Forest Ecology and Management 310 (2013) 147–155

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Effects of pine plantations on structural and functional attributes of forested streams

Aingeru Martínez [a,*], Aitor Larrañaga [a], Javier Pérez [a], Enrique Descals [b], Ana Basaguren [a], Jesús Pozo [a]

[a] Laboratory of Stream Ecology, Department of Plant Biology and Ecology, University of the Basque Country, UPV/EHU, P.O. Box 644, 48080 Bilbao, Spain
[b] Instituto Mediterráneo de Estudios Avanzados, IMEDEA (CSIC), Miquel Marquès 21, 07190 Esporles (Mallorca), Spain

ARTICLE INFO

Article history:
Received 28 May 2013
Received in revised form 5 August 2013
Accepted 13 August 2013

Keywords:
Alnus glutinosa
Fungal colonization
Decomposition
Macroinvertebrates
Pinus radiata

ABSTRACT

In low-order forested streams, watershed-scale land-use modifications, such as the replacement of native vegetation by conifer monocultures, can affect energy inputs into streams and trophic interactions within these donor-controlled food webs. We examined the effects of *Pinus radiata* plantations on structural (benthic macroinvertebrate communities) and functional (alder and pine leaf-litter breakdown) attributes of headwater streams. We compared three streams draining pine plantations with three draining natural deciduous forests. We found differences in the structure of benthic macroinvertebrate communities, namely lower densities of shredders in streams flowing through pine plantations. Breakdown rates of alder leaves was a 20% lower in streams draining pine plantations, and breakdown of pine needles, a much lower quality material, was slower than that of alder and did not differ between stream types. Although fungal activity was similar in all streams, lower detritivore densities under pine plantations could explain the lower rate of alder breakdown in these environments. The present study points out that pine monocultures alter the structure of benthic macroinvertebrate communities and reduce detritus processing capacity of streams. However, these effects were weaker than expected due to the presence of deciduous riparian forest in pine streams.

1. Introduction

Natural terrestrial ecosystems are altered by human activities encompassing broad-scale land-use changes related to natural resource acquisition (forestry, agriculture and mining) or urban and industrial development (settlements and transport infrastructures). These alterations can have ecological impacts on running waters (Zhang et al., 2009; Magbanua et al., 2010). In low-order forested streams, in which food-webs are based on detrital inputs from surrounding forest (Wallace et al., 1997), modifications in watershed vegetation can alter the quantity, quality and seasonality of leaf-litter inputs (Abelho and Graça, 1996; Pozo et al., 1997; Molinero and Pozo, 2004). The variation in detritus quality may influence decomposer colonisation and activity (Bärlocher and Oertli, 1978; Dang et al., 2007; Kearns and Bärlocher, 2008) and the feeding rates, growth, densities and survival of detritivores (Graça, 2001; Albariño and Balseiro, 2002; Campos and González, 2009; Larrañaga et al., 2009). As a consequence, important ecosystem processes, such as leaf-litter decomposition, can be affected (Lecerf et al., 2005; Lecerf and Richardson, 2010). Replacement of native vegetation by conifer monocultures of exotic species with very different traits is a widespread forestry practice in biomes where broadleaved forests dominate naturally. Compared with the major species of broadleaves, conifer litter is considered a poor quality food resource for microbial decomposers and invertebrate detritivores due to its toughness, low nitrogen concentration and elevated levels of lignin and polyphenols (Sedell et al., 1975; Bärlocher and Oertli, 1978; Quinn et al., 2000a,b; Girisha et al., 2003). Therefore, dissimilarities have been reported in the structure of biotic communities between streams under native broadleaved forests and those flowing through exotic conifer monocultures (e.g. Harding and Winterbourn, 1995; Friberg, 1997; Laitung et al., 2002; Yoshimura, 2007). However, these structural shifts and their consequences on a key functional process such as leaf litter decomposition have shown contradictory results: both an enhancement (Whiles and Wallace, 1997) and a slowness (Riipinen et al., 2010) of breakdown rates in streams under pine monocultures have been reported, revealing the need for further studies to gain a deeper understanding of the perturbations created by these plantations.

The present study was carried out in the province of Biscay (Atlantic region of northern Spain), where the replacements of deciduous forests (mainly dominated by *Quercus* sp. and *Fagus sylvatica* L.) by *Pinus radiata* D. Don monocultures comprise the 62% of forested surface. Our goal was to determine the effects of *P. radiata* plantations on structural attributes (structure of benthic

* Corresponding author. Tel.: +34 946015939; fax: +34 946013500.
E-mail address: aingeru.martinez@ehu.es (A. Martínez).

0378-1127/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2013.08.024

macroinvertebrate communities) and functioning (as measured by *Alnus glutinosa* (L.) Gaertner leaves and *P. radiata* needles breakdown) of low-order forested streams. We hypothesized that streams flowing through exotic pine plantations, (1) would show altered decomposer and detritivore communities due to the impoverishment of the detrital resources and (2) as a consequence, leaf litter breakdown rates would be lower than in nearby streams under deciduous riparian forest.

2. Materials and methods

2.1. Study sites

This study was conducted in six low-order (2–3) streams distancing less than 40 km with siliceous substrate flowing into the Atlantic Ocean (Cordillera Cantábrica, Northern Spain). In this region, the climate is temperate with an average annual air temperature of around 14 °C and a mean annual precipitation of 1200 mm, without droughts in summer. Three of the streams drain native deciduous forests (deciduous sites, D), oak, *Quercus robur* L., and beech, *F. sylvatica*, being the dominant tree species. The other three streams drain mature (>20 years of age) *P. radiata* plantations (pine sites, P) that occupy patches that naturally will be covered with oak and beech. Anthropogenic impacts in the basins, apart from the pine plantations, are negligible (Table 1). Although in total we visited 29 streams before the study, only these six were chosen due to their similarities in size, geological substrate and water physicochemistry. We sacrificed statistical power by reducing the number of sites included in the work in an attempt to isolate the effects of land use changes by pine plantations from other confounding factors. For these six streams the riparian forest and streambed substrate were described in a 50 m-long reach. Riparian tree species were identified and densities estimated in five 10 m^2 areas along both stream margins (100 m^2 in total). Streams under pine plantations presented a narrow strip of riparian forest composed by native deciduous trees (mainly *A. glutinosa*) with some scattered pines (mean tree density of 0.46 trees m^{-2}), which abruptly becomes a densely planted pine monoculture further from the stream. The relatively long harvesting cycle of pine in the area (30–35 years) allows the development of a riparian native forest strip as other studies show (Brockerhoff et al., 2003; Langer et al., 2008). Catchments dominated by pine plantations did not reveal recent clear-cuttings or other works done by heavy machinery. At deciduous sites, there was a mean density of 0.34 native trees m^{-2} (mainly *A. glutinosa*) in their riparian forest (Table 1). The granulometric composition of the streambed was estimated visually and three categories incorporating Wentworth grain size classes (Wentworth, 1922) were used: percentage of 'boulders' (>256 mm), 'cobbles' (64–256 mm) and 'gravel-sand' (<64 mm) (Table 1).

2.2. Water quality

Water parameters were monitored during the study period at each site (November 2009–April 2010). Water temperature was continuously measured (every hour) using SmartButton temperature data loggers (ACR Systems Inc., Surrey, BC, Canada). Every site was visited 8–9 times and conductivity, pH, dissolved oxygen (WTW multiparametric sensor) and river flow (Martin Marten Z30, Current Meter) were measured. Water samples (1 l) were collected and filtered in the laboratory (preweighed 0.7 μm pore size glass fibre filters, Whatman GF/F) on each occasion. An aliquot of the filtered water was used to determine alkalinity by titration to an end pH of 4.5 (APHA, 2005) and the remainder was stored (−20 °C) for later analyses. The filters were oven-dried (70 °C, 72 h), ashed (500 °C, 12 h) and weighed to obtain fine particulate matter (FPM) and fine particulate inorganic matter (FPIM). Fine particulate organic matter (FPOM) was estimated by the difference between the two weights. Nutrient analyses of the water were conducted using capillary ion electrophoresis for nitrate (Agilent CE), the manual salicylate method for ammonium, the sulphanilamide method for nitrite and the molybdate method for soluble reactive phosphorus (SRP) (APHA, 2005).

2.3. Structural attributes: benthic standing stock and macroinvertebrate communities

In January 2010, five benthic samples (Surber 0.09 m^2, 0.5 mm mesh size) were taken from randomly chosen riffles at each study site. Very coarse particulate organic matter was separated from macroinvertebrates on an 8-mm sieve. This sieve enabled *in situ* separation of the fauna from the organic matter in the same sample for use in consumer-resource correlations (Martínez et al., 2013). The rest of the sample was preserved in 70% ethanol. The

Table 1
Location and characterization of catchment area of studied streams.

	D1	D2	D3	P1	P2	P3
Latitude	43°12′ 32″N	42°59′ 48″N	42°59′59″N	43°05′39″N	43°56′49″N	43°05′57″N
Longitude	3°16′3″W	2°52′47″W	2°53′00″W	2°53′54″W	2°59′49″W	2°55′15″W
Basin (Ha)	225	361	357	137	220	404
Altitude (m)	315	420	400	251	190	225
Reach slope (%)	20.5	14.2	13.3	19.1	16.0	12.0
Width (m)	3.52	3.27	3.73	3.23	3.63	4.52
Land use (%)						
Native vegetation	99.7	97.4	97.8	3.4	3.2	33.0
P. radiata plantations	0.3	2.6	2.2	88.1	96.3	65.3
Other plantations	0.0	0.0	0.0	4.2	0.0	0.0
Farming	0.0	0.0	0.0	4.3	0.5	1.7
Tree canopy cover (%)	42.2	50.5	55.05	45.5	62.8	48.5
Riparian forest						
Tree density (No. ind. m^{-2})	0.61	0.23	0.18	0.43	0.33	0.64
Tree richness	5	6	2	6	5	6
% pine	0	0	0	7	27	2
Granulometric composition (%)						
>25 cm	85.8	66.5	55	78.3	49.3	86.7
6–25 cm	10.8	12.7	13.4	15.3	20.8	9.2
<5 cm	3.4	20.8	31.6	6.4	29.9	4.1