

Organic matter dynamics along a stream-order and elevational gradient in a southern Appalachian stream

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Introduction

Predictions of the River Continuum Concept include changes in physical factors such as geomorphology and temperature along a stream-order gradient (VANNOTE et al. 1980). Changes in macroinvertebrate diversity (ALLAN 1975), biomass (GRUBAUGH et al. 1996), and functional feeding group composition (MINSHALL et al. 1983) have been shown along such gradients. Changes in a variety of ecosystem processes along stream continua have also been demonstrated (MINSHALL et al. 1983, NAIMAN et al. 1987). HURYN & WALLACE (1987) and GRUBAUGH et al. (1996) found that macroinvertebrate habitat varies both longitudinally and locally and that sampling a single habitat (patch) may not be sufficient to reflect community composition throughout a stream continuum. Our objective was to investigate whether selected organic matter processes vary with patch type along a stream-order/elevational gradient.

Study site

The study was conducted at Coweeta Hydrologic Laboratory in the southern Appalachian Mountains in North Carolina, USA. Four sites along a stream-order and elevational gradient in the Ball Creek/Coweeta Creek basin were selected for measuring litterfall input, benthic organic matter (BOM) storage and leaf breakdown. The Ball Creek/Coweeta Creek riparian zone is a mixed deciduous forest with an overstory composed of several oaks, hickory, maple, birch and tulip poplar, and a dense understory of

rhododendron. Sampling sites consisted of stream reaches representing four orders (2-5) and a drop in elevation of ca. 400 m. Characteristics of the four sites are shown in Table 1.

Methods

Sampling sites were 50-m reaches of stream containing at least one riffle and one pool. Litterfall was sampled using litter traps (0.3 × 0.4 × 0.3 m). Fifteen traps were suspended across the stream and five were placed along each stream bank in September 1992. Traps were emptied twice monthly during October and November, then monthly for one calendar year. Litter was sorted into three categories: leaves, sticks and other (flowers, seeds, nuts, fragments). Benthic organic matter (BOM) was collected quarterly from three patch types (cobble-riffle, rock-face, and sandy-reach) using a coring device coupled with a bilge pump (STOUT et al. 1993). BOM was separated into three fractions: fine benthic organic matter (FBOM), coarse benthic organic matter (CBOM) and wood. Leaf breakdown rates for three leaf species were estimated using a litterbag technique (e.g. BENFIELD 1996) in two patch types: riffle and pool. The study was designed to include a "fast" (tulip poplar, *Liriodendron tulipifera* L.), a "medium" (white oak, *Quercus alba* L.) and a "slow" (Rhododendron, *Rhododendron maximum* L.) species based on known breakdown rates (WEBSTER & BENFIELD 1986).

Table 1. Physical characteristics of the Ball Creek/Coweeta Creek system.

Site	Stream order	Catchment area (ha)	Elevation (m above sea level)	Water surface slope (%)	Mean annual discharge (m ³ s ⁻¹)
WS27	2	39	1159	38.6	0.02
UBC	3	119	847	9.4	0.10
LBC	4	690	690	7.1	0.27
CC	5	1548	671	2.9	0.58

Results and discussion

Litterfall

The distribution of litter input to the streams over the year was typical for temperate deciduous forests in eastern U.S.A., i.e. the bulk of input occurred in autumn (Fig. 1). Total annual litterfall ranged from about 460 g m⁻² at high elevation/low-order sites (WS27 & UBC) to >600 g m⁻² at the low elevation/high-order sites (LBC & CC) and the differences between the two classes of sites were significantly different (Fig. 2). We did not measure "lateral movement" but previous studies at Coweeta streams have shown lateral movement to be generally 15–30% of annual litterfall (WEBSTER et al.

1990). This downstream trend likely reflects differences in tree species composition and density in riparian forest along the gradient.

There were site differences in the quality of litter reaching the streams. Leaves comprised the largest fraction of litterfall at all sites and sticks contributed substantially at the 4th- and 5th-order sites (Fig. 3). The "other" material composed smaller but significant fractions of litterfall, especially at the 3rd-order site. Generally, inputs for all three classes of litter were higher at the two downstream sites except for "other" at the 3rd-order site (Fig. 3).

Benthic organic matter

Standing stock benthic organic matter (all patches combined) was generally highest at the 2nd-order site (WS27) and declined downstream, demonstrating a stream order and elevational gradient in a downstream direction (Fig. 4). However, the 3rd-order site (UBC) did not appear to fit the general pattern for CBOM and wood, i.e. values were lower than at the 2nd- and 4th-order sites. FBOM declined downstream but differences among sites were not sta-

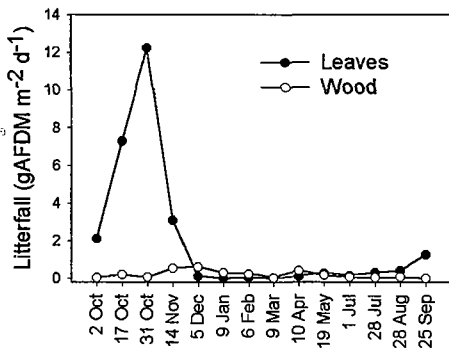


Fig. 1. Annual litterfall of leaves and wood at Coweeta Creek.

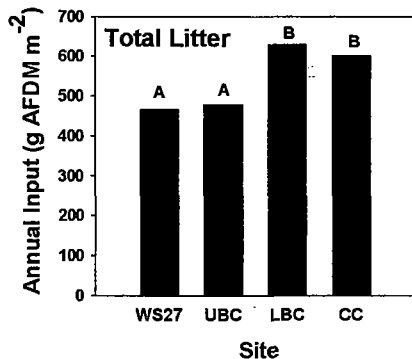


Fig. 2. Mean total litter input at each site. Values with the same letter were not significantly different (ANOVA followed by LSD test, $\alpha = 0.05$).

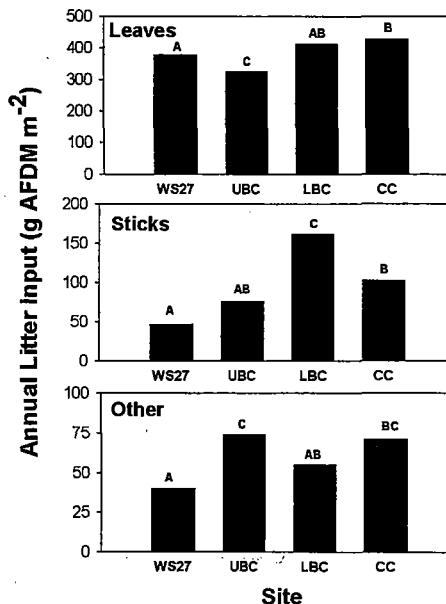


Fig. 3. Mean input of each litter type at each site. Values with the same letter were not significantly different (ANOVA followed by LSD test, $\alpha = 0.05$).

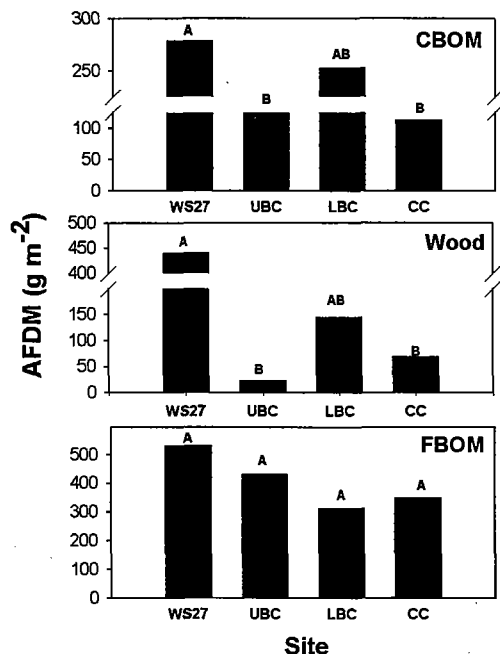


Fig. 4. Mean standing stock of the three classes of benthic organic matter at each site with all patches combined. Values with the same letter were not significantly different (ANOVA followed by LSD test, $\alpha = 0.05$).

tistically significant. The observed pattern was somewhat predictable in that more retention structures and lower discharge in low order streams should retain CBOM, wood and FBOM to a greater degree than in higher order streams (e.g. BILBY & LIKENS 1980, WALLACE et al. 1982, MINSHALL et al. 1983).

Patch type was a significant factor in the distribution of the three classes of BOM at all sites. There was significantly more CBOM, wood and FBOM in the sandy-reach patches than in the cobble-riffle or rock-face patches (Fig. 5). The sandy-reach patches in this stream are depositional zones occurring in association with pools or at the stream side and were sites of greatest organic matter storage (HURYN & WALLACE 1987). Much of the BOM recovered here was buried beneath the sediments as was the case in other studies (e.g. SMOCK 1990).

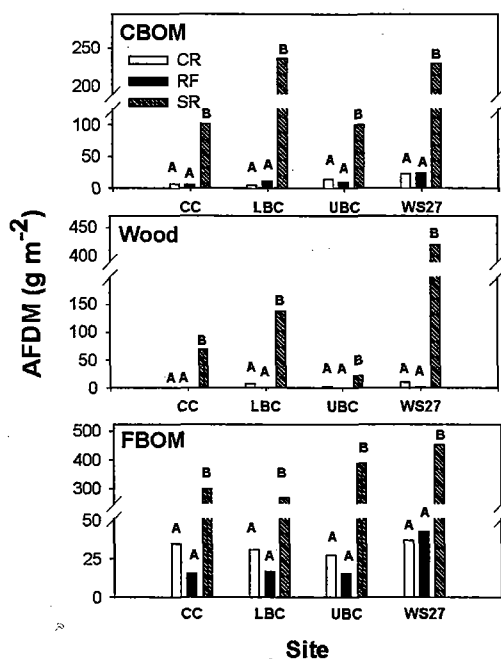


Fig. 5. Mean patch-specific standing stock of the three classes of benthic organic matter at each site (CR, cobble-riffle, RF, rock face, SR, sandy reach). Values with the same letter were not significantly different (ANOVA followed by LSD test, $\alpha = 0.05$).

Leaf breakdown rate

All species broke down faster, or about equally fast, in riffles than in pools except white oak at the 2nd-order site (Figs. 6, 7). The values were significantly different in 8 of the 12 comparisons. There was a general trend of faster breakdown rates with increasing stream order for all species in both patch types (Fig. 8). Two notable exceptions were white oak and tulip poplar, which broke down faster at 2nd-order site pools than at the remaining pool sites.

Patch type (riffle versus pool) was an important factor in leaf breakdown in this system as has been shown for other streams (e.g. CUMMINS et al. 1980, MEYER 1980). Lack of current, burial and reduced numbers of shredders have been implicated as important factors in explaining why leaves break down slower in pools than riffles (WEBSTER & BENFIELD 1986).

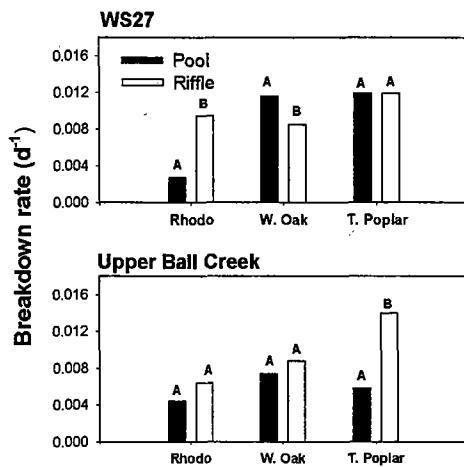


Fig. 6. Leaf breakdown rates for the three leaf species at WS27 and UBC. Values with the same letter are not significantly different. Breakdown rates were compared using a general linear model with dummy variables (KLEINBAUM et al. 1988, $\alpha = 0.05$).

The general trend of faster breakdown rates downstream seems counter to most predictions, but has been shown in other studies (e.g. BENFIELD & WEBSTER 1985). One explanation given is that artificial leaf packs constitute an additional resource in an area of relatively low CBOM and wood, thereby attracting shredders, which results in artificially faster processing rates. Also, higher discharges at downstream sites may result in more physical breakage than at upstream sites contributing to the observed differences (WEBSTER & BENFIELD 1986).

Acknowledgments

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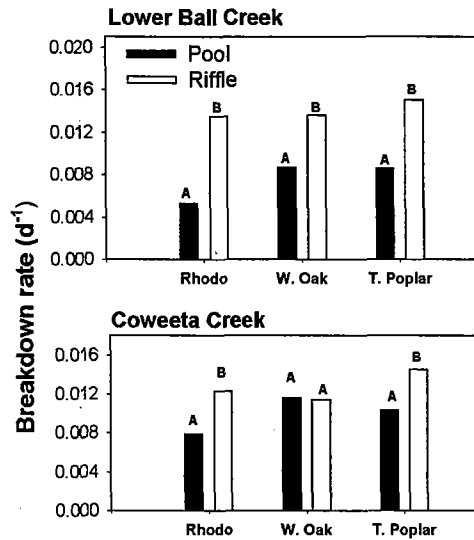


Fig. 7. Leaf breakdown rates for the three leaf species at LBC and CC. Values with the same letter are not significantly different. Breakdown rates were compared using a general linear model with dummy variables (KLEINBAUM et al. 1988, $\alpha = 0.05$).

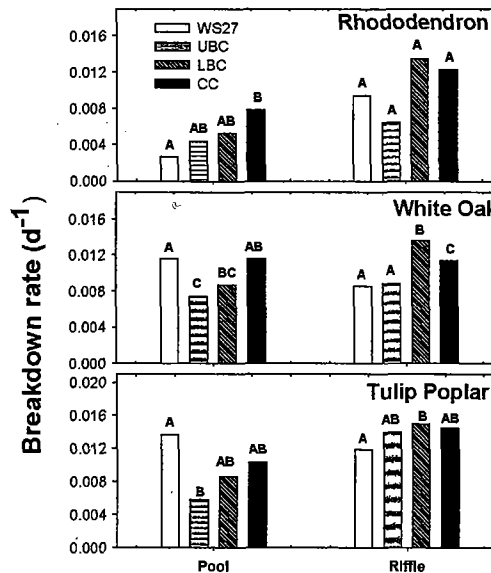


Fig. 8. Leaf breakdown rates for the three leaf species for each patch type at each site. Values with the same letter are not significantly different. Breakdown rates were compared using a general linear model with dummy variables (KLEINBAUM et al. 1988, $\alpha = 0.05$).

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