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Leaf-litter breakdown as an indicator of the impacts by flow regulation in headwater streams: Responses across climatic regions

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ABSTRACT

The aim of this study was to evaluate changes in leaf-litter breakdown rates due to flow regulation, through weirs and water diversions, in headwater mountain streams. In order to find common patterns and reveal singularities that might occur in different regions, we studied 17 streams located in 4 different climatic regions of the peninsular Spain (Cornisa Cantábrica, Cordillera Litoral Catalana, Sierra de Guadarrama, and Sierra Nevada). Regions showed a continentality gradient (assessed using the Gorczynski continentality index) from 7.7% (Cornisa Cantábrica) to 32% (Sierra Nevada). We hypothesized that stream regulation would impair habitat conditions and guilds associated with leaf litter breakdown, leading to a slowdown of litter breakdown rates. We further hypothesized that the extent to which breakdown rates changed downstream of fluvial regulation would depend on the combination of the nature and scale of the fluvial regulation and the environmental setting of each region. In all cases we found that leaf litter breakdown rates were lower downstream of the regulation. This change was most pronounced in the Sierra Nevada region, where the breakdown rate decreased by 50.7%, and least pronounced in the streams of Cornisa Cantábrica, where breakdown rates decreased by 20.8% downstream of regulation. In terms of the Gorczynski index, the extent to which fluvial regulation led to slow down litter breakdown decreased from continental to oceanic regions. Richness and sporulation rates of aquatic hyphomycetes did not show significant differences either between upstream and downstream sites, or between regions. In all regions we detected a consistent trend of lower abundance and biomass of shredders colonizing litter bags in sites downstream of flow regulation. Also, there were significant differences in the composition of macroinvertebrate communities between regions, which could be the cause of the differences in the leaf litter breakdown rates observed from one region to another. We conclude that changes of streamflow rates in headwaters slow down leaf litter breakdown rates downstream of the disturbance, but the magnitude of this slowdown is substantially influenced by the continentality of the region in which the stream is located. The differences in breakdown rates between upstream and downstream sites can be mainly ascribed to a reduction in shredder abundance in the latter, which is likely to be caused by altered in-stream habitat and riparian vegetation downstream of the point of flow regulation.

1. Introduction

Increasing levels of human activity are exacerbating pressures on water resources. Among these pressures, an ever increasing number of fluvial systems are subject to flow regulation through dam construction or stream water abstractions and diversions,

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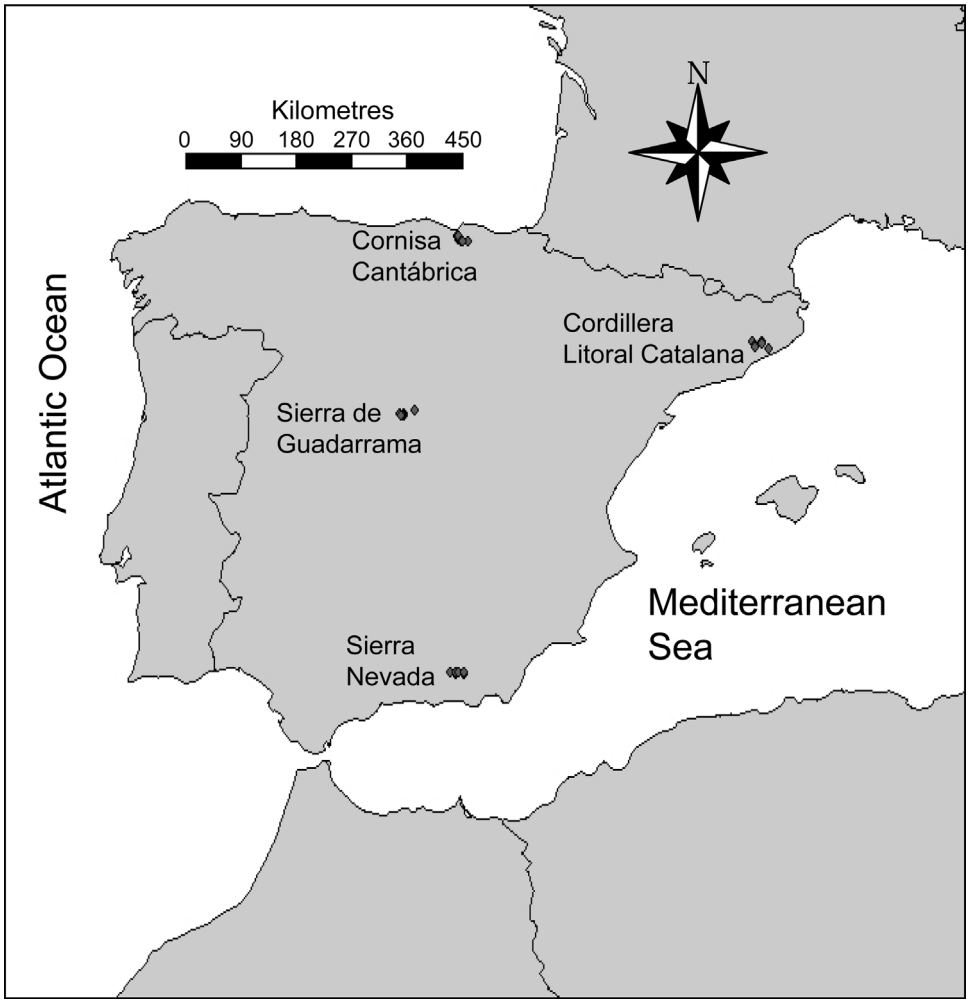

Fig. 1. Locations of the 4 geographical study regions in the peninsular Spain: Cornisa Cantábrica (CC), Cordillera Litoral Catalana (CLC), Sierra de Guadarrama (SG) and Sierra Nevada (SN).

with major impacts on the regime and magnitude of their discharge (Baron et al., 2002; Carlisle et al., 2011; Vörösmarty et al., 2010). The consequences of regulation on fluvial ecosystems have been amply studied from different perspectives, such as benthic communities (Casado et al., 1989; Pozo et al., 1997; Ogbeibu and Oribhabor, 2002; Rehn, 2008), flow regimes (Robinson et al., 2004; Magilligan and Nislow, 2005), the physical structure of the channel (Magilligan et al., 2008) or the chemical composition of water (Camargo et al., 2005) and changes in the sedimentary transport and river bed (Pitlick and Wilcock, 2001; Dade et al., 2011). Dams and water diversions alter the river flow regime, in-stream habitat availability and the energy sources to the communities, decreasing leaf litter inputs, but increasing fine detritus (Poff et al., 1997; Bunn and Arthington, 2002).

Most earlier investigations have focused on the impact of large dams on rivers of intermediate orders, but fewer studies have been concerned with effects of flow regulation on small headwater streams (Casas et al., 2000; Camargo et al., 2005; Dewson et al., 2007; Death et al., 2009), despite the fact that they constitute the highest percentage of all river reaches (Downing et al., 2012), and maintain exceptional biodiversity (e.g. Clarke et al., 2008; Finn et al., 2011) at the fluvial network scale.

Headwater streams flowing through forested catchments receive great amounts of particulate organic matter from the riparian environment with important consequences for aquatic food webs (e.g. Wallace et al., 1999, 2015) through leaf litter breakdown, a key process in these ecosystems (Fisher and Likens, 1973; Webster and Benfield, 1986). Leaf litter breakdown in streams has been shown to be sensitive to a variety of anthropogenic impacts, and is thus an important area to consider in addition to the more widely studied structural indicators of change (Simon et al., 2009; Woodward et al., 2012). Leaf litter breakdown may be affected by a wide range of factors such as water temperature and velocity, nutrient and dissolved oxygen concentrations, or sedimentation (Webster and Benfield, 1986; Royer and Minshall, 2003). Since damming and water withdrawal may potentially affect all these variables, changes in leaf litter breakdown rates are also to be expected. Nevertheless, the high number of intervening factors and their interaction with regional and local environmental conditions, coupled with idiosyncrasies of the regulation mechanisms, can add complexity to the process, making it difficult to predict how litter breakdown will respond to regulation in different environmental settings. Indeed, the relative importance of the factors involved in leaf litter breakdown may differ between locations or geographical areas, and this may be an important influence on the magnitude and the direction of the effect of regulation on breakdown rates. Thus, some studies (Casas et al., 2000; Dewson et al., 2007; Death et al., 2009) did not find clear effects of flow regulation on litter breakdown, while others (e.g. Nelson and Roline, 2000) reported faster litter breakdown upstream than downstream of regulated sites.