Habitat Structure and Woody Debris in Southern Appalachian Wilderness Streams

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Abstract: Stream habitat and large woody debris (LWD) loadings were inventoried in 2 southern Appalachian wilderness streams by the basinwide visual estimation technique. Little Santeetlah Creek, in a wilderness watershed that has never been harvested, contained 4 times as much wood and nearly twice as many habitat units (e.g., pools and riffles) as did Lost Cove Creek in a forested watershed, typical of the southern Appalachians, that was clearcut 80 years ago. Where stream widths were similar, pools and riffles in Little Santeetlah were smaller and more numerous than in Lost Cove Creek. Naturally occurring LWD influenced the structure and configuration of habitat in southern Appalachian Mountain streams.

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Large woody debris (LWD) is a major element in habitats of streams flowing through old-growth forests (Franklin et al. 1981, Harmon et al. 1986, Bisson et al. 1987). In their description of major ecological features of old-growth forests in the West, Franklin et al. (1981) conclude that: "Logs are critical to maintenance of physical and biological stability in headwater streams. Debris dams create stepped stream profiles that dissipate energy. . . . Such dams, with their associated plunge pools . . . , provide a range of habitats needed to maintain a full array of stream and stream-margin organisms." In eastern North America, only small amounts of true old-growth forest (i.e., forest areas never harvested for timber or cleared for homesteads) escaped major expansion of the logging industry which began after 1880. Because of its rarity and historical value, most of the remaining eastern old-growth is currently managed as wilderness. In rare instances, preserved old-growth forest may be sufficiently large to encompass an entire headwater stream basin. These remnant old-growth forests provide a picture of what stream habitat would be in the absence of human disturbances of forest harvest or land clearing.

Wilderness has also been established in areas that were logged in the last century. In these areas, the management goal is eventually to recreate, through protection, the relatively pristine conditions of old-growth forest. Ecological characteristics of streams flowing through second-growth forest in these previously logged or settled wilderness areas probably differ from those in streams that drain old-growth wilderness forest. In particular, the amount and size of woody material that each forest contributes to stream habitats is directly linked to the vegetative composition of the riparian zone. The amount and size distribution of LWD and the number, frequency, and type of habitat units (e.g., pools and riffles) are the components of stream habitat that we will address.

The purpose of this paper is to describe the stream habitat found in a North Carolina stream within a watershed composed entirely of true old-growth forest. Secondly, we compare stream habitat in a North Carolina wilderness watershed that was harvested about 80 years ago to habitat in the old-growth stream.

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Methods

Two headwater stream systems in North Carolina's Appalachian Mountains were selected for this study. Soils in both watersheds are loamy and geological substrates are metasedimentary (D. Manning, pers. commun.). Both streams are presently managed by the U.S. Forest Service as wilderness, but have different histories of forest management.

Little Santeetlah Creek drains the Joyce Kilmer Memorial Forest in the Nantahala National Forest of western North Carolina. This forested tract was set aside in 1936 as a memorial to the poet, Joyce Kilmer, and has never been logged. In 1975, the Memorial Forest was included in the Joyce Kilmer–Slickrock Wilderness Area, and has been managed as a wilderness since then. The upper watershed, one of the few virgin forest tracts remaining in the southern Appalachians, is dominated by tulip poplar (*Liriodendron tulipifera*), eastern hemlock (*Tsuga canadensis*), sycamore (*Platanus occidentalis*), basswood (*Tilia* spp.), beech (*Fagus grandifolia*), and oaks (*Quercus* spp.). Prior to the chestnut blight, American chestnut (*Castanea dentata*) was a major canopy dominant, as evidenced by the very large chestnut logs remaining on the forest floor. Rainbow trout (*Oncorhynchus mykiss*) occupy lower reaches of Little Santeetlah Creek, and brook trout (*Salvelinus fontinalis*) become more common in the headwaters. Other species of fish found in this stream include darters (*Etheostoma* sp.), sculpin (*Cottus* sp.), suckers (Catastomidae), dace (*Rhinichthys* sp.), and shiners (*Notropis* sp.). For this study, we inventoried 6.4 km of stream beginning at the confluence with Big Santeetlah Creek (average width 4.9 m) and working upstream to where habitat for trout becomes intermittent. Overall, the gradient of the stream system was about 10%, and elevation ranged from 620 m to 1,210 m.

Love Cove Creek is located within the Wilson Creek Area of the Pisgah National Forest. Lost Cove, typical of forested watersheds in the Appalachian Mountains, was logged about 80 years ago when entire drainages, including streamsides, were clearcut. Presently the watershed is vegetated by mixed hardwoods: oak, hickory (*Carya* spp.), maple (*Acer* spp.), yellow birch (*Betula alleghaniensis*), and sycamore. A major flood occurred in the drainage in the 1940s. Although not yet formally set aside under provisions of the 1974 Wilderness Act, Lost Cove is being considered for Wilderness status and is now managed as if it were wilderness. Rainbow trout and brown trout (*Salmo trutta*) are found throughout the inventoried section of Lost Cove Creek; brook trout occur only in the uppermost habitat units. In addition to the species listed above for Little Santeetlah Creek, madtoms (*Noturus* sp.), striped jumprocks (*Scartomyzon rupiscartes*), sunfish (*Lepomis* sp.), smallmouth bass (*Micropterus dolomieui*), stonerollers (*Campostoma anomalum*), and chubs (*Nocomis* sp.) are present. We inventoried approximately 11.0 km of stream in this system beginning at the confluence with Rockhouse Creek (480 m elevation, average width 7.7 m) and working upstream (to 710 m elevation), including a tributary, Sassafrass Creek (maximum 800 m elevation). Overall gradient is 2%–3%, although Sassafrass Creek has a gradient of 13%.

Both stream systems were inventoried during summer 1988, with visual estimation techniques and the basin survey method of Hankin and Reeves (1988). Habitat units were identified and assigned to 1 of 4 habitat types (modified from Platts et al. 1983): pools (unbroken surface, slow velocity deep water), glides (rippled surface, faster velocity shallow water, often uniform small substrate), riffles (streambed substrate protrudes through water surface, gradient <12%), and cascades (large boulder or bedrock substrate, gradient >12%). Length along thalweg for each unit was measured with a hip chain, and the area (m^2) of each pool and glide and width (m) of each riffle and cascade was visually estimated. Twenty percent of pools and glides, 10% of riffles, and about 7% of cascades were measured for calibration of the visual estimates. Woody debris >5 cm diameter and >1 m long in each habitat unit was counted and assigned to 1 of 7 size classes (Table 1).

Habitat area estimates were calibrated according to equations developed by Hankin (1986) and Hankin and Reeves (1988). Programs written in SAS statistical software for personal computers were used for all data analyses.

Results and Discussion

For this paper, we will be primarily concerned with the amounts of LWD in the basins and comparative numbers of units of each habitat type. The method of Hankin and Reeves (1988) includes procedures for calibrating habitat area estimates; basinwide estimates of habitat for the 2 basins are compared in Table 2.

Table 1. Size classes for large woody debris in streams.

Size class	Length	Diameter
1	>1 and <5 meters	5–10 cm
2	" " " "	>10–50 cm
3	" " " "	>50 cm
4	>5 meters	5–10 cm
5	" "	>10–50 cm
6	" "	>50 cm
7	Root wads	

Table 2. Descriptions of stream habitat in 2 study streams. Total units are the sums of pools, riffles, and cascades. Areas (m^2) are average sizes of pools and riffles.

	Pools (*N*/km)	Riffles (*N*/km)	Total units (*N*/km)	Pool area (m^2)	Riffle area (m^2)
Little Santeetlah	81	49	156	21.4	43.7
Lost Cove	47	27	79	123.6	87.5

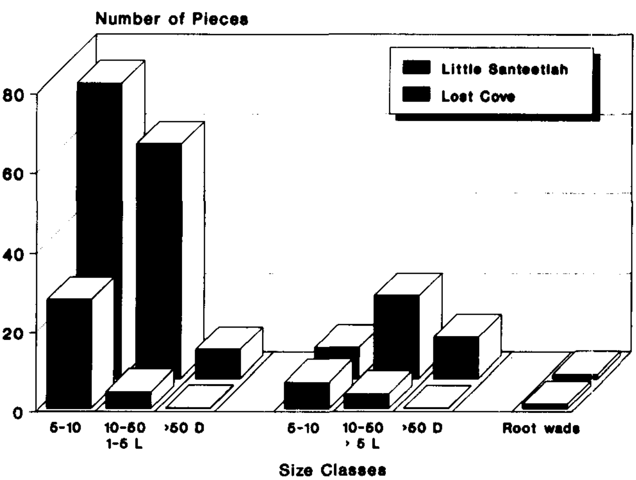

Figure 1. Average number of pieces (per km) of large woody debris (LWD) in Lost Cove Creek (logged) and Little Santeetlah Creek (old-growth), grouped by diameter and length size classes. Size classes 1–7 (see Table 1) are displayed from left to right (diameters given in cm and lengths in m).

Little Santeetlah Creek had a total of 1,157 pieces of LWD over the 6.4 km length surveyed. Wood was distributed among all size classes, including the largest, most stable pieces >50 cm diameter (Fig. 1). Much of this wood was eastern hemlock logs, common in the riparian zone of this stream; chestnut logs, although common on the forest floor upslope, were not found in the stream. Larger pieces of wood form the basis of debris dams that retain an abundance of smaller pieces (classes 1 and 2) of LWD in this stream (Fig. 1).

Compared to Little Santeetlah Creek, Lost Cove Creek had much less large woody debris: 476 pieces in 11.0 km. When standardized to a per km basis, Little Santeetlah had more than 4 times as much wood per km as did Lost Cove. Distributions of LWD among the 7 size classes were also different for the 2 stream systems (Fig. 1). Except for root wads, more wood was found in each size class in Little Santeetlah than Lost Cove. The contrast between woody structure in Lost Cove Creek, in a "mature" forested watershed, and structure in Little Santeetlah, in a true "old growth" forested stand, is apparent in figure 1. Increased woody complexity is expected in old growth compared to second growth forest streams (Franklin et al. 1981, Harmon et al. 1986).

The smallest size class (No. 1) of LWD is relatively common in all stream systems in the southern Appalachians (pers. observ.). Short, small diameter LWD is relatively mobile and does not add significantly to the structure of habitats unless associated with larger woody pieces or incorporated into a debris dam (Bilby and Likens 1980). About 78% of the LWD tallied in Lost Cove Creek was in classes 1 and 4, which represents recruitment of small diameter material, like branches and small trees, from the second-growth riparian forest.

Large woody debris in classes 2, 3, 5, and 6 contributes most to creation of habitat units, especially pools, because this material is large enough to be stable in normal flows (Bilby 1984, Bisson et al. 1987). These sizes also contribute more structure to fish habitat by providing more cover. In Lost Cove Creek, almost no LWD in the largest diameter (>50 cm) size classes was found in the stream, reflecting the absence of large trees in the watershed. Wood in the larger size classes was probably removed from Lost Cove Creek at the time of logging or was transported downstream during floods or simply lost through normal decomposition. Larger, habitat forming pieces will not be recruited into the stream until the surrounding forest matures and achieves more characteristics of old-growth forest. In contrast, large amounts of wood >50 cm diameter were found in Little Santeetlah Creek. The larger diameter pieces of LWD are created only in older stands that contain large trees. Even after living trees reach large diameters, some time may pass before many of these trees die and are recruited into the stream system by natural mortality, wind throw, or bank undercutting.

Density of root wads was nearly identical in both streams (1.1–1.2 per km). Root wads are generally created when the stream undercuts a streambank tree, which then topples or is felled by wind. Root wads are highly desirable habitat components because they are stable, especially when still attached to the tree bole, and provide complex cover after soil is washed away from the woody mass (Swanson et al. 1984, Bisson et al. 1987). Although no attempt was made to group root wads by size, those attached to the old-growth derived LWD in Little Santeetlah Creek were much larger than root wads observed among the second-growth LWD in Lost Cove Creek (pers. observ.).

If LWD plays a role in formation of habitat units, we would expect to see more pools and riffles in Little Santeetlah Creek. Since our discrimination between pools and glides was subjective, we combined these habitat types and, in the discussion that follows, will refer to them collectively as "pools." By definition, cascades are formed as a function of geomorphology, especially by the presence of boulders and bedrock; cascades are relatively uncommon in both systems and will not be discussed further. Little Santeetlah Creek contained more smaller pools and riffles and total habitat units per km of stream than did Lost Cove Creek (Table 2). Pool:riffle ratios (1.7:1) were nearly identical in the 2 streams.

Representative stream segments of approximately the same width and length from each stream were plotted to illustrate the differences between habitat unit structure and sequencing (Fig. 2). Little Santeetlah had a greater number of units, and average size of units was smaller (Table 2). Additional complexity was introduced because some units occurred side-by-side instead of in the distinctly linear configuration of Lost Cove Creek (Fig. 2).

In contrasting these 2 streams, we found that the stream draining old-growth forest, Little Santeetlah Creek, had 4 times as much wood and almost twice as many pools and riffles as did Lost Cove Creek, in a typical second-growth southern Appalachian watershed. Furthermore, habitat-forming large pieces of wood (size classes 2–3 and 5–7 in Table 1) were more likely to be found associated with habitat units in Little Santeetlah Creek (Fig. 1). Pools and riffles were smaller for a given stream width, and stream habitat was more complex in the stream surrounded by old-growth. We conclude that naturally occurring LWD is an important component of southern Appalachian Mountain stream systems in old-growth forests. Large woody debris provides more than cover and substrate for fish and macroinvertebrates, it also plays a role in creating and maintaining major habitat features such as pools and riffles.

Both streams are in areas managed for wilderness, and little or no direct

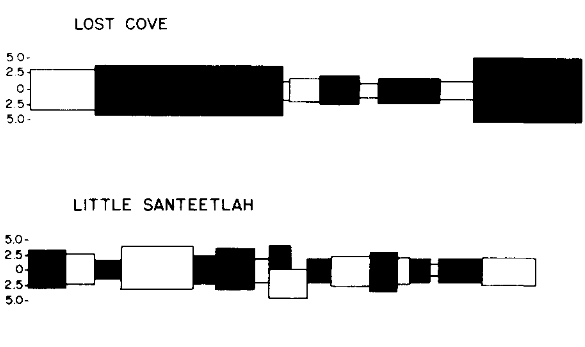

Figure 2. Schematic diagram of 2 segments of Lost Cove Creek (89 m long) and Little Santeetlah Creek (82 m long). Both streams are nearly identical in width; numbers on the left indicate distance (m) from center of the stream. Dimensions and configuration of pools (unshaded boxes) and riffles (shaded boxes) are accurately represented, but sinuosity of streams has been eliminated from this diagram.

manipulation of riparian areas and stream habitat has occurred in the recent past. In Little Santeetlah Creek watershed, where vegetation has been protected, recruitment of LWD into the stream is entirely due to natural processes. Wilderness streams in second-growth forests, however, differ from old growth in basic stream habitat characteristics. Managers who emphasize protection and enhancement of vegetation for natural recruitment of LWD will enhance headwater stream habitat.

Literature Cited

Bilby, R.E. 1984. Removal of woody debris may affect stream channel stability. J. For. 82:609–613.

Bilby, R.E. and G.E. Likens. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology 61:1107–1113.

Bisson, P.A., R.E. Bilby, M.D. Bryant, C.A. Dolloff, G.B. Grette, R.A. House, M.L. Murphy, K.V Koski, and J.R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. Pages 143–190 *in* E.O. Salo and T.W. Cundy, eds. Streamside management: forestry and fishery interactions. Univ. Wash., Seattle.

Franklin, J.F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PNW-118. 48pp.

Hankin, D.G. 1986. Sampling designs for estimating the total number of fish in small streams. U.S. Dep. Agric. For. Serv. Res. Pap. PNW-360. 33pp.

——— and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45:834–844.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, Jr., and K.W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res. 15:133–302.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Dep. Agric. For. Ser. Gen. Tech. Rep. INT-138. 70pp.

Swanson, F.E., M.D. Bryant, G.W. Lienkaemper, and J.R. Sedell. 1984. Organic debris in small streams, Prince of Wales Island, southeast Alaska. U.S. Dep. Agric. For. Ser. Gen. Tech. Rep. PNW-166. 12pp.