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Organic matter dynamics in Hugh White Creek, Coweeta Hydrologic Laboratory, North Carolina, USA

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Hugh White Creek is a 2nd-order stream at Coweeta Hydrologic Laboratory in western North Carolina, USA. The 61.1-ha watershed drained by this stream was logged in the early 1900s but has been undisturbed since it became part of the National Forest in 1923, except for the death of one of the dominant forest trees (*Castanea dentata*) by chestnut blight in the 1930s (Douglass and Hoover 1988, Swank and Crossley 1988). The major forest trees are now oaks (*Quercus* spp.), hickories (*Carya* spp.), red maple (*Acer rubrum*), and yellow poplar (*Liriodendron tulipifera*). Streamside vegetation also has considerable birch (*Betula* spp.) and dense stands of rhododendron (*Rhododendron maximum*). The watershed has been used as a reference for hydrologic studies and except for one 3-y period has been continuously gaged since 1937. The stream has been the site of many ecological studies since being chosen as a reference for a clearcut logging experiment in 1975 (Gurtz and Wallace 1984). In addition to measurements made on Hugh White Creek, many other streams at Coweeta have been studied by various researchers, and we have used some data from other streams in this summary.

The climate at Coweeta is mild and humid (Swift et al. 1988). Mean monthly air temperatures range from 3°C (January) to 22°C (July). Annual precipitation is 188 cm for the watershed drained by Hugh White Creek. Rainfall occurs fairly evenly throughout the year though is somewhat less probable in autumn. On average 133 storms occur annually. Only 2–10 % of annual precipitation occurs as snow.

The main channel of Hugh White Creek is 1125 m long and has a high gradient typical of small mountain streams of the southern Appalachians (Table 1). Average water temperature is about 12°C (Stout et al. 1993), and discharge has averaged 19 L/s over the past 57 y. Baseflow is typically high in winter and spring, when evapotranspiration is low, and lower during the growing season and early fall. Throughout the year discharge is modified by frequent storms (Swift et al. 1988).

The relatively resistant crystalline rocks of Coweeta provide very low levels of dissolved nutrients to the streams. Data from Hugh White Creek reported by Swank and Waide (1988) and Golladay et al. (1992) show NO_3-N of 3–4 μg/L, NH_4-N of 3–9 μg/L, and SRP of 2 μg/L. Ca averages 0.39–0.45 mg/L and K 0.34 mg/L. Alkalinity is low (<10 mg $CaCO_3$/L) and pH is circumneutral (6.7).

TABLE 1. Physical characteristics and organic matter parameters for Hugh White Creek. All organic matter parameters are in AFDM.

Variable	Value	References and notes
Physical characteristics		
Latitude	35°N	
Order	2	
Watershed area (ha)	61.1	Swank and Crossley (1988)
Streambed area (m^2)	8085	Webster et al. (1990)
Gradient (m/m)	0.15	Webster et al. (1990)
Mean annual water temperature (°C)	12	Stout et al. (1993)
Mean annual discharge (L/s)	19	Swift et al. (1988)
Mean annual precipitation (cm)	188	Swift et al. (1988)
Inputs (g m^{-2} y^{-1})		
Gross primary production	5.8	Webster et al. (1983)
Litterfall	506.3	Webster et al. (1990)
Lateral movement	71.2	Webster et al. (1990)
Groundwater DOM	132	Meyer and Tate (1983)
Throughfall	18	Meyer and Tate (1983)
Standing crops (g/m^2)		
CBOM > 1 mm (not including wood)	213	Golladay et al. (1989)
FBOM < 1 mm	166	Golladay et al. (1989)
Wood > 1 mm	5446	Golladay et al. (1989)
Outputs		
Autotrophic respiration (g m^{-2} y^{-1})	2.9	50% GPP
Heterotrophic respiration (g m^{-2} y^{-1})	221.6	Schaeffer (1993), Tank et al. (1993)
Particulate transport (kg/y)	4326	Webster et al. (1990)
Dissolved transport (kg/y)	1796	Meyer and Tate (1983)

Inputs

Periphyton primary production was measured in 1977–1979 (Hains 1981) and 1980–1981 (Webster et al. 1983) using ^{14}C uptake on natural substrates in water-recirculating chambers similar to those used by Hornick et al. (1981). Primary production averaged 0.3 mg C m^{-2} h^{-1}. Assuming that carbon is 45% of dry weight, that production occurs 12 h per day, and that ^{14}C uptake approximates net primary production, annual NPP was about 2.9 g AFDM m^{-2} y^{-1} (Webster et al. 1983). This very low rate of primary production is apparently due to light limitation (Lowe et al. 1986). Visible light reaching streams on forested watersheds at Coweeta can be much less than 1% of the light above the forest canopy (Webster and Patten 1979). However, low nutrient levels and scarcity of stable substrates may also limit primary production. Bryophytes are abundant where substrates are stable, but their production has not been measured.

Allochthonous inputs of particulate organic matter were measured in 1983–1984 (Webster et al. 1990). Litterfall was measured in 0.25-m^2 rectangular traps. Four traps were placed over or adjacent to the stream at each of 5 sites along the main stream. Also, two 40-cm wide lateral movement traps were placed on each bank at each site. Material in the traps was collected 10 times over 12 mo. The material was dried and sorted into leaves and wood (whole leaves were identified to species when possible), and subsamples were ashed to determine percent organic matter. Total AFDM of litterfall averaged 506.3 g m^{-2} y^{-1} of which 415.4 g was leaves and 90.9 g was wood. Four types of leaves accounted for over 70% of the litterfall: birches 27.1%, oaks 17.6%, rhododendron 14.2%, and yellow poplar 12.6%. Total lateral movement was 98.1 g m^{-1} y^{-1}, 88.8 g leaves and 9.2 g wood. Assuming equal lateral movement from each side over the total 2932 m of stream in the watershed (Webster et al. 1990), total lateral movement on an areal basis was 71.2 g m^{-2} y^{-1}.

DOC input to Hugh White Creek was measured by Meyer and Tate (1983). Water samples were collected from 6 seeps every 2 wk for 1 y. DOC concentrations in these samples were multiplied by total water discharge from the watershed with an adjustment to account for concentration changes during storms. Volume and DOC concentration of throughfall (channel interception) were measured in five 2 × 0.15-m metal troughs. Samples were collected at 2-wk intervals. From their data, Meyer and Tate (1983) estimated total subsurface water input of 522–548 kg C/y for the entire stream network. Throughfall input was 74 kg C/y. Assuming that DOC represents 50% of dissolved organic matter and using a total streambed area of 8085 m^2, the inputs of dissolved organic matter were 132 g m^{-2} y^{-1} from subsurface water and 18 g m^{-2} y^{-1} from throughfall.

Standing crops

Benthic organic matter, except for wood >1 cm diameter, was measured quarterly in 1985–1986 (Golladay et al. 1989). On each date 60 samples were collected with a 0.071-m^2 circular sampler. Material in the sampler was passed through a 1-mm mesh net. The material in the net (CBOM) was dried, weighed, and subsampled to determine AFDM. A subsample of the material passing through the net was filtered, dried, weighed, ashed, and reweighed; and FBOM was calculated from the volume of sample and the volume of subsample. In summer 1985, small (1–5 cm diameter) and large (>5 cm diameter) wood was measured in 1-m wide transects across the stream. One transect was randomly selected in each of 20 equal segments of the main stream. All small wood was collected, wet weighed in the field, and subsampled. Subsamples were weighed, dried, reweighed, ashed, weighed again, and used to estimate the total AFDM of small wood in the sample area. When possible, the same procedure was used for smaller pieces of large wood—small logs were weighed individually and subsampled. For logs too large to weigh, diameter and length were measured to determine volume. A subsample was measured, dried, weighed, ashed, and reweighed, and used to calculate the AFDM of the log. Total BOM averaged over the year was 5825 g/m^2. Of this total, 166 g/m^2 was FBOM, 213 g/m^2 was CBOM not including wood >1 cm diameter (leaves, fruits, flowers, small sticks, etc.), 312 g/m^2 was small wood, and 5134 g/m^2 was large wood.

Outputs

Respiration of BOM has not been measured in Hugh White Creek, but Tank et al. (1993) measured respiration on CBOM from Ball Creek, the stream into which Hugh White Creek drains, and Schaeffer (1993) measured respiration of FBOM from Ball Creek. Tank et al. (1993) measured respiration on birch and rhododendron leaves and small sticks using oxygen change in opaque, water-recirculating chambers (Tank and Mussen 1993). Respiration (mg O_2·g $AFDM^{-1}$·h^{-1}) averaged 0.12 mg on birch leaves, 0.08 mg on rhododendron leaves, and 0.01 mg on sticks. To calculate respiration in Hugh White Creek, we used the following assumptions: an average of birch and rhododendron leaves is applicable to all leaf material; RQ = 1; respired organic matter is 50% carbon. Multiplying respiration rate by leaf standing crop gives 139.9 g m^{-2} y^{-1} of total leaf respiration. Using similar assumptions, respiration on small wood is 20.5 g m^{-2} y^{-1}. We have not attempted to estimate respiration on large wood, so our estimate of total respiration is undoubtedly low.

Schaeffer (1993) collected FBOM from 3 sites on Ball Creek and measured respiration in the laboratory with a Gilson respirometer. The average respiration was 0.041 μL O_2·mg $AFDW^{-1}$·h^{-1}. Assuming an ideal gas at 12°C, this value was converted to mass and, using other assumptions as above, we calculated an average FBOM respiration rate of 0.369 g g^{-1} y^{-1}. Multiplying this value by the FBOM standing crop gives 61.2 g m^{-2} y^{-1} annual FBOM respiration.

Samples of particulate organic matter in transport were collected from Hugh White Creek during baseflow and during 9 storms in 1984–1985 (Golladay et al. 1987). Storm samples were collected with an ISCO automated sampler at frequencies ranging from 5 min to several h depending on storm intensity. We collected 15 to 25 samples during each storm. Samples were filtered (0.45 μm glass fiber filter), dried, weighed, ashed, and reweighed, and organic particle concentration was calculated as mass loss on ashing. Because of the hysteritic nature of the relationship between particle concentration and discharge (e.g., Golladay et al. 1987), it was not possible to use simple rating curves to calculate annual transport. Using data from that study, Webster et al. (1990) developed an empirical model of organic particle concentration based on: 1) the relationship between particle concentration and the rate in increase in discharge during rising hydrographs, and 2) concentration and time since peak during falling hydrographs. From the model, particle transport from Hugh White Creek during 1984–1985 was estimated at 4326 kg/y. Approximately 80% of this transport occurred during storms.

DOC export was estimated from grab samples collected at 2-wk intervals and from samples taken during storms in 1979–1980 (Meyer and Tate 1983). Export was calculated on a seasonal basis using mean non-storm concentrations for non-storm periods and a concentration–discharge regression for storms. Annual export was estimated at 873–923 kg C/y or (assuming carbon is 50% of organic matter) 1796 kg/y DOM.

Conclusions

Work on Hugh White Creek is continuing. The work summarized here provides a baseline for long-term measurements of organic processes in this stream and in this region. Our current emphasis is remeasurement of litter inputs and rates of leaf breakdown, measurement of primary production using oxygen production methods, and remeasurement of CBOM standing crop. In addition to studies of organic process, considerable work has been done and is continuing on nutrient dynamics, biofilm development, and the structure and production of invertebrate communities in Hugh White Creek.

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Organic matter dynamics in Sycamore Creek, a desert stream in Arizona, USA

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Sycamore Creek is an intermittent Sonoran Desert stream in the Basin and Range Province 32 km northeast of Phoenix, Arizona, USA. The drainage basin (505 km^2) varies in elevation from 427 to 2164 m and is composed of igneous and metamorphic rock with shallow overlying soils and unconsolidated sediments (Thomsen and Schumann 1968). Precipitation in the Sycamore Creek watershed averages only 34 and 58 cm/y in lower and upper elevations, respectively, and nearly all falls as rain (Thomsen and Schumann 1968). Evapotranspiration is quite high (pan evaporation = 310 cm/y); consequently mean annual discharge from this 5th-order river is only 0.8 m^3/s (US Geological Survey 1989–1993), and on average only 8% of precipitation runs off (Grimm 1993). Rain at higher elevations in the watershed feeds permanent flow in lower-elevation reaches of Sycamore Creek. High-elevation precipitation recharges aquifers that drain into porous alluvium. Lower-elevation permanent reaches occur where geologic faulting brings impervious bedrock to the surface. Downstream from these "sources," surface flow may exist for a few m to several km before water seeps back into sediments.

Rain is bimodally distributed with peaks during winter (January–March) and the summer "monsoon" of late July through September. Winter precipitation is usually gentle and spans one or more d, whereas summer rain occurs as short, localized thunderstorms. Runoff from storms produces spates (flash floods) in streams of the Sonoran Desert that are among the most severe in North America (Baker 1977, Ely et al. 1993). Winter storm flow typically remains elevated for some time. In contrast, summer thunderstorms frequently produce flash floods during which discharge rises rapidly then recedes within hours. Stream flow is lowest in summer (0.01–0.05m^3/s) and highest in winter (0.1–2.5 m^3/s).

Vegetation in the Sycamore Creek watershed is chiefly Sonoran Desert scrub except in the highest elevations where juniper (*Juniperus* spp.), oak (*Quercus* spp.), piñon pine (*Pinus edulis*), and ponderosa pine (*P. ponderosa*) occur. Riparian vegetation is sparsely distributed along a channel that is >20 m wide, and thus trees do not appreciably shade the stream. Shrubs (<2 m high) such as seep willow (*Baccharis salicifolia*) and burro bush (*Hymonoclea monogyra*) are common along the wetted channel, while large trees such as sycamore (*Platanus wrightii*), cottonwood (*Populus fremontii*), mesquite (*Prosopis glandulosa*), ash (*Fraxinus pennsylvanica velutina*), willow (*Salix goodingii*), and walnut (*Juglans major*) are restricted to stream margins inundated only during highest flows.

Distinct longitudinal changes in geomorphol-

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