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Trout use of woody debris and habitat in Wine Spring Creek, North Carolina

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Abstract

Wine-Spring Creek basin, in the mountains of North Carolina's Nantahala National Forest, is an ecosystem management demonstration site, iu which ecological concepts for management and restoration are tested. Large woody debris (LWD) is an important link between streams and the adjacent riparian forest, but evidence for the connection between LWD and trout in southern Appalachian streams is limited. Woody debris loadings, trout habitat, and brook trout (*Salvelinus fontinalis*) and rainbow trout (*Oncorhynchus mykiss*) were inventoried for the entire 9.8 km that trout occupy in Wine Spring Creek. Compared to two reference streams in North Carolina old-growth forests, Wine Spring Creek had less LWD, evidence of conditions associated with mid-successional riparian forests. More units in Wine Spring Creek lacked LWD altogether and accumulations of two or more pieces of LWD were less common than was the case in the reference watersheds. On average, about 71% of pools and riffles in Wine Spring Creek were occupied by trout, compared to about 90% in reference streams. Trout nearly always occupied pools with at least two pieces of LWD, but rates of occupancy for pools with one or no LWD pieces and riffles were unusually low compared to reference streams. Habitats on the lower and middle reaches on the mainstem of Wine Spring Creek had highest trout numbers and were nearly always occupied by trout. In these reaches, riparian ages were older and stream habitat had abundant LWD or boulder substrate. Upper reaches of Wine Spring Creek and its tributaries, however, were characterized by less mature riparian forest, less LWD and little boulder substrate, low rates of trout occupancy, and lower trout numbers. These conditions are the basis for an LWD addition experiment in headwater reaches. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Brook trout; Ecosystem management; Large woody debris; Rainbow trout; Southern Appalachian Mountains; Trout; Trout habitat Trout streams

1. Introduction

In recent years, resource agencies like the U.S. Forest Service have adopted the ecosystem management approach. Wine Spring Creek basin, in the mountains of North Carolina's Nantahala National Forest, is an ecosystem management demonstration site in which researchers and managers are working together, and with the public, to implement ecosystem management (Meyer and Swank, 1996). Among other principles, an ecosystem management approach embraces complexity and connectedness, incorporates the landscape context of systems, and seeks to ensure long-term sustainability (Christensen et al., 1996).

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Trout are a highly valued resource in the southern Appalachians, where they are at the southern end of their range in eastern North America and trout productivity tends to be low. Several factors may be limiting trout populations in these streams. Traditionally, trout management has focused on directly manipulating trout populations (e.g., stocking) or engineering in-stream habitat (Seehorn, 1992) to remedy possible limiting factors. Under ecosystem management, trout habitat is considered in the huger context of the watershed and riparian areas, and long-term sustainability is emphasized over short-term solutions like stocking.

In a forested watershed like Wine Spring Creek, large woody debris (LWD) is a major link between the forest in the riparian zone and adjacent stream habitat (Naiman et al., 1992). Large woody debris is defined as woody debris ≥10 cm diameter (Meehan, 1991); it contributes structure and hiding cover, maintains physical stability, and provides a range of habitats for stream organisms (Keller and Swanson, 1979; Bilby and Likens, 1980; Dolloff, 1986; Harmon et al., 1986; Bisson et al., 1987; Grant et al., 1990; Naiman et al., 1992). Streams that flow through old-growth forests have more LWD than streams in second-growth forest (Silsbee and Larson, 1983; Harmon. et al., 1986; Bisson et al., 1987; Flebbe and Dolloff, 1995), except where carry-over of predisturbance LWD is significant (Hedman et al., 1996). Well-developed, mature riparian forests, then, can provide a sustainable supply of LWD for streams. But, evidence for links between LWD and organisms in southern Appalachian streams is limited (Flebbe and Dolloff, 1995; Wallace et al., 1996; Hilderbrand et al., 1997).

Within stream systems, a contimmm of habitat scales is recognized (Frissell et al., 1986). Reaches – as used here, sections of stream between confluences – may have different habitat characteristics that reflect different geology, size, slope, flow regime, history of human use aud management, and riparian age. Within reaches, habitat units (defined by breaks in water flow) are often classified as slow-water (pool) and fast-water (riffle, including steep cascades) types (Hawkins et al., 1993). Southern Appalachian trout generally prefer pool habitat over riffle habitat. Reaches and habitat unit types may be used to stratify stream habitat; that is, to reduce the overall system variability to increase power to find meaningful patterns.

A first step of ecosystem management for trout in Wine Spring Creek was to establish the relation between LWD from the riparian forest, trout habitat, and trout use of the habitat in Wine Spring Creek This paper reports research designed to address three objectives:

1. determine amounts and size distribution of LWD in Wine Spring Creek and compare to reference streams in watersheds dominated by old-growth,
2. determine trout distribution among Wine Spring Creek habitat units with different amounts of LWD and compare to the reference streams; and
3. compare habitat, LWD, and trout use of habitat among reaches within Wine Spring Creek that have different histories, positions in the landscape, and physical characteristics.

2. Methods

2.1. *Watershed description*

Wine Spring Creek is a 1126 ha watershed (915–1655 m elevation) in Macon County, North Carolina (Fig. 1). The following description is based on continuous inventory stand condition (CISC) data and planning documents of the Wayah Ranger District. Watershed vegetation is a mixture of hardwood forest types, predominantly upland hardwood (61%), north-

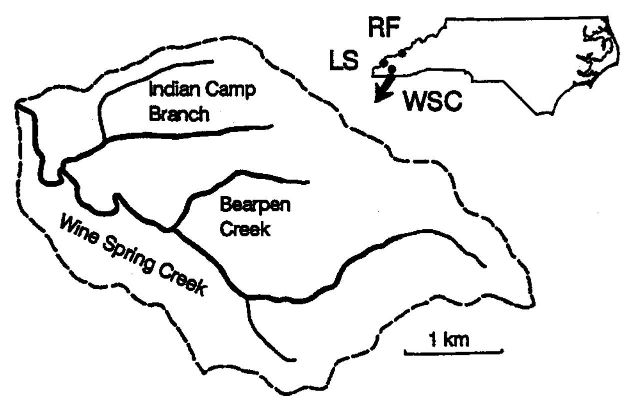

Fig. 1. Watershed map of Wine Spring Creek (WSC) and location in North Carolina. Dashed lines are watershed bounties, and solid lines are streams. Heavier solid lines denote portions of stream that have trout. Locations of old-growth reference streams in North Carolina are also noted: Right Fork of Raven's Fork (RF) and Little Santeetlah Creek (LS).

em hardwood (24%), cove hardwood (7%), and hemlock-hardwood (7%); stand ages range from 3 to 132 years, with over 75% in the 50 to 110 year age classes. Sections of Wine Spring Creek below the confluence with Bearpen Creek and nearly all of Indian Camp Branch are managed for a habitat of mature forests; timber harvests are not planned for this area. Some stands adjacent to the lower end of Wme Spring Creek have been aged at over 100 years, but most are 60-100 years old. The upper part of Wme Spring Creek and all of Bearpen Creek are managed for habitats of mixed ages and a sustainable supply of timber; here, most areas along the stream are about 50-60 years old.

Riparian vegetation was described by C.W. Hedman (unpublished data, 1993) as mixed mesophytic: overstory species include tulip poplar (*Liriodendron tulipifera* L.), white basswood (*Tilia heterophylla* Vent.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), yellow buckeye (*Aesculus octandra* Marsh.), yellow birch (*Betula alleghaniensis* Britton), black birch (*B. lenta* L.), red maple (*Acer rubrum* L.), sugar maple (*A. saccharum* Marsh.), oak (*Quercus* 'spp.), Fraser magnolia (*Magnolia fraseri* Walt), black cherry (*Prunus serotina Ehrh.*), and hickory (*Carya* spp.); rhododendron (Rhododendron *maximum* L.) is prominent in the midstory.

Where Wine Spring Creek enters Nantahala Lake (915 m elevation), it is a third-order stream (based on blue lines on 7.5' U.S. Geological Survey topographic maps), approximately 3.5 m wide. Wine Spring Creek has two major tributaries, Indian Camp Branch (second-order) and Bearpen Creek (first-order) (Fig. 1); these tributaries and the three mainstem reaches differ in several characteristics (Table 1). Two minor unnamed tributaries (Fig. 1) did not have trout and will not be considered here.

Of the 12.2 km of perennial stream in the basin approximately 9.8 km are occupied by trout on a continuing basis (Fig. 1), to elevations of ca. 1330 m on the mainstem and 1380 m on. Bearpen Creek. Two trout species are present: rainbow trout (*Oncorhynchus mykiss*), which occur in all stream reaches of the basin (Fig. 1) except for Bearpen Creek; and brook trout (*Salvelinus fontinalis*), which are restricted to Bearpen Creek and a small adjacent section of Wine Spring Creek Fishing pressure is low, partly because access is limited and terrain is rugged, and few trout reach catchable size (180 mm) (unpublished data). A small population of sculpin (*Cottus* sp.) occurs in the lowest reach of Wine Spring Creek.

2.2. *Sampling und analysis methods*

A basin-wide survey (Hankin and Reeves, 1988; Dolloff et al., 1993) of habitat units, woody debris, and trout was conducted in Wine Spring Creek during August, 1991. This survey method involves complete enumeration of all habitat units and LWD, estimation of habitat unit area, and a system-wide sample of trout populations.

Habitat units were identified as slow-water (847 pools) or fast-water (444 riffles) habitat. Length along stream thalweg was measured for each unit with a hip chain, and the area (in m^2) of each pool or width (in m) of each riffle was visually estimated Visual estimates were calibrated by measuring widths of 10% of riffles and areas of 20% of pools with a tape measure. Habitat area estimates were calibrated according to equations developed by Hankin and Reeves (1988) and Dolloff et al. (1993).

Woody debris greater than 10 cm diameter and 1 m long in each habitat unit was counted and assigned to one of five LWD size classes (Fig. 2). All pieces of LWD that had some portion within the bankful channel were counted, including spanning pieces that

Table 1
'Descriptions of five reaches within Wine Spring Creek

Reach name	Reach extent	Length (km)	Dominant substrate	Gradient (%)
Lower Wine Spring Creek	Lake to Indian Camp	1.25	boulder	8
Mid Wine Spring Creek	Indian Camp to Bearpen	1.86	cobble–boulder	7
Upper Wine Spring Creek	above Bearpen	3.03	cobble	6
Indian Camp Branch	entire	2.20	fines-gravel-cobble	12
Bearpen Creek	entire	1.50	fines	16

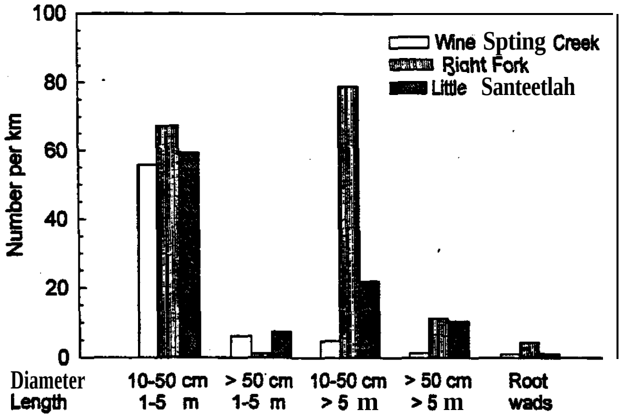

fig. 2. **Average number of pieces of large woody debris (LWD) per km of stream in Wine Spring Creek and the two reference streams. Dimensions of five LWD size classes are noted on tbe horizontal axis.**

would be wetted during bankful flows. One or two major substate components were identified for each unit: bedrock, boulder (>30 cm); cobble (1 l-30 cm), large gravel (l-10 cm), small gravel (2-10 mm), or fines (<2 mm, including sand silt, clay, or organic debris).

In each measured habitat unit, snorkelers visually estimated numbers of trout (Dolloff et al., 1993). A total of 166 pools and 45 riffles were snorkeled during midday hours under good visual conditions. About 10% of the snorkeled habitat units were sampled by multiple-pass depletion (Zippin, 1958) electrofishing to verify snorkel counts of trout (Hankin and Reeves, 1988). Units for snorkeling and electrofishing were distributed systematically (every fifth or tenth unit) throughout the basin after random selection of the first (downstream) unit.

Two old-growth reference streams (Fig. 1) were surveyed in 1988 using the same method (Flebbe and Dolloff, 1995). Right Fork of Raven's Fork is a second-order stream (1280-1580 m elevation) in the Great Smoky Mountains National Park and Little Santeetlah Creek is a third-order stream (620-1210 m elevation) in the Joyce Kihner-Slickrock Wilderness Area of North Carolina. Additional details on these streams can be found in Flebbe and Dolloff (1995).

The basin-wide survey method was designed to produce whole-basin estimates of fish and fish habitat (Hankin and Reeves, 1988). For this paper, these data were also treated as a sample of the population of habitat units in the basin. The systematic sampling scheme described here was assumed to produce a sample as representative of the population as a random sample would have given (Cochran, 1977; Hankin and Reeves, 1988). Habitat unit data were analyzed by whole basin and by reach as defined in Table 1.

To determine the relation between trout and LWD, trout data were matched with the corresponding habitat data. The number of pieces of LWD was determined for each snorkeled habitat unit. If trout were either observed in a unit by snorkeling or captured by electrofishing, they were assumed to be present in the unit.

For hypotheses concerned with counts of items in classes, chi-square tests were used. Recommendations of Zar (1996, pp. 466 and 502) concerning minimum cell frequency for unbiased chi-square tests were followed. Trout numbers (number/unit) and density (number/m^2) were not normally distributed, and comparisons were made with nonparametric tests, followed by a nonparametric pairwise comparison procedure (Neter et al., 1990, p. 646). Where the normality assumption was met, t-tests were used. In all statistical tests, α=0.05 was used.

3. Results

3.1. *Basin-wide*

Wme Spring Creek had 69 pieces of LWD per km, considerably less than the counts in the reference streams (163/km in Right Fork and 101/km in Little Santeetlah Creek Fig. 2). Woody debris was not uniformly distributed among size classes for any stream (P<0.001; Fig. 2). Distributions of LWD among sire classes for the three streams differed significantly (P<0.001; Fig. 2). Generally, Wine Spring Creek had less LWD than the reference streams in each size class. The 56 pieces/km of LWD in the first size class in Wine Spring Creek was inflated by the presence of 90 pieces of wood in 23 engineered stream structures; without this wood, Wme Spring Creek, would have only 47 pieces/km in the first size class. Differences between Wine Spring Creek and the reference streams were particularly dramatic for LWD >5 m in length.

Table 2
Number **of snorkeled stream units with different amounts of large woody debris (LWD). (A) Wme Spring Creek vs. two reference streams; row distributions are significantly different (P<0.05). (B)** *pools vs. riffles; row* **distributions are not significantly different (P>0.05)**

	Pieces of LWD				
	0	1	2	3	14
A. Among streams					
Wine Spring Creek	173	15	9	2	12
Right Fork	71	23	20	14	14
Little Santeetlah	87	27	12	7	9
B. *Between habitat types in Wine Spring Creek*					
Pools	135	13	7	1	10
Riffles	38	2	2	1	2

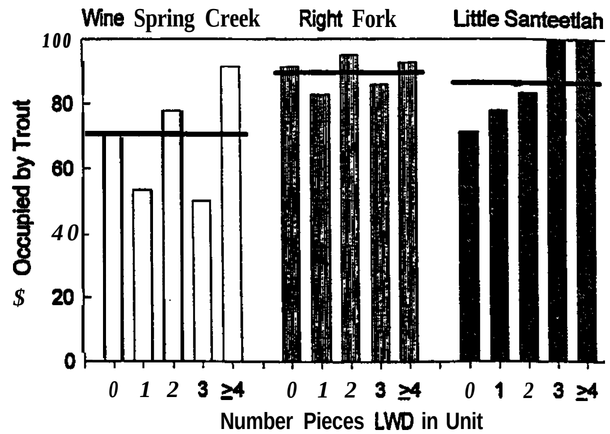

Fig. 3. Selection of habitat units with large woody debris (LWD) by trout in Wine Spring Creek and two reference streams. Height of each bar represents the percentage of units with *0*, 1, 2, 3, or ≥4 pieces of LWD that are occupied by trout. Horizontal lines across each set of bars represent the average rate of occupancy for that stream; bars higher than this line are overoccupied and bars lower are underoccupied compared to this average.

Individual habitat units in Wine Spring Creek had from zero to ten pieces of LWD, although 95% of the 1291 habitat units had fewer than four pieces of LWD and 77% had no LWD. Of the 211 snorkeled habitat units in Wine Spring Creek, 82% lacked LWD (Table 2(A)). In contrast, only 50 and 61% of snorkeled habitat units in the reference streams lacked LWD (Table 2(A)). Frequencies of units with 0, 1, 2, 3, and ≥4 pieces of LWD in Wine Spring Creek differed significantly from frequencies in the two reference streams (P<0.05; Table 2(A)).

Pools outnumbered riffles 1.9 : 1 in Wme Spring Creek, but average riffle area (36 m^2) was more than twice that of pools (15 m^2). Overall area in pools was ca. 81% of the area in riffles. Although pools were smaller and constituted less total area in Wme Spring Creek than did riffles, trout numbers and densities were significantly higher (Mann-Whitney U test, P<0.05) in pools (1.85 trout/unit; 0.14 trout/m^2) than riffles (1.40 trout/unit; 0.05 trout/m^2). Basin-wide, 2080±305 (estimatefs.e.) trout lived in pools and 1453±489 trout lived in riffles, out of a total of 3533±576 trout.

Overall, 71% of snorkeled habitat units in Wme Spring Creek were occupied by trout: 75% of pools and 56% of riffles were occupied. Average areas of pools (16 m^2) and riffles (29 m^2) occupied by trout were twice that of units that lacked trout (t-tests significant; P<0.05). For pools, number of trout in units with LWD was significantly greater than in units without LWD (l-tailed Mann-Whitney U test, P=0.02), but trout densities were not significantly different (P>0.05). For the basin as a whole and for riffles, neither trout numbers nor densities were significantly different between units with and without LWD (P>0.05).

The 71% occupancy rate in Wine Spring Creek was much lower than in **the reference** streams, where 90 and 87% were occupied (Fig. 3). In Wine Spring Creek, trout nearly always occupied units with at least four pieces of LWD, but occupancy of units with fewer or no LWD pieces was unusually low (Fig. 3). Observed distribution in Wine Spring Creek of occupancy among units with 0, 1, 2, 3, and ≥4 pieces of LWD differed significantly from the overall occupancy rate of 71% (P<0.001); likewise, distributions in Little Santeetlah Creek, but not in Right Fork, differed significantly from their respective overall occupancy rates. Distribution of occupancy rates for Wine Spring Creek, represented by the height of bars in Fig. 3, differed from Little Santeetlah Creek (P=0.02) but not from Right Fork (P=0.15), and the reference streams did not differ from each other (P=0.33).

Pools and riffles did not differ significantly (P=0.78) in frequencies of units with 0, 1, 2, 3, and ≥4 pieces of LWD (Table 2(B)). However, occupancy rates for pools with *0*, 1, 2, 3, and ≥4 pieces of LWD were significantly different (P<0.001) from occu-

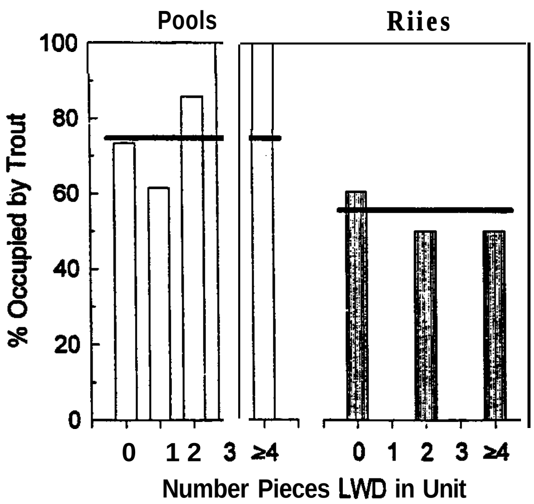

Fig. 4. Selection **of habitat units witb large woody debris (LWD) by trout in pools and riffles of Wine Spring Creek Details as for Fig.** *3.*

pancy rates for riffles (Fig. 4). Occupancy rates for pools were not significantly different from the overall pool occupancy rate of 75% ($P=0.16$), but occupancy rates for riffles differed significantly from the overall riffle occupancy rate of 56% ($P<0.001$).

3.2. *Individual reaches*

Counts of LWD differed for each of the five reaches (Table 3). Greatest LWD loadings occurred in the mid-Wme Spring Creek reach (112 pieces/km, Table 1) and the lower portion (1.1 km) of the upper Wme Spring Creek reach, between Bearpen Creek and the unnamed tributary (214 pieces/km). Above the tributary, most of the 48 pieces/km was in engineered stream structures. Sample sizes were not adequate to compare riffles and pools within or among reaches.

Numbers of trout and trout density differed significantly among the live reaches (Kruskal-Wallis, $P<0.05$). Nonparametric comparisons between pairs of reaches were significant for trout numbers ($P<0.05$) but not significant for trout density ($P>0.05$), except as discussed below.

In lower Wine Spring Creek 94% of units (93% of pools, 100% of riffles) were occupied by trout, but no snorkeled units had LWD (Table 3). In this section, 75% of habitat units had boulders as a major substrate component. This reach had both the highest numbers and highest density of trout (Table 3); trout numbers were not significantly different from those in mid-Wine Spring Creek and trout densities were significantly different from both Bearpen Creek and Indian Camp Branch (Table 3).

In mid-Wine Spring Creek, 87% of units (95% of pools, 50% of riffles) were occupied by trout and LWD was higher than in any other reach (Table 3). Trout numbers were not significantly different from lower and upper Wine Spring Creek (Table 3). Units with LWD had significantly more trout (2.91 trout/unit) than did units without LWD (1.82 trout/unit) (l-tailed Mann-Whitney U test, $P=0.02$). Boulders were major substrate components for 67% of habitat units, and cobble was important for 59% of habitat units.

Units with LWD in upper Wme Spring Creek had significantly more trout (2.94 trout/unit) than did units without LWD (1.43 trout/unit) (l-tailed Mann-Whitney U test, $P=0.02$). Occupancy rates dropped to 66% (Table 3). Nearly 75% of habitat units had cobble substrate; boulders were important in <40% of the units. The LWD count (Table 3) included 23 engineered structures above the tributary, which broke up long cobble riffles into pools, but provided relatively little habitat complexity. Nearly all of the natural LWD was confined to the portion of this reach below

Table 3
Large woody debris (LWD) and trout in five reaches within Wine Spring Creek. Trout numbers and densities are averages of snorkeled units

	LWD (no./km)	Occupancy (%)	Trout numbers (No./unit)	Trout density (No./m^2)
Lower Wine Spring Creek	0	94	3.47	0.17
Mid Wine Spring Creek	112	87	2.09	0.12
Upper Wme Spring Creek	107 [a]	66	1.85	0.12
Indian Camp Branch	29	54	0.65	0.12
Bearpen Creek	55	52	0.61	0.05

[a] LWD in this reach includes 90 pieces of wood in 23 engineered structures; if this LWD is excluded, the reach has 87 pieces of LWD/km.

the tributary. Below the tributary, occupancy rates were 78%; above it, trout occupied only 58% of habitat units.

The four snorkeled units in Indian Camp Branch that had wood all lacked trout, and average number of trout (0.7 1 trout/unit) in the 44 units without LWD was less than half that in the basin as a whole (1.72 trout/unit in units without LWD). Only 54% of Indian Camp Branch units were occupied by trout. Large gravel or cobble were each important substrate elements in about half of the habitat units, but 63% of units also had tines as a major substrate component.

In Bearpen Creek where trout occupied about 52% of units, neither trout numbers nor densities were significantly different between units with, and without LWD (l-tailed Mann-Whitney U test, $P>0.05$). The average number of trout per unit (0.61) was much lower than in the basin as a whole (1.75) and was significantly different from all reaches except Indian Camp Branch and the upper Wine Spring Creek reach. Fully 94% of habitat units had fines as a major component of substrate, with small or large gravel or cobble each important in 20–40% of units.

4. Discussion

In Wme Spring Creek, like many watersheds in the southern Appalachians (Dolloff, 1996), the forest was logged to the stream during the early years of this century (Hedman, unpublished data). Trees in the mid-successional riparian forests of Wine Spring Creek are not yet as large as those of the reference watersheds, and because the amount and size of LWD in streams is a function of the age and size of woody material that the riparian forest can contribute, Wine Spring Creek had less LWD, especially in larger size classes, than did the. reference streams in old-growth watersheds (Fig. 2). These results are similar to findings in other southern Appalachian studies (Silsbee and Larson, 1983; Flebbe and Dolloff, 1995).

Longer pieces of LWD are often material from fresh blow-downs, and large-diameter pieces of LWD can only be produced by mature forests. Larger pieces, especially those that are longer than stream width, are more stable (Bisson et al., 1987; Naiman et al., 1992) and improve trout habitat by creating pools (Bilby and Likens, 1980; Bisson et al., 1987; Naiman et al., 1992; Hilderbrand et al., 1997). Over time, longer pieces of LWD are broken up into the shorter size classes. Hedman (unpublished data) found LWD loadings in Wine Spring Creek sites were significantly lower than other mid-successional stream systems in the southern Appalachians (Hedman et al., 1996) and that carry-over debris (left over from the time of logging) is a significant part of current LWD. He suggests that Wine Spring Creek is in a transition stage where carry-over debris is disappearing but the riparian forest has not yet generated significant new debris (Hedman, unpublished manuscript; Hedman et al., 1996). Hedman also found evidence that American chestnut (*Castanea dentata* Marsh.) had been salvaged from some Wine Spring Creek sites, rather than contributing to LWD in the stream.

More units in Wine Spring Creek lacked LWD altogether and units with two or more pieces of LWD were less common than was the case in the reference watersheds, especially Right Fork (Table 2). In unlogged streams, LWD is more likely to be aggregated into debris dams than to occur as single pieces of LWD, compared to logged streams (Silsbee and Larson, 1983). Where several pieces of LWD are found together, more complex habitat and cover can be created than in units where single pieces occur (Harmon et al., 1986).

Trout occupied habitat units in Wme Spring Creek at lower rates than they do in the two North Carolina reference streams in old-growth watersheds (Fig. 3). Trout nearly always occupied habitat units with at least four pieces of LWD, similar to occupancy rates in reference streams, but rates of occupancy for units with fewer or no LWD pieces were unusually low. Although Wine Spring Creek trout selected units, especially pools, with multiple pieces of LWD (Figs. 3 and 4), these units are comparatively rare (Table 2).

Trout selected pool habitat over riffles, as evidenced by higher rates of occupancy and higher numbers and density in pools. As a result, although pool habitat area is only 8 1% that of riffle area in Wine Spring Creek, nearly 1.5 times as many trout live in pools than in riffles. Trout were more likely to occupy pools with multiple pieces of LWD than pools that lack LWD; in fact, occupancy rates in Wine Spring Creek pools with multiple pieces of LWD were similar to rates in reference streams (Figs. 3 and 4). Furthermore, trout numbers in pools with LWD were greater than in pools without LWD. In pools, LWD often serves as a habitat-forming element, producing scouring action, and creating complex cover. For riffles, however, LWD had little or no influence on trout occupancy or numbers (Fig. 4). In riffles, multiple pieces of LWD are often scattered through the unit and not oriented in a way that creates pools (personal observation).

Trout habitat, occupancy rates, and numbers differed among Wme Spring Creek reaches (Tables 1 and 3). Trout occupied most units in lower reaches of the mainstem, but occupancy rates of tributaries and upper reaches of the mainstem were lower (Table 3). Trout numbers were higher in the lower reaches than in the headwaters (Table 3). The lowest reach on Wme Spring Creek had little LWD, but most habitat units there have boulder substrate. Boulders, like LWD, are roughness elements that carve out pool habitat for trout (Sullivan et al., 1987). Both gradient and width were higher in this reach than upstream (Table 1), and as gradient and width increase, the potential for downstream loss of LWD increases (Harmon et al., 1986; Bisson et al., 1987). In the middle section of Wme Spring Creek, between the two main tributaries, LWD loadings were high and boulders less important in habitat units.

In the upper reach of Wme Spring Creek, trout occupancy was low and trout numbers were high in pools but low in riffles. In this reach, riffle substrate was primarily cobble, too small to provide structure for trout habitat. Below the small tributary, natural LWD was an important component of pools. But above the tributary, upper Wine Spring Creek resembles Indian Camp Branch and Bearpen Creek, where trout occupy only about half of habitat units and trout numbers and LWD counts were quite low. According to Wayah Ranger-District records (unpublished), this section of stream was 'cleaned' of natural LWD when the 23 structures were installed in the mid-1970s and during subsequent maintenance of structures. All three headwater reaches are narrow streams with small-sized substrate, and although overall gradient is high in the two tributary reaches (Table 1), stream power may not be adequate to move LWD downstream (Keller and Swanson, 1979; Bisson et al.,. 1987). Generally, small headwater stream reaches have higher LWD loadings than reaches downstream (Keller and Swanson, 1979; Bilby and Likens, 1980; Harmon et al., 1986; Bisson et al., 1987; Naiman et al., 1992). In all three headwater reaches, where LWD is low, the riparian forest is younger than in lower reaches, and probably provides less LWD input; all these reaches had relatively poor trout habitat and low trout numbers.

In the most simple terms, the process of adaptive management, central to implementation of ecosystem management (Christensen et al., 1996; Thomas, 1996), is a cycle of ...evaluation, planning, action, monitoring, evaluation,. ..This study represents an initial phase of monitoring and evaluation: although trout densities in the reaches of Wine Spring Creek below Bearpen Creek (Table 3) were lower than the $0.35/m^2$ in Right Fork (Flebbe and Dolloff, 1995), nearly all units had at least one trout and either LWD or boulders provided complex habitat. Other factors may limit trout densities here. Addition of LWD in these reaches would not be warranted at this time (Hilderbrand et al., 1997), and as the riparian forest matures and provides new LWD, the conditions should be sustainable. Additional LWD could improve conditions for trout in the upstream reaches of Wme Spring Creek and its tributaries, where habitat (substrate composition and low LWD) was poor and trout occupancy, numbers, and density were low. The next adaptive management steps are planning and action, followed by another phase of monitoring and evaluation. In September 1997, LWD was experimentally added to three sites in the upstream reaches of Wme Spring and Bearpen Creeks, with monitoring and evaluation already underway.

5. Conclusions

Wine Spring Creek had less LWD, especially in the larger size classes that represent stable or new material, than the two reference streams in North Carolina old-growth watersheds. More units in Wme Spring Creek lacked LWD and accumulations of two or more pieces of LWD were less common than was the case in the reference watersheds. For riffles, trout numbers and occupancy rates were low and amounts of LWD did not influence either. Trout nearly always occupied pools with at least two pieces of LWD, but occupancy rates for pools with little or no LWD were low compared to the reference streams. Habitats on the lower and middle reaches on the mainstem of Wine

Spring Creek had highest trout numbers and were nearly always occupied by trout. In these reaches, riparian ages are older and stream habitat had abundant LWD or boulder substrate. Upper reaches of Wine Spring Creek and its tributaries, however, had less mature riparian forest, less LWD and boulder substrate, low rates of trout occupancy, and lower trout numbers.

Sites in the upper reaches of Wme Spring and Bearpen Creeks, which have little LWD and relatively poor trout habitat, have been selected for experimental additions of LWD. This study will evaluate changes in habitat and trout populations in experimental and control sections over the next several years, to complete the adaptive management cycle.

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