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Longitudinal and temporal patterns of benthic coarse particulate organic matter in the Agüera stream (northern Spain)

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ABSTRACT

Benthic coarse particulate organic matter (CPOM) was studied between November 92 and December 93 at four sites along the longitudinal gradient of the Agüera stream system (Northern Spain). CPOM was sorted in four main categories: leaves (several species), fruits and seeds, twigs and debris. Headwater site showed higher densities of total CPOM, leaves and twigs than downstream reaches, but no regular longitudinal pattern of change was noticed. The ranges of mean CPOM standing stock at the sampling sites were 20.5–74.1 g AFDW m^{-2} (site B), 9.9–47.7 g AFDW m^{-2} (site 5), 4.3–21.4 g AFDW m^{-2} (site 7) and 9.8–37.9 g AFDW m^{-2} (site 9). The particulate matter at downstream sites was in a more advanced stage of breakdown probably as a result of processing and transport from upstream reaches. Leaves species composition of benthic CPOM clearly reflected the type of riparian vegetation at each site. The timing of inputs and the hydrologic regime appeared to act together influencing temporal dynamics of benthic CPOM. A gradual temporal change in species composition of benthic leaf litter was observed under natural mature deciduous forest: first alder, later chestnut and finally oak.

1. Introduction

Small streams draining forested catchments receive important amounts of particulate organic material from the surrounding terrestrial environment (e.g. Cummins et al., 1983; Minshall et al., 1983; Conners and Naiman, 1984). This organic matter, mostly leaf litter, constitutes the main food and energy source for the stream biota (Fisher and Likens, 1973). The retention of particulate material in channels depends on many factors such as the hydrologic regime (e.g. Webster et al., 1987), bed geomorphology (e.g. Jones and Smock, 1991), particle size (e.g. Ehrman and Lamberti, 1992), growth of macrophytes (e.g. Angradi, 1991), presence of debris dams (e.g. Bilby and Likens, 1980), vegetation canopy (e.g. Cummins et al., 1989),

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type of riparian vegetation (e.g. Gurtz et al., 1988), among others. Several studies (e.g. Speaker et al., 1984; Prochazka et al., 1991; Snaddon et al., 1992; Webster et al., 1994) have shown that CPOM is retained, and it can be processed at a short distance from the input point. In fact, these works reveal that, in retention experiments, 200 meters are usually enough to retain a high percentage of released leaves.

Modification of land uses in a catchment by human activities (grassland, wood cutting, planations of exotic species) can alter directly the distribution and availability of coarse particulate organic matter in the channel at different temporal and spatial scales. In recent years, many papers have assessed the changes both in quantity and quality of materials caused by these disturbances (e.g. Golladay et al., 1989; Webster et al., 1990; Bilby and Bisson, 1992; Delong and Brusven, 1993).

The rivers of the Basque Country (Northern Spain) are potential forested running waters but the agricultural and forestry practices have strongly modified their basins. Because of this, inputs, density and outputs of organic matter in streams have been altered and therefore instream functioning. The Agüera stream, however, is an example where mature deciduous forests still remain in headwaters, downstream reaches being surrounded mainly by crops, meadows and forestry planations of *Pinus radiata* and *Eucalyptus globulus*.

Bearing in mind these types of disturbances, the aims of the present study were: 1, to study temporal and longitudinal patterns of benthic coarse particulate organic matter in the channel of the Agüera stream; 2, to assess the influence of land uses on the composition, structure and distribution of this resource.

2. Material and methods

Benthic coarse particulate organic matter (CPOM >1 mm) was sampled monthly between Novermber-92 and December-93 at four sites of the Agüera stream watershed (Northern Spain). The location, climatology and main features of this waterway can be found in other works (e.g. Pozo, 1993; Basaguren and Riaño, 1994; Elosegui and Pozo, 1994; González et al., 1994).

The location of sites chosen for the present work are shown in Fig. 1 and the main characteristics are summarized in Table 1. Site B is a headwater reach with an unaltered deciduous forest (*Quercus robur, Alnus glutinosa, Castanea sativa* and *Corylus avellana*) that cover the channel. Sites, 5, 7 and 9 are located downstream in the main channel. Riparian trees are absent from site 5, which is surrounded by crops. Land use is of *Eucalyptus globulus* plantations at site 7, and of meadows at site 9, at both sites with deciduous species in the banks.

The Confederación Hidrográfica del Norte de España provided data on daily discharges at site 9 (the lowest reach).

For quantifying benthic CPOM, samples were taken randomly in the wetted channel. 5 replicates of benthic material were collected, each one in an area of 0.36 m^2. A 1 mm mesh net were located downstream for retaining the removal material.

In the laboratory, CPOM was sorted in four main categories: leaves, fruits and seeds, twigs (<1 cm diameter) and other (very fragmented, unidentified material) that we refer as debris. Furthermore, leaf category was classified in leaves of oak

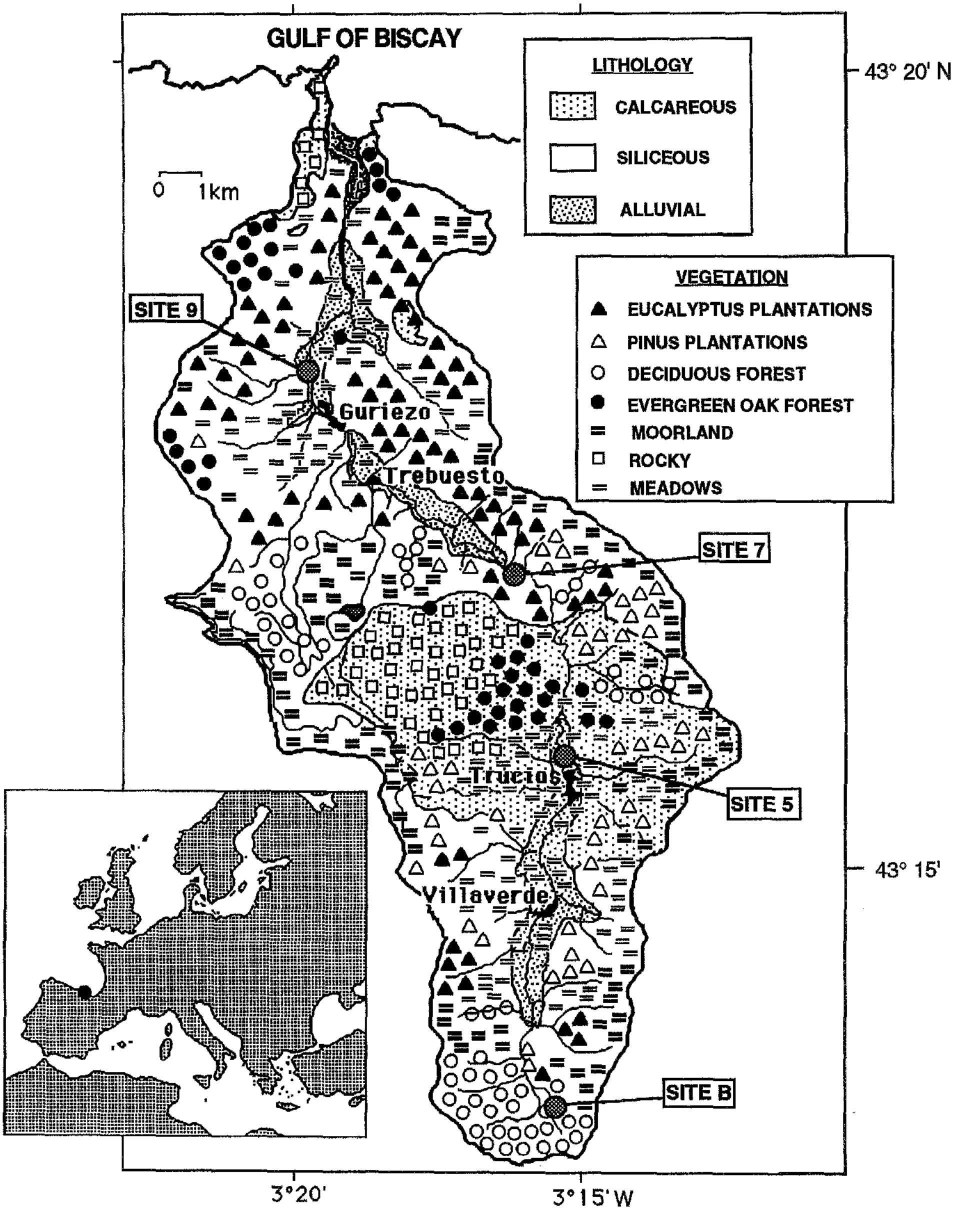

Figure 1. The Agüera stream watershed. Location of sampling sites, land uses and geological features

Table 1. The main characteristics of sampling sites

	Sites			
	B	5	7	9
Order	1	3	3	3
Elevation (m)	350	130	80	15
Drainage area (ha)	184	4762	6906	11 535
Mean flow (l/s)	40	770	1686	3 141
Mean width (m)				
Channel	3.7	11	18	22
Wetted channel	1	6	10	14
Vegetation				
Surrounding	Deciduous	Croplands	Eucalyptus	Meadows
Riparian	Deciduous	Grasses	Eucalyptus/Deciduous	Deciduous
Cover				
Riparian	Dense	Uncovered	Dense	Dense
Wetted channel	Dense	Uncovered	Medium	Medium
Bank slope	Steep	Moderate	Low	Low

(*Quercus robur*), alder (*Alnus glutinosa*), chestnut (*Castanea sativa*), hazel (*Corylus avellana*), eucalyptus (*Eucalyptus globulus*), pine (*Pinus* sp.), sycamore (*Platanus* sp.) and evergreen oak (*Quercus ilex*).

Material was dried (70 °C, 72 hours), weighed and burned (500 °C, 12 hours) to determine the organic content (ash free dry weight, AFDW).

Tests for significant difference were carried out using analysis of variance (2 way ANOVA), performed with log transformed data. Multiple comparisons were made using the Tukey test (Zar, 1984).

3. Results

The highest amount of total CPOM in the stream bed was recorded at site B (range 20.5–74.1 g AFDW m^{-2}) with a mean value for the study period of 59.6 g AFDW m^{-2} (Table 2). Sites 5 (range 9.9–47.7 g AFDW m^{-2}) and 9 (range 9.8–37.9 g AFDW m^{-2}) showed mean values around 20 g AFDW m^{-2}, whereas site 7 (range 4.3–21.4 g AFDW m^{-2}) presented the smallest mean, 12.2 g AFDW m^{-2}. Leaves, twigs and debris contributed with a similar percentage of the total CPOM at site B. However, debris was the prevailing category in the other stations, reaching 66 % of total CPOM at site 5 (where riparian trees were absent). Fruits and seeds was the category that recorded smallest values, representing only 3–4 % at sites B, 5 and 9, and 11 % at site 7. Within the category of leaves, the prevailing species at each site were good indicators of the riparian vegetation type (asterisk in table 2).

Quercus robur and *Alnus glutinosa* were found together in all the stations. *Castanea sativa* was only important at site B, while downstream *Platanus* sp. and *Quercus ilex* appeard at site 5, and *Eucalyptus globulus* at sites 7 and 9.

Table 2. Mean values ($\bar{x}$, g/m^2) and percentage of benthic CPOM categories at the four sites during the period November 92 – December 93. The number of asterisks (*) indicates the relative abundance of riparian vegetation species at each site

	Sites							
	B		5		7		9	
	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%
Total	59.6	100	21.2	100	12.2	100	19.9	100
Twigs	19.6	32.9	3.3	15.6	3.1	25.4	2.7	13.6
Debris	19.1	32.1	14.0	66.0	4.8	39.3	9.0	45.2
Fruits and seeds	2.6	4.4	0.7	3.3	1.4	11.5	0.7	3.5
Leaves	18.3	30.7	3.2	15.1	2.9	23.8	7.5	37.7
Quercus robur	10.4	17.5***	0.7	3.3	0.8	6.6***	3.6	18.1***
Castanea sativa	3.5	5.9**	0.3	1.4	0	0	0.1	0.5
Corylus avellana	1.4	2.4*	0.1	0.5	0.1	0.8	0.1	0.5
Alnus glutinosa	2.8	4.7***	0.6	2.8	1.0	8.2***	1.6	8.1**
Platanus sp.	0	0	0.6	2.8	0.2	1.7	1.1	5.5***
Pinus sp.	0.1	0.1	0.2	1.0	0	0	0.1	0.5
Eucalyptus globulus	0	0	0	0	0.7	5.7**	0.6	3.0
Quercus ilex	0	0	0.3	1.4	0	0	0	0
Other leaves	0.1	0.1	0.4	1.9	0.1	0.8	0.3	1.5

Significant spatial differences in density were found for both total CPOM and categories, except for fruits and seeds (Table 3). Site B usually showed higher densities of total CPOM, leaves and twigs than the stations located downstream. However, there was not a regular longitudinal pattern of change downstream, although the smallest values generally occured at site 7.

Temporal changes of benthic CPOM (total and categories) are shown in Figs. 2 and 3. The hydrologic regime during the study period seemed to affect mainly the amount of leaves and total CPOM, which increased during winter under stable flow conditions, particularly at forested sites (Figs. 2 and 3). Although no clear seasonal patterns have been found for most of the categories, significant temporal changes in the amount of material occurred (Table 3).

In the headwater station (B), leaves peaked in autumn and winter, and the lowest values were found during spring and summer. Debris at this site followed the opposite trend to that of leaves. With lower values than at site B, stations 5 and 9 registered minima of leaves during winter, while site 7 was characterized by low values of this material through time, peaking in February and in September. Fruits and seeds did not show significant temporal differences at any site.

The contribution of different species of leaves to the particulate organic pool in the stream changed through the year at all stations (Fig. 4). There was a higher richness of species in summer and autumn than in winter, when oak leaves represented the bulk of total leaves. The undisturbed headwater station (B) clearly showed a gradual temporal change in the relative importance of the different leaf

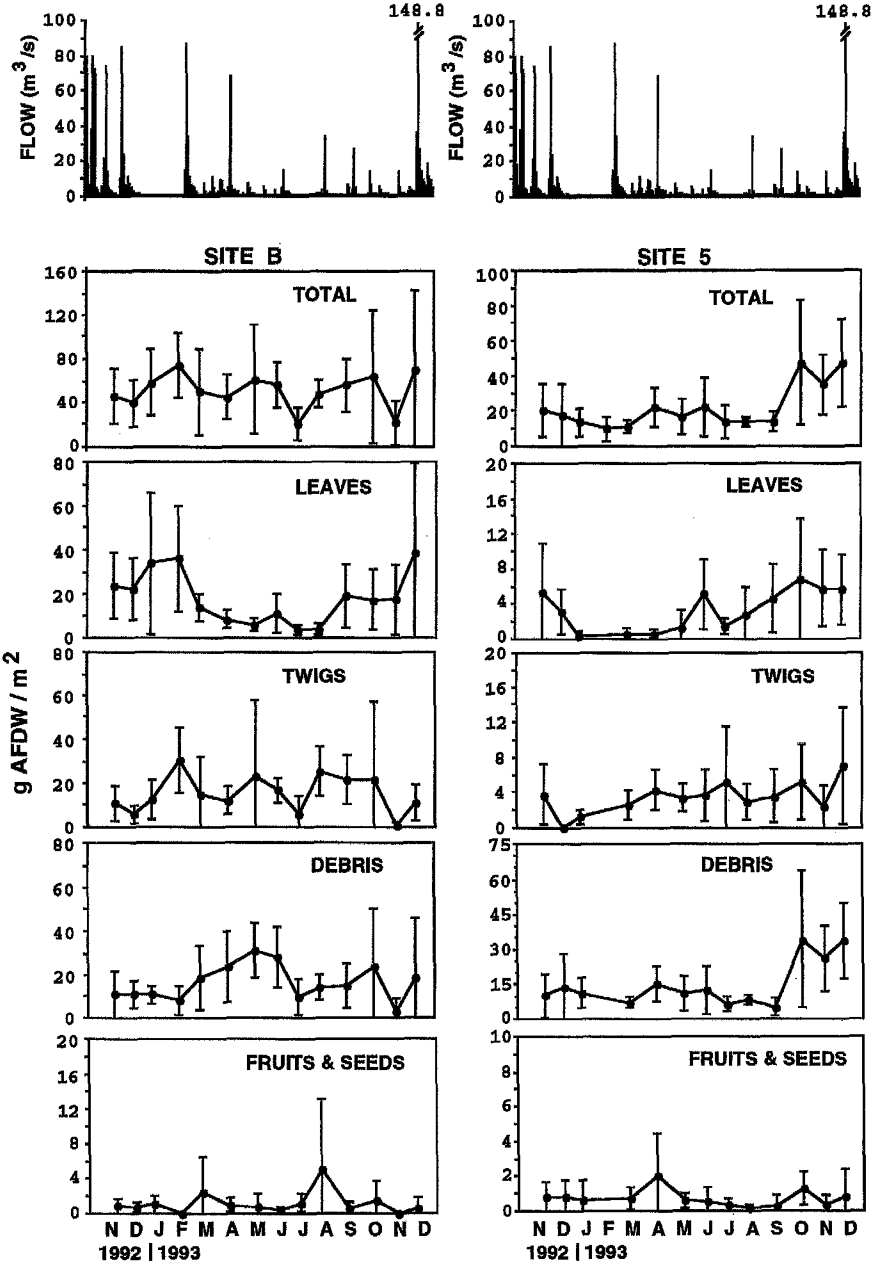

Figure 2. Temporal variation of benthic coarse particulate organic matter (total and categories) at sites B and 5. Error bars are standard deviation around the mean. Daily discharge (measured near the stream mouth) is shown at the top

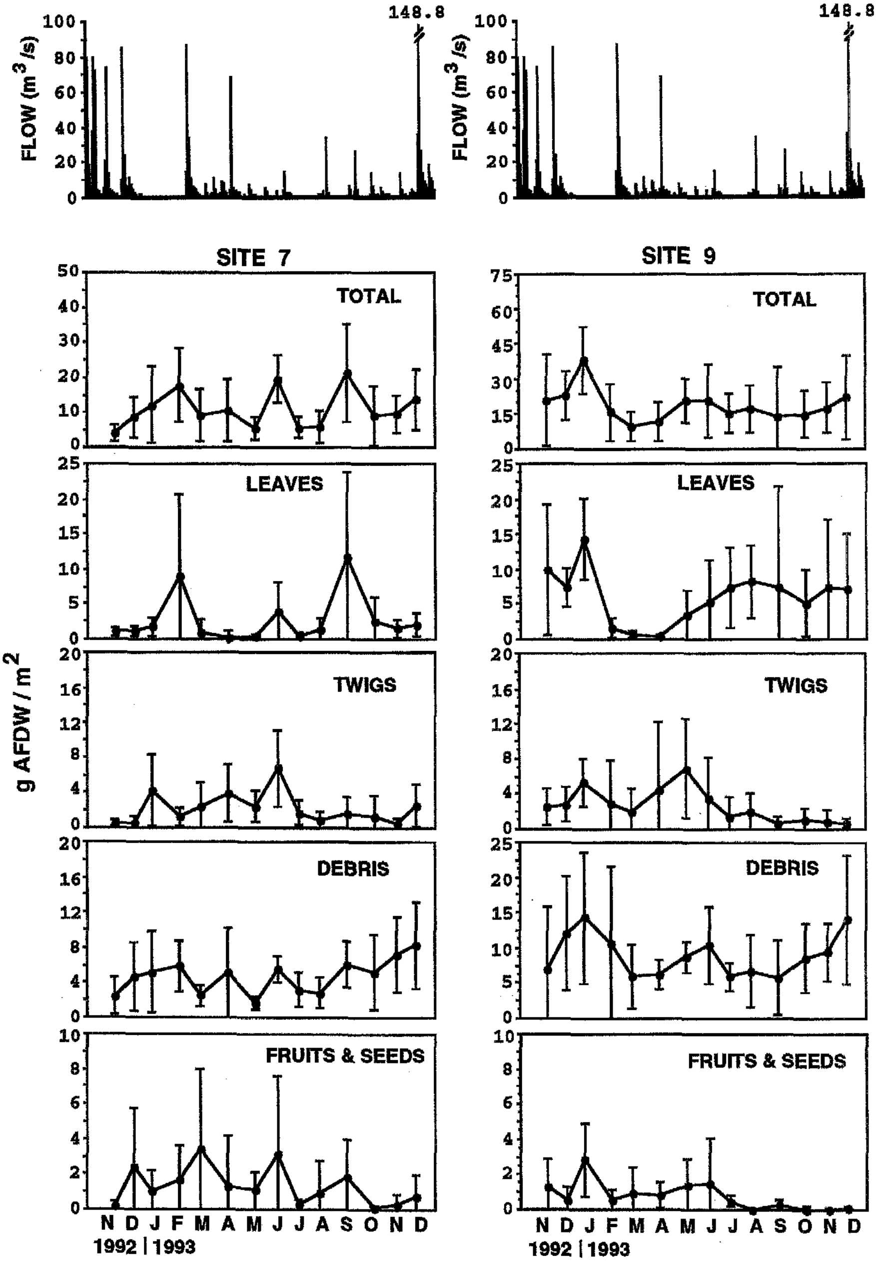

Figure 3. Temporal variation of benthic coarse particulate organic matter (total and categories) at sites 7 and 9. Error bars are standard deviation around the mean. Daily discharge (measured near the stream mouth) is shown at the top

Table 3. Summary (p values) of several two-factor analysis of variance on benthic CPOM (total and categories). Multiple comparisons are made by using the Tukey test. Underline means no significant differences. We summarize in this table only comparison between sites

Categories	Time	Site	Interaction	Site comparison
Total	0.0104	0.0001	0.0007	B>59>7
Leaves	0.0001	0.0001	0.0001	B>9>57
Twigs	0.0001	0.0001	0.0001	B>597
Debris	0.0001	0.0001	0.0001	B59>7
Fruits and Seeds	0.307	0.2447	0.1256	N.S.

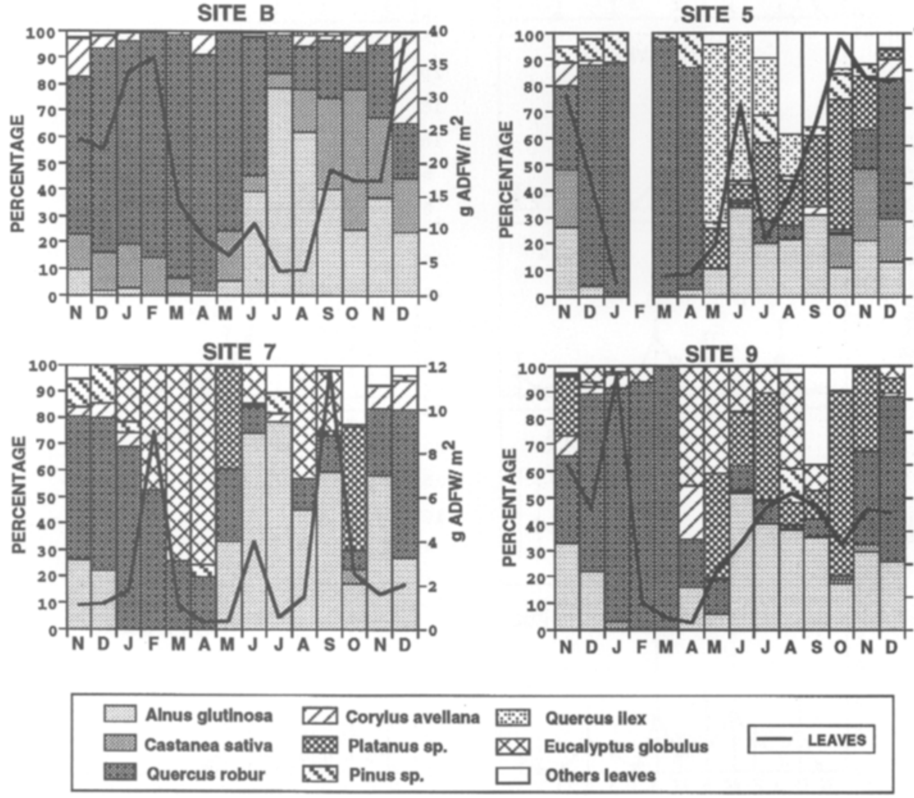

Figure 4. Temporal changes in the relative importance of leaves species from the streamed at the four sites studied. The line represents total leaves (g/m^2)

species, with *Quercus robur* dominating during winter-spring, *Alnus glutinosa* during summer and *Castanea sativa* in autumn.

4. Discussion

The longitudinal pattern of the amount of benthic CPOM in the Agüera stream seems to respond not only to the change in stream size (Vannote et al., 1980; Minshall et al., 1983) but also to local characteristics of each reach. The unaltered riparian deciduous forest, the dense vegetation canopy, which ensures large inputs of particulate organic matter, the narrow channel and efficient structures of retention as debris dams, branches and roots (Bilby and Likens, 1980; Ehrman and Lamberti, 1992; Chergui et al., 1993) would explain the high accumulation of CPOM in the headwater reach. However, downstream, an interpretation is more complex due to the different land uses and the level of disturbance of the riparian vegetation, the main source of CPOM. Higher values of CPOM at sites 5 and 9 than at site 7, located between them, indicate that neither stream size nor existing trees on the banks can explain the benthic CPOM distribution in the Agüera stream. Other factors such as flow velocity and channel morphology could also influence benthic CPOM amounts by affecting retention efficiencies (Snaddon et al., 1992; Maridet et al., 1995).

The predominance of the debris category in stations 5, 7 and 9 indicates that particulate matter was at a more advanced stage of decomposition in downstream reaches than in headwaters (site B), where leaves, twigs and debris had similar relative importance. These spatial differences in the composition could be due to differences in sources of CPOM. Thus, at site B the close riparian environment would represent the main source of organic matter, while at the other sites, the transport from upstream reaches should become more important. Site 5 clearly reflected this fact: the absence of trees on its banks and the importance of the debris category within the benthic CPOM indicate that a great amount of this material is originated from upstream reaches. The same can be said for eucalyptus leaves found at site 9 where this species was absent from the banks.

However, in the stations where riparian trees were present, the majority of leaves on the stream bed reflected the type of the surrounding terrestrial vegetation.

In temperate regions the highest CPOM standing stock occurs in late autumn following the period of highest annual litterfall (Iversen et al., 1982; Bärlocher, 1983). In the Agüera stream, the input of autumn-shed leaves is poorly reflected by the dynamics of benthic CPOM under changing discharge conditions. As an example, maximal leaf shedding at site B occurs from October to January, peaking in November (unpublished data). Thus, only when high inputs coincide with a period of low discharge, an increase of these materials on the stream bed would be expected. This seemed to occur in winter. The timing of inputs and the hydrologic regime appear to act together influencing temporal dynamics of benthic CPOM. This seems to be a reason for the lack of a significant relationship between CPOM and discharge (neither between CPOM and the length of the time period since the last spate). Twigs could also contribute to mask a discernible seasonal pattern of

CPOM. According to Sykes and Bunce (1970), this material shows no tendency to enter the stream in any particular month.

The start and completion of shedding are not well defined because of inter and intra-specific differences (Bretschko, 1990). At site B, the composition of the benthic leaf category showed a gradual change of species through time: first alder, later chestnut and finally oak, mainly due to the marked sequence often showed by the litter fall in the surrounding terrestrial ecosystems (Chauvet and Jean-Louis, 1988) and coincident with our own observations (unpublished data). Downstream, this gradual change was more complex due to a greater richness of species from spring to autumn.

Because of the different temporal dynamics of shedding of riparian trees, the period of inputs of terrestrial-derived material into the stream was extended, increasing the food availability for the biotic community. In this way, the community can find leaves of different species and characteristics: recent-fallen leaves and litter at different stages of decomposition. This may favour their utilization by different functional groups. However, at sites where the climax vegetation has been replaced by exotic plantations (e.g. eucalyptus), the quantity and quality of benthic organic material as well as its temporal distribution have been changed. Maximal leaf fall of eucalyptus seems to occur mainly in summer (Campbell et al., 1992). However, the smaller values than expected recorded at site 7, surrounded by eucalyptus plantations, indicated a low efficiency of retention in this channel or a restriction to inpus of eucalyptus leaves due to the barrier formed by other plant species on the banks (Pozo et al., 1994). In this sense, maintaining autochthonous riparian vegetation may be an important tool in the management of fluvial systems similar to ours as it ensures a diverse supply of organic matter to the stream and several leaf peaks through the year.

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