Science of the Total Environment 503-504 (2015) 251–257

Contents lists available at ScienceDirect

Science of the Total Environment

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

Effects of flow scarcity on leaf-litter processing under oceanic climate conditions in calcareous streams

Aingeru Martínez *, Javier Pérez, Jon Molinero, Mikel Sagarduy, Jesús Pozo

Laboratory of Stream Ecology, Department of Plant Biology and Ecology, University of the Basque Country, P.O. Box 644, 48080 Bilbao, Spain

HIGHLIGHTS

- The effects of droughts on litter decomposition in temperate streams were assessed.
- The contribution of decomposers and detritivores was studied.
- Detritivore activity is more affected than microbial decomposition by droughts.
- Water properties condition the effects of droughts on macroinvertebrate behavior.

ARTICLE INFO

Article history:
Received 11 April 2014
Received in revised form 20 May 2014
Accepted 6 June 2014
Available online 22 June 2014

Keywords:
Chalk basins
Droughts
Atlantic climate
Alder decomposition
Microbial decomposers
Macroinvertebrates

ABSTRACT

Although temporary streams represent a high proportion of the total number and length of running waters, historically the study of intermittent streams has received less attention than that of perennial ones. The goal of the present study was to assess the effects of flow cessation on litter decomposition in calcareous streams under oceanic climate conditions. For this, leaf litter of alder was incubated in four streams (S1, S2, S3 and S4) with different flow regimes (S3 and S4 with zero-flow periods) from northern Spain. To distinguish the relative importance and contribution of decomposers and detritivores, fine- and coarse-mesh litter bags were used. We determined processing rates, leaf-C, -N and -P concentrations, invertebrate colonization in coarse bags and benthic invertebrates. Decomposition rates in fine bags were similar among streams. In coarse bags, only one of the intermittent streams, S4, showed a lower rate than that in the other ones as a consequence of lower invertebrate colonization. The material incubated in fine bags presented higher leaf-N and -P concentrations than those in the coarse ones, except in S4, pointing out that the decomposition in this stream was driven mainly by microorganisms. Benthic macroinvertebrate and shredder density and biomass were lower in intermittent streams than those in perennial ones. However, the bags in S3 presented a greater amount of total macroinvertebrates and shredders comparing with the benthos. The most suitable explanation is that the fauna find a food substrate in bags less affected by calcite precipitation, which is common in the streambed at this site. Decomposition rate in coarse bags was positively related to associated shredder biomass. Thus, droughts in streams under oceanic climate conditions affect mainly the macroinvertebrate detritivore activity, although macroinvertebrates may show distinct behavior imposed by the physicochemical properties of water, mainly travertine precipitation, which can override the flow intermittence effects.

1. Introduction

Temporary rivers and streams represent a high proportion of the total number, length and discharge of running waters around the world (Larned et al., 2010; Acuña et al., 2014). Nevertheless, in spite of their numerical importance, historically the study of intermittent streams has received less attention than that of perennial ones (Datry et al., 2011a). Drought events can be imposed by natural and anthropogenic factors, such as climatic conditions, lithological features of watersheds (e.g. karstic geology) or damming and water withdrawals. Nowadays, related with predictions of global climate change on temperature and rainfall dynamics (IPCC, 2013), the number of ecological studies on temporary streams is growing exponentially (Datry et al., 2011a), specially in semi-arid and Mediterranean regions (e.g., Muñoz, 2003; Bonada et al., 2006; Álvarez and Pardo, 2009; Sponseller et al., 2010), which suffer a drought period during summer. Moreover, these works are mainly focused on biotic communities and structural attributes, but the consequences of desiccation on ecosystem processes are still poorly studied.

A key process in the functioning of low-order forest streams is leaf litter decomposition, since detritus inputs from surrounding vegetation

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

http://dx.doi.org/10.1016/j.scitotenv.2014.06.018

constitutes the main source of matter and energy in these systems (Wallace et al., 1997). Leaf litter decomposition is influenced by a series of environmental factors such as temperature (Ferreira and Chauvet, 2011; Martínez et al., 2014), catchment land use (Lecerf and Richardson, 2010; Martínez et al., 2013a), dissolved nutrients (Greenwood et al., 2007; Pérez et al., 2012), pH (Larrañaga et al., 2010; Dangles et al., 2004) or oxygen saturation (Medeiros et al., 2009). One of the main drivers of this process in streams is flow regime, leaf processing being consistently lower in temporary streams than in perennial systems due to the lack of aquatic detritivores as well in semi-arid regions (Herbst and Reice, 1982; Boulton, 1991; Maamri et al., 1997; Pinna and Basset, 2004) as under oceanic climate conditions (Langhans and Tockner, 2006; Datry et al., 2011b; Schlief and Mutz, 2011). However, the effects of droughts on microbial activity vary between regions, being less severe under oceanic conditions since the humid weather during winter can maintain substrates moist enough for microbial development (Langhans and Tockner, 2006).

Despite regular and abundant rainfalls, in oceanic climate regions, natural intermittent streams are often found in calcareous areas, even during fall-winter, the rainiest period. Chalk streams are especially susceptible to prolonged drought (Berrie, 1992) due to the porosity of calcareous substratum. Waters of calcareous streams present high concentrations of $CaCO_3$. In fact, in some calcareous streams a travertine precipitation may occur resulting in a layer that covers the stream bottom and the standing substrates. This feature influences litter decomposition, enhancing the process when the travertine deposition is not continuous (Carter and Marks, 2007; Miliša et al., 2010) or slowing down when a compact and continuous layer happens (Casas and Gessner, 1999). In this kind of systems the effects of droughts have been studied, but mainly focused on structural attributes as fauna (Agnew et al., 2000; Boulton, 2003), lacking information about the effects on a functional attribute as leaf litter decomposition.

Thus, our main objective was to assess the effects of flow cessation on litter decomposition under oceanic climate conditions in calcareous streams. For this, leaf litter of alder (*Alnus glutinosa* L. Gartner), a common and autochthonous tree species in riparian forests of oceanic climate regions in Europe, was incubated in four calcareous streams with different flow regimes. The relative importance and contribution of decomposers and detritivores to litter processing as a function of flow scarcity were evaluated. We hypothesize that 1) drought events negatively affect leaf litter decomposition and 2) the effects of droughts are more pronounced on the process mediated by detritivores than that of mediated by microorganisms.

2. Materials and methods

2.1. Study site

The study was carried out in four calcareous streams (S1, S2, S3 and S4) with different flow regimes in the headwater of the Nervión River catchment (Basque Country, north Spain). One of the streams (S3) presented a continuous travertine layer covering the bottom. The climate is oceanic with an average annual air temperature of around 14 °C and a mean annual precipitation around 1000–1200 mm. The four streams drain catchments of more than one hundred hectares (Table 1), a usual threshold for a permanent discharge regime in this region for siliceous streams (among the so many streams studied by us in the region for the last two decades, only the work by Otermin et al. (2002) has shown flow cessation in a stream which catchment was 83 ha). However, in the present study in calcareous streams, the observed differences in water flow stability are not directly related with the size of the catchment area, but probably the geologic substrate and its distribution in the basin. All catchments are covered mainly by natural vegetation dominated by forests of Portuguese oak *Quercus faginea* Lam.

2.2. Stream discharge and drought characterization

During the study period (24 November 2011–24 April 2012), we measured stream discharge biweekly to monthly (Martin Marten Z30, Current-meter) and recorded qualitative information about the flow condition (running water, disconnected pools, dry channel) to assess conditions of drought. Additionally, we collected stream discharge data at 10-minute intervals from a gauging station (www.bizkaia.net) located 7–10 km downstream in the main course of the same catchment (43° 2′ 4″N, 2° 59′ 59″ W), from 1 September 2011 to 30 April 2012.

Table 1
Location, reach characterization and water physicochemical characteristics of the studied streams (mean ± SE; n = 6–10). For water temperature, daily mean values and their range are shown (n = 121–154). Days of flow cessation represent the days with absence of superficial flow from 1 September 2011 to 30 April 2012.

	S1	S2	S3	S4
Latitude	42° 58′ 30″ N	43° 1′ 45″ N	42° 59′ 11″ N	43° 0′ 44″ N
Longitude	3° 1′ 43″ W	3° 5′ 22″ W	2° 58′ 13″ W	3° 3′ 58″ W
Basin (km^2)	3.11	3.54	1.54	4.07
Altitude (m a.s.l)	390	520	400	570
Width (m)	5.2 ± 0.6	3.9 ± 1.5	1.40 ± 0.3	4.0 ± 1.6
Land cover (%)				
Rocky area	12.1	24.0	2.4	13.5
Native vegetation	53.6	58.8	86.1	67.3
Forest plantations	11.6	0.0	1.4	0.0
Pasture	22.7	17.2	3.4	19.2
Other	0.0	0.0	6.7	0.0
Flow ($L\ s^{-1}$)	123.2 ± 70.2	49.4 ± 20.9	8.5 ± 3.0	34.8 ± 16.2
Flow cessation (days)	0	0	74	129
Water temperature (°C)	9.10	6.73	8.00	6.80
	(6.45–15.02)	(2.41–11.00)	(5.81–10.17)	(3.17–10.65)
% O_2 saturation	100.3 ± 1.2	100.7 ± 1.5	103.5 ± 3.2	108.0 ± 3.6
Conductivity (μS/cm)	353.6 ± 12.9	289.0 ± 26.2	450.1 ± 34.0	290.0 ± 19.5
Alkalinity (meq L^{-1})	2.97 ± 0.10	2.61 ± 0.21	3.75 ± 0.24	2.68 ± 0.19
pH	8.07 ± 0.11	8.35 ± 0.16	8.17 ± 0.18	8.53 ± 0.14
Chloride (mg Cl L^{-1})	10.43 ± 0.97	5.13 ± 1.15	19.08 ± 1.07	5.63 ± 0.82
Sulfate (mg S L^{-1})	3.18 ± 0.32	1.98 ± 0.22	5.21 ± 0.22	1.91 ± 0.40
Calcium (mg Ca L^{-1})	39.4 ± 1.6	31.8 ± 1.7	47.5 ± 1.8	33.9 ± 1.7
Sodium (mg Na L^{-1})	6.20 ± 0.71	3.05 ± 0.20	12.25 ± 0.44	3.16 ± 0.44
SRP (μg P L^{-1})	12.00 ± 3.53	11.68 ± 2.46	10.98 ± 1.98	11.23 ± 5.83
Nitrate (μg N L^{-1})	918.7 ± 76.0	438.2 ± 47.3	139.5 ± 13.8	688.2 ± 142.0
Nitrite (μg N L^{-1})	1.95 ± 0.30	1.94 ± 0.30	1.94 ± 0.32	1.93 ± 0.41
Ammonium (μg N L^{-1})	44.7 ± 2.5	42.9 ± 1.9	40.5 ± 4.0	44.3 ± 2.3