled specimens were fixed and identified to the lowest taxonomic resolution possible, mostly to genus or species level. Specialists of each group were consulted to confirm the identifications. Since taxonomic resolution was not the same for all sampled organisms, each taxon will be referred to along the text as 'trophic species' whenever cited in a food web context. By definition, 'trophic species' are those taxa