Relations among riparian grazing, sediment loads, macroinvertebrates, and fishes in three central Pennsylvania streams

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Abstract: We assessed relations among riparian grazing, sediment loads, macroinvertebrates, and fishes in three streams in adjacent catchments in central Pennsylvania. The catchments consisted mostly of agricultural and forest lands. Lengths of streams subjected to riparian grazing were 2.5 km along Cedar Run and 4.1 km along Slab Cabin Run; there was no riparian grazing along Spring Creek. Median daily discharge and temperatures during summer and winter were significantly different among streams. Annual sediment yields were 113, 255, and 273 t in Spring Creek, Cedar Run, and Slab Cabin Run, respectively. Substrate permeability of potential spawning sites for brown trout (*Salmo trutta*), and densities of benthic macroinvertebrates were significantly higher in Spring Creek than in the other streams. Densities of wild brown trout were 5-23 times higher in Spring Creek than in Cedar Run and Slab Cabin Run. Although there were marked differences among streams with and without riparian grazing, other watershed attributes could have had some influence on these streams.

Résumé : Nous avons évalué les relations existant entre le broutage riverain, la charge de sédiments, les macro-invertébrés et les poissons, dans trois petits cours d'eau de bassins-versants voisins, dans le centre de la Pennsylvanie. Ces bassins-versants étaient principalement recouverts de terres agricoles et de forêts. Le broutage riverain touchait 2,5 km du Cedar Run et 4,1 km du Slab Cabin Run, alors que les berges du ruisseau Spring n'étaient soumises à aucun broutage. Le débit quotidien moyen ainsi que les températures estivales et hivernales étaient sensiblement différents selon les cours d'eau. La production annuelle de sédiments était de 113 t pour le ruisseau Spring, de 255 t pour le Cedar Run et de 273 t pour le Slab Cabin Run. La perméabilité des substrats pouvant servir de frayères à la truite brune (*Salmo trutta*) et la densité des macro-invertébrés benthiques étaient significativement plus élevées dans le cas du ruisseau Spring que dans celui des deux autres cours d'eau. De même, la densité des truites brunes sauvages était 5–23 fois plus élevée dans le ruisseau Spring que dans le Cedar Run et le Slab Cabin Run. Il existe donc des différences marquées entre les cours d'eau soumis et non soumis au broutage riverain, mais il est possible que d'autres caractéristiques des bassins-versants aient eu une incidence sur ces cours d'eau.
[Traduit par la Rédaction]

Introduction

Livestock grazing in riparian zones has been linked to instream habitat degradation and salmonid recruitment failures. Removal of riparian vegetation increases variability in stream discharge, water temperature, and sediment loads (Barton and Taylor 1985; Cunjak and Power 1986; Hillman and Griffith 1987). Variable discharges in degraded streams may cause salmonid recruitment failures. Sando (1981) determined that large flow fluctuations in a Montana river resulted in complete mortality of eggs in 90% of redds. High turbidities also contribute to poor salmonid health and slowly alter salmonid microhabitat (Tappel and Bjornn 1983; Sigler et al. 1984; Redding et al. 1987; Chapman 1988).

It is difficult to compare effects of grazing and associated non-point-source pollution on streams in the Pacific Northwest and the Intermountain West to those in the humid East, primarily because vegetative cover in the East mutes denudation processes (Ritter 1986). Sediment losses in the West are characterized by high turbidities relative to discharge, whereas in the East, much greater discharges are needed to produce comparable turbidities (Wilson 1977). The lack of studies on effects of riparian grazing on stream biota in the East provided the impetus for this project.

We conducted this study in the Spring Creek watershed, central Pennsylvania, where earlier studies showed that poor recruitment of brown trout (*Salmo trutta*) in sections of Spring Creek was due to high sediment loads originating from two tributaries draining agricultural basins (Beard and Carline 1991). We assessed conditions in two streams with extensive riparian grazing and in a third stream with no riparian grazing. Our objectives were to document streamflow, sediment load, and substrate composition, and relate density and diversity of macroinvertebrate and fish communities to differences among streams.

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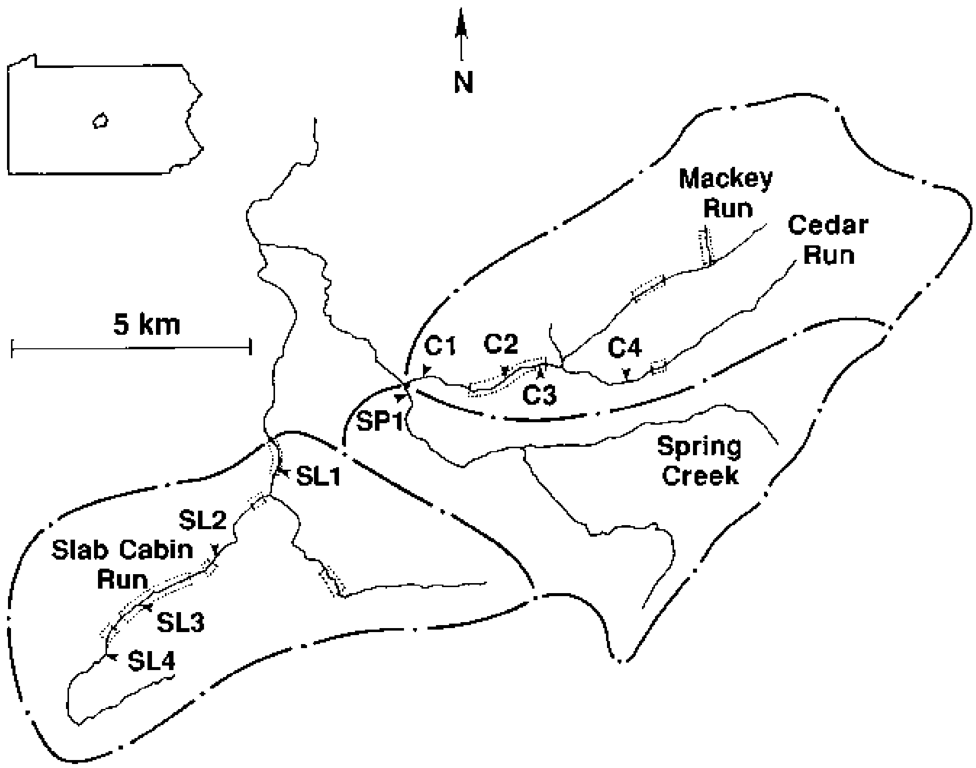
Materials and methods

The Spring Creek watershed (381 km^2), which lies within the Ridge and Valley physiographic province of central Pennsylvania (Fig. 1), drains into Bald Eagle Creek, a tributary to the West Branch of the Susquehanna River. Much of the stream water comes from limestone aquifers (Giddings 1974); hence, pH (7.7–8.4) and alkalinity (ca. 200 mg·L^{-1} as $CaCO_3$) are relatively high. Average precipitation in the basin is about 102 cm·year^{-1}. During this study, 1991 was the

Fig. 1. Spring Creek watershed in central Pennsylvania and boundaries of three catchments with designations for fish and benthos sampling sites. Locations of riparian pasture >200 m long are highlighted.



driest year since 1931 and precipitation in 1992 was near average (NOAA 1991–1992).

Slab Cabin Run (Fig. 1) is 14.4 km long, drains 44 km^2 of agricultural (55%) and forest lands (43%), and receives treated wastewater from a treatment facility near the headwaters. A wellfield, located adjacent to the stream about 5.5 km below the stream's source, supplies about 6.62 million liters per day of potable water. About 4.1 km of the stream flows through unfenced pastures, where nearly the entire streambank is eroding.

Cedar Run is 7.9 km long and drains a 46 km^2 basin that is 85% agricultural, and the remainder is forestland. About 60% of Cedar Run and its main tributary, Mackey Run, flow through 2.5 km of unfenced pasture. Some of the pastured streambank has been stabilized with riprap and about 50% of it is eroding.

The upper segment of Spring Creek, starting at its confluence with Cedar Run, is about 6 km long and drains 34 km^2 of approximately equal areas of agriculture, forestland, and urban development. There are no riparian pastures in the catchment.

Continuous stream stage recorders were installed at the downstream boundaries of each basin in August 1991 (Fig. 1). At least 20 measurements of stream discharge were made at a wide range of stages in each stream. Quadratic regression equations ($r^2 > 0.99$) were used to convert water-level data to discharge. Temperature recording devices were placed on the streambed at each of the gauging stations and temperatures were recorded hourly.

We collected weekly water samples at each gauging site during baseflow, and we used automatic water samplers (ISCO) that were programmed to begin several hours before storm events were anticipated. During storms, samples were collected at 3-h intervals; during summer months when storms were of short duration, samples were taken at 1-h intervals. Between September 1991 and August 1992 we collected samples during 75% of the storms. We analyzed 240 samples for turbidity, in nephelometric turbidity units (NTU), with a Hach Portalab Turbidimeter (Model 16800) and 95 for total suspended solids (TSS) by filtering (0.45 μm), drying, and weighing them (American Public Health Association et al. 1989). A quadratic regression of turbidity versus TSS was developed to estimate TSS of samples for which only turbidity was measured.

We employed a linear interpolation method to estimate sediment loads. We used either single daily observations of TSS or a mean for all samples collected during a 24-h period and interpolated between days for which TSS measurements were made. Total daily discharge was multiplied by observed or estimated TSS to estimate daily sediment load.

We established one sampling station in Spring Creek, four in Cedar Run and four in Slab Cabin Run (Fig. 1), to characterize stream morphology, substrate composition, benthos, and fish communities; station lengths averaged 250 m. We sampled at only one station (ungrazed) in Spring Creek, because during dry periods much of the streamflow percolates into the streambed about 1 km upstream of its confluence with Cedar Run. Groundwater emerges about 500 m upstream from the confluence, upstream of where our station was located. Stream length with perennial flow at this location was considered insufficient for establishment of more than one sampling site. In both Cedar Run and Slab Cabin Run, two sampling stations were located in heavily pastured fields and two were in ungrazed fields with well-vegetated streambanks.

We measured water depth and velocity at 10–15 points along 9–14 transects at each of the sampling stations and characterized substrate size in July 1992 and 1994. Transects were spaced one stream width apart. The streambank at each end of the transect was classified as stable or eroding. Eroding streambanks had steep or vertical slopes with no vegetation. In May 1992, we used a 15 cm diameter stovepipe sampler (McNeil and Ahnell 1964) to collect substrates from sites that had a depth, velocity, and substrate size similar to those used for spawning by brown trout (Beard and Carline 1991). Four samples were taken from each of the nine stations, dried, and sieved through a series of 12 screens with openings ranging from

Table 1. Channel characteristics of grazed and ungrazed reaches of Spring Creek, Cedar Run, and Slab Cabin Run.

Stream and station	Mean width (m)	Mean depth (cm)	Mean velocity (cm·s^{-1})	Discharge (m^3·s^{-1})	Eroding streambank (%)	Substrate (%)		
						Silt-sand	Gravel	Cobble
Spring Creek								
Ungrazed								
SP1	5.6	21	17	0.197	10	4	17	79
Cedar Run								
Ungrazed								
C1	8.1	18	20	0.248	0	5	59	36
C4	6.3	22	12	0.159	10	36	60	4
Grazed								
C2	6.6	31	14	0.225	48	52	8	40
C3	6.4	21	19	0.223	59	33	34	33
Slab Cabin Run								
Ungrazed								
SL2	4.3	21	11	0.085	12	82	17	1
SL4	2.4	11	17	0.042	0	6	76	18
Grazed								
SL1	7.4	12	12	0.104	100	57	11	32
SL2.5[a]	4.9	21	4	0.046	100	90	0	10
SL3	2.5	19	10	0.051	100	82	1	17
Means of all sites								
Ungrazed	5.34	18.6	15.4	0.146	6.4[b]	26.6	45.8[b]	27.6
Grazed	5.56	20.8	11.8	0.130	81.4	62.8	10.8	26.4

Note: Measurements were made in summer 1992 and 1994.
[a]Midway between SL2 and SL3.
[b]Ungrazed versus grazed reaches significantly different (Kruskal-Wallis test, $P < 0.05$).

0.25 to 12.7 mm. The percentage by weight of material retained by each sieve was used to calculate the geometric mean particle size and the sorting coefficient, which is a measure of the size distribution of sediment particles. The Fredle index, which is the ratio of geometric mean particle size to sorting coefficient, provides a measure of substrate permeability (Lotspeich and Everest 1981).

We collected benthic macroinvertebrates from riffles using Surber samplers in June and August 1992; three samples per station were collected each time. Samples were sorted and identified to family. The frequency and abundance of taxa in each sample were analyzed with a Shannon diversity index (Pielou 1984).

We used direct current (200 V) electrofishing gear to inventory fish communities in May and August 1992. Trout densities were estimated at all nine sites by using the Zippin successive removal method (Zippin 1958) in a 250-m reach. All trout were weighed to the nearest gram, measured to the nearest millimeter, and released. Age-0 brown trout were readily distinguished from age-1 and older brown trout (hereafter referred to as age-1+) by examination of length-frequency distributions. We used software developed by Van Deventer and Platts (1989) to estimate densities and 95% confidence intervals for age-0 and age-1+ brown trout. These age-1, age-0 changes are global changes. When the computed lower 95% confidence interval was less than the total number caught, we used the total catch as the lower confidence interval. We carefully electrofished a subsection (50 m) of each sample reach and attempted to collect all species observed; these data were used to characterize fish communities.

Results

Stream morphology

Stream width and depth were similar among grazed and ungrazed stations and among streams (Table 1). The most striking difference among sampling stations was the nearly complete lack of woody vegetation in the riparian zone of pastured reaches. In ungrazed reaches, the streambank was vegetated with a mixture of grasses, shrubs, and trees. About 6% of the ungrazed streambanks were eroded in contrast to about 81% in grazed areas. In ungrazed reaches, there was significantly less silt and sand substrates and more gravel than in grazed reaches.

Stream hydrology

There was a significant difference (Kruskal-Wallis test, $P < 0.001$) in median discharge among streams; Spring Creek had the highest discharge and Slab Cabin Run, the lowest (Table 2). Slab Cabin Run had the most variable discharge and Cedar Run was the least variable. Runoff from a nearby highway interchange contributed to peak discharges in Spring Creek. Total daily discharge per unit basin area in Spring Creek was three times that in Cedar Run and about five times higher than in Slab Cabin Run. Wellwater withdrawals from the Slab Cabin Run basin probably reduced streamflows, because these withdrawals were about 0.75 times the median daily discharge.

Median daily TSS was significantly different (Kruskal-Wallis test, $P < 0.001$) among streams; it was lowest in Spring Creek and about seven times higher in Slab Cabin Run (Table 2). Annual sediment yield was lowest in Spring Creek and more than twice as high in Cedar Run and Slab Cabin Run. When annual water yield and basin area are taken into account, sediment yield in Slab Cabin Run was highest, nearly five times greater than in Spring Creek.

Temperature

Stream temperatures were largely a function of discharge.

Table 2. Daily discharge, concentration of total suspended solids (TSS), and sediment yield of Spring Creek, Cedar Run, and Slab Cabin Run, September 1991 to August 1992.

Stream and statistic	Median daily discharge ($m^3 \cdot s^{-1}$)	Total daily discharge ($m^3 \cdot km^{-2} \cdot d^{-1}$)	Median daily TSS ($mg \cdot L^{-1}$)	Annual sediment yield: tonnes	Annual sediment yield: t·million $m^{-3} \cdot km^{-2}$
Spring Creek					
Median	0.38	953	5		
Range	0.16–2.61		1–260		
Total				113	0.24
Cedar Run					
Median	0.19	349	25		
Range	0.11–0.99		7–486		
Total				255	0.70
Slab Cabin Run					
Median	0.10	192	37		
Range	0.004–3.63		6–1237		
Total				273	1.15

Note: Median daily discharge and TSS were significantly different among streams (Kruskal-Wallis test, $P < 0.001$).

Table 3. Water temperatures (°C) of Spring Creek, Cedar Run, and Slab Cabin Run, September 1991 to August 1992.

Stream	Mean daily range	Instantaneous maximum	January daily median	August daily median
Spring Creek	3, 13.8	17.8	7.4	11.3
Cedar Run	(–0.5, 23.0	25.6	4.6	15.6
Slab Cabin Run	–0.3, 21.3	27.8	0.25	16.2

Note: Median temperatures in January and August were significantly different among streams (Kruskal-Wallis test, $P < 0.001$).

Spring Creek, which had the highest discharge, had the narrowest range of mean daily temperatures, the lowest instantaneous maximum temperature, the warmest temperatures in January, and the coolest in August (Table 3). Cedar Run was intermediate among streams with respect to discharge and temperature, while Slab Cabin Run had the lowest discharge and the most extreme temperatures.

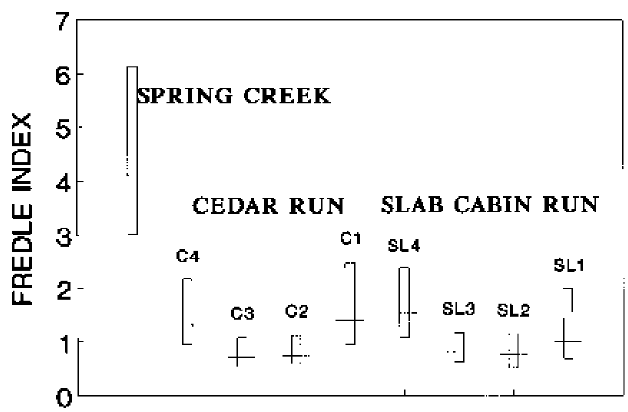
Substrate composition

Substrate composition of potential trout spawning sites varied among streams, but not among stations (Fig. 2). The median Fredle index of substrates in Spring Creek (4.12) was significantly different (Kruskal-Wallis test, $P < 0.01$) than the median index in Cedar Run (0.97) and Slab Cabin Run (0.98). Fredle indices among stations were not significantly different ($P > 0.05$) in either Cedar Run or Slab Cabin Run. Thus, substrate permeability in Spring Creek was substantially higher than in the two streams with extensive streambank grazing.

Benthic macroinvertebrates

Benthic communities differed among streams. The dominant taxa in Spring Creek were amphipods and dipterans, which were mostly Chironomidae (Table 4). Isopods, amphipods, and dipterans were the dominant taxa in Cedar Run while dipterans were most abundant in Slab Cabin Run. There were no trends in median number of taxa found in the three streams. In May and August, Spring Creek had significantly ($P < 0.05$) greater numbers of benthic macroinvertebrates than the other two streams, where densities were not significantly different ($P > 0.05$). In May the Shannon diversity index was significantly ($P < 0.05$) higher in Cedar Run than in the other two streams, but in August there were no differences in diversity.

Fig. 2. Median and range of Fredle index values for potential brown trout spawning sites in Spring Creek, Cedar Run, and Slab Cabin Run, June 1992. Four substrate samples were collected at each site, whose designation corresponds to Fig. 1.



Fish populations

Fish communities were similar among stations within streams. We found only four fish species in Spring Creek and Cedar Run; slimy sculpins were the most abundant followed by brown trout (Table 5). In Slab Cabin Run we collected 12 species of which longnose dace, common white suckers, and slimy sculpins were the most numerous. The bluegills in Cedar Run and the banded killifish in Slab Cabin Run are not normally found in coldwater streams in this region.

Densities of age-1+ brown trout were judged significantly different among streams, because 95% confidence intervals of population estimates did not overlap (Table 6). In Spring Creek, May and August estimates ranged from about $1200 \cdot ha^{-1}$ to $1900 \cdot ha^{-1}$, which were approximately 5 times greater than the average density in Cedar Run and 22 times greater than that in Slab Cabin Run. Similarly, in August, density of age-0 brown trout in Spring Creek was about 13 times greater than the mean density in Cedar Run and 23 times

Table 4. Composition of macroinvertebrate communities and median number of taxa, density, and diversity in Spring Creek, Cedar Run, and Slab Cabin Run, May and August 1992.

	Spring Creek		Cedar Run		Slab Cabin Run	
	May	August	May	August	May	August
Taxa (%)						
Amphipoda	61	56	17	17	2	14
Isopoda	0	0	30	22	1	1
Coleoptera	3	5	2	11	[a]	1
Diptera	21	29	21	35	70	47
Ephemeroptera	3	3	1	1	1	2
Trichoptera	7	5	14	11	2	16
Oligochaeta	2	[a]	6	[a]	22	10
Turbellaria	3	[a]	1	1	1	5
Other	[a]	2	8	2	1	3
Median number of taxa	17		11.5		10	
		14		13.5		14.5
Density (no.·m^{-2})	17 980*x*		4422*y*		3944*y*	
		15 279*x*		6838*y*		4100*y*
Diversity index	1.19*x*		1.81*y*		1.19*x*	
		1.32*x*		1.60*x*		1.61*x*

Note: Density and diversity values in rows followed by the same letter were not significantly different (Kruskal-Wallis test, $P > 0.05$).

[a]Less than 0.5% of total number.

Table 5. Percentage composition of fish communities in Spring Creek, Cedar Run, and Slab Cabin Run, May and August 1992.

	Percent of total number collected		
	Spring Creek	Cedar Run	Slab Cabin Run
Brown trout (*Salmo trutta*)	26.1	13.3	1.4
Slimy sculpin (*Cottus cognatus*)	72.0	75.4	10.5
White sucker (*Catostomus commersoni*)	1.4	11.1	30.5
Longnose dace (*Rhinichthys cataractae*)			37.7
Blacknose dace (*Rhinichthys atratulus*)	0.5		3.3
Creek chub (*Semotilus atromaculatus*)			2.4
Fallfish (*Semotilus corporalis*)		<0.1	
Pearl dace (*Margariscus margarita*)			0.1
Common shiner (*Luxilus cornutus*)			0.3
Fathead minnow (*Pimephales promelas*)			8.5
Tessellated darter (*Etheostoma olmstedi*)			0.8
Bluegill (*Lepomis macrochirus*)		0.2	
Banded killifish (*Fundulus diaphanus*)			4.4

Note: Data were combined from all stations for both months.

greater than that in Slab Cabin Run. In Cedar Run the variation in trout density was not related to grazing, but in Slab Cabin Run the highest density was found in an ungrazed reach (SL4), which had little agricultural activity upstream of it.

Discussion

Results of this study of stream reaches subject to intensive riparian grazing are generally consistent with other published studies. Although the focus here was on conditions of the riparian zones, stream morphology, hydrology, sediment loads, and biotic communities reflect the cumulative effects of conversion of forestland to agriculture, urban and infrastructure development, and groundwater withdrawals. While it is impossible to ascribe differences in communities to specific watershed attributes, an examination of conditions among streams allows us to make some inferences about causative factors.

Streamflows differed significantly among sites and low flows in Slab Cabin Run may have contributed to the sparse trout population. Groundwater withdrawals in Slab Cabin Run undoubtedly reduced streamflow, which was most apparent during the 1988 drought when flows between pools were negligible. In contrast, the Spring Creek site supported a high density of trout during this drought (Beard and Carline 1991). It is likely that Slab Cabin Run would not support as large a trout population as Spring Creek, even if riparian grazing in the Slab Cabin Run basin was completely eliminated.

Differences in water temperature among streams was probably related to several factors. The absence of riparian shading in large sections of Cedar Run and Slab Cabin Run must have contributed to high summer temperatures (Gorman and Karr

Table 6. Estimated densities (95% confidence intervals in parentheses) of age-0 and age-1+ brown trout in Spring Creek, Cedar Run, and Slab Cabin Run, May and August 1992.

	May		August	
Stream and station	Age group	Estimate (no.·ha^{-1})	Age group	Estimate (no.·ha^{-1})
Spring Creek			0	3512 (702, 18 012)
	1+	1893 (1892, 2250)	1+	1238 (988, 1560)
Cedar Run				
C1			0	269 (170, 526)
	1+	363 (363, 368)	1+	170 (169, 181)
C2			0	336 (244, 756)
	1+	513 (513, 529)	1+	672 (647, 723)
C3			0	409 (372, 474)
	1+	255 (255, 277)	+1	197 (197, 212)
C4			0	36 (35, 43)
	1+	129 (129, 137)	1+	94 (94, 108)
Mean			0	263
	1+	315	1+	283
Slab Cabin Run				
SL1			0	0
	1+	15 (15, 31)	1+	15 (15, 31)
SL2			0	0
	1+	35 (35, 70)	1+	35 (35, 70)
SL3			0	0
	1+	48 (48, 96)	1+	48 (48, 96)
SL4			0	599 (599, 790)
	1+	136 (136, 218)	1+	245 (245, 327)
Mean			0	150
	1+	59	1+	86

1978; Claire and Storch 1983; Yankey et al. 1991). Streamflow and proximity of monitoring sites to sources of groundwater inputs were also important. Spring Creek, where temperature varied least, had the highest streamflow and a large groundwater inflow was less than 1 km upstream of the monitoring site. Cedar Run had substantially more streamflow than Slab Cabin Run and less extreme temperatures in summer and winter. We do not believe that the relatively high summer temperatures in Slab Cabin Run adversely influenced the brown trout population, because in sections of Spring Creek about 22 km downstream of the Spring Creek – Cedar Run confluence, summer temperatures exceed those in Slab Cabin Run yet trout densities are among the highest in the entire watershed (R. Carline, unpublished data).

Channel morphology was not substantially different among and within streams. Large woody debris, which has been positively correlated with salmonid density (Elliott 1986), was scarce in both ungrazed and grazed reaches. This was not unexpected in the grazed reaches, where woody vegetation was absent from the riparian zone. The lack of large woody debris in ungrazed sections was probably due to the young age of trees in the riparian zone and the relatively long distances (5–10 km) from forestlands in the extreme upstream portions of these catchments. The most notable differences among grazed and ungrazed reaches were the amount of eroding streambank and the predominance of fine substrates in the streambed.

Yankey et al. (1991) conducted a 10-year study on non-point-source pollution in Rock Creek, Idaho, and concluded that eroded streambanks in grazed areas were a major source of sediment. They estimated that at least 48% of streambank length in Rock Creek, similar to our estimates for Cedar Run and Slab Cabin Run, was eroded. They also estimated that sediment from grazed areas was two to five times greater than that from croplands. We did not attempt to quantify the sources of sediment; hence, we cannot assess the relative contributions of streambanks and cropland to total sediment yields.

Differences in sediment loads and substrate composition among streams seemed to account for at least some of the differences in benthic communities. Densities of benthic organisms were highest in Spring Creek where sediment loads were lowest. Macrobenthos density declines with increasing sediment loads and reduced substrate size (Rabeni and Minshall 1977; Minshall 1984). The shift in dominance from amphipods in Spring Creek to chironomids in Slab Cabin Run is also consistent with observations of streams in forested and agricultural catchments (Dance and Hynes 1980). However, densities of ephemeropterans and trichopterans, which are sensitive to changes in water quality (Lenat 1984), did not demonstrate consistent trends among streams.

Substrate composition probably had a direct effect on brown trout by influencing reproductive success. Beard and Carline (1991) found that the Fredle index of trout spawning sites in the mainstem of Spring Creek was substantially higher (3.0–4.1) than in Cedar Run (0.97) and Slab Cabin Run (0.98), where few age-0 trout were found. The Fredle index in our Spring Creek station (4.1) was comparable with sites farther downstream, where embryo survival was high. Providing that our selection of potential spawning sites for substrate analyses was representative, we would predict that embryo survival in Cedar Run and Slab Cabin Run would be low. It is possible that spawning activity in these streams could alter substrate composition and result in higher Fredle indices than we measured. Nonetheless, it has been convincingly demonstrated that increases of fine materials in salmonid spawning sites reduce embryo survival (for review see Chapman 1988).

Though differences in recruitment among streams could readily account for differences in density of age-1+ brown trout, other factors may have played a role. Invertebrate food resources, which were clearly higher in Spring Creek than in the other streams subjected to grazing, may have contributed to differences in trout density among streams. Another apparent habitat difference was the lack of overhanging bank vegetation in the grazed sections in contrast to ungrazed ones, where grasses and shrubs provided a substantial amount of cover along the banks. Aquatic vegetation and grass cover along banks are regarded as important habitat features of productive trout streams (Hunt 1979).

The relatively simple fish communities found in Spring Creek and Cedar Run are typical of first- and second-order coldwater streams in this physiographic province. As stream order and water temperatures increase, fish diversity increases. This pattern is also common in western U.S. streams; Decker and Erman (1992) also found that fish diversity increased with increasing temperature. Fish diversity was highest in Slab Cabin Run, which had the warmest summer temperatures.

For the most part, differences among catchments with intensive riparian grazing and the reference site were rather striking. Our results are consistent with findings from a large number of studies in western United States (Armour et al. 1991). We conclude that riparian grazing along streams in the East has effects similar to those in the West, despite major climatic differences. Further studies on grazing effects in the East should document how stream ecosystems respond to habitat restoration of intensively grazed riparian zones.

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