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Original Research Article

Effects of riparian forest management on Chilean mountain in-stream characteristics

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ABSTRACT

We assessed the effect of forest management practices on temporal differences in riparian litterfall input and autumnal leaf litter processing of 3 evergreen plant species, using independently 2 mesh sizes (for two of the three species), between two contrasting headwater streams draining (a) near-pristine and (b) harvested evergreen old-growth forests in Chile (39° S). Additionally, we compared rainfall, streamflow, suspended sediment concentration, and the in-stream invertebrate community, collected two years after logging in the harvested microcatchment. The harvested forested stream had higher runoff, suspended sediment concentration and input of litter (3377 kg ha^{-1} yr^{-1}) than the pristine stream (3166 kg ha^{-1} yr^{-1}). However, leaf-litter decay rates were faster for the pristine (ranging from $k = -0.0120$ to -0.0024 day^{-1}) than for the harvested forest stream ($k = -0.0049$ to -0.0023 day^{-1}) depending on leaf species and litterbag type. Likewise, the pristine stream revealed higher shredder taxa richness than harvested stream, suggesting a higher correlation with the decomposition rate and leaf mass losses. Therefore, the results of our study suggest that despite the implementation of best management practices on riparian forests, there are detectable shifts in the structure and functioning of aquatic invertebrate community in the Andean streams of south-central Chile.

1. Introduction

The forest land cover in south-central Chile (39–55° S) supports a large timber industry (Echeverría et al., 2006). It has been estimated that Chilean old-growth native forests are being logged at a rate of 120 000–200 000 ha per year, of which 60–80% have been replaced with exotic tree plantations (Altieri and Rojas, 1999). These activities have altered the natural riparian vegetation of most Chile's aquatic systems, but their effects have not been totally addressed by scientific studies.

Forest management activities in headwater areas can potentially degrade water quality and the physical habitats within streams (Carroll et al., 2004), affecting woody debris, leaf litter and sediment supplies (Webster et al., 1990; Gurnell et al., 1995; Giller and O'Halloran, 2004), modifying physicochemical conditions and invertebrate diversity (Danger and Robson, 2004; Davies et al., 2005),

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and altering hydrology, nutrient fluxes and productivity (Campbell and Doeg, 1989; Lockaby et al., 2004; Lin and Wei, 2008). Therefore, proper forestry best management practices (BMPs, *sensu* Aust and Blinn (2004)) should be implemented to minimize effects on streams. Timber harvesting has the potential to affect the quantity, quality, and timing of allochthonous inputs from riparian vegetation (Campbell et al., 1992; Delong and Brusven, 1994; Xiong and Nilsson, 1997), with concomitant effects on leaf litter processing and aquatic invertebrate communities (Lockaby et al., 2004; Davies et al., 2005).

Riparian litterfall is widely recognized as an extremely important structural and functional component of headwater streams (Benfield, 1997; Webster et al., 1999; Abelho, 2001; Graça and Canhoto, 2006). Within undisturbed forest ecosystems, litter from the riparian areas constitutes a key energy source for stream biota (Wallace et al., 1997; Gessner and Chauvet, 2002; Benfield, 2006), affecting food chains, nutrient cycling and productivity (Cummins et al., 1989; Boulton and Boon, 1991; Wantzen et al., 2008). Aquatic fungi and leaf-eating invertebrates (shredders) are the main organisms assimilating the energy from litter in low-order streams (Abelho and Graça, 1998; Graça, 2001; Graça et al., 2001).

Although litter decomposition has been widely studied in both aquatic and terrestrial environments around the world, few studies have examined leaf litter decomposition in headwater streams in a riparian silvicultural management context within South American temperate old-growth rainforests (Valdovinos, 2001; Albariño and Balseiro, 2002). However, this information is important to understand how forest management practices influence stream trophic dynamics (Guevara et al., 2009).

In Chile there are important natural private reserves (Holmes, 2015; Rivera and Vallejos-Romero, 2015) such as San Pablo de Tregua (39° S, Panguipulli Municipality) with relevant and unique biodiversity and native forest. In this private protected area, researches and data collection started in 2002 to establish the effects of timber harvesting on water quality and quantity and on other biogeochemical factors (*e.g.*, forestry, soil dynamics, terrestrial and aquatic invertebrates, biodiversity; see Redel et al., 2008; Schlegel and Donoso, 2008; Lara et al., 2009; Oyarzún et al., 2011) as a representative (montane) area of the Chilean Andes. The hydrobiological research proposals were established following the watershed-ecosystem approach of the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire (United States) under a LTER perspective (Likens, 2013). To determine the effect of forestry activities on structural and functional role of benthic invertebrates, previous experimental trials were carried out on selected microcatchments. Seasonal litterfall input, mixed (summer 2007, January to March) and single leaflitter decomposition, and colonization by invertebrates during autumn 2007 (March to June) were registered (sensu Guevara et al., 2009). In this paper we show additional results obtained from that experiment. We hypothesized that riparian management practices would affect the litterfall supply to the stream channel and, consequently, in-stream litter decomposition, with the fastest decomposition rates in pristine forest headwater streams and the slowest in disturbed ones. We also expected benthic invertebrate assemblages to change as a consequence of forest harvesting, with less shredder taxa in managed forest streams than in pristine forested streams. The outcome of this study will be helpful for the management of riparian forest ecosystems in Chile, where such studies are scarce. The objectives of the present investigation were to (a) assess the temporal pattern of riparian litterfall in two evergreen forested streams located in the Andean mountains, and (b) compare leaf litter decomposition in streams draining natural and managed forests in south-central Chile, linking forest management to stream consumers and organic matter processing.

2. Methods

2.1. Study area

The study was conducted in two streams located at San Pablo de Tregua Experimental Forest, in the Andes mountains, South-Central Chile (39°38′ S, 72°05′ W, 600–1600 m a.s.l.; Fig. 1). The area consists of typical old-growth mixed evergreen (*e.g., Laureliopsis philippiana* Looser, *Dassyphyllum diacanthoides* (Less.) Cabr., *Saxegothaea conspicua* Lindl), and deciduous forests (*e.g., Nothofagus alpina* (P. et E.) Oerst; Schlegel and Donoso, 2008). Soils are deep to moderately Andisols derived from recent coarse volcanic ash (Veblen et al., 1996) and pumicitic material, overlying andesitic and basaltic lavas and fluvio-glacial sediments (Newton et al., 2007). The soil show high carbon storage capacities in relation with soil age relative to the evolution of the mineral phase (Neculman et al., 2013). The region has a humid, cool temperate climate, with short and dry summers with an average maximum temperature of 20 °C in February and a minimal mean temperature of 5 °C in August, even with snow events (Lara et al., 2002). Mean annual precipitation is *ca.* 5000 mm (Neira, 2005), concentrated in autumn and winter. Monthly average discharge of the three streams and precipitation for the years 2003–2007 are shown in Fig. 2.

One of the streams runs through undisturbed natural evergreen forest (hereafter pristine) with predominance of *Myrceugenia planipes* (H. et A.) Berg, *Laureliopsis philippiana* and *Saxegothaea conspicua*. Another stream runs through a harvested evergreen forest (hereafter harvested), originally with the same tree composition as the "pristine" stream, but subjected to selective logging 60 years ago. The forest has undergone natural post-harvest succession, but there was a change in its composition and structure due to the incorporation of the companion old-growth tree, *Dassyphyllum diacanthoides* (Redel et al., 2008). In November 2006, this catchment was thinned extracting 40% of the total basal area through a BMPs program during forest harvesting (*i.e.*, selective cutting, skidding was done by ox dragging and residues were left on site and a 15-m riparian buffer zone was preserved). Some characteristics of the two forests and streams studied are given in Table 1 (see more details in Oyarzún et al., 2011).