Effects of Clear-cut Logging on Wood Breakdown in Appalachian Mountain Streams

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ABSTRACT: Red oak (*Quercus rubra*) sticks, approximately 10-cm long and in three size classes (large, 3-cm diam, 22-55 g; medium, 1-2-cm, 12-22 g; small, <1-cm, 3-12 g) were placed at five sites in two second-order streams at Coweeta Hydrologic Laboratory. One stream, Big Hurricane Branch, drains a watershed logged in 1976 (WS 7); the other stream, Hugh White Creek, drains an uncut reference watershed (WS 14). Ten sticks of each size class were collected from each site at 6-month to 1-year intervals from September 1981 through November 1985. Calculated breakdown rates ranged from 0.107 to 0.281 y^{-1}. Breakdown rates were significantly different among size classes on both watersheds—smaller sticks lost mass faster than larger sticks. Breakdown rates of similar size sticks were significantly faster in Big Hurricane Branch, the disturbed stream, than in Hugh White Creek. Faster rates of wood breakdown in Big Hurricane Branch may be associated with higher stream NO_3-N levels, greater stream channel instability and greater invertebrate abundance on sticks.

INTRODUCTION

Woody debris plays an important stabilizing role in stream ecosystems (Heede, 1972; Swanson *et al.*, 1976; Bilby, 1981; Mosley, 1981; Likens and Bilby, 1982). Organic matter tends to accumulate into debris dams behind logs large enough to span stream channels and not be displaced by stream flow (Bormann *et al.*, 1969; Swanson and Lienkaemper, 1978; Likens and Bilby, 1982). Such aggregation of material and retention in debris dams conserves allochthonous inputs and increases instream processing of organic matter (Bilby and Likens, 1980; Triska and Cromack, 1980; Bilby, 1981). These debris dams produce a stepped pattern of stream bed morphology, reducing stream power, erosiveness and sediment transport (Heede, 1972; Fisher and Likens, 1973; Swanson *et al.*, 1976; Keller and Swanson, 1979; Bilby, 1981) and filter dissolved and suspended particulate material from the water column (Swanson and Lienkaemper, 1978; Keller and Swanson, 1979; Bilby, 1981; Mosley, 1981; Triska *et al.*, 1982). Decomposing woody debris also appears to be an important site of nitrogen fixation and immobilization (*e.g.*, Buckley and Triska, 1978; Aumen *et al.*, 1983, 1985a, 1985b; Baker *et al.*, 1983; Melillo *et al.*, 1983) and, in addition woody debris creates habitat for aquatic organisms (Anderson and Sedell, 1979; Molles, 1982). Finally, fine particles eroded from the surface of decomposing wood may contribute significantly to the fine organic matter pool and provide a food source for downstream communities (Naiman and Sedell, 1979; Ward and Aumen, 1986).

Logging has been a common disturbance to the forests of North America and results in a variety of long-term effects on streams. Removal of terrestrial vegetation results in increased streamflow (*e.g.*, Kovner, 1956; Hewlett and Hibbert, 1961) and stream temperature (Swift and Messer, 1971). Logging may also increase stream sediment loads (Lieberman and Hoover, 1948; Tebo, 1955; Brown and Krygier, 1971; Paustain and Beschta, 1979) and nutrient levels (Likens *et al.*, 1970; Swank and Douglass, 1975; Vitousek and Melillo, 1979; Martin *et al.*, 1984). Perhaps the most significant result of forest logging is the alteration of the energy base of stream ecosystems. Following forest cutting, allochthonous leaf inputs to streams are greatly reduced (Webster and Waide, 1982). Rapid regrowth of riparian vegetation may return the stream to a detritus base within a few years (Swanson *et al.*, 1982; Webster *et al.*, 1983); however, the composition of detrital inputs may change considerably from mostly late successional, decay-resistant litter to rapidly decaying, early successional litter (Webster *et al.*, in press). Following logging, alteration in both the quantity and quality of leaf litter inputs to streams may result in inadequate food availability for stream consumers. Immediately following logging, inputs of woody debris (slash) may be relatively high, and inputs of small wood to streams may continue throughout the early and intermediate stages of forest recovery as self-thinning of successional vegetation occurs (Likens and Bilby, 1982).

Traditionally, wood has been viewed as a relatively decay-resistant, low-quality food resource for stream consumers. However, Willoughby and Archer (1973) demonstrated that wood is rapidly colonized by aquatic hyphomycetes, a preferred food resource for stream consumers (Anderson and Sedell, 1979; Cummins and Klug, 1979). Also, many common larval stream insects colonize and ingest decaying wood or the microorganisms growing on its surface (Dudley and Anderson, 1982; Pereira *et al.*, 1982; Anderson *et al.*, 1984). Following forest disturbance, accumulations of woody debris may be an important resource to stream consumers; wood may provide stable substrate for colonization and be a potential food resource during the early stages of stream recovery. We examined the importance of small woody debris in streams by examining insect colonization and breakdown rates of wood in a stream draining a recently clear-cut watershed and a stream draining mixed hardwood forest.

SITE DESCRIPTION

This work was conducted at Coweeta Hydrologic Laboratory, Macon County, North Carolina. Stick breakdown was measured in two second-order streams. The first, Big Hurricane Branch drains watershed 7, a 58.7-ha experimental watershed, which was lightly grazed by cattle from 1941-1942 and cable-logged during the winter of 1976-1977. Regrowth is dominated by hardwood sprouts, herbs, vines and seedlings (Boring *et al.*, 1981). The second stream, Hugh White Creek, drains watershed 14, a 61.1-ha long-term reference watershed. Watershed 14 was selectively logged prior to 1925 but except for chestnut blight has been undisturbed for 60 years. Further characteristics of the streams are listed in Table 1.

METHODS

Red oak sticks (*Quercus rubra*) were collected from a single downed tree at Coweeta. The tree had been dead for approximately 1 year. Care was taken to collect sticks from elevated branches with bark still intact. Sticks were air-dried, cut into 10-cm lengths, and sorted into three size categories: large > 3-cm diam, 22-55 g; medium 1-2-cm diam, 12-22 g; and small < 1-cm diam, 3-12 g. Two sticks of each size were weighed, tagged and individually tethered using monofilament line tied to galvanized steel gutter nails. Stick packs (250 total) were placed in shallow cobble riffles (three sites on Big Hurricane Branch, two sites on Hugh White Creek) by hammering the gutter nails into the stream substrate.

TABLE 1.—Characteristics of the study streams

	Stream	
	Big Hurricane	Hugh White
Watershed	7	14
Area (ha)	58.7	61.1
Main channel length (m)	1225	1125
Gradient (m/m)	0.19	0.15
Average annual discharge (L/sec)	18.5	19.4
Average annual temperature (C)	10.2	9.8

Stick packs were placed in the streams on 26 July 1981, and five packs were picked up from each site at 6-month to 1-year intervals through November 1985 (pickup dates: 21 September 1981, 29 January 1982, 19 April 1983, 22 October 1983, 18 November 1984, 25 November 1985). Packs were collected by placing the tethered sticks and associated detritus into a 1-mm mesh aquarium net and then pulling the nail from the stream bottom. Stick packs were placed in plastic bags, returned to the laboratory and placed on ice. Invertebrates were removed from the sticks by washing with a water jet and soft bristle brush, rinsed onto a 125-μm sieve, sorted live and preserved in 70% ethanol. Insects (except Diptera) were identified to genus, counted and assigned to functional group according to Merritt and Cummins (1984). Diptera were identified to family, counted and where possible assigned to functional group. Chironomids were counted but not assigned to a functional category. Other invertebrates were identified to order or family, counted, and assigned to functional groups based on descriptions of food habits (Pennak, 1978).

Stick packs were air-dried to a constant weight and the weight remaining of each stick was recorded. Homogenized subsamples were ashed at 550 C for 40 min to obtain ash-free dry weight (AFDW). Exponential breakdown rates (-k) were calculated by regressing ln (percent remaining) against exposure time (reviewed by Webster and Benfield, 1986).

RESULTS

Wood breakdown rates.—Breakdown rates (-k) were significantly different (linear regression, slope$\neq$0, $\alpha = 0.05$) from zero for regressions of ln (percent remaining) vs. time for all wood sizes at each site. Within streams, there were no significant differences between sites (analysis of covariance, $\alpha = 0.05$) in the breakdown rates of similar-sized sticks, so data from the sites was pooled in subsequent analyses (Table 2). For each stick size, breakdown rates were always significantly faster (analysis of covariance, $\alpha = 0.05$) in Big Hurricane Branch, the disturbed stream than in Hugh White Creek, the reference stream. The time until 50% breakdown (T_{50} values) ranged from 13.9 years for small sticks to 23.1 years for large sticks in Big Hurricane Branch, and from 24.2 to 36.7 years in Hugh White Creek (Table 2). In Hugh White Creek, the breakdown rate of small sticks was significantly faster than medium or large sticks (analysis of covariance, $\alpha = 0.05$). In Big Hurricane Branch, small and medium sticks decayed significantly faster than large sticks (analysis of covariance, $\alpha = 0.05$). The breakdown rates of each size class of sticks appeared to be constant in each stream over the course of the study.

By the April 1983 sample, sticks in both streams had lost large pieces of bark which appeared to have sloughed from the sticks. The remaining bark was soft but the wood beneath was still hard. At the end of the study (November 1985), most of the bark was missing from sticks in both streams, but the remaining wood had a firm texture. Sticks collected from Big Hurricane Branch were deeply grooved, presumably the result of invertebrate activity.

TABLE 2.—Breakdown rates (-k) of three sizes of red oak sticks. T_{50} values are time until 50% breakdown estimated from regressions of ln (percent remaining) vs time

Stream	Size	n	Breakdown rate (y^{-1})	SE	T_{50}	r^2
Big Hurricane	small	196	0.281	0.014	13.9	0.68
	medium	212	0.241	0.014	16.1	0.59
	large	215	0.169	0.005	23.1	0.82
Hugh White	small	136	0.161	0.010	24.2	0.67
	medium	145	0.122	0.007	32.1	0.63
	large	138	0.107	0.005	36.7	0.76

Invertebrate abundance on stick packs.—Taxa richness (number of taxa) and density (organisms per pack) were significantly higher on stick packs from Big Hurricane Branch than from Hugh White Creek (Table 3). Chironomidae were the most abundant organisms on stick packs in both streams accounting for 33.5% of total invertebrate abundance in Big Hurricane Branch and 39.2% in Hugh White Creek. Chironomid densities were significantly higher in Big Hurricane Branch than in Hugh White Creek (ANOVA, $\alpha = 0.05$). Collectors were the second most abundant group of organisms on stick packs in the disturbed stream and accounted for 22.5% of total invertebrate density. Collectors were less common in the reference stream (ANOVA, $\alpha = 0.05$) and accounted for 13.5% of total invertebrate abundance.

Scrapers represented 19.5% of the invertebrate density in Big Hurricane Branch and 8.5% in Hugh White Creek. The most abundant scraper was *Lype* sp. (Trichoptera: Psychomyiidae) which represented 90% of the scraper density in Big Hurricane Branch and 75% in Hugh White Creek. *Lype* sp. is commonly associated with small woody substrates in Coweeta streams (J.B. Wallace, pers. comm.) and constructs a retreat of silk and detritus covering grooves in pieces of submerged wood (Wiggins, 1977). *Lype* sp. densities were significantly higher (ANOVA, $\alpha = 0.05$) on sticks in Big Hurricane Branch than in Hugh White Creek.

Shredders and predators combined accounted for 21% of total density on stick packs in Big Hurricane Branch and 36% in Hugh White Creek. Predator densities were significantly greater (ANOVA, $\alpha = 0.05$) on stick packs in Big Hurricane Branch than in Hugh White Creek. There was no significant difference in shredder densities on stick packs between streams. No gougers were collected from stick packs. However, the food habits of many Coweeta invertebrates are poorly understood and thus xylophagous invertebrates, if present, may have been placed in one of the other groups.

Pattern of invertebrate colonization.—A one-way analysis of variance followed by a least squares means analysis was used to make comparisons of invertebrate density on stick packs between pickup dates for each stream. A protected alpha level of 0.05 was used to determine significant differences in invertebrate densities between sample dates.

In Big Hurricane Branch, the disturbed stream, taxa richness was highest in the August 1982 stick collection, then declined throughout the rest of the study (Fig. 1A). The August 1982 collection had significantly more taxa than the 1983 or 1985 collections, with the other pickup dates having intermediate taxa richness. In Hugh White Creek, the reference stream, the pattern of taxa richness was less distinct. The November 1984 collection had significantly more taxa than April 1983, all other dates were intermediate in taxa richness. Invertebrate density on stick packs in Big Hurricane Branch was highest on the first pickup date and generally declined over the study (Fig. 1B). The last collection (November 1985) had significantly fewer organisms than the October 1983, November 1984 or January 1982 collections. On the other dates intermedi-

TABLE 3.—Invertebrate abundance and densities on stick packs. Values are number per pack and represent averages over the entire study. * indicates a significant difference between streams (ANOVA, $\alpha = 0.05$)

	Big Hurricane Branch				Hugh White Creek		
	Mean	SE	n		Mean	SE	n
# taxa	9.84	0.42	109	*	5.22	0.29	77
Density	38.91	2.36	109	*	15.17	1.31	77
Chironomids	13.03	1.57	109	*	5.95	0.77	77
Collectors	8.66	0.73	109	*	2.05	0.28	77
Lype	6.82	0.89	109	*	1.03	0.19	77
Shredders	4.18	0.52	109		3.47	0.66	77
Predators	3.96	0.35	109	*	2.03	0.20	77

ate invertebrate densities were observed. In Hugh White Creek the pattern of invertebrate density was similar to Big Hurricane Branch, sticks collected on the first pickup (September 1981) had significantly higher densities than any other date. Chironomid density strongly influenced overall invertebrate densities observed on stick packs (Fig. 2A). In both streams, chironomid density was significantly higher on sticks collected on September 1981 than any other date. Chironomid densities on sticks declined from the first pickup through the end of the study in both streams.

Lype sp. densities were highest on sticks collected in October 1983 in Big Hurricane Branch (Fig. 2B). Peak density was significantly higher than those observed on any other collection date. In Hugh White Creek, there was no significant difference in *Lype* densities among pickup dates.

In Big Hurricane Branch collector, predator and shredder abundance on stick packs was highest in the middle of the study (1982-1984) and declined through the end, with the November 1985 collection being significantly lower than peak densities. In Hugh White Creek shredder densities were highest on sticks on the first pickup date and declined throughout the study. Collector densities increased throughout the study, and predator densities were variable on sticks in Hugh White Creek.

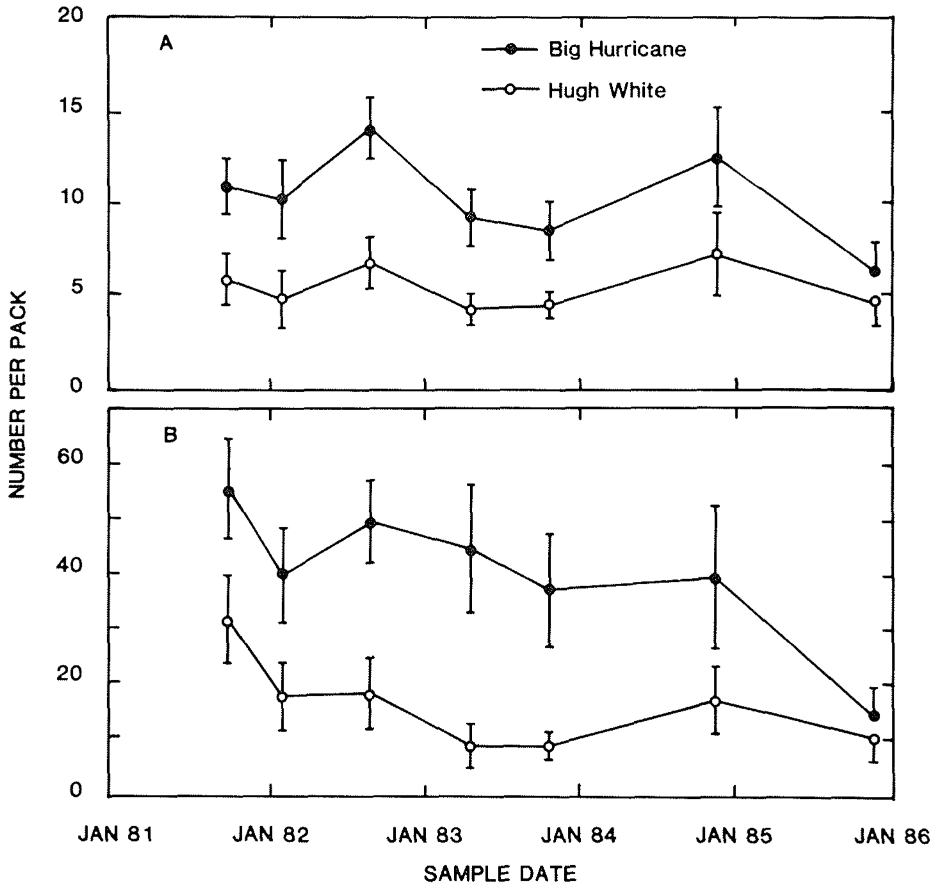

Fig. 1.—(A) Taxa richness and (B) invertebrate density on stick packs in Coweeta streams. Values are mean number per pack and standard errors

Discussion

Wood breakdown in terrestrial and aquatic systems.—Wood decomposition is a complex process governed by a variety of interacting factors including wood composition, presence of microbial inhibitors, moisture availability presence of oxygen, nutrient availability, and ambient temperature (reviewed by Harmon *et al.*, 1986). However, it is possible to make some generalizations about wood degradation. Decomposition rates decrease with increasing wood diameter and percent composition of heartwood (Triska and Cromack, 1980). Generally, gymnosperm wood degrades more slowly than angiosperm wood, with differences attributed to lower percent living tissue, simpler structural composition, lower nutrient levels, higher percent lignin and greater concentrations of microbial inhibitors in gymnosperm wood (Triska and Cromack, 1980; Melillo *et al.*, 1984; Harmon *et al.*, 1986). In aquatic systems, slow diffusion rates of oxygen restrict decomposer activity to the surface layers of large woody debris (Triska and Cromack, 1980; Aumen *et al.*, 1983; Harmon *et al.*, 1986). On land, ample oxygen enables penetration of large woody debris by microbes and gallery-forming invertebrates resulting in faster wood degradation than observed in most aquatic systems (Triska and Cromack,

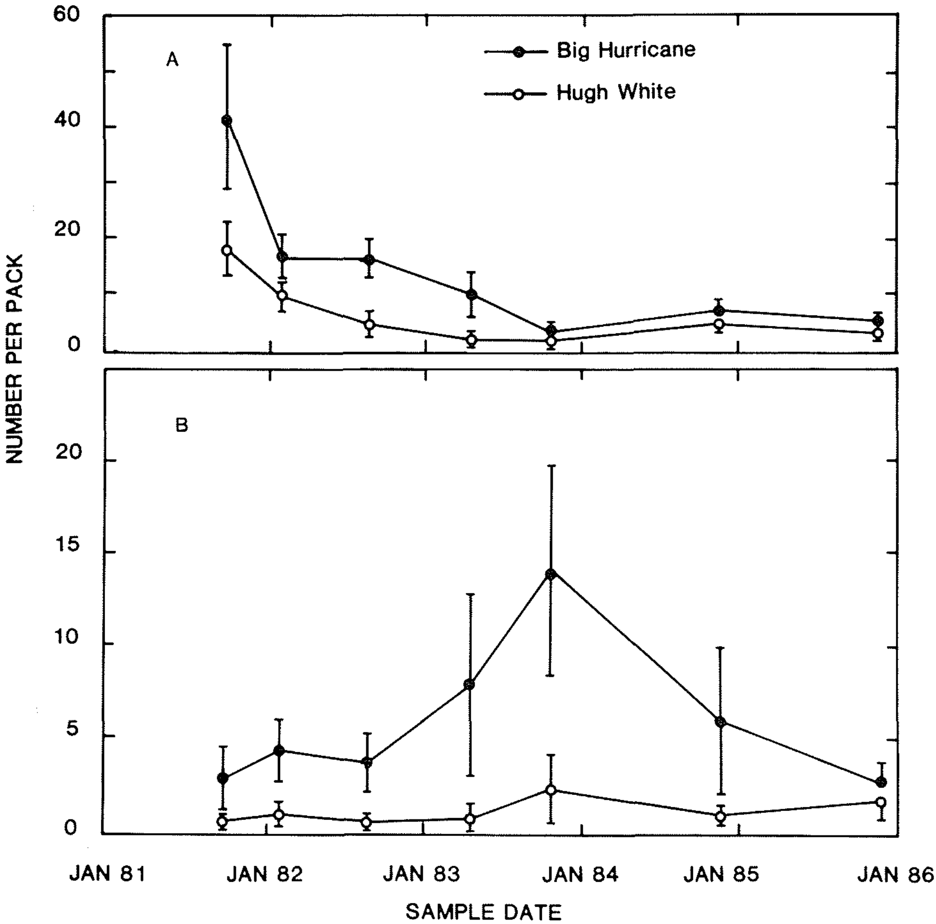

Fig. 2.—(A) Chironomid density and (B) *Lype* sp. density on stick packs in Coweeta streams. Values are number per pack and standard errors

1980; Harmon *et al.*, 1986). In terrestrial systems, wood decomposition rates are often limited by temperature (optimum 10-30 C) and moisture (Harmon *et al.*, 1986). In aquatic systems, problems with oxygen diffusion limiting decomposition become less critical with decreasing wood diameter (and increasing surface area); thus small woody debris often decomposes more rapidly in aquatic systems than on land (Triska and Cromack, 1980).

In a comparison of breakdown rates of woody debris from different ecosystems, the slowest rates observed were for large (>30 cm diam) gymnosperm logs decaying on the floor of a coniferous forest (Graham and Cromack, 1982) (Table 4). The range of rates we observed in this study (0.107-0.281 y^{-1}) were similar to the breakdown rates observed by other investigators. The fastest wood breakdown rate observed in aquatic sys-

TABLE 4.—Selected breakdown rates of woody debris in terrestrial and aquatic ecosystems. Values are decay coefficients in $years^{-1}$, diameter of the material is indicated in centimeters

Reference	k (y^{-1})	Species	Site
Graham and Cromack (1982)	0.0119	Sitka spruce <60 cm *Picea sitchensis*	terrestrial
	0.0230	Western hemlock <30 cm *Tsuga heterophylla*	terrestrial
Fogel and Cromack (1977)	0.059-0.089	doug. fir ~1 cm *Pseudotsuga menziesii*	terrestrial
Harmon (1982)	0.04-0.18	deciduous and conifer species, 5-15 cm	terrestrial (standing dead)
Abbott and Crossley (1982)	0.059-0.139	Chestnut oak, 1-5 cm *Quercus prinus*	terrestrial
MacMillan (1981)	0.0295	oak >5 cm *Quercus* spp.	terrestrial
Chamie and Richardson (1978)	0.182	Willow ~1 cm *Salix* spp.	wetlands
	0.082	Bog birch ~1 cm *Betula pumila*	
Hodkinson (1975)	0.120	Spruce, bark *Picea glauca*	pond
Brinson (1977)	0.28	Black gum, 0.2-1.5 cm *Nyssa aquatica*	swamp
Day (1982)	0.179-0.305	Red maple ~3 cm *Acer rubrum*	swamp stream
Blackburn and Petr (1979)[1]	0.76	*Eucalyptus* spp. bark	
Melillo *et al.* (1983)[1]	1.20	Alder chips *Alnus rugosa*	headwater stream
	0.95	Birch chips *Betula papyrifera*	
	0.40	Aspen chips *Populus tremuloides*	
	0.35	Spruce chips *Picea mariana*	
	0.25	Fir chips *Abies balsamea*	
This study	0.107-0.281	Red oak, 1-3 cm *Quercus rubra*	headwater stream

[1]estimated from figures in the text

tems was for alder chips (1.20 y^{-1}, *e.g.*, Melillo *et al.*, 1983) and can be attributed to the high surface area of wood chips, and composition of alder wood (*i.e.*, high nitrogen, low lignin).

Abbott and Crossley (1982) reported breakdown rates of 0.138 y^{-1} at mesic sites and 0.059 y^{-1} at xeric sites for 1-5-cm diam chestnut oak sticks on Watershed 7 at Coweeta. Breakdown rates we observed in Big Hurricane Branch (which drains WS-7) averaged 0.281 y^{-1} for 1-3 cm diam red oak sticks. Although we used somewhat smaller sticks in our study, these results suggest that the temperature and moisture regime reduces decomposition rates of small woody debris in terrestrial compared to aquatic systems (*e.g.*, Triska and Cromack, 1980).

The breakdown of leaf litter in aquatic systems ranges from 0.365-3.65 y^{-1} with the slowest rates observed for the Pinaceae (conifers) and the fastest observed for the Tiliaceae (basswood) (reviewed by Webster and Benfield, 1986). The breakdown rate of conifer litter appears to be of the same magnitude as the breakdown rate of the most labile fine, woody debris; however, breakdown rates of deciduous leaf litter are generally an order of magnitude or more faster than those observed for fine wood.

FACTORS AFFECTING WOOD BREAKDOWN

As described in the introduction, logging changes streams in a variety of ways. Our study demonstrated clear, statistically significant differences between breakdown rates in the two streams, but because of the design of our study (*i.e.*, no replication of treated or reference streams) we cannot statistically attribute the difference in breakdown rates directly to watershed logging. However, many of the changes in streams associated with logging have also been demonstrated to have a strong effect on the breakdown rates of organic matter in aquatic systems.

Stream temperatures.—Ambient temperature strongly influences decomposition rates of organic material in aquatic systems (reviewed by Harmon *et al.*, 1986; Webster and Benfield, 1986). Since increases in stream temperature have been observed following logging (*e.g.*, Swift and Messer, 1971), the increased breakdown rates we observed might be attributed to higher stream temperatures in Big Hurricane Branch. Swift (1983) found that stream temperatures in Big Hurricane Branch were elevated immediately following logging, but within 3 years temperatures had returned to predisturbance levels. Average temperatures (measured from August 1984 through July 1985, Table 1) indicated no significant differences between the streams (Paired t-test, $P > 0.50$), though temperatures of Hugh White Creek fluctuated somewhat more than those of Big Hurricane Branch being somewhat higher during summer and lower during winter. During our study, stream temperature probably did not contribute substantially to differences in wood breakdown rates observed between streams.

Stream nutrient levels.—The decomposition rate of woody debris in aquatic systems is often limited by its nutrient composition (Triska and Cromack, 1980; Melillo *et al.*, 1984). Since the C/N ratio of woody debris ranges from 300-1300, the availability of nitrogen can strongly influence decomposition rates (Triska and Cromack, 1980; Melillo *et al.*, 1984). Aumen *et al.*, (1983, 1985a, 1985b) reported that the addition of NO_3-N stimulated mineralization of ^{14}C-labelled lignocellulose in laboratory microcosms. The lignocellulose mineralization rate increased with increasing NO_3-N concentration up to a level of 10 mg/liter NO_3-N; at that point carbon availability appeared to limit decomposition (Aumen *et al.*, 1985a). During our study NO_3-N levels in Big Hurricane Branch averaged 0.059 mg/liter and in Hugh White Creek averaged 0.004 mg/liter. Elevated NO_3-N levels in the disturbed stream probably stimulated microbial activity and thus may have accelerated the rate of wood decomposition.

Stream channel instability.—Differences between stick breakdown rates in Big Hurricane Branch and Hugh White Creek also may have resulted from differences in streambed stability. Since watershed logging in 1976-1977, Big Hurricane Branch has carried high levels of sediment (Gurtz *et al.*, 1980; Webster *et al.*, 1983; Webster and Golladay, 1984; Webster *et al.*, in press). Following road construction during spring 1976, two major storms washed considerable amounts of sediment into Big Hurricane Branch. Increased sediment transport observed since logging is probably due to redistribution of this material. As a result of sediment movement, some of the stick packs in Big Hurricane Branch were alternately submerged and left dry as the stream shifted in its channel. Sticks subjected to wetting and drying appeared to lose bark and decay more rapidly than sticks that were continuously wet. The mechanism for this accelerated breakdown may be mechanical effects of wetting, drying, freezing and thawing. Alternately, Barlocher *et al.* (1978) suggested that leaf breakdown was accelerated in temporary pools because microbial action during dry periods enhanced the nutritional value of the material to invertebrates.

Invertebrate colonization and activity.—Dudley and Anderson (1982) reported that wood colonization by invertebrates occurs in three distinct stages. Initially, new wood is colonized by organisms seeking a smooth, hard substrate—chironomids are often important early colonists. During the second stage, as algae and fungi become abundant on the wood surface, grazer, scraper and collector densities increase. Finally, as fungi penetrate the wood surface and it begins to soften, wood becomes available as a food resource for wood gougers and generalized shredders. We observed a similar pattern of colonization in this study. In both the disturbed and reference streams, chironomids were the most abundant early colonists. In both streams, highest chironomid densities were observed on the first sample date, at 2 months into the study. As exposure continued, collectors and *Lype* sp. became more abundant. Collector and *Lype* densities were much higher in Big Hurricane Branch than in Hugh White Creek. We believe that increased light and nutrient levels in Big Hurricane Branch following logging stimulated the growth of periphyton on stick packs and may account for the increased colonization by collecting and grazing insects. Although we did not measure periphyton directly, evidence from a study by Lowe *et al.* (1986) during the spring of 1983 indicated that light levels strongly limit primary production in undisturbed Coweeta streams. Periphyton standing stocks on artificial substrates were substantially higher in Big Hurricane Branch than in Hugh White Creek. As our study proceeded some of the tethered sticks gradually became buried by stream sediments at both sites and average invertebrate densities declined. We may not have observed the final stages of wood colonization and utilization by invertebrates.

The higher taxa richness and invertebrate densities observed in Big Hurricane Branch undoubtedly contributed to faster wood breakdown rates. The apparent attractiveness of wood as a substrate in the disturbed stream may be a result of changes in the availability of conditioned leaf material following watershed logging. Webster *et al.* (in press) reported that detrital inputs to Big Hurricane Branch changed following logging from mostly late successional, decay-resistant litter to rapidly decaying, early successional litter. Benthic organic matter levels >1 mm (sampled quarterly from July 1985-April 1986) averaged 124.2 g/m^2 in Big Hurricane Branch and 213.0 g/m^2 in Hugh White Creek (Golladay, 1987) and indicate a substantial reduction in the availability of food resources for organisms dependent on coarse detritus. Although reduced during logging, leaf breakdown rates in Big Hurricane Branch appear to have been accelerated following logging (Table 5). Webster and Waide (1982) hypothesized that artificial leaf packs represented "islands" of food that attracted consumers in an otherwise food-limited environment. They also found that following logging, invertebrates would colonize leaf packs of species normally ignored (*e.g.*, rhododendron) by stream consumers. These studies indicate that consumers in Coweeta streams are flexible in their food habits. In the absence of preferred foods, they appear to colonize less desirable or lower quality food resources.

IMPACT OF ACCELERATED WOOD BREAKDOWN

Following forest logging and accompanying decreases in leaf litter availability: small woody debris may be an important food resource for consumers in Coweeta streams. Although of lower quality than leaf litter, its persistence and abundance may make it an important resource until the riparian vegetation recovers and re-establishes the predisturbance pattern of detrital inputs. However, increased stick breakdown rates following logging may have other impacts on stream ecosystem function. Organic matter accumulations (leaves and sticks with no wood >5 cm in diam) are the most common morphological features in Coweeta streams (Golladay *et al*, 1987). Debris dams are not common because stream flows are seldom of sufficient magnitude to move and consolidate large woody debris. These accumulations of organic debris are important sites of nutrient uptake and particle retention in small streams (Swanson and Lienkaemper, 1978; Keller and Swanson, 1979; Bilby, 1981; Mosley, 1981; Triska *et al.*, 1982). There are significantly fewer organic matter accumulations in Big Hurricane Branch compared to Hugh White Creek (average 1.12 per 25-m reach and 2.66 per 25-m reach, Golladay *et al.*, 1987). In addition, storm export of fine particulate organic matter is much higher in Big Hurricane Branch than in Hugh White Creek (Golladay *et al.*, 1987). Finally, fine benthic organic matter standing stocks in Big Hurricane Branch (annual average 112.8 g AFDW/m^2) are substantially lower than Hugh White Creek (annual average 165.8 g AFDW/m^2) (Golladay, 1987), and it would appear that Big Hurricane Branch is less retentive than Hugh White Creek. Apparently, increased organic matter processing has resulted in the gradual deterioration of organic matter accumulations, the primary retention structures in Big Hurricane Branch. If increased rates of wood processing continue, decreased retention of nutrients and organic matter in Big Hurricane Branch may continue for sometime. Thus, although the presence of woody debris may buffer the effects of forest disturbance by serving as a food source for those organisms flexible enough in food habits to use it, increased processing and decreased retention may reduce the resources available to consumers dependent on nutrients and organic material normally retained in the stream.

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TABLE 5.—Leaf breakdown rates (day^{-1}) in Big Hurricane Branch before and after the completion of logging in 1977, in 1982 and in Hugh White Creek, a reference stream. Values in parenthesis are number of samples and coefficients of determination (r^2)

	BHB[1] Pre-logging	BHB[1] 1976-1977	BHB[1] 1977-1978	BHB[2] 1982-1983	HWC[2] 1982-183
Dogwood	0.0219	0.0134	0.0219	0.0536	0.0297
Cornus florida	(104,0.74)	(45,0.77)	(84,0.81)	(4,0.98)	(6,0.88)
Red maple	—	—	—	0.0237	0.0109
Acer rubrum				(6,0.98)	(7,0.97)
White oak	0.0064	0.0038	0.0090	0.0116	0.0056
Quercus alba	(143,0.78)	(44,0.91)	(84,0.79)	(6,0.96)	(7,0.97)
Rhododendron	0.0037	0.0011	0.0105	0.0128	0.0047
Rhododendron maximum	(156,0.37)	(45,0.65)	(82,0.59)	(6,0.93)	(7,0.73)

[1]Data from Webster and Waide (1982)
[2]Regression analysis performed on the means of 5 bags per leaf species per sample date

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