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Evaluation of Brook Trout Introductions into a Headwater Stream in Eastern Kentucky

by

James R. Axon and Edward W. Carroll

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ABSTRACT

A natural population of brook trout was successfully established at Bad Branch after stocking 3-4 inch fingerlings at a rate of about 200 fish per mile in 1980 and 1981. The standing stock of brook trout above the falls was 153 fish per mile and 31 pounds per acre in 1982. The population density remained good, despite the severe drought conditions in 1983 and 1985-1987. Bad Branch had higher population densities of brook trout in 1986 and 1987 when compared to densities of brook trout in other streams in Kentucky. Natural reproduction occurred each year from 1982-1987. Brook trout survived to at least age 3+ at Bad Branch; the largest fish captured was 13.8 inches long. Brook trout began to exceed 10 inches in length at age 2+, which is the minimum length limit for brook trout on several streams in Kentucky. The results of this study have led the Kentucky Department of Fish and Wildlife Resources to develop natural populations of brook trout in other suitable streams.

Two streams in Bell and Harlan counties were the first streams in Kentucky to have self-sustaining brook trout *Salvelinus fontinalis* populations developed as a result of introductions in 1968 by U.S. Fish and Wildlife Service (USFWS) personnel. Beginning in the early 1980's, the Kentucky Department of Fish and Wildlife Resources (KDFWR) placed greater emphasis on trout management in Kentucky's streams. One of the objectives in this effort was to establish self-sustaining trout populations in suitable streams. Headwater streams located above 2,000 ft msl that had maximum temperatures not exceeding 68°F, sufficient flow, forested watershed, relatively undisturbed, and little, if any, competitive fish species were considered for establishing brook trout.

Bad Branch, located in Letcher County, was the first stream selected by the KDFWR to introduce brook trout for the purpose of developing a self-sustaining brook trout population. This stream met all of the qualifications for consideration as a potential brook trout stream based on data reported from the Kentucky Nature Preserves Commission (KNPC) (Harker et al. 1980). To determine the success of these stockings, a study was implemented in 1981 on the potential of establishing wild trout populations in streams as part of D-J Project F-50, District Fisheries Investigation.

STUDY AREA

Bad Branch is located in the Upper Cumberland River drainage within the proclamation boundaries of Jefferson National Forest in Letcher County. This stream arises at an elevation of 2,720 ft msl on Pine Mountain and flows for 3.0 mi before entering Poor Fork at 1,758 ft msl. A 60-ft falls is located about 1.0 mile above the stream's mouth. An east prong to Bad Branch flows for 1.4 mi before entering Bad Branch. A small impoundment is on the east prong 0.3 mi above its confluence with Bad Branch. The gradient from the stream's headwater to its mouth is 321 ft/mi. The Bad Branch drainage lies within the Appalachian Plateau Province, Cumberland Mountains Section. About 98% of the watershed is in forest. Kentucky Nature Conservancy has a management lease for 1,000 acres in the watershed and owns 103 acres. Another 435 acres are owned by the KNPC. Bad Branch was designated as a Kentucky Wild River in 1986.

METHODS

Brook trout, 3-4 in long, were stocked in Bad Branch in 1980 (600 fish) and in 1981 (650 fish) at a rate of about 200 fish per stream mile. These fish were stocked in sections where this species was expected to range, which was 3.2 mi from 1,800 ft msl elevation upstream. Fish were stocked for 2 years to establish consecutive year classes of adults prior to the first anticipated year of natural reproduction in the fall of 1981.

Physical-chemical determinations were made on 20 July 1981 and 18 August 1987. Dissolved oxygen, alkalinity, pH, and stream temperature were recorded at two stations in 1981 using a Hach portable water quality kit. Station 1 was located 300 yd upstream from the mouth of Bad Branch. Station 2 was located 1 mi above the 60-foot falls (Figure 1). Physical-chemical data was also recorded at a station 1,500 ft above the mouth of Bad Branch in 1987.

Qualitative evaluation of instream physical characteristics at each of the same

two stations were made by visual estimation (gravel size composition, pool/riffle ratio, type of fish shelter) and tape measurement (stream width and depth).

Macroinvertebrates were collected in the spring, summer, and fall of 1981 at two stations located 113 yd above the mouth (Station 1) and 300 yd above the falls (Station 2). Two square meter quadrants were sampled at each station using the "kick" method (Penrose 1980). Samples were preserved in 60% ethyl alcohol and later sorted by species and enumerated to determine species composition, density, species diversity, and species equitability. Species diversity (d) was calculated using the modified Shannon-Weaver index (Lloyd et al. 1968). Equitability was determined by the method described by Lloyd and Ghelardi (1964).

Post stocking surveys of the fish population in Bad Branch were conducted each year in 1982-1987 utilizing a backpack electroshocking unit. In 1982, four 200-ft sections were electrofished - two sections in each area above and below the 60-ft falls. Each section contained at least 2 pools and riffles. Leslie's depletion method (Ricker 1975) was used to estimate the standing stock of fish. In the remaining survey years, an estimated two-thirds of the entire study area was electrofished. All fish captured were measured to the nearest 0.1 in; weights were taken from a representative sample of fish. Scale samples were collected from brook trout in 1982 to determine age and growth characteristics, using the direct proportion method. Otoliths were removed from 15 brook trout in 1987 to view growth rings for aging these fish.

RESULTS AND DISCUSSION

Water quality was assessed at Bad Branch in 1981 and 1987 and found to be excellent as coldwater habitat for brook trout (Table 1). The KNPC also reported excellent water quality in Bad Branch from a 1979 study (Harker et al. 1980). The maximum stream temperature recorded was 65°F, which is indicative of headwater streams in Kentucky that are order I and II streams (Kuehne 1962), have constant flow supplied by ground water, and are in watersheds that are nearly 100% forested. Fish habitat is abundant in Bad Branch in the form of boulders, undercut banks, ledges, logs, tree roots, and brush. Particle size of bottom material is diverse, with riffles having 20% gravel and 30% rubble (Table 2). The rubble is particularly conducive to good macroinvertebrate production (Sprules 1947). The gravel serves well as spawning substrate for brook trout.

The macroinvertebrate population indices in Bad Branch were indicative of a stream with excellent water quality (Tables 3 and 4). The mean density of macroinvertebrates was moderate at 314 individuals/m^2, which was similar to the 320 individuals/m^2 collected by the KNPC in 1979. Trichopterans and ephemeropterans were the most abundant macroinvertebrates collected. Crayfish were also collected, but were not identified to species. The KNPC identified four species of crayfish in 1979. Crayfish provide an important source of food to brook trout. Ensign (1988) reported on composition of food items in brook trout stomachs from a stream in the Great Smoky Mountains National Park. The percent of relative wet weight was highest for terrestrial food items (63.8%), but crayfish ranked second at 5.4%. Several individual brook trout from one stream in Kentucky have been found to heavily utilize crayfish extensively as a food item (John Boaze, Fish and Wildlife Associates, Inc., personal

communication). Brook trout from within other Kentucky streams have also been observed to contain crayfish. The diversity index ($\bar{d}$) was high (>3) in the spring and summer at both stations. A $\bar{d}$ value of greater than 3 indicates unpolluted conditions (Wilhm and Dorris 1966); a value less than 1 indicates degraded conditions. Equitability (e) values were high (>1) above the falls at Station 2 in the spring and fall. Equitability is sensitive to slight levels of degradation and ranges usually from 0 for polluted conditions to 1 for clear water. Station 1 below the falls had e values less than 1 in the spring and fall, but they were still above 0.3; slight degradation generally exists when e values are 0.0 to 0.3.

Six species of fish were captured from electrofishing in Bad Branch in 1982, the year following the second and final year of stocking 3-4 inch brook trout (Table 5). Two additional species, green sunfish *Lepomis cyanellus* and northern hog sucker *Hypentelium nigricans*, were collected in later years. Bluegill and green sunfish were escaped fish from a small lake on the right prong of Bad Branch. The KNPC collected three other species of fish in 1979 that were not captured during this study - central stoneroller *Campostoma anomalum*, rainbow darter *Etheostoma caeruleum*, and stripetail darter *Etheostoma kennicotti*. Only brook trout, creek chub *Semotilus atromaculatus*, and bluegill *Lepomis macrochirus* were recorded from above the falls in 1982. Creek chub was the most abundant species of fish in Bad Branch, but was second to brook trout in biomass.

Standing stock of brook trout in Bad Branch was estimated at 111 fish/mile and 16.9 lb/acre in 1982. More than half of the total weight of all fish (32.6 lb/acre) was brook trout. The population of brook trout was much greater above the falls (Table 6). There were an estimated 31.0 lb/acre above the falls versus 2.7 lb/acre below. The biomass above the falls slightly surpassed the expected 30 lb/acre based on standing stock data from brook trout streams in other streams in the Appalachian Mountain range (Ratledge 1967, Wydoski 1978).

There were more brook trout captured each year above the falls than below in 1982-1987 (Table 7). Young-of-year brook trout, from natural reproduction, were captured in 5 of the 6 years of sampling fish. The low numbers of trout in 1984-1985 were due in part to an inefficient backpack electrofishing unit and the severe drought in 1983. A new unit was used in 1986 and 1987 when the highest number of trout were captured. The catch per hour of electrofishing (CPUE) was also highest during those years (Table 8).

The length distribution of brook trout captured throughout the study ranged from 2.2 to 13.8 in long (Table 8). There are at least four year classes of fish in the population - age 0+ through age 3+. Brook trout were aged to be as old as age 3+ based on otoliths from 15 fish captured in 1987 (Table 10). This is atypical for brook trout streams in the Southeast in nearby states, where brook trout seldom exceed the age of 2+. The number of potential spawning fish, age 1+ and older ($\geq$5 in class), is very good based on the length frequency of brook trout in 1986 and 1987. The number of trout in each of the 6-10 in classes during those years was good; the frequency of trout markedly declined past the 10-inch class.

A regulation was implemented in 1989 on designated brook trout streams, based partly on the findings of this study, that allows daily and possession limits of two brook trout that are at least 10 in long. Use of only artificial lures and flies with a single hook is permitted to fish for brook trout in those streams.

The success of reproduction and survival of brook trout in Bad Branch from study results in 1982 and 1983 led to the stocking of three additional streams with brook trout in 1985 and 1986 by the KDFWR. These streams qualified, based on ratings from inventory data of their fish populations and habitat, to be managed for establishing natural brook trout populations.

The population densities of brook trout at Bad Branch in 1986 and 1987 were somewhat similar to that recorded in two other streams in Kentucky in 1988. The CPUE was 27.6 in 1986 and 44.0 in 1987 at Bad Branch compared to 34.8 at Shillalah Creek and 35.1 at Parched Corn Creek in 1988. If the CPUE for only age 1 and older fish is compared, the population density was 18.6 fish/hour in 1986 and 37.0 in 1987 at Bad Branch versus 26.1 at Shillalah Creek and 18.0 at Parched Corn Creek. This is a better indicator of population density, since the success of capturing age 0+ fish is more variable due to their small size, ability to hide under coarse gravel and small rubble, and concentration in riffle areas. The CPUE of age 1 and older fish is also a good indicator of the adult population density.

The proportional stock density (PSD), based on a stock size of $\geq$5 in and a quality size of $\geq$8 in (Anderson 1980), was determined for brook trout captured in 1986 and 1987. The PSD was 51 in 1986 and was 81 in 1987. The PSD in 1986 was within the preferred range of 40-60. The 1987 PSD was higher than preferred, partially due to a few of the age 1+ fish already exceeding 8 inches in length (Table 10). The age 1 (1986 year class) fish were evidently poorly represented in the 1987 catch, which may be partially due to severe drought conditions in 1985-1987.

The mean lengths at ages 1 and 2 for brook trout captured from Bad Branch in 1982 were 3.7 and 7.1 in, respectively (Table 9). This is good growth compared to growth rates reported for brook trout from streams in the Appalachian Mountain range (Bridges 1958, Ratledge 1968, Wydoski 1978). Some of the age 2+ brook trout already exceed 10-in, the minimum length limit for brook trout on several Kentucky streams; age 2+ fish ranged from 7.6 to 10.2 in long when captured in July 1982. Brook trout particularly grew well after age 1. Growth of brook trout was possibly enhanced by their ability to ingest crayfish by age 1+. The weight-length relationship ($W = 0.56 + 0.095L$) was calculated from 20 age 1 and older brook trout captured in 1987 (Figure 2).

CONCLUSIONS AND RECOMMENDATIONS

The reproductive success, growth, length, and age distribution and population density of brook trout all indicate a well-established and viable population has developed in Bad Branch. These population indices should serve well in using as a comparison to measure success in establishing brook trout in other streams in Kentucky.

At the present time, anglers are not allowed to fish Bad Branch. The KNPC has closed Bad Branch to fishing for the sake of preserving the area's unique species of plants. Hopefully, this decision can be changed in view of the low number of angler trips anticipated to the stream each year. The KDFWR and KNPC need to discuss if there are any possible alternatives to allow fishing on Bad Branch.

The fish population at Bad Branch should be sampled by the KDFWR with a backpack

electrofishing unit above and below the falls at least every 5 years. Species composition, length distribution, and catch-per-hour of electrofishing need to be determined from those samples for above the falls, below the falls, and combined. If anglers are eventually allowed to fish Bad Branch, a volunteer survey card should be provided at primary access points to survey all users of the area and obtain information on angler use and success.

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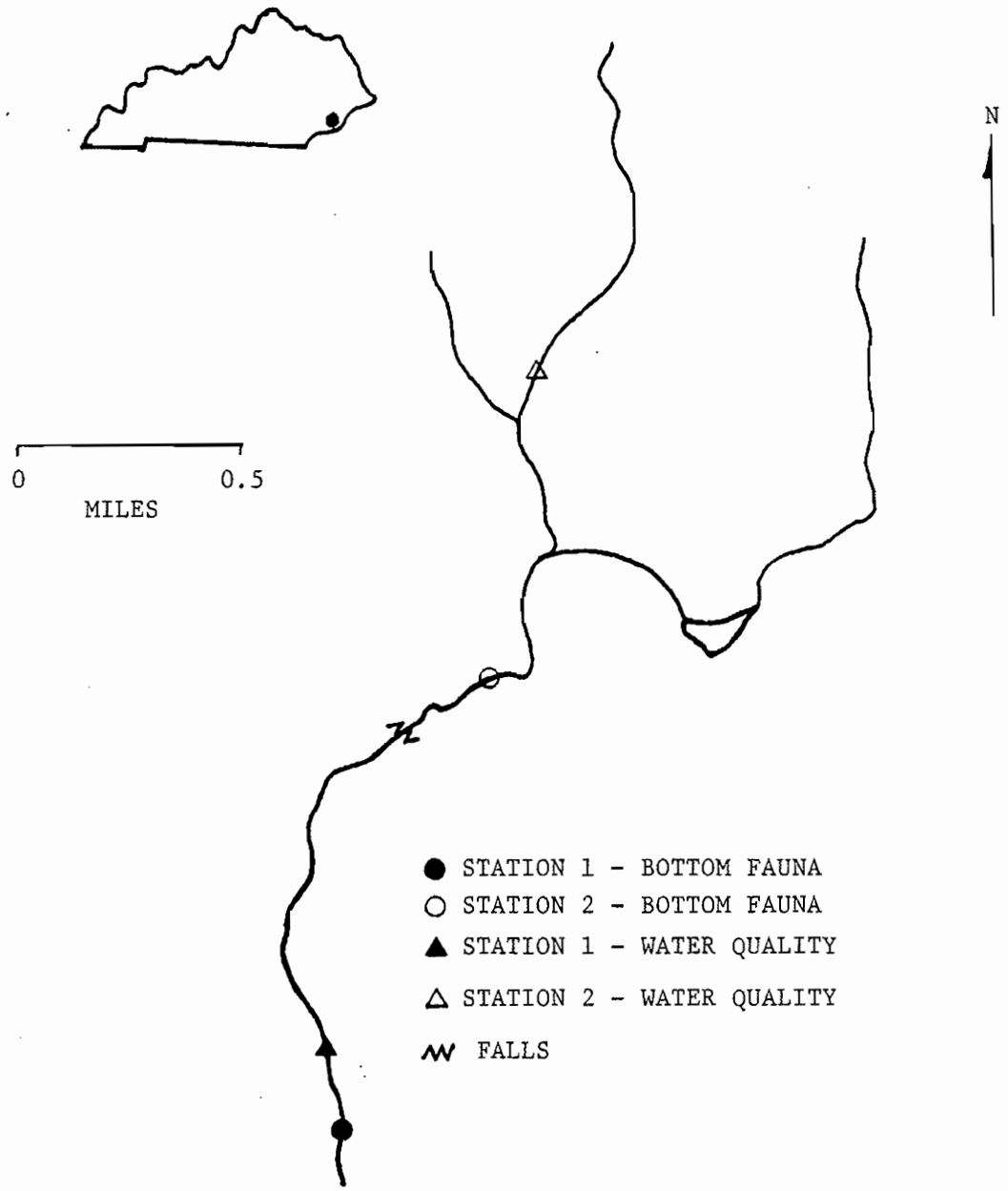

Figure 1. Water quality and bottom fauna sampling stations at Bad Branch in 1982.

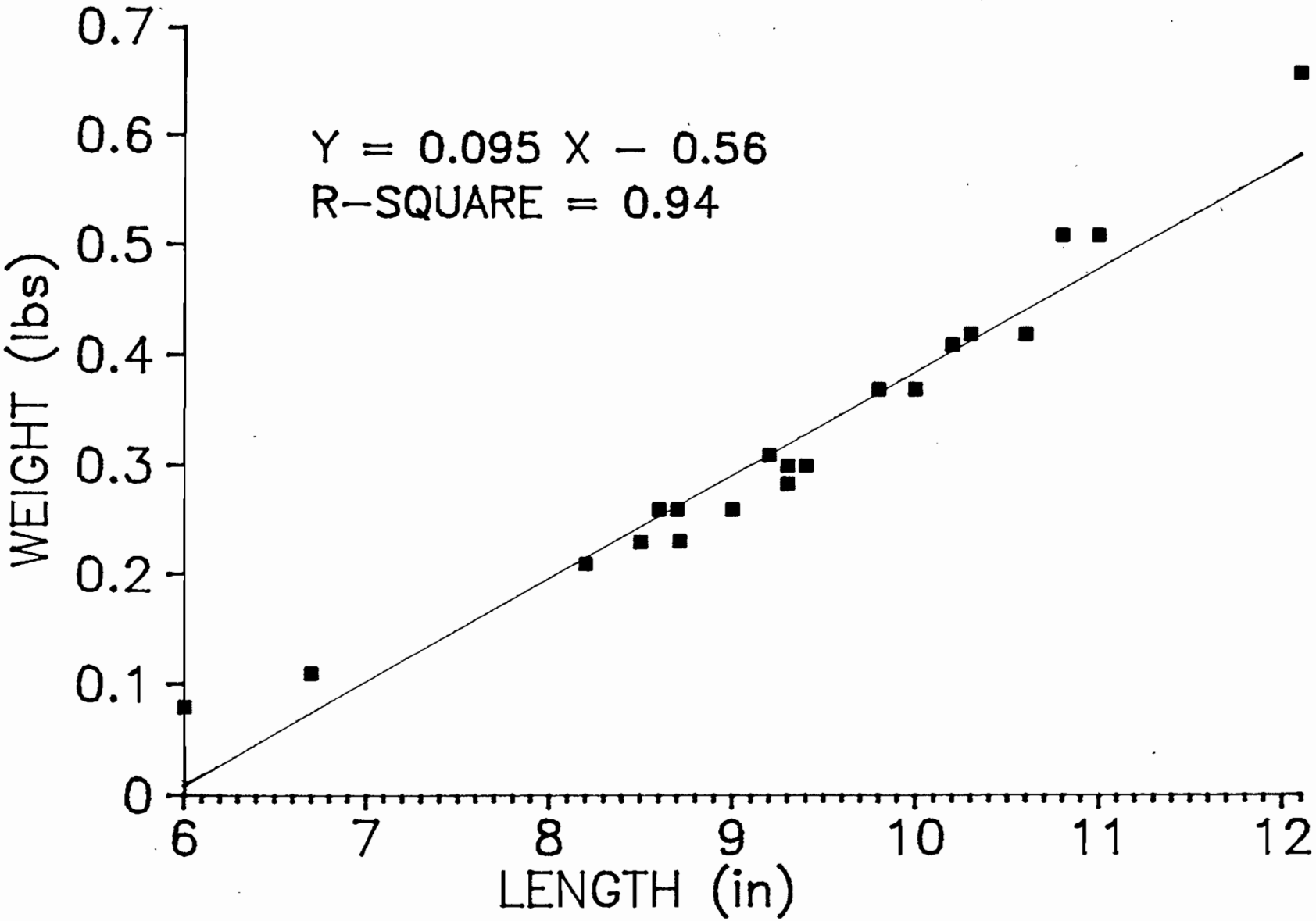

Figure 2. Weight-length relationship for brook trout at Bad Branch.

Table 1. Physical-chemical determinations at Bad Branch at two stations on 20 July 1981 and immediately below the falls on 19 August 1987.

Station[a]	Date	Water temp. (°F)	Dissolved oxygen (mg/l)	pH	Alkalinity (mg/l)	Velocity (ft/sec)	Mean width (ft)	Mean depth (in)	Discharge (ft^3/sec)	Fish shelter	Shade (%)	Poor-riffle ratio (%)
1	7/20/81	65	9.0	6.0	0	1	5	3.5	1.46	Abundant: undercut banks, boulders, ledges, logs, brush	75-100	10/90
2	7/20/81	65	6.0	6.5	0	1	5	3.0	1.25	Abundant: undercut banks, ledges, tree roots, logs, brush	75-100	25/75
	8/18/87	63	9.3	7.4	61	1	12	12	1.75	Abundant: boulders	75-100	30/70

[a]Station 1 was 300 yd above the mouth of Bad Branch; Station 2 was 1 mi above the falls. The 1987 station was 1,500 ft above the mouth.

Table 2. Chemical and physical data from Bad Branch at 11:00 am on 19 August 1987.

Date: 8/19/87 Time: 11:00 am Name of stream: Bad Branch

Exact location: 1,500 ft above mouth of Bad Branch Order: II

CHEMICAL AND PHYSICAL CHARACTERISTICS

Air temp.: 80°F Surface temp.: 63°F D.O.: 9.3 mg/l pH: 7.4

Alkalinity: 61 mg/l Stream Condition: Low Current Velocity: 1.0 ft/sec

Volume of flow: 1.72 ft^3/sec Annual flow: constant Pollution: absent

Fish shelter: Abundant Type: Boulders Riparian zone: 20-30 m

Shade: 75-100%

Bottom type: (1) Pool area: Bedrock - 10% Boulder (>12 in) - 30%

Large rubble (6-12 in) - 10% Small rubble (3-6 in) - 10%

Course gravel (1-3 in) - 10% Fine gravel (0.1-1 in) - 10%

Sand - 20%

(2) Riffle area: Bedrock - 0% Boudler (>12 in) - 40%

Large rubble (6-12 in) - 20% Small rubble (3-6 in) - 10%

Course gravel (1-3 in) - 10% Fine gravel (0.1-1 in) - 10%

Sand - 10%

Pool-Riffle ratio in section: 30/70

Aquatic vegetation: sparse Type: algae

Observations on macroinvertebrates: Dominant organisms - crayfish

Major land usage in the watershed: silviculture; approximately 95% forested

Table 3. Macroinvertebrates sampled in two square meters using the "kick"method. Station locations were: Station 1 - approximately 113 yd above mouth; Station 2 - approximately 300 yd above the falls.

Family	Species	May 10 station 1	May 10 station 2	July 29 station 1	July 29 station 2	November 24 station 1	November 24 station 2
Enchytraeidae		5	1	3	1		
Branchiobdellida				1			
Asellidae	Asellus sp.					1	
Cambaridae	Cambarus sp.	6	6	29	48	1	
Hydrachnellae				1			
Peltoperlidae	Peltopela sp.			33	14	6	3
Leuctridae	Leuctra sp.	3	11	97	40	32	19
Perlidae	Acroneuria sp.	60	17	119	47	280	404
Baetiscidae	Baetisca carolina	1					
Leptophlebiidae	Paraleptophlebia sp.	12	4	35	17	3	2
Siphlonuridae	Ameletus sp.		10	18	12	1	7
Heptageniidae	Heptagenia sp.	4	11	169	81	18	8
Cordulegastridae	Cordulegaster sp.	3	1	10	4	1	2
Aeschnidae	Boyeria vinosa		1	3	4	1	
Gerridae	Gerris remigis	1					
Veliidae	Rhagovelia obesa			5	13		
Hydropsychidae	Chewmatopsyche sp.	31	12	410	168	170	47
Hydroptilidae		19	4	117	23	7	1
Rhyacophilidae	Rhyacophila sp.		6	44	8	6	7
Philopotmidae	Dolophilodes sp.			58	6	59	9
Polycentropodidae	Polycentropus sp.	7		2	1		
Limnephilidae	Pycnopsyche sp.		4		4		
	Astenophylax sp.		4	2	14	2	5
Miscellaneous trichopteran adults and pupae				9	3		
Psephenidae	Psephenus sp.			3			
	Ectopria sp.			3	5		1
Dryopidae	Helichus sp.	6	6	26	16	1	2
Elmidae	Promonesia sp.	1		4		4	
	Stenelmis sp.	2	1	92	25	14	
Tipulidae	Hexatoma sp.	12	11	32	20	6	9
Heleidae	Probezzia sp.	3	1		1	3	1
Simuliidae	Simulium sp.	2	2	1			
Chironomidae	Group A	56	10	142	35	6	26
	Group B	3		10	38		
Rhagionidae	Atherix sp.	2		56	9	1	2
Tabanidae	Tabanus sp.	1	7	2	2	3	4
Amphiumidae[a]			3	4	3		
Total		235	133	1,539	661	626	559
No./m^2		118	67	770	331	313	280
Mean no./m^2 per season at both stations		93		551		297	
Mean no./m^2 from both stations for all three seasons				314			

[a]Unidentified salamander species.

Table 4. Diversity index ($\bar{d}$)[a] and equitability (e)[b] values for benthic macroinvertebrate samples at Stations 1 and 2 during the spring, summer, and fall of 1981 at Bad Branch in Letcher County.

	Station	
	1	2
Spring		
$\bar{d}$	3.22	4.06
e	0.59	1.11
Summer		
$\bar{d}$	3.71	3.88
e	0.59	0.74
Fall		
$\bar{d}$	2.46	1.77
e	0.33	0.23

[a] $\bar{d}$ values below 1.0 indicate degraded water quality conditions; 1.0-3.0 reflect moderate degradation, and >3.0 represent unpolluted conditions.
[b] e values range from 0 for polluted water quality conditions to 1 for clean water; slight degradation generally results in e being 0.0 to 0.3.

Table 5. Length frequency and standing stock of fishes in Bad Branch using Leslie's depletion method from electrofishing four 200 ft sections of stream on 21-22 July 1982.

Species	No.	Lb	Inch class[a]									No. per		Lb per	
			1	2	3	4	5	6	7	9	10	mi	acre	mi	acre
Brook trout	16	2.11		2	2		1	6	2	1	2	111	133	14.12	16.88
Blacknose dace	11	0.05	3	7	1							76	91	0.33	0.40
Creek chub	117	1.59	12	37	50	12	5		1			812	971	10.64	12.72
White sucker	1	0.14							1			7	8	0.94	1.12
Bluegill	17	0.16		17								118	141	1.07	1.28
Arrow darter	1	0.02			1							7	8	0.13	0.16
Total												1,131	1,353	27.24	32.56

[a]1.0-1.9 in fish = 1 in class; 2.0-2.9 in fish = 2 in class, etc.

Table 6. Standing crop of fishes above and below the falls at Bad Branch using Leslie's depletion method from electrofishing two 200 ft sections of stream below the falls and two 200 ft sections above during 20-21 July 1982.

Species	No.	Lb	No. per mi	No. per acre	Lb per mi	Lb per acre
			Below the falls			
Brook trout	5	0.17	69	83	2.28	2.72
Blacknose dace	11	0.05	153	183	0.67	0.80
Creek chub	56	0.87	777	930	11.64	13.92
White sucker	1	0.14	14	17	1.87	2.24
Arrow darter	1	0.02	14	17	0.27	0.32
Total	74	1.25	1,027	1,229	16.73	20.00
			Above the falls			
Brook trout	11	1.94	153	183	25.96	31.04
Creek chub	61	0.72	846	1,013	9.64	11.52
Bluegill	17	0.16	236	282	2.14	2.56
Total	89	2.82	1,235	1,478	37.74	45.12

Table 7. Length frequency while electrofishing at Bad Branch above the falls compared to below the falls in 1982-1987.

Date/location	Inch class[a] 2	3	4	5	6	7	8	9	10	11	12	13	No.
7/20-21/82													
Above falls	1			1	4	2		1	2				11
Below falls	1	2			2								5
7/22/83													
Above falls	9	8		1	2				1				21
Below falls		4						2	1				7
8/2, 9/5/84													
Above falls		1			2			1					4
Below falls													0
8/26/85													
Above falls				1			3		2				6
Below falls													0
7/30,31/86													
Above falls	10	7		1	5	6	3	6	2		1		41
Below falls	1	1				7	2	1	2	2		1	17
8/19/87													
Above falls	5	2				1	5	6	5	1	1		26
Below falls				1	3	2	5	4	3				18

[a]1.0-1.9 in fish = 1 in class; 2.0-2.9 in fish = 2 in class, etc.

Table 8. Length frequency and catch per hour of brook trout while electrofishing at Bad Branch in 1983-1987.

Date	Hours of sampling	Inch class 2	3	4	5	6	7	8	9	10	11	12	13	No.	No./ hour
7/22/83	2.00	9	2		1	2			2	2				28	14.0
8/2, 9/5/84	0.75		1			2			1					4	5.3
8/26/85	1.00				1			3		2				6	6.0
7/30,31/86	2.10	11	8		1	5	13	5	7	4	2	1	1	58	27.6
8/19/87	1.00	5	2		1	3	3	10	10	8	1	1		44	44.0

[a]1.0-1.9 in fish = 1 in class, 2.0-2.9 in fish = 2 in class, etc.

Table 9. Age and growth (in) of brook trout captured from Bad Branch during 20-21 July 1982.

Year class	No.	Age 1	2	Mean length (in) at capture	Length range (in) at capture
1982	4			2.7	2.2-3.0
1981	7	3.7		6.3	5.9-6.9
1980	5	3.7	7.1	9.0	7.6-10.2
Mean		3.7	7.1		

Table 10. Number of brook trout per inch class at each age from trout captured from Bad Branch on 19 August 1987, based on 15 of the 44 captured fish that were aged by viewing their otoliths.

Age	Inch class 5	6	7	8	9	10
1+	1			1		
2+		1	2	5	2	1
3+						2