Dynamics of Lotic Ecosystems

Edited by

Thomas D. Fontaine, III
Savannah River Ecology Laboratory
University of Georgia

Steven M. Bartell
Environmental Sciences Division
Oak Ridge National Laboratory

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22. THE ROLE OF SHREDDERS IN DETRITAL DYNAMICS OF PERMANENT AND TEMPORARY STREAMS

J. M. Kirby, J. R. Webster, and E. F. Benfield

Biology Department
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

ABSTRACT

It has been suggested that leaf-shredding insects have an important role in breakdown of leaf detritus and the production of particulate organic matter (POM) in streams. This role was evaluated by comparing detrital dynamics in three permanent and three temporary tributaries of Guys Run, Rockbridge County, Virginia. In general, the streams with fastest leaf breakdown, highest low-flow POM concentrations, and largest average POM particle sizes were found to have the greatest shredder and total insect densities. It was concluded that this is further evidence for the importance of shredders in woodland streams.

INTRODUCTION

Leaves form the major trophic base of many streams, especially small headwater streams draining forested watersheds in the eastern deciduous forest of North America. Leaves entering these streams are broken down by a combination of physical, chemical, and biological factors, including mechanical breakage, leaching of water-soluble compounds, microbial decomposition, and invertebrate feeding. Our concern in this chapter is the importance of invertebrate feeding on leaf breakdown rates and generation of small particles of detritus. Detritivores have relatively low assimilation efficiencies (e.g., Berrie, 1976), and much of the leaf material ingested by detritivores (or shredders, Cummins, 1973) is returned to the stream greatly reduced in size. This fine particulate organic matter (FPOM) provides an energy source for other components of the stream fauna, which feed on deposits of FPOM or filter FPOM from suspension (Short and Maslin, 1977; Wallace et al., 1977). The importance of shredder activity in stream detrital dynamics has been difficult to quantify, however (Anderson and Sedell, 1979). The importance of shredders in leaf breakdown and FPOM generation has been evaluated by two general techniques: breakdown rates in streams with different shredder abundances have been compared, and detritus use budgets have been calculated from shredder ingestion or production data. Hart and Howmiller (1975), Iversen (1975), and Sedell et al. (1975) compared leaf breakdown in two or more streams and, in each case, suggested that differences in breakdown rates were caused by differences in the invertebrate fauna. Also, Petersen and Cummins (1974) found slower leaf breakdown rates in channels where shredders were excluded than in those where they were present.

Fisher and Likens (1973) found that macroconsumers accounted for only a small portion of the energy flow in Bear Brook. However, Cummins (1971) estimated that detritivores in a woodland stream ingested almost 32% of gross large particulate organic matter (LPOM) input on a daily basis, and Webster and Patton (1979) calculated that annual detritivore ingestion in a small stream at Coweeta Hydrologic Laboratory was approximately 80% of leaf fall. In another study, Grafius and Anderson (1979) found that, though *Lepidostoma quercina* production was only a small portion of the total secondary production in Berry Creek, this shredder produced sufficient FPOM to support 25 to 50% of the simuliid production in the stream. Finally, on the basis of laboratory experiments, Cummins et al. (1973) concluded that shredders have an important influence on energy flow in detritus-dominated stream ecosystems.

In this study we compared rates of leaf breakdown and POM transport in three permanent and three temporary streams draining small forested watersheds. Since the periodic dry period of temporary streams has been shown to greatly reduce the number of invertebrates in such streams (e.g., Clifford, 1966; Williams and Hynes, 1976), we anticipated that shredder influences on leaf breakdown and POM production should be evident in a comparison of these two types of streams.

DESCRIPTION OF STUDY AREA

Transport of particulate organic matter and leaf breakdown rates were measured in six first-order tributaries of Guys Run, a tributary of the Calfpasture River (James River Basin, Rockbridge County, Virginia; 79°39′ W longitude, 38°58′ N latitude) (Figure 1). Most of the 19-km^2 watershed of Guys Run is located within the Goshen Wildlife Mangement Area. Overstory vegetation is primarily oak, hickory, maple, and pine, with an understory of dogwood, rhododendron, and mountain laurel. The six tributaries of Guys Run used in this study are typical of the low-order, low-nutrient streams of the southern Appalachian Mountains. Glade Brook, Beckney Hollow, and Three Dwarf Run have channel flow throughout the year, with highest flows in winter and lowest flows in summer. Dry Branch, Tower Branch, and Grave Branch are temporary streams, with no channel flow during late summer and autumn. Stream lengths, gradients, and watershed areas for the six streams are given in Table 1.

METHODS

Leaf breakdown rates were examined in the six study streams by using nylon mesh bags (10 by 10 cm, with 1-cm openings) filled with approximately 5 g of dried and weighed red maple (*Acer rubrum*) leaves. Thirty bags were placed in each stream on January 20, 1979, and five bags were recovered from each site on six dates, beginning on February 10, 1979, and ending on July 5, before the temporary streams dried up. Retrieved leaf bags were placed on ice and transported to the laboratory, where invertebrates were recovered and preserved for identification. The leaf material was air-dried to constant weight and weighed. Subsamples (1 g) from each bag were ashed for 15 min at 500°C to determine ash-free dry weight (AFDW) of the remaining leaf material. Breakdown rates (Jenny et al., 1949; Olson, 1963) were calculated by regressing log-transformed percent weight remaining against exposure time. Breakdown rates were compared by analysis of covariance (Sokal and Rohlf, 1969).

Particulate organic matter was collected from the six study streams on seven dates beginning in January 1979 and ending in January 1980. Large POM size fractions were collected by pouring measured volumes of water through a 20-μm plankton net. Water was also collected in carboys to obtain samples of smaller particles. All POM samples reported in this

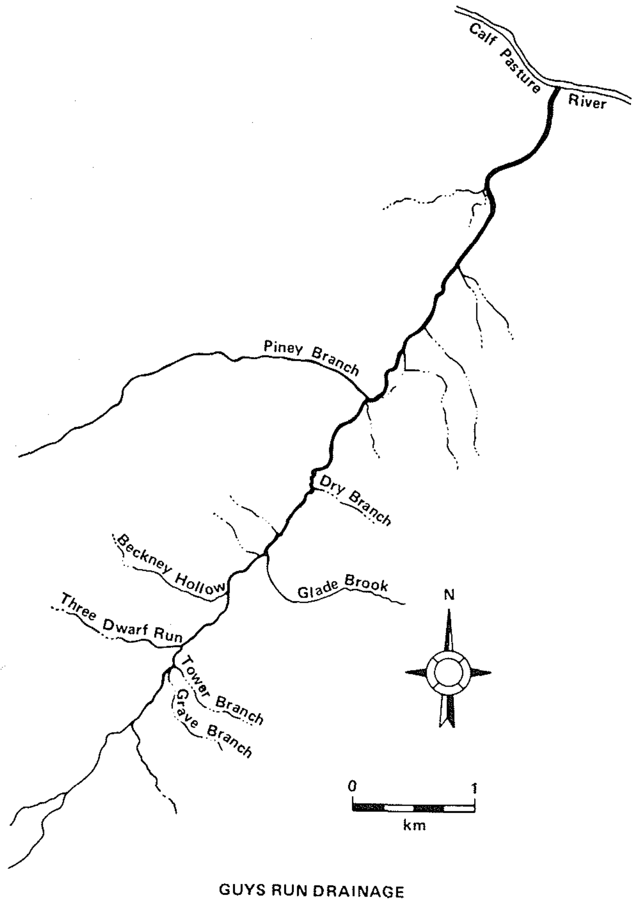

Figure 1. Map of Guys Run study area.

Table 1. Stream Length, Gradient, and Watershed Areas for Three Permanent and Three Temporary Streams in the Guys Run Watershed

Stream	Stream length, m	Stream gradient, m/m	Watershed area, km^2
Permanent streams			
Glade Brook	400	0.22	1.13
Beckney Hollow	1350	0.08	0.83
Three Dwarf Run	550	0.06	0.38
Temporary streams			
Dry Branch	549	0.15	0.33
Tower Branch	555	0.13	0.94
Grave Branch	1173	0.05	0.36

paper were collected during non-storm periods. Samples were analyzed with wet filtration system (Gurtz et al., 1980). Measured volumes of water or resuspended net samples were filtered with suction through a series of stainless-steel screens into the following size classes: >234 μm, 105 to 234 μm, 43 to 105μm, and 25 to 43 μm. Material collected on the screens was resuspended and collected on preashed, preweighed Gelman A/E glass-fiber filters. An aliquot of material passing through the 25-μm screen was filtered through a glass-fiber filter to provide a 0.5 to 25 μm size fraction. All samples were oven-dried for 24 h at 50° C, desiccated (24 h), weighed, ashed 15 min at 500° C, rewetted to restore water of hydration (Weber, 1973)], redried, desiccated, and weighed. We calculated POM concentrations (mg AFDW/l) and average particle sizes (based on weight) from these weights.

RESULTS AND DISCUSSION

Breakdown of red maple leaf packs in the six study streams is shown in Figure 2. Glade Brook and Beckney Hollow, two of the permanent streams, had breakdown rates significantly faster than the other four streams (Table 2). Leaf breakdown in Three Dwarf Run, the smallest of the three permanent streams, was more similar to that in the temporary streams. Of the three temporary streams, leaf breakdown in Dry Branch was more rapid than breakdown in Grave Branch and faster, but not statistically significantly so, than in Tower Branch. There were no significant correlations between breakdown rates and stream gradients, steam velocity, or watershed area. Leaf breakdown rates of red maple measured in this study were all slower than the rate of 0.0298/day found by Thomas (1970) for a small stream in Tennessee but similar to the 0.0062/day breakdown rate measured in Augusta Creek by Petersen and Cummins (1974).

Shredder and total insect density on leaf packs increased with time, especially after about 70 days, once the leaves became conditioned (Figure 3). The dominant shredders found on the leaves were two Trichoptera (*Lepidostoma* sp. and *Pycnopsyche* sp.), three Plecoptera (*Leuctra* sp., *Peltoperla* sp., and *Pteronarcys proteus*), and a Diptera (*Tipula* spp). Densities of shredders and total insects reflected leaf breakdown rates. Two permanent streams, Glade Brook and Beckney Hollow, which had the fastest breakdown rates, had highest insect densities. Three Dwarf Run (permanent) and Grave Branch (temporary), the two streams with the slowest leaf breakdown rates, had consistently low insect densities. In Tower Branch and Dry Branch (both temporary),

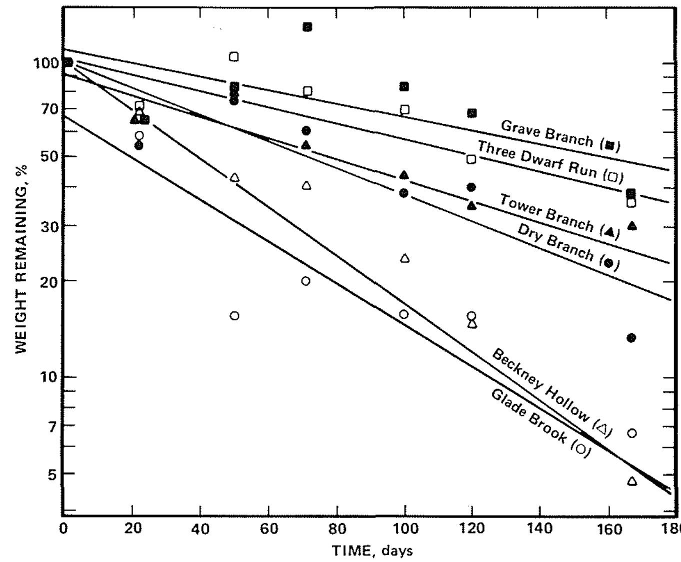

Figure 2. Leaf breakdown in the six study streams. Each point represents the average of five samples. Lines were fit by regression.

Table 2. Red Maple Leaf Breakdown Rates in the Six Study Streams

Stream	N	r^2	Breakdown rate/day	95% Confidence interval	Analysis of* covariance
Beckney Hollow	35	0.72	0.0175	±0.0078	
Glade Brook	35	0.66	0.0149	±0.0075	
Dry Branch	35	0.65	0.0098	±0.0050	
Tower Branch	35	0.53	0.0077	±0.0051	
Three Dwarf Run	35	0.46	0.0059	±0.0045	
Grave Branch	34	0.33	0.0045	±0.0047	

*Vertical bars indicate rates that were not significantly different (α = 0.05).

which had intermediate breakdown rates, shredder densities were low at the end of the study, but peaks of shredder abundance (primarily *Leuctra* sp. in both cases) were noted after 90 days of exposure in Tower Branch and 125 days in Dry Branch.

On dates when comparisons were possible, POM concentrations were generally higher in the permanent than in the temporary streams (Figure 4). Concentrations in the permanent streams were highest in summer,

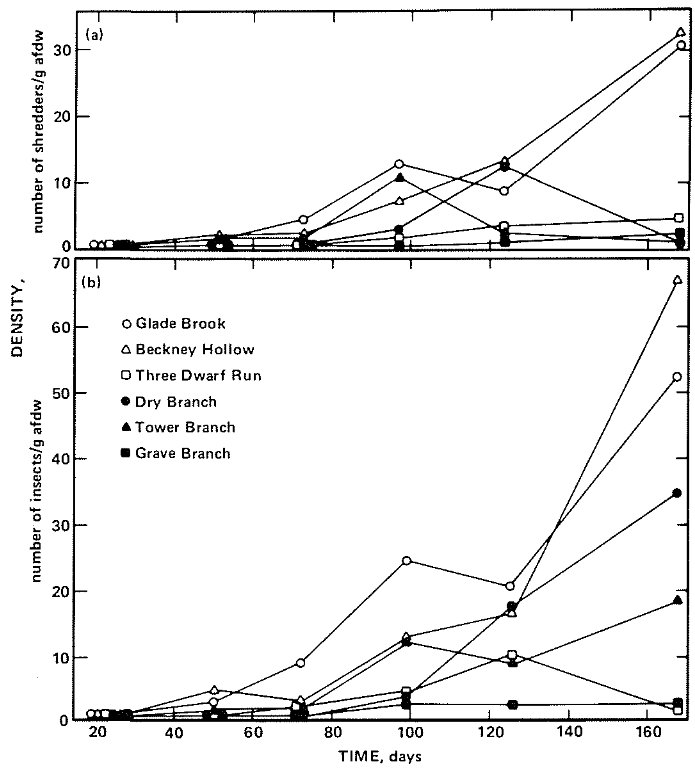

Figure 3. Densities of shredders and total insects on leaf packs in the six study streams. Each point is the mean from five samples.

lowest in winter, and intermediate in spring and autumn. During the peak period (May to September), POM concentrations were consistently highest in Beckney Hollow, lowest in Three Dwarf Run, and intermediate in Glade Brook. Among the temporary streams, Dry Branch generally had the highest POM concentration. Trends in the average POM particle sizes were not as clear, but followed the same general pattern. The average particle size was usually largest in Beckney Hollow and Glade Brook (both permanent) and smallest in Tower Branch and Grave Branch (both temporary). Three Dwarf Run (permanent) and Dry Branch (temporary) were intermediate.

The POM concentrations were generally lower than concentrations measured in other small streams in the southern Appalachian Mountains (Gurtz et al., 1980). Higher POM concentrations were also found in small streams in Pennsylvania (Sedell et al., 1978), Michigan (Wetzel and

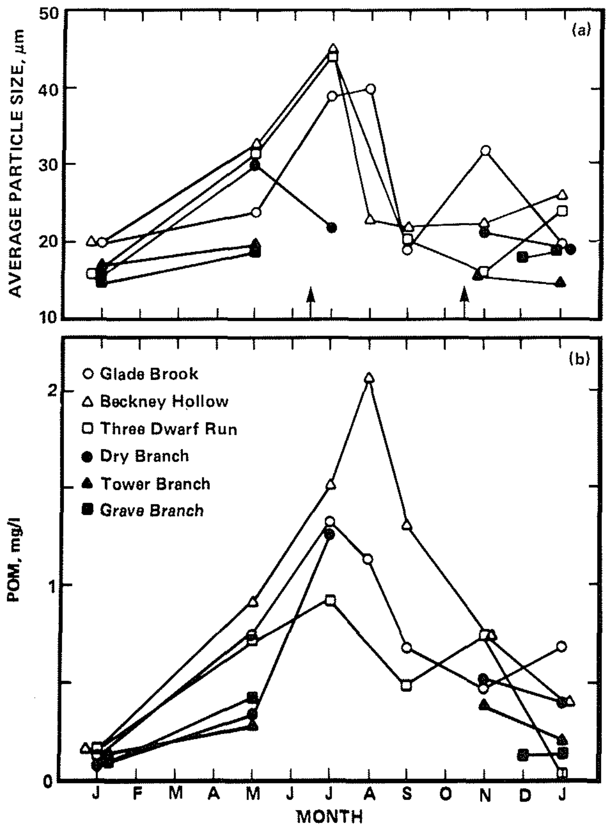

Figure 4. Particulate organic matter (POM) concentrations and average particle sizes in the six study streams. Temporary streams were dry from early June to mid October, as indicated by arrows on part a of the figure.

Manny, 1977), and Mississippi (de la Cruz and Post, 1977). Concentrations more similar to ours (annual average 1 mg/l) were reported from Hubbard Brook streams (Bormann et al., 1969; Fisher and Likens, 1973; Bilby and Likens, 1979) and streams in the western United States (Maciolek, 1966; Maciolek and Tunzi, 1968; Sedell et al., 1978; Naiman and Sedell, 1979). Our average particle size was generally smaller than the 37 to 65 μm found in Hugh White Creek, a second-order stream in North Carolina (Gurtz et al., 1980), but larger than that (5 to 12 μm) reported by Naiman and Sedell (1979) for first- and second-order streams in Oregon. The average particle sizes we observed were well below the particle sizes found in shredder feces (J. O'Hop, University of Georgia, personal communication).

The results of this study suggest that shredders have a significant influence on the rates of leaf breakdown and POM production in tributaries of Guys Run. In two permanent streams, Glade Brook and Beckney Hollow, we observed the fastest leaf breakdown, greatest low-flow POM concentrations, largest average POM particles sizes, and the greatest abundances of shredders on leaf packs. In contrast, in the two temporary streams with the longest dry periods, Tower Branch and Grave Branch, we found significantly slower breakdown, lower POM concentrations, smaller average POM particle sizes, and lower shredder densities. This suggests that in streams where shredders are abundant their feeding accelerates weight loss from leaves, and the relatively large particles in their feces become a major portion of the POM carried by the streams, resulting in a larger average POM particle size.

It might be argued that shredder densities are not relevant, but that greater POM concentrations, larger particle sizes, and faster leaf breakdown are results of flows and greater stream power in Beckney Hollow and Glade Brook since it is well known that as stream power increases during storms, POM transport increases (e.g., Bilby and Likens, 1979). If greater POM transort in the permanent streams was caused by their greater stream power, we would expect the greatest POM transport and largest particle sizes in winter when flows were high, and lower transport and smaller particle sizes during low summer flows. We observed just the opposite, however. In summer, even with lower flows, daily transport at base flow was higher than daily transport at winter base flows. For example, in July 1979, daily transport in Beckney Hollow was 436 g/day at a flow of 3.3 l/s. In January 1980, at a flow of 23.8 l/s transport in the same stream was only 235 g/day.

Two of the streams we studied failed to fit our preconceived ideas about temporary and permanent streams. Three Dwarf Run, one of the permanent streams, had slower leaf breakdown, lower POM concentrations, and smaller particle sizes than the other permanent streams. In these respects, Three Dwarf Run was more like the temporary streams. Dry Branch, a temporary stream, illustrated the opposite situation by having detrital characteristics more like a permanent stream. Shredder and total insect densities in both of these streams were also the opposite of what we anticipated. Shredder and total insect densities were generally high in Dry Branch but very low in Three Dwarf Run. We are unable to explain why these two streams failed to fit the permanent-temporary pattern, but the correlations between detrital characteristics and shredder densities further support our argument for the importance of shredders.

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