Forest Ecology and Management 401 (2017) 17–32

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

# Breakdown of instream wood in low order forested streams of the Southern Chilean mountain ranges

Andrés Iroumé [a,b], Virginia Ruiz-Villanueva [c,d,*], Lorenzo Picco [e,f]

[a] Universidad Austral de Chile, Faculty of Forest Sciences and Natural Resources, Valdivia, Chile
[b] RiNA Natural and Anthropogenic Risk Research Center, Universidad Austral de Chile, Valdivia, Chile
[c] Dendrolab.ch, Institute of Geological Sciences, University of Bern, Bern, Switzerland
[d] Institute for Environmental Sciences, University of Geneva, Geneva, Switzerland
[e] University of Padova, Department of Land, Environment, Agriculture and Forestry, Legnaro, Italy
[f] Universidad Austral de Chile, Institute of Civil Engineering, Faculty of Engineering, Valdivia, Chile

ARTICLE INFO

*Article history:*
Received 9 January 2017
Received in revised form 26 June 2017
Accepted 28 June 2017

*Keywords:*
Woody debris
Large wood breakage
Large wood decay
Depletion
Mountain channels

ABSTRACT

We analyzed instream wood depletion or breakdown in terms of wood breakage (defined as the reduction in length) and decay (reduction in diameter) on channel segments of three low-order mountain streams located in southern Chile. We used a unique database, composed of 1049 individually tagged logs, which were measured and their position was georeferenced between 2005 and 2014, and re-measured and re-georeferenced after the rainy winter period of 2015. Results showed that median breakdown at the end of the survey ranged between 5 and 27% and between 10 and 25% for median decay, with highest values of 83 and 72% respectively. While median annual breakage ranged between less than 1 and 4 $\%\cdot\text{year}^{-1}$ and median annual decay between 1 and 4 $\%\cdot\text{year}^{-1}$. According to our results, breakdown of instream wood is influenced by many factors, the most significant being initial log size (both length and diameter), their orientation, residence time and fluvial transport (i.e. displacement length). Wood density and initial tree height at the time of recruitment were also analyzed, aiming to better understand breakage and decay processes. Results showed that in-channel logs were, as expected, less dense than living trees, and very decayed logs significant loose density compared to fresh logs. The differences between initial log size and potential minimum tree height at the time of recruitment ranged between 29 and 64%. We believe that our findings illuminates on wood depletion processes on low order streams in the Chilean mountain ranges, and can be easily extrapolated to other streams with similar conditions; however, the natural heterogeneity among river environments and hydrological conditions during the survey period may influence breakage and decay processes. Therefore, we encourage other researchers to provide data on breakdown of instream wood from different regions.



## 1. Introduction

The role of instream wood in rivers and floodplains is very well documented (Gurnell et al., 2002; Gurnell, 2013; Le Lay et al., 2013; Wohl, 2013; Ruiz-Villanueva et al., 2016a). Instream large wood (LW) influences hydraulics, and thus sediment dynamics and eventually river morphology (Montgomery et al., 2003). The presence of wood in river systems also benefits their ecological status favoring habitats and refuges for some species (Benke and Wallace, 2003; Gulis and Suberkropp, 2004; Nagayama et al., 2012; Vera et al., 2014). However, transport and deposition of LW during floods can cause damage to infrastructures and populations in urbanized areas (Comiti et al., submitted for publication; Wohl et al., 2016). Therefore understanding LW dynamics is of great interest to better comprehend the fluvial ecosystem and the interactions and feedbacks between flow, sediment and vegetation (including LW), but also to better identify and prevent potential hazards. LW is stable most of the time in the river channels, but during medium and high flows it can become very mobile (Ravazzolo et al., 2015). One important aspect to enhance LW mobility is wood breakdown or depletion, including biochemical decay and physical or mechanical breakage (Harmon et al., 1986; Bilby, 2003). These processes may strongly modify LW mass balances and budgeting (Martin and Benda, 2001; Benda and Sias, 2003).

* Corresponding author at: University of Geneva, Institute for Environmental Sciences (ISE), 66 Boulevard Carl-Vogt, 1205 Geneva, Switzerland. Tel.: +41 (0)22 379 07 97.

*E-mail address:* virginia.ruiz@unige.ch (V. Ruiz-Villanueva).

http://dx.doi.org/10.1016/j.foreco.2017.06.058
0378-1127/

In scientific literature several studies analyze biochemical decay of LW in stream environments (Golladay and Webster, 1988; Murphy and Kroski, 1989; Hyatt and Naiman, 2001; Bilby, 2003), while mechanical breakage has received less attention (Comiti et al., 2006; Wohl and Goode, 2008; Merten et al., 2013), although physical and mechanical processes seem predominant during flood events (Steeb et al., 2016). Hydraulic forces in combination with channel morphology and sediment dynamics influence wood breakage and decay (Wohl, 2013). The main hydraulic forces that influence breakage are drag and lift forces acting on the wood pieces, but also when wood pieces are transported, mechanical processes such as impact with other pieces, clasts and boulders or living trees along the channel banks are responsible for breakage (Wohl, 2013). Sediment dynamics affect decay and breakage via abrasion, removing softened wood and progressively weakening pieces and decreasing their size (Harmon et al., 1986; Wohl, 2013).

Instream wood breakdown (in terms of decay and breakage) is influenced by external variables such as climate and riparian forest composition (some tree species are particularly susceptible to breakage or decay; Gurnell et al., 2002), making climate a first-order variable on wood decay in the channel or on the floodplain (Wohl, 2013). Therefore, decay is highly dependent on tree species, wood chemistry, piece size and stream environment (Harmon et al., 1986; Scherer, 2004; Naiman et al., 2002; Benda and Sias, 2003).

Larger pieces, which have a lower surface to volume ratio, may suffer slower microbial decomposition (Bisson et al., 1987; Spänhoff and Meyer, 2004). According to Merten et al. (2013) longer and thinner pieces are more likely to break. Although, as pointed out by Wohl (2013) long pieces (relative to channel width) with large diameter (relative to flow depth) tend to be most the resistant to decay, abrasion and breakage. Thick pieces are also resistant to breakage, as the diameter of pieces cannot be affected by breakage but by slower abrasion phenomena (Comiti et al., 2006). Shape of pieces such as the presence of branches or root wads, also plays an important role in breakage and decay. For example, the anchor of the root wad may hold in place the bottom end of the log while the thinner top end may be subject to breakage; or when a conifer tree falls into the channel, it tends to shatter and scatter its branches, producing cylindrical pieces, whereas a broadleaf tree may yield more complex wood pieces (Gurnell et al., 2002).

The position of LW pieces within the stream network may also influence breakage (Meleason et al., 2007). As observed in the Rhone River in France, wood is usually recruited in the mountain tributaries, characterized by steep slopes, high flow velocities and shallow water depths, which according to Moulin and Piégay (2004) contribute to physical breakage, as a result of abrasion of individual wood pieces and interactions during the simultaneous transport of sediment and wood within shallow water depths, explaining the absence of leaves and branches as well as the small lengths of wood pieces (Moulin and Piégay, 2004). The resulting smaller pieces are likely to be more easily transported, travelling longer distances and exposed to other breakdown processes during transport (Merten et al., 2013). Therefore quantifying and analyzing the relationship between log size, decay status and LW breakage would greatly contribute to understanding LW transfer along channel networks (Rigon et al., 2012). However, the importance of different processes depleting LW and particularly the quantification of LW breakage, are still not well understood (Hassan et al., 2005).

Wood breakdown has been measured in the form of small branches (Tank and Webster, 1998), or different types of sticks (Young et al., 2008; Aristi et al., 2012), however the breakdown of instream wood has been rarely measured in the form of entire logs (Merten et al., 2013) and even more exceptionally over long periods of time (>1 year). This work aims to fill that gap. We tested some of the above mentioned hypothesis regarding breakage and decay, asking the following questions: (i) how is LW breakage and decay influenced by tree type and size?; (ii) are LW piece location within the stream and LW piece orientation important variables in LW breakage and decay?; (iii) is breakage increased by the degree of decay or the time of residence?; (iv) are the stream characteristics (i.e. morphology and hydrodynamics) the most important drivers of breakage and decay?

To answer these questions we analyzed several years of LW measurements in three low-order mountain streams located in southern Chile. This database is built upon surveys using 1049 tagged LW (wood pieces at least 1 m in length, and at least 10 cm in diameter; Iroumé et al., 2014, 2015), and allowed us to address the key issues on wood depleting processes from stream channels. Our gathered data has been previously used to examine instream wood mobilization in detail (Iroumé et al., 2015) herein we have broadened this information and used new analyses to focus primarily on breakdown processes (i.e., breakage and decay). However, as the survey was not initially designed to analyze breakage and decay, we also address here some limitations and do recommendations for future studies.

## 2. Materials and methods

### 2.1. Study sites and channel surveys

We analyzed three channel segments of the Pichún, Tres Arroyos and Vuelta de Zorra catchments located in the eastern slopes of the Coastal mountain range, Malalcahuello–Nalcas Forest National Reserve in the Andes mountain range and in the Valdivian Coastal Reserve, respectively (Fig. 1 and Table 1).

They are low-order streams (level three in the Strahler's ordering system), with mean segment slopes of 0.1 $m{\cdot}m^{-1}$ for Pichún and Tres Arroyos and 0.04 $m{\cdot}m^{-1}$ for Vuelta de Zorra. The mean channel widths are ∼5 m in Pichún, ∼10 m in both Tres Arroyos and Vuelta de Zorra, while the bankfull depths are 0.8 m in Pichún, ∼1 m in Tres Arroyos and Vuelta de Zorra, respectively. The length of the study segments was 2188 m for Pichún, 2070 m for Tres Arroyos and 1557 m for Vuelta de Zorra. Table 1 summarizes the main geomorphic characteristics of the segments and the tagged wood pieces.

Forest cover is relatively high in the three sites, with 98, 70 and 99% (Pichún, Tres Arroyos and Vuelta de Zorra respectively) of the drainage areas covered by native forests and plantations of exotic tree species. Native forests in the three catchments are dominated by *Nothofagus* spp., and exotic are *Eucalytus* spp. in Vuelta de Zorra and *Eucalytus* spp. and *Pinus radiata* in Pichún.

Precipitation and discharge are monitored in all catchments with continuous digital recorders. Long term total annual precipitations are ∼1190 mm (Pichún), ∼2500 mm (Tres Arroyos) and ∼2300 mm (Vuelta de Zorra), respectively. The streams have pluvial regimes with maximum discharges occurring during the winter rainy months (May to August), with snowfall also influences the Tres Arroyos basin. Further descriptions of these sites can be found in Andreoli et al. (2007, 2008), Comiti et al. (2008), Iroumé et al. (2010, 2011, 2014, 2015) and Ulloa et al. (2011).

Along the three study streams, LW were tagged with numbered metal plates and measured in length and mid-diameter, using a measuring tape and a tree caliper, respectively. According to Iroumé et al. (2010), the measurements precision is 5 cm and 1 cm for length and diameter, respectively. The different surveys allowed to calculate breakage and decay as the reduction of length and diameter (see Section 2.2). Therefore, small errors might be recorded, especially regarding decay and the repeated