Limnologica 53 (2015) 17–25

Contents lists available at ScienceDirect

Limnologica

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

Stream macroinvertebrate communities change with grassland afforestation in central Argentina

J.A. Márquez[a,c,*], L. Cibils[a,c], R.E. Principe[a,c], R.J. Albariño[b,c]

[a] Departamento de Ciencias Naturales, Universidad Nacional de Río Cuarto (UNRC), Córdoba, Argentina
[b] Laboratorio de Fotobiología, INIBIOMA, CONICET – Universidad Nacional del Comahue, Bariloche, Argentina
[c] CONICET, Argentina

ARTICLE INFO

Article history:
Received 29 December 2014
Received in revised form 14 May 2015
Accepted 18 May 2015
Available online 23 May 2015

Keywords:
Pinus elliottii
Headwater streams
Benthos
Córdoba mountains
Functional feeding groups

ABSTRACT

Lotic ecosystems are highly affected by land use changes such as afforestation of natural areas for management or commercial purposes. The aim of this study was to analyze the effect of pine plantations on benthic invertebrate communities in mountain grassland streams. Additionally, we assessed if the hydrological period modifies the effect of afforestation on stream invertebrates. Three headwater streams draining grasslands (reference streams) and three draining plantations of *Pinus elliottii* were selected in a mountain watershed of Córdoba province (Argentina). Hydrologic and physicochemical variables were registered and benthic invertebrate samples were collected in each stream at two different hydrological periods. Total invertebrate abundance, richness and diversity were reduced in afforested streams as well as the number of indicator taxa. In addition, invertebrate functional structure (i.e. taxonomic richness and total and relative abundance of functional feeding groups, FFG) showed differences between streams with different riparian vegetation and between hydrological periods. Total abundance of all FFGs was lower in afforested streams and scrapers' relative abundance was higher in grassland streams at the low water period. In addition, in most FFGs richness was diminished in afforested streams. Changes in light intensity, hydrology and coarse organic matter inputs produced by afforestation alter fluvial habitats and consequently the composition and trophic structure of invertebrate communities in grassland streams of Córdoba mountains.

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) (Foley et al., 2005). These alterations can have strong and long lasting ecological impacts on fluvial systems (Allan and Flecker, 1993; Fausch et al., 2010). Low-order open streams are characterized by communities based on the availability of sunlight establishing "green" food webs (i.e. primary producers-based) (Delong and Brusven, 1998; Thompson and Townsend, 2004a). Modifications in watershed vegetation and, most directly, in riparian areas can alter the quantity, quality and seasonality of external resource inputs into streams (e.g. altering sunlight regimes, allochthonous organic matter dynamics) (Naiman et al., 2005) as well as affecting the regime of environmental stressors (e.g. sediment inputs and loading, temperature and chemistry concentrations). Those changes may have strong effects on the feeding rates, growth, densities and survival of aquatic populations resulting in changes in their communities both in taxonomic and functional attributes (Sponseller et al., 2001; Thompson and Townsend, 2004a; Richardson, 2008).

In recent centuries, reafforestation and afforestation have become common practices to recover or convert new lands to timber production or to reduce erosion. These forestry practices result in significant landscape alterations, impacting the catchments that drain plantations (van Dijk and Keenan, 2007). In particular, the replacement of natural grassland with pines alters sunlight regimes and organic matter dynamics. Perennial tree species shade lotic systems throughout the year and also cause an increase in the income of coarse particulate organic matter (CPOM), mainly leaves, branches and trunks in the streams (Giller and O'Halloran, 2004). The pine needles have a very low decaying rate (Webster and Benfield, 1986) due to their thick cuticle and the presence of resins that can function as inhibitory substances for decomposers and detritivores (Bärlocher and Oertli, 1978a, 1978b). Thereby, pine needles and trunks accumulate and create natural dams

* Corresponding author at: Universidad Nacional de Río Cuarto (UNRC), Departamento de Ciencias Naturales, Córdoba, Argentina. Tel.: +54 3584676426..
E-mail address: javier.marquez.zoologia@gmail.com (J.A. Márquez).

http://dx.doi.org/10.1016/j.limno.2015.05.002
0075-9511/

which modify fluvial habitats (Hilderbrand et al., 1997; Collier and Halliday, 2000).

Catchment afforestation with species that have contrasting ecological characteristics compared to those commonly found in their hosting environment may also have strong effects on water yield. Large leaf biomass and the high growth rate of the conifers may increase evapotranspiration by two ways, a greater evaporative capacity of the canopy by interception and a better access to soil water (Jobbágy et al., 2006). Direct changes in hydrology have already been acknowledged with detrimental effects of exotic plantations (pines) replacing native temperate forests in the water yield of large catchments in Chile (Little et al., 2009). Similarly, Farley et al. (2005) found that tree plantation in grasslands and shrublands reduced up to 40% and 75% (pines and eucalyptus, respectively) of the annual water discharge. These studies pointed out that the effects were proportionally stronger in low flow periods, raising concern on the environmental costs that afforestations face while delivering their better known benefits of wood, runoff regulation, erosion control, and carbon sequestration. In this way, afforestation provides new productive opportunities but it may also alter essential services that ecosystems provide such as water supply or watershed hydrological regulation (Jobbágy et al., 2006; Little and Lara, 2010).

The evaluation of forestry impacts is essential for the implementation of management strategies and the conservation of water resources and biota in headwater streams. The use of benthic invertebrate communities as an indicator of land use effects in a catchment as well of direct perturbation in the aquatic environment is widespread in many regions of the world (Roy et al., 2003; Gabriels et al., 2010; Dos Santos et al., 2011; Ansah et al., 2012). Aquatic macroinvertebrates have proven to be an efficient diagnostic tool in monitoring water quality and ecological integrity of river systems (Rosenberg and Resh, 1993; Bonada et al., 2006) because they integrate anthropogenic impacts across different spatial and temporal scales.

In the seventies, Argentine's federal laws promoted afforestation with introduced fast-growing species (primarily pines, eucalyptus and Salicaceae) in vast regions originally occupied by grasslands (Jobbágy et al., 2006). For instance, large extensions of semi-arid grasslands in mountainous landscapes in central Argentina were afforested with pines, which were also planted into riparian areas, with potential negative effects on the structure and functioning of watercourses. Several studies have reported that in catchments dominated by deciduous forests or gramineous vegetation, pine plantations alter both composition of aquatic invertebrate assemblages and organic matter dynamics (Death et al., 2003; Thompson and Townsend, 2004a; Richardson, 2008; Miserendino and Masi, 2010). Although the conversion of grasslands to implanted forest of exotic pines should produce strong environmental changes in aquatic systems, (e.g. altering sunlight regime, moderating temperature and increasing the amount of organic matter inputs) affecting the quantity and quality of resources, the response of stream invertebrate communities remains unstudied.

Considering that benthic invertebrates in mountain streams of Córdoba province (central Argentina) are adapted to a broad spectrum of spatio-temporal environmental gradients (Corigliano, 1998; Principe et al., 2007), afforestation of grassland catchments may produce varied responses in benthic communities. Changes in both resources and environmental variables might lead to a lower diversity in afforested streams, with the disappearance of sensitive species and the increased abundance of tolerant species. In relation to functional groups, the abundance of shredders may increase in afforested streams due to the large inputs of riparian coarse particulate organic matter. However it has been observed that shredders are not abundant in these mountain streams (Principe et al., 2010). Moreover, changes in light intensity entering the stream may affect algal abundance and production. In that way, scrapers are expected to decrease in afforested environments. Oppositely, if invertebrates in grassland streams are generalists, periphyton and allochthonous organic matter could be used alternatively as a food resource with little changes in invertebrate communities at both taxonomic and functional levels.

The abiotic environment set the main stage for evolutionary development of specific traits and associated life-history strategies in ecosystems (Lytle and Poff, 2004). Water current exerts a drag force on individual organisms and, due to episodic fluctuations and substrate dislodgement, can be a powerful disturbance force as well. However, current benefits the biota through mass transfer processes and transporting food resources to animals. In that way, community structure is highly determined by flow conditions (Biggs et al., 2005). Water temperature, which determines species distribution, also affects community structure. Stream temperature is expected to be moderate during summer months under shading of implanted pines which may either alleviate physiological stress of sensitive species imposed to high temperatures occurring in grassland streams or may delay invertebrate feeding and growth or both with consequences for species fitness (Huryn et al., 2008).

Our aim was to analyze the effect of grassland replacement by pine plantations on benthic invertebrate communities in mountain grassland streams. Our study region is characterized hydrologically by two contrasting periods, a rainy season occurring between spring and late summer (Austral region) when stream flows and occasional spates are high and a dry season with low stream flow between autumn and winter. Recently, Jobbágy et al. (2013) demonstrated a 50% reduction in the annual water yield in those afforested catchments compared to their paired grassland ones occurring during the rainy season in coincidence with seasonal tree growth. Water temperature is also higher during spring-summer, potentially resulting in higher differences in stream thermal regimes than in autumn-winter. Considering that higher environmental differences are expected during the rainy season, we hypothesize that the direction and magnitude of changes in invertebrate community structure are to be emphasized between afforested and grassland streams compared to the dry season.

Materials and methods

Study area

The study was carried out in streams of the Ctalamochita river upper basin, Córdoba, Argentina (Fig. 1). This river is one of the main tributaries of the Carcaraña river and belongs to La Plata river basin. Headwaters of the Ctalamochita river are located in grasslands of the Comechingones mountains between 800 and 1500 m a.s.l. The lithology is dominated by granitic rocks but localized patches of metamorphic rocks (gneiss, schist, migmatite) can also be found. Annual precipitation in the region reaches 725 mm occurring mostly between spring and the end of summer (Austral region: October–March) (Cabido et al., 2003) determining a relatively dry mountainous landscape. Maximum air temperature reaches 34 °C in summer (December–March) and decreases up to −5 °C in winter (June–September). Grasslands are dominated by *Festuca hieronymi*, *Nassella filiculmis*, *Schizachyrium condensatum* and *Eragrostis airoides* (Oggero and Arana, 2012). They are primarily used for cattle and sheep grazing and other human activities like extraction of medicinal and aromatic herbs and fauna that contribute to landscape modification (Cabido et al., 2003).

Most afforested areas in the region were established in the late 1970s as a result of a tax deferral plan implemented by the Córdoba government. Currently, 36,000 ha of the Sierras de los