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Notes and Comments

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COMPOSITION AND POSSIBLE ORIGIN OF DETRITAL MATERIAL IN STREAMS¹

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Stream detritus consists in part of fragmented plant material, microbial biomass and by-products, and precipitated dissolved organic material (Cummins 1974, Davis 1980, Dahm 1981). Streams, however, also transport and store mineral-soil particles on which large amounts of organic matter are already adsorbed when the particles enter the stream (Avnimelech and McHenry 1984). Adsorbed organic material also forms layers upon mineral surfaces within the stream bed (Lock 1981, Hynes 1983, Rounick and Winterbourn 1983). The amount of adsorbed C and N in streams and the importance of this material as a food and nutrient source are largely unknown.

Fragmented plant material is lighter than organo-mineral particles and can be separated from the latter by repeated flotation in a medium of specific gravity $\approx 1.6 \text{ g/cm}^3$ (Coughlan et al. 1973, Sollins et al. 1983, Spycher et al. 1983). In the present study, we used this density fractionation technique to provide initial data on the composition of detritus from several small streams. We also compared density and chemistry of the stream and floodplain detritus with those of materials that might serve as a source for the detritus: soil from the forest adjacent to the floodplain and submerged waterlogged wood and foliage.

Materials and Methods

Sampling sites. Most samples used in this initial survey came from Mack, Grasshopper, and Quartz Creeks, third-order streams in the Cascade Mountains of Oregon, USA, in or near the H. J. Andrews Experimental Forest. Samples were also taken from Berry and Oak Creeks, small streams near Corvallis, Oregon.

Mack Creek flows from an old-growth forest dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). The stream gradient is 10% and elevation is 760 m at the sampling site. Vegetation along Quartz Creek is dominated by a 35-yr-old stand of red alder (*Alnus rubra*). The stream gradient is $\approx 5\%$ and elevation 550 m at the sampling site. The sampling site at Grasshopper Creek (stream gradient 10%, elevation 915 m) lies within a clearcut completed in 1977. At the Berry Creek site the stream gradient is $< 0.5\%$ and elevation is $\approx 80 \text{ m}$, and at Oak

Creek values are 4–5% and 155 m. Riparian vegetation at Oak and Berry Creeks includes red alder, bigleaf maple (*Acer macrophyllum*), and various shrub species.

Sampling methods. An initial sample was excavated from Berry Creek in March 1982 from a diversion channel used for experiments (Baker et al. 1983). A second set of samples was excavated with a shovel in June 1982 from the upper 10–20 cm of pool sediments at Grasshopper and Quartz Creeks, from sand and gravel bars within Grasshopper and Quartz Creeks, and from a pool bank at Quartz Creek. Because excavation yielded large amounts of coarse mineral particles, the next set of samples was collected with a bilge pump, which removes mainly fine particles from the pool bottoms. These suction samples were collected in 1982 from Mack and Quartz Creeks (late August) and from Grasshopper Creek (early September).

For comparison, forest soil was excavated in fall 1982 from three pits at Mack Creek and three at Quartz Creek, all located at the base of the slope but above the stream channel (a topographic position referred to here as toe-slope). The litter layer was removed and a 0–10 cm depth sample was taken. Recently fallen, waterlogged foliage was collected in September 1983 from Oak Creek. The leaves, mainly red alder, were thoroughly macerated with a blender. Several pieces of submerged Douglas-fir wood were collected from Mack Creek in July 1983 and were returned wet to the laboratory; only the readily fragmented material was analyzed.

Laboratory analysis. After the sediment was sieved (2 mm) to remove stones and coarse organic debris, it was centrifuged, and most of the water was decanted. For soils and submerged wood, centrifugation was unnecessary. All residues were then resuspended in a concentrated NaI solution that was adjusted to a specific gravity of 1.8 g/cm^3 with a hydrometer; the suspension was centrifuged, and the supernatant decanted. The residue was resuspended in 1.8 g/cm^3 NaI and the process repeated until all material with specific gravity $< 1.8 \text{ g/cm}^3$ had been removed; this usually required 2–3 cycles, and occasionally 5–6. The final residue (F3) was scraped onto a $1.0 \mu\text{m}$ polycarbonate filter and washed thoroughly, first with 1 mol/L NaCl and then with distilled water.

The decanted supernatants were combined and adjusted to a specific gravity of 1.4 g/cm^3 by adding distilled water, and the centrifugation process was repeated. The residue (F2) and the material in the supernatant (F1) were collected and washed with 1 mol/L NaCl and then with distilled water. All centrifugation was at 6000 rpm for 10 min. Surfactants were not used to improve dispersion because these adsorb on particles and inflate C contents (Young and Spycher

TABLE 1. Dry mass and composition of density fractions of foliage, submerged wood, and soil from Cascade Range riparian zones. F1 < 1.4 g/cm³, F2 = 1.4–1.8 g/cm³, F3 > 1.8 g/cm³. For entries that represent means of three or more samples, SE shown in parentheses.

Parameter	Fraction	Submerged foliage*	Submerged wood*	Toe-slope soil†	Floodplain soil‡	Pool sediment	
						Excavated§	Suction
Dry mass (% of sample)	F1	15	23¶	1 (<1)	0 (0)	0	2 (1)
	F2	76	76¶	15 (5)	<1 (<1)	<1	19 (4)
	F3	9	<1¶	84 (5)	>99 (<1)	>99	78 (5)
Carbon (% of total sample C)	F1	17	19	2 (<1)	0 (0)	0	5 (3)
	F2	80	81	41 (7)	19 (9)	10	43 (6)
	F3	3	<1	57 (7)	81 (9)	90	53 (6)
Nitrogen (% of total sample N)	F1	13	21	1 (<1)	0 (0)	0	4 (2)
	F2	84	79	31 (7)	3 (2)	2	27 (5)
	F3	3	<1	68 (7)	97 (2)	98	69 (5)
C/N ratio	F1	33	148	33 (3)	..#	..	54 (7)
	F2	24	179	32 (3)	70	51	55 (8)
	F3	27	...	19 (1)	8 (2)	5	25 (2)

* Single well-mixed composite sample, except as indicated by ¶.

† Mean of six soil pits, three at each site.

‡ Mean of three samples.

§ Mean of two samples.

|| Mean of five samples.

¶ Mean of two composite samples.

. . . insufficient material for analysis.

1979). Samples were not dispersed chemically or ultrasonically.

Fractions (F1–F3) were oven-dried (95°C), weighed, and ground (0.5 mm). C was analyzed with a Leco 12 automatic analyzer, and N was analyzed by Kjeldahl digestion (Se/CuSO₄ catalyst) followed by ammonium analysis by autoanalyzer (Technicon method number 334-74A/A). For Fe, Al, and Mn analyses, samples were digested in HF and analyzed by atomic absorption spectrophotometry (graphite furnace).

Results

Visual examination of the fractions separated from sediments and soils showed that the densimetric procedure successfully separated the fibrous material from most mineral and organo-mineral particles. The heaviest fraction (F3) from all samples appeared to be almost completely free of fibrous material. Clay- and silt-size mineral particles adhered to the fibrous debris in the lighter fractions (F1 and F2), but these particles were firmly attached and are probably best regarded as an integral part of the partly decomposed debris.

As expected, most of the foliage (91%) and submerged wood (99%) was light material (F1 and F2) (Table 1). In contrast, every toe-slope soil sample contained >60% of its dry mass in the heaviest fraction (F3), which accounted for 30–80% of the total soil C and 40–85% of the total soil N.

The floodplain and pool samples collected by excavation contained nearly all of their dry mass in the heaviest fraction (F3). Soil samples collected from the floodplain had less F1 and F2 material than did the

toe-slope soils. F3 accounted for a smaller but still major proportion of the pool samples collected by suction (Table 1), despite the fact that the suction method preferentially skimmed light material off the surface of the pool bed. This pattern held across all four sites and all sampling dates.

The heaviest fraction (F3) also accounted for most of the C and N in all pool sediment samples (Table 1). The proportion was again smaller for the samples collected by suction (53% of the C, 69% of the N) than for those collected by excavation (90% of the C, 98% of the N).

In each of the pool and floodplain samples, the two lighter fractions (F1 and F2) had similar, fairly high C/N ratios. The heaviest fraction (F3) consistently had a much lower C/N ratio (Table 1). The C/N ratio of F1 and F2 varied little with site or collection method, but the C/N ratio of F3 was affected markedly by collection procedure. The suction-collected fines averaged 25 ± 2 (SE), whereas the excavated floodplain and pool sediment samples together averaged 7 ± 1 . The latter value is extremely low relative to C/N ratios of F3 fractions of the toe-slope soils (19) and other Pacific Northwest soils (Young and Spycher 1979, Sollins et al. 1983, Spycher et al. 1983, Sollins et al. 1984).

Al, Fe, and Mn concentrations were measured in the stream-channel and floodplain light fractions (F1 and F2) because these lighter particles could have formed by co-precipitation of dissolved organics with polyvalent metal hydroxides (Davis 1980, Dahm 1981). Values ranged from 0.9 to 2.2% for Al, 0.5 to 4.1% for Fe, and 0.017 to 0.11% for Mn. Concentrations were

higher in F2 than in F1 but showed no clear pattern associated with site or collection method.

The Al and Fe values for F1 and F2 were unexpectedly high; analysis of the foliage of the four riparian tree species that account for >90% of the litterfall at our sites yielded much lower mean values (\pm SE in all cases) for Al ($0.021 \pm 0.09\%$) and Fe ($0.015 \pm 0.004\%$) but not for Mn ($0.057 \pm 0.018\%$). The F1 and F2 particles appeared to be coated with a combination of firmly adherent crystalline and amorphous mineral material, which could have accounted for the high Al and Fe concentrations.

Discussion

Fragmented but otherwise unaltered plant debris did not compose the bulk of the detrital C and N in the stream-channel and floodplain materials (<2 mm) that we sampled. The heaviest fraction (>1.8 g/cm³) accounted for the majority of the C and N in the fine detritus from the four streams but for only a small to negligible proportion of C and N in waterlogged riparian foliage and wood. Even the F1 material was substantially different in composition from the original plant material, Al and Fe having accumulated in large amounts.

The F3 material that we isolated could have been soil particles on which organic matter was already adsorbed when the particles entered the stream (Avnimelech and McHenry 1984), or it could have been particles that became coated with organics while in the stream bed (Hynes 1983, Rounick and Winterbourn 1983). It is unlikely that the F3 particles resulted solely from the co-precipitation of organic and inorganic solutes because the F3 material included a substantial amount of crystalline mineral matter, as evidenced by its physical appearance and high density.

Regardless of its origin, organic material adsorbed on mineral surfaces warrants further study as a source of or sink for C and N in streams. For example, Rounick and Winterbourn (1983) reported assimilation efficiencies ranging from 18 to 74% for stream invertebrates feeding on organic material adsorbed on stones. Ward and Cummins (1979) found, however, that detritivores fed stream detritus grew more slowly than those fed finely ground foliage. Such variable growth rates and assimilation efficiencies are to be expected if varying amounts of the detrital C and N in streams occur as relatively recalcitrant organo-mineral complexes.

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