COMPARISON OF WILD AND HATCHERY BROOK TROUT IN SPRUCE FLATS BRANCH, GREAT SMOKY MOUNTAINS NATIONAL PARK

RESEARCH/RESOURCES MANAGEMENT REPORT No. 8

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COMPARISON OF WILD AND HATCHERY BROOK TROUT IN SPRUCE FLATS BRANCH, GREAT SMOKY MOUNTAINS NATIONAL PARK

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W. Douglas Harned

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ABSTRACT

The brook trout of Great Smoky Mountains National Park at one time were found to inhabit many mountain streams down to an elevation of approximately 610 meters (2,000 ft.). The range of the species has since decreased at an alarmingly rapid rate in most drainages since the early part of this century. Reasons for the disappearance of the only salmonid native to the southern Appalachians appears to be a combination of factors. Among them, improper logging practices and the widespread introduction of the rainbow and brown trout are probably the most detrimental. The purpose of this study was to evaluate the effects of hatchery and F_1 wild strain brook trout fingerlings planted in a stream devoid of trout species. It might be possible from the planting to determine which strain is the better competitor.

The results of the experiment indicated that the two strains suffered less mortality in the upper stream section where streamside cover was abundant and blacknose dace were fewer in number. Both brook trout strains had high percent mortality, but fewer F_1 wild fingerlings were lost. The hatchery strain in the upper stream section had the best growth over the six-month study period, but its genetic background lends itself

to this performance. If the fingerling plant was successful, a range extension for the species might be realized.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The brook trout, Salvelinus fontinalis (Mitchill) of the Great Smoky Mountains National Park (GSMNP), are relatively scarce and are found only in remote, headwater streams (Lennon, 1967). Any increase in exploitation of the brook trout in the Park or damaging alteration of the habitat might have serious consequences for the remnant populations.

During recent years, surveys have been conducted in the Park to determine the status of brook trout populations. Current findings by Park employees reveal a continual decrease of brook trout inhabited waters (Figure 1). If the present trend in the brook trout range continues, the species might disappear from the southern Appalachian Mountains within the next 10-20 years (R. Jones and P. Wilkins, personal communication). As a result, this problem has been given top priority status by the Department of the Interior.

The decrease in brook trout range in the southern Appalachians is unique in that the species has greatly extended its range to include waters in western North America, South America, Eurasia, Africa, and New Zealand (MacCrimmon and Campbell, 1969). Brook trout introduced

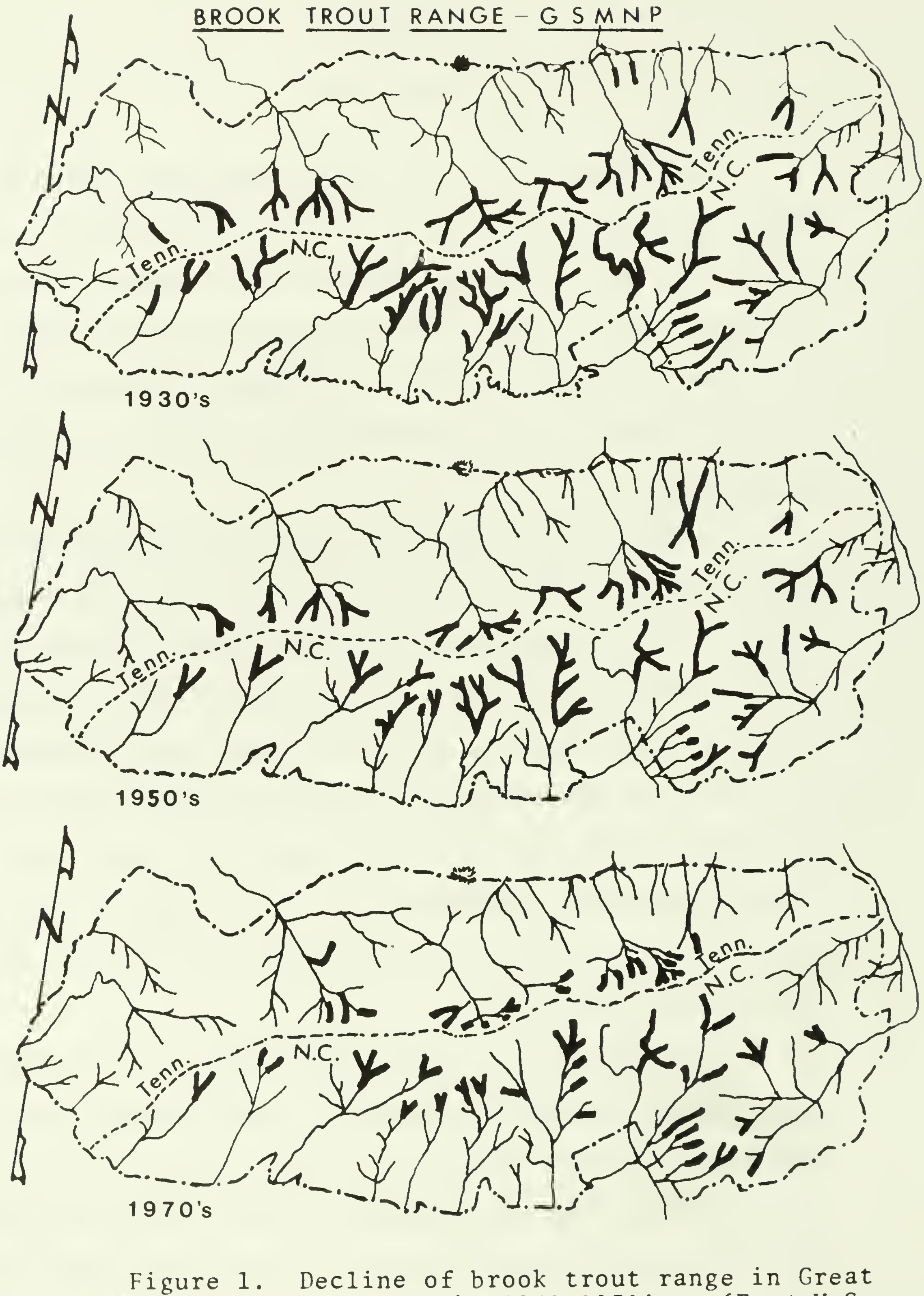

Figure 1. Decline of brook trout range in Great Smoky Mountains National Park, 1930-1970's. (From U.S. Fish and Wildlife Service, Gatlinburg, Tennessee.)

into streams in the western U.S. have thrived to the point of virtual exclusion of other trouts (Reed and Bear, 1966).

The original range of the brook trout in the streams of the southern Appalachians extended from about 610 meters (2,000 ft.) elevation to the headwaters. King (1937) felt their lower limit depended to a large degree on the temperature of the water. This in turn depended on the direction and degree of slope, type of forest cover, and the nature and density of the vegetation immediately adjoining the stream banks.

Today, brook trout are usually found above 1,066 meters (3,500 ft.) in elevation. The reason for the decline in range is uncertain, but it is probably the result of a combination of factors. They are as follows:

1. Widespread introduction of the rainbow and brown trout into the area appears to have created competition detrimental to brook trout.

2. Early logging and its attendant clearing and building of railroads eliminated brook trout from numerous drainages.

3. Heavy fishing pressure and illegal use of dynamite reduced many brook trout populations.

In years past, the reclaiming of former brook trout waters has had only limited success in this region

(Lennon and Parker, 1959). The failures were blamed in part, to the planting of hatchery fish of the New England strain and subsequent competition of the planted fingerlings with rainbow and brown trout.

The purpose of this experiment was two-fold:

1. To compare growth and condition, movement and recovery of F_1 wild and hatchery strains of brook trout in a stream having no other salmonids.

2. To gather information regarding the feasibility of extending brook trout range by planting fingerlings in selected streams.

CHAPTER II

DESCRIPTION OF STUDY AREA

The Drainage

Spruce Flats Branch (SFB) is located in the northwestern section of GSMNP where it flows through Blount and Sevier Counties, Tennessee. The length of the stream is approximately 4 kilometers (2.5 mi.) from its headwaters to its confluence with Middle Prong. The headwaters arise at an elevation of 975 meters (3,200 ft.), while the elevation at the mouth of SFB is 488 meters (1,600 ft.). The gradient of the stream is 122 meters per kilometer (600 ft. per mi.).

History of the Drainage

The forested land which prevailed in what is now GSMNP had been practically undisturbed until about a century ago. The lumber companies that came to this region eventually controlled and exploited 85 percent of the land presently within the Park. Middle Prong and SFB were both logged extensively.

The Little River tract contained the Middle Prong and SFB drainages. It was in this tract that widespread destruction of timber stands and elimination of brook trout from streams occurred (Figures 2, 3, and 4). The

Figure 2. Skidder and loader in action in the Middle Prong drainage in 1926.

Figure 3. The result of improper logging in the Middle Prong drainage, 1926.

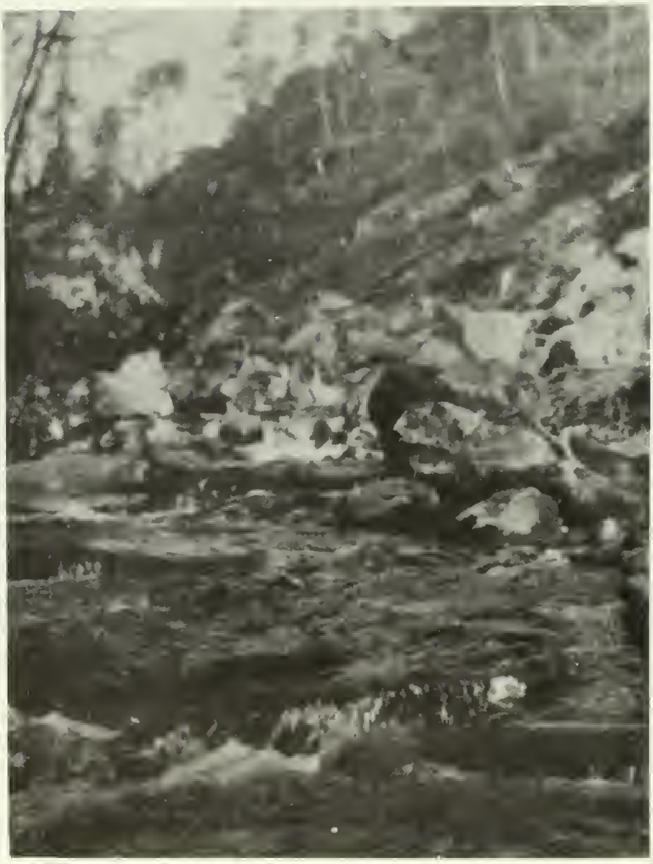

Figure 4. Photograph of clear-cutting down to the stream resulting in elimination of brook trout habitat, 1926.

Little River Lumber Company (Figure 5) held timber-cutting rights to this area, but was only one of 18 lumber companies engaged in this practice in what is now GSMNP. Towns like Townsend thrived on the activities of the lumber industry from 1920-1935 (Neuman and Nelson, 1965). Campbell (1969) reported that the last cutting by the Little River Lumber Company was on the SFB in 1938. This is presumed to be the last area to be logged in lands acquired for GSMNP.

Geology of the Drainage

The bedrock geology of the watershed consists primarily of Precambrian rocks of altered sedimentary and metamorphic compositions. These rocks form the majority of the Precambrian formation exposed in Tennessee and are collectively called the Ocoee Series (Miller, 1974). The Ocoee Series were formed from sediments--muds, sands, and gravels--derived from an ancient land mass. Some of the rocks of the Ocoee Series are made up of innumerable pebbles of quartz and feldspar. These rocks antedated the Cambrian period of the Paleozoic era and are more than 500 million years old (Stupka, 1960).

Climate

The SFB drainage basin appears to exhibit the effects of climatic differences with changes in elevation.

Figure 5. Little River Lumber Company, Townsend, Tennessee, 1926.

Shanks (1954) found great differences in climate at various elevations in GSMNP. Precipitation and air temperature change in the study area at higher elevations. Rainfall increases with altitude, while the air temperature decreases at an average rate of 1.24° C (2.23° F) per 305 meters (1,000 ft.). Air temperatures steadily increase during March, April, and May, while a reverse condition prevails in the fall.

The Stream

The SFB study area includes 2.07 kilometers (6,800 ft.) of stream. The mean width of the stream is approximately 228 centimeters (7.5 ft.). The volume of flow varies according to the seasonal precipitation levels, but is approximately .113 cubic meters per second (4.0 cfs) most of the year.

Electrofishing in the stream revealed that the only fish species present in the stream before the planting of brook trout fingerlings was the blacknose dace *Rhinichthys atratulus* (Hermann) (Figure 6). Sampling revealed a greater dace abundance in lower elevations of the stream. Although no salmonid species were found with extensive electrofishing, the brook or "speckled trout" were thought to have been native to the drainage before logging occurred (R. Brackin, personal communication).

In addition to the blacknose dace, salamanders

Figure 6. Blacknose dace in Spruce Flats Branch.

(*Desmognathus* spp. and *Eurycea bislineata*) were abundant in the study area. Crayfish were abundant in the drainage with many large individuals sighted.

SFB was divided into two sections of 1,036 meters (3,399 ft.) each and were designated A and B (Figure 7). Sections A and B were measured into 17 subsections (61 meters per section). Surveyors tape attached to trees along the stream served to define subsection boundaries. No artificial barriers were established to prevent movement of fingerling brook trout between subsections or between Sections A and B; however, fish fauna in Middle Prong were unable to immigrate into SFB due to the height of several waterfalls at the base of the stream (Figure 8). These waterfalls serve as natural barriers and help explain the absence of salmonid species above the falls.

Differences in Section A and Section B

There are several differences in the general appearance of Section A and Section B in SFB. In Section A the first five subsections are characterized by a steep gradient and pools, while the remaining subsections upstream are in flattened relief with little change in gradient and few pools. The majority of the water in Section A is shallow and with scant streamside cover (Figure 9). Except for a period in early spring when moderate scouring of the stream occurs, the pools in Section A are heavily silted.

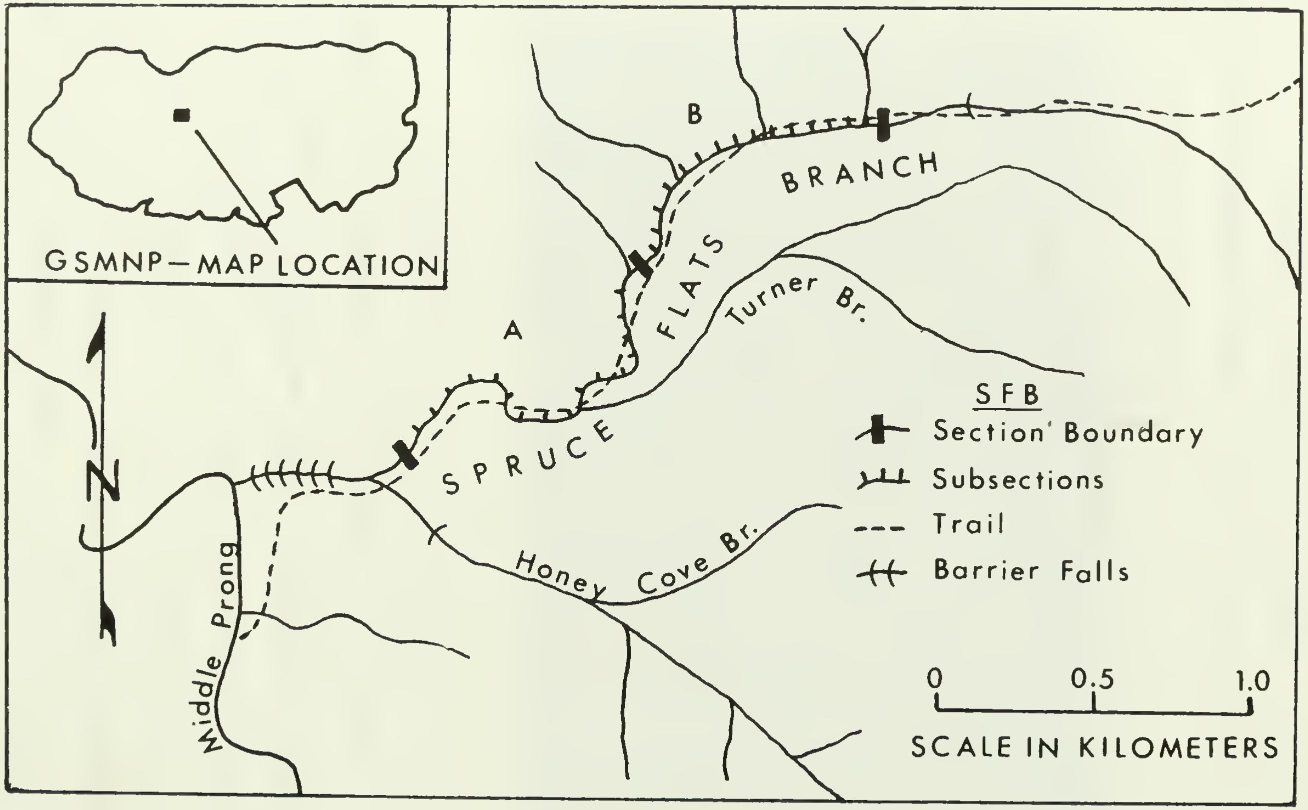

Figure 7. Map of study area.

Figure 8. Barrier waterfalls.

Figure 9. Section A--Spruce Flats Branch.

Section B is generally characterized by a steeper continuous gradient than in Section A, and a consistent series of pools and riffles in the majority of its subsections (Figure 10). Observation of pools in Section B reveals a lighter silt load than in Section A. Streamside vegetation is profuse in Section B, particularly the upper subsections.

The lower (Section A) and middle (Section B) elevations of the SFB drainage reveal a transition in vegetation types as an increase in elevation is reached. Whittaker's (1956) analyses of vegetation patterns of GSMNP corresponds with changes in flora types observed in SFB. Pine forests are located in the lower subsections of Section A. They are found on the dry hillsides and ridges. The Virginia pine, Pinus virginia, represents the xeric tree class and is found from 488 meters (1,600 ft.) to approximately 549 meters (1,800 ft.). The flowering dogwood (Cornus florida), striped maple (Acer pennsylvanicum), and red maple (Acer rubrum) are centered in the oak-hickory forest found near the upper subsections of Section A. Large trees common in a climax forest are absent in the study area as a result of the logging operations in the late 1930's.

The upper section of the study area, Section B, contains the mesic forests. The cove hardwood and eastern

Figure 10. Section B--Spruce Flats Branch.

hemlock forests are found in this section. Yellow birch (Betula allegheniensis), yellow poplar (Liriodendron tulipifera), American beech (Fagus grandifolia), and Fraser magnolia (Magnolia fraseri) are the most numerous trees of the cove forest community. The cove hardwood forest is restricted to the smaller ravines in the drainage. Eastern hemlock (Tsuga canadensis) is prevalent along the upper subsections of Section B. These are also second growth stands as a result of extensive timber cutting in the drainage.

The climate of low elevations 457-762 meters (1,500-2,500 ft.) is typical of a deciduous forest. Deciduous trees form 73 percent, hemlock 14 percent, and pine species 13 percent of total canopy stems in the low elevation moisture gradient transect (Whittaker, 1956).

White rhododendron (Rhododendron maximum) and doghobble (Leucothoe editorum) are the principle shrubs along SFB, primarily in Section B of the study area. The white rhododendron creates a dense canopy over the stream making electrofishing difficult. Light penetration is greatly reduced in the subsections where shrub growth is abundant.

CHAPTER III

MATERIALS AND METHODS

Research in the field and the laboratory was conducted from October 1974 to December 1975. On October 8, 1974, wild brook trout were collected in the West Prong, Little Pigeon River in GSMNP for the purpose of collecting their eggs for future release as fingerlings in SFB. The fish were collected by electrofishing with a 700-volt A.C. back-pack power unit mounted on a packboard with a gasoline motor as the power source. An electrode system devised by biologists of the U.S. Fish and Wildlife Service consisted of a car antenna modified to serve as one electrode, while a metal rod with a collecting-net at the end served as the other electrode.

Twelve large brook trout were collected and served as the parent stock for the F_1 wild brook trout fingerlings used in the study. These parent fish were some of the largest brook trout ever collected in GSMNP according to Park fisheries biologists (R. Jones and A. Kelly, personal communication). The mean fork length of the 5 males was 28.32 centimeters (11.15 in.). Their mean weight was 349.00 grams (11.20 oz.). The 7 females had a mean fork length of 25.17 centimeters (9.90 in.). Their mean weight was 241.40 grams (7.76 oz.). Figure 11 shows a male in breeding colors, while Figure 12 shows a female in spawning condition.

After collecting the brook trout, they were transported to holding facilities at Pheasant Fields in the Tellico Wildlife Management Area. Tricaine Methanesulfonate (MS-222) was used to facilitate the handling of the trout while stripping eggs and milt from them. The dry method of egg fertilization was followed (Leitritz, 1972). Approximately 400 eggs were taken to Buffalo Springs Fish Hatchery on October 17 where they were placed in incubators until hatching. Water temperature was 13° C (56° F) during incubation. The eggs hatched in late November, and the resulting F_1 wild strain fingerlings were fed commercial trout feed until their planting in SFB in early May 1975. An attempt to collect eggs from a hatchery strain of brook trout at Pheasant Fields in November was unsuccessful.

Hatchery trout fingerlings used in the study were obtained from a commercial hatchery in Brevard, North Carolina. The hatchery fingerlings were of the New England (Maryland) strain. The fingerlings were hatched in late December 1974. These fish were the nearest to the age of the F_1 wild fingerlings that could be located. The hatchery strain fingerlings were also fed commercial trout feed until planted in SFB.

Figure 11. Male brook trout in breeding colors.

Figure 12. Female brook trout in spawning condition.

Planting tables developed by Embody (1927) and modified by Davis (1938) and Needham (1969) were used for determining brook trout fingerlings needed in Section A and Section B of SFB. The stream was classified as a B-2 or average stream according to their rating system. The letter B refers to the grade of pools and shelter of the stream. The number 2 refers to food grade. Streams are rated by the author's judgment. A qualitative and quantitative sampling of the stream for macroinvertebrates was done before planting to determine food grade rating.

According to planting rates for a stream such as SFB, 460 brook trout fingerlings 77-104 millimeters (3-4 in.) total length were needed for planting with an expected mortality rate of 30 percent (Embody, 1927); however, 497 fingerlings were planted in the stream study sections. This was done to help compensate for any fingerlings lost due to transport en route to SFB. The author is confident that whatever error may have occurred in planting numbers was not of sufficient magnitude to significantly affect the observed results.

Prior to planting, each fingerling was marked by cold branding with liquid nitrogen. Both F_1 wild and hatchery strain fingerlings were sorted for uniformity of size, counted, measured (total length in millimeters), and weighed to the nearest gram. Branding materials and methods of Raleigh, McLaren, and Graff (1973) were followed. Individual fish were lightly anaesthetized in a solution of MS-222 and received 3-single digit cold brands. It was suggested that a dorsal, ventral, and lateral brand be applied to each fish (R. F. Raleigh, personal communication). The time duration per single digit brand was 1.5 seconds. The F_1 wild strain fingerlings were branded on the right side, while the hatchery strain fish were branded on the left side (Figure 13). Raleigh further suggested that an open, simple, clean brand is best. An X-brand was used for cold branding the F_1 wild fingerlings planted in Section A. A 7-brand was applied to the F_1 wild fish planted in Section B. Hatchery strain fish planted in Sections A and B received cold brands of J and H, respectively. The numbers of fingerlings branded and planted in both sections are summarized in Table I. Section A was greater in width; therefore, a greater number of fingerlings were to be planted in that section.

Future determination of growth, condition, movement, percent recovery, and food habits of the fingerlings depended upon successful branding. No mortality from cold branding was observed in either strain.

All of the fingerlings were transported to SFB in sealed water-filled plastic bags. The plastic bags each received a small amount of oxygen from an oxygen cylinder before the bags

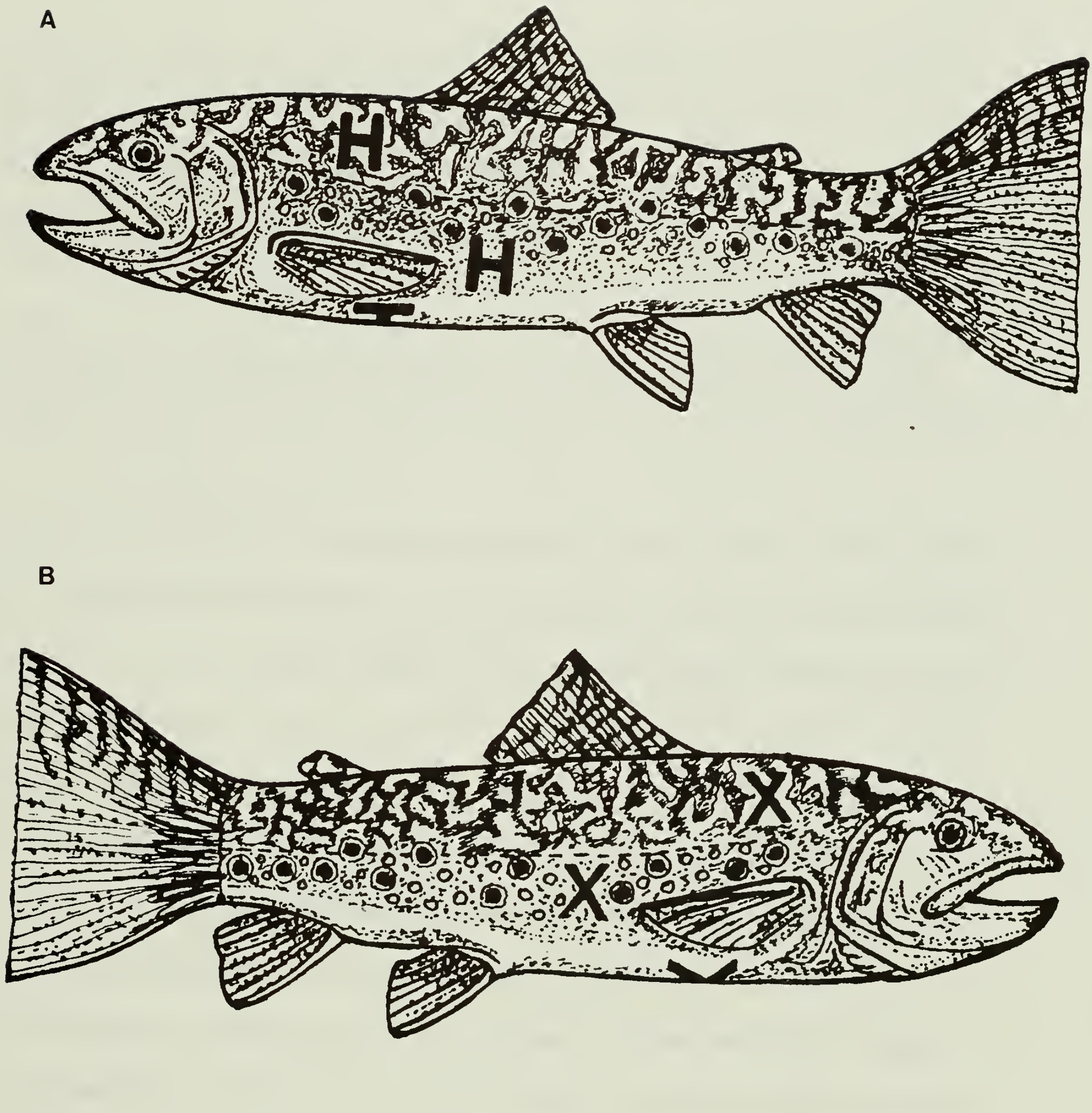

Figure 13. Dorsal, lateral, and ventral cold-brands. A. Hatchery fingerling. B. F_1 wild fingerling.

TABLE I

NUMBERS AND BRANDS OF FINGERLINGS PLANTED IN SECTIONS OF SPRUCE FLATS BRANCH

Strain	Total Number Planted	Brand and Number Planted in Section A	Brand and Number Planted in Section B
F_1 wild	237	X - 131	7 - 106
Hatchery	260	J - 140	H - 120

were sealed to ensure the survival of the fish before reaching the planting locations in the study area. Hatchery and F_1 wild fingerlings were planted May 2-3, 1975. Release of the fish in the study area was done according to cold brand number or letter group; however, each branded group, whether hatchery or F_1 wild, was distributed randomly within study section boundaries.

Certain physical and chemical parameters of the stream were tested in order to help explain success or failure of a brook trout plant. The water temperatures of Section A and Section B were recorded each month with a stream-pocket thermometer (° C). Temperatures were recorded from the same stream subsections in Sections A and B during collecting trips in order to determine if significant differences in the two sections existed. Water chemistry of Spruce Flats Branch was carried out using a Hach Kit-Model DR-EL "Direct Reading" Portable. Conductivity was measured with a Model RA-2A Conductivity Meter. Certain field observations were made pertaining to stream conditions and habitat adjacent to the stream, but these observed changes were not mechanically measured.

The two strains of brook trout were sampled once a month by electrofishing from June-November 1975. Sampling with the electroshocker was begun below Section A, throughout Sections A and B, and approximately 100 meters (328 ft.) above Section B. In order to sample as efficiently as possible, one man collected fingerlings with the back-pack shocker, and two assistants recorded needed data.

The following data were recorded for each fingerling sampled: (1) the subsection where recovered; (2) the cold brand number or letter; (3) brand clarity; (4) weight of fish; (5) length of fish; and (6) any other pertinent information. Portable gram scales weighed fish to the nearest gram, and a metric ruler measured the fish to the nearest millimeter (total length). After data were collected from each fingerling, the fish was released or kept for later analyses of stomach contents.

In order to better understand fingerling growth and feeding habits, a systematic and broad sampling of stream macroinvertebrates was done. Qualitative and quantitative sampling was planned monthly in the two sections. Riffle areas were sampled using a square-foot Surber sampler with two or three samples collected from each section per month. These samples were collected from subsections chosen at random. Six artificial substrate samples were used in riffle areas of both sections and were anchored to the stream bottom. These samplers were constructed similar to the design used by McDaniel (1974). Modifications for this study consisted of 10 millimeter-thick (3/8 in.) exterior grade plywood cut into four plates 152 millimeters (6 in.) square. These plates were covered on one side with an artificial webbing material (also 152 millimeters square) and all were spaced 1.5 centimeters apart with 15 millimeter (5/8 in.) plastic pipe. An eye-bolt was run through the center of the plywood plates and plastic pipe. Two nuts screwed onto the eye-bolt held the sampler together. These quantitative samplers were usually collected for macroinvertebrates every six to eight weeks in order to give the organisms time to colonize them.

Qualitative sampling of macroinvertebrates was accomplished by picking organisms from over-turned rocks and disturbed leaves and sticks. Also, the kicking of disturbed bottom toward a fine-mesh window screen was an often-used method.

Samples collected with the Surber sampler and artificial substrates were sieved in the field with a U.S. Standard No. 30 sieve. The artificial substrate samplers were placed in a bucket with water and dismantled. After careful washing the individual plates and picking active or hidden aquatic organisms from the webbing material, the water in the bucket was poured through a sieve to remove excess sand. All samples were placed in 1-liter containers and preserved in 70 percent ethanol. Each sample was labelled and taken back to the laboratory for sorting and identification. Qualitative samples were picked in the field and preserved similarly to the quantitative samples. Individual insects were keyed to genus whenever possible. Insects collected either in bottom fauna samples, or stomach samples, were identified with the aid of Ross (1944, 1967), Burks (1953), Usinger (1963), Johannsen (1969), and Hitchcock (1974).

Food habits were determined from the 22 brook trout fingerlings collected during the length of the field study. The fish were preserved in a 1-liter container of 10 percent formalin solution and stored at the laboratory for later examination. Fifty-seven blacknose dace stomachs were also collected to determine if interspecific competition between native dace and the planted brook trout fingerlings might occur as a result of similar feeding habits. Numbers of blacknose dace per subsection were also counted as a possible means of determining whether interspecific competition might be different between Section A and Section B.

Brook trout and dace stomachs were slit lengthwise, and their contents were flushed into individual vials. The vials were filled with 40 percent isopropyl alcohol and labelled for later identification.

As mentioned previously, individual organisms were keyed to family and, if possible, to genus. Terrestrial insects were often keyed only to order. Head capsule numbers was the only method used in determining the total number of organisms per individual fish. Mean number and volume of organisms in stomachs of brook trout and dace were determined following an earlier study of Tebo and Hassler (1963). Frequency of occurrence of organisms in the 22 trout stomachs and 57 dace stomachs was also analyzed. Frequency of occurrence was determined by dividing the total number of stomachs the food item was found in by the total number of stomachs in that category.

The growth of the two strains of fingerling brook trout was determined from monthly sampling on SFB. Relative growth rate methods were used to compare fingerling growth (Rounsefell and Everhart, 1960). In addition, the growth of both strains planted in Section A was compared to the same two strains planted in Section B.

The coefficient of condition [$K = wt\ (g) \times 10^5/$ total length (mm^3)] was calculated from individual field measurements of the fingerlings. Mean coefficient of condition was derived from these data. It was possible to compare the coefficients of condition of hatchery and F_1 wild strains with one another and compare condition of fingerlings within the same strain (i.e., Section A hatchery fish versus Section B hatchery fish).

Monthly electrofishing inventories on the stream made it possible to assess the dispersal of the planted fingerlings. Clear identification of cold brands on fingerlings was necessary to determine upstream and downstream movement within and outside Sections A and B. If movement patterns were detected during the study, it might be possible to ascertain environmental factors which influence trout movement.

Recovery of fingerlings from monthly electrofishing in SFB was expressed as percent recovery per month. This was derived by dividing initial planting numbers into monthly recoveries. Fish collected previously for stomach sample analyses should be deducted from the initial totals when figuring monthly recoveries. Percent recovery of hatchery and F_1 wild fish was compared; in addition, fingerlings of both strains planted in Section A were compared to the two strains in Section B.

CHAPTER IV

RESULTS

Chemical and Physical Analyses of SFB

Certain chemical and physical factors which might influence the planting and survival of fingerling brook trout were tested before the planting and after the study was concluded (see Table II). Water temperatures in the stream were read during the course of the study and differences in Section A and Section B were analyzed with a paired Student's "t" test (Table III). No significant difference between stream sections was found at the .05 probability level.

Comparison of Brook Trout and Condition

Mean length, weight and condition of the hatchery and F_1 wild strains are summarized in Tables IV and V. No data was collected during September due to electro-shockers being inoperable. Initial mean length and weight of F_1 wild fish were greater than hatchery fish. Mean coefficient of condition (K) varied between strains. Monthly recovery of the fingerlings indicated that both strains increased in total length and weight; however, the mean coefficient of condition increased steadily only in the hatchery fish in Section B. Monthly data for

TABLE II

CHEMICAL ANALYSIS OF WATER FROM SPRUCE FLATS BRANCH [a]

Date	pH	D.O.	Hardness as $CaCO_3$	Alkalinity $CaCO_3$	Hardness (Total)	CO_2	Iron (Fe)	Sulfate (SO_4)	Specific Conductance Micromhos at 25° C)	Turbidity (JTU)
4/15/75	6.7	10	10	10	10	5	.06	10	20	4
11/7/75	7.2	12	10	10	10	4	.05	9	20	0

[a]Unless otherwise noted, measurements are in mg/1.

TABLE III

COMPARISON OF WATER TEMPERATURES IN SECTION A AND SECTION B OF SPRUCE FLATS BRANCH USING A PAIRED "T" TEST[a]

Date Temperature Read	Section A Water Temperature °C	Section B Water Temperature °C
6/5/75	17.2	16.7
7/5/75	18.0	17.8
7/12/75	17.9	17.8
7/18/75	17.8	17.7
8/5/75	18.9	18.9
8/24/75	19.4	20.0
9/6/75	18.9	18.9
10/4/75	10.5	10.5
10/27/75	13.3	13.3
11/9/75	12.8	12.8
11/28/75	3.9	6.1

[a]H_o: $u_1 = u_2$, D.F. = 10(11-1), C.I. = 95 percent, T_{table} = 2.228, Calculated "t" = -0.732 - Accept H_o.

TABLE IV

MEAN LENGTH, WEIGHT, AND COEFFICIENT OF CONDITION OF F_1 WILD STRAIN BROOK TROUT FINGERLINGS AT TIME OF PLANTING AND RECOVERY IN SPRUCE FLATS BRANCH

Planting and Recovery Date	X-Brand (Section A)				7-Brand (Section B)			
	No.	TL (mm)	Wt. (g)	Coeff. Cond. (K)	No.	TL (mm)	Wt. (g)	Coeff. Cond. (K)
5/3/75[a]	131	102.73	13.43	1.24	106	111.66	14.06	1.01
6/5/75	8	122.75	21.50	1.14	15	118.80	20.33	1.13
7/5/75	10	119.10	19.60	1.14	21	124.09	19.57	0.99
8/5/75	11	116.90	19.09	1.15	16	119.31	18.93	1.08
10/4/75	7	130.57	18.85	0.81	12	127.58	19.66	0.90
11/9/75	10	128.90	24.60	1.11	11	130.72	23.00	0.97

[a]Planting date.

TABLE V

MEAN LENGTH, WEIGHT, AND COEFFICIENT OF CONDITION OF HATCHERY STRAIN BROOK TROUT FINGERLINGS AT TIME OF PLANTING AND RECOVERY IN SPRUCE FLATS BRANCH

Planting and Recovery Date	J-Brand (Section A)				H-Brand (Section B)			
		Mean				Mean		
	No.	TL (mm)	Wt. (g)	Coeff. Cond. (K)	No.	TL (mm)	Wt. (g)	Coeff. Cond. (K)
5/2/75[a]	140	73.33	4.33	1.10	120	70.53	3.54	1.01
6/5/75	2	87.00	9.00	1.37	7	81.28	7.71	1.45
7/5/75	2	85.00	9.00	1.48	14	89.28	9.07	1.28
8/5/75	-	-	-	-	8	93.87	11.62	1.39
10/4/75	1	100.00	18.00	1.80	12	100.33	11.41	1.12
11/9/75	-	-	-	-	11	106.18	16.72	1.38

[a]Planting date.

hatchery fish in Section A were inconclusive due to insufficient data.

Relative percent growth of the two strains and fingerlings in Section A and B are compared in Figures 14 and 15. Hatchery fingerlings had a greater relative growth throughout the study, with H-brand fingerlings in Section B gaining the greatest length and weight. F_1 wild fingerlings grew better in Section A than in B.

Quantitative Sampling of Bottom Fauna

In an attempt to assess any possible differences in bottom fauna in Section A and Section B, mean numbers of organisms per square foot were tested using the Student's "t" test for significance (Table VI). Mean numbers of organisms sampled by quantitative methods revealed no significant differences at the .05 probability level.

Variation of Dace Numbers

The Student's "t" test compared the mean numbers of blacknose dace in three lower and middle subsections of Section A to mean numbers of dace in three upper sub-sections of Section B. The means and dace numbers per subsection are given in Table VII. Significant differences between dace numbers in the two sections were found at the .05 probability level.

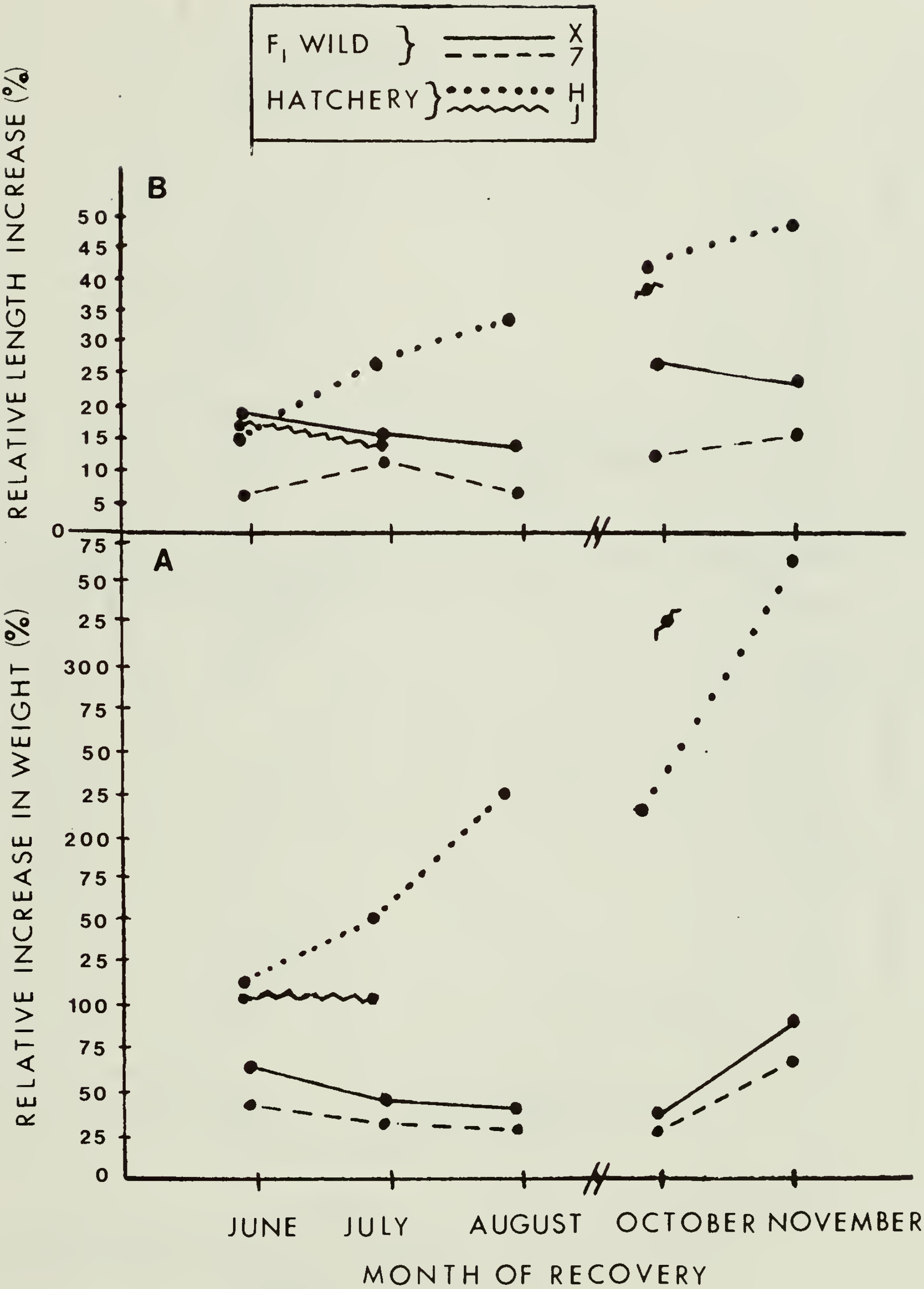

Figure 14. Monthly changes in relative percent growth of two strains of brook trout fingerlings in Spruce Flats Branch. A. Percent increase in weight. B. Percent increase in length.

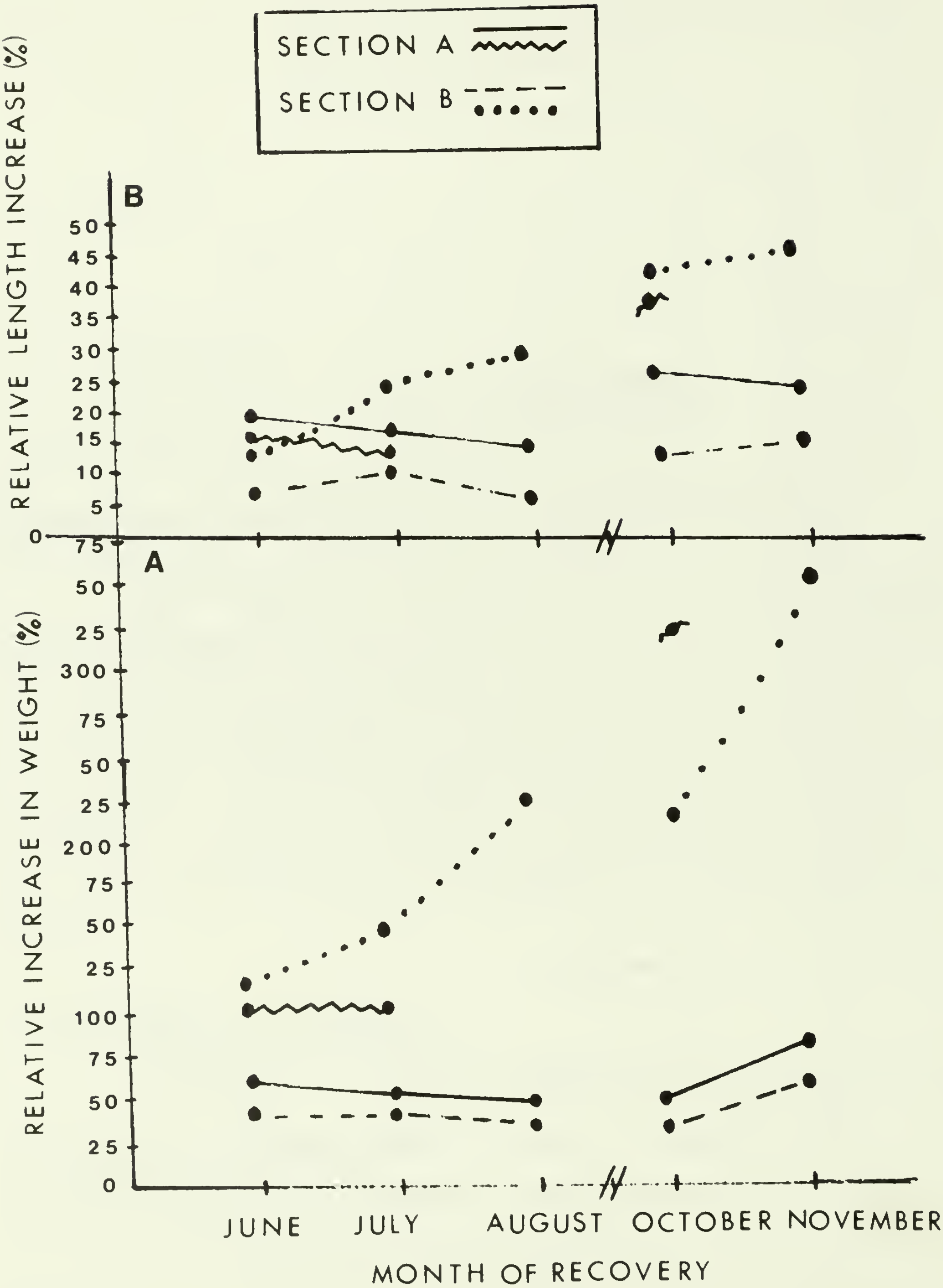

Figure 15. Monthly changes in relative percent growth of brook trout fingerlings planted by section in Spruce Flats Branch. A. Percent increase in weight. B. Percent increase in length.

TABLE VI

MEAN NUMBERS OF ORGANISMS IN SECTIONS A AND B OF SPRUCE FLATS BRANCH[a]

Data Collected	Section A				Section B			
	No. Sq. Ft. Surber Samples	Mean No. Organisms	No. Sq. Ft. Artificial Substrate	Mean No. Organisms	No. Sq. Ft. Surber Samples	Mean No. Organisms	No. Sq. Ft. Artificial Substrate	Mean No. Organisms
5/30/75	3	27.00			3	17.66		
6/18/75	2	35.00			2	30.50		
7/12/75	2	9.00			2	9.00		
8/24/75	2	25.50	3	25.66	2	22.00	3	6.33
10/27/75	3	24.66			3	21.33		
12/7/75			3	25.66			3	56.33

[a]H_o: $u_1 = u_2$, D.F. = 6(7-1), C.I. = 95 percent, T_{table} = 2.447, Calculated "t" = 0.220 - Accept H_o.

TABLE VII

COMPARISON OF BLACKNOSE DACE NUMBERS IN SECTION A AND SECTION B OF SPRUCE FLATS BRANCH USING "t" TEST FOR INDEPENDENT MEANS[a]

	Section A[b]		Section B[c]	
Date Observation	Subsection	No. Blacknose Dace	Subsection	No. Blacknose Dace
11/9/75	4	42	30	4
	6	77	32	6
	12	105	34	8

[a]H_o: $u = u_2$, D.F. = 4(6-2), C.I. = 95 percent, T_{table} = 2.776 - Reject H_o, Calculated "t" = 3.76.

[b]SD = 31.56, $S\bar{d}$ = 18.24, $\bar{x}$ = 74.66.

[c]SD = 2.00, $S\bar{d}$ = 2.00, $\bar{x}$ = 6.00.

Food Habits of Brook Trout Fingerlings

Results of examining 22 brook trout stomachs are given in Table VIII and Figure 16. Aquatic adult insects (38.9 percent), terrestrial insects (19.5 percent), and immature dipterans (14.2 percent) comprised the greatest percentage by numbers of the brook trout diet during the study period. Immature forms of Trichoptera (8.3 percent), Ephemeroptera (3.2 percent), and Plecoptera (2.7 percent) were not as significant in the diet of the fingerlings as were the surface organisms.

Terrestrial Homoptera and Hemiptera were found to occur most frequently in the 22 stomachs examined. They were obtained from 16 stomachs, while Collembola and adult Diptera were obtained from 14. Chironomidae and *Simulium* were found in 11 stomachs, Heptageniidae nymphs in 7, and crayfish in 6. Several other organisms were collected, but none occurred as frequently as did the above organisms. Four hundred-forty organisms were identified from 21 fingerling stomachs. Only one stomach was empty.

Food Habits of Blacknose Dace

Results of examining 57 blacknose dace stomachs are given in Table IX and Figure 17. Immature Trichoptera (27.0 percent) and Diptera (23.0 percent) comprised the

TABLE VIII

TOTAL NUMBER AND FREQUENCY OF OCCURRENCE OF ORGANISMS IN STOMACH CONTENTS OF 22 BROOK TROUT COLLECTED IN SPRUCE FLATS BRANCH DURING JULY-NOVEMBER, 1975[a]

Organism	No. in Stomach	Percent of Total	Frequency of Occurrence
Trichoptera			
Diplectrona	6	1.4	5
Parapsyche	1	0.2	1
Lepidostoma	12	2.7	5
Neophylax	10	2.3	5
Cyrnellus	1	0.2	1
Glossosoma	3	0.7	2
Sortosa	1	0.2	1
Ironoquia	1	0.2	1
Psilotreta	1	0.2	1
Undetermined	1	0.2	1
Total	37	8.3	
Ephemeroptera			
Heptageniidae	7	1.6	7
Baetidae	6	1.4	3
Ephemera	1	0.2	1
Undetermined	0	0.0	0
Total	14	3.2	
Diptera			
Dixidae	3	0.7	3
Simulium	24	5.5	11
Chironomidae	29	6.6	11
Heleidae	6	1.4	5
Undetermined	0	0.0	0
Total	62	14.2	
Plecoptera			
Peltoperla	4	0.9	4
Nemoura	4	0.9	3
Chloroperlidae	3	0.7	3
Undetermined	1	0.2	1
Total	12	2.7	

TABLE VIII (continued)

Organism	No. in Stomach	Percent of Total	Frequency of Occurrence
Coleoptera			
Elmidae	2	0.5	2
Dytiscidae	1	0.2	1
Undetermined	2	0.5	2
Total	5	1.2	
Decapoda	6	1.4	6
Collembola	37	8.4	14
Aquatic adults			
Diptera	163	37.1	14
Trichoptera	4	0.9	2
Plecoptera	4	0.9	3
Total	171	38.9	
Terrestrials			
Hymenoptera	29	6.6	11
Homoptera and Hemiptera	36	8.2	16
Arachnida	5	1.1	4
Coleoptera	1	0.2	1
Aphids	4	0.9	2
Diptera	6	1.4	5
Isopoda	1	0.2	1
Orthoptera	4	0.9	2
Total	86	19.5	
Annelida	6	1.4	5
Vertebrate			
Salamanders	4	0.9	4
Total	440		

[a]Mean length of 109 millimeters; range 83-143 millimeters. Taken during months of July, August, October, and November, 1975.

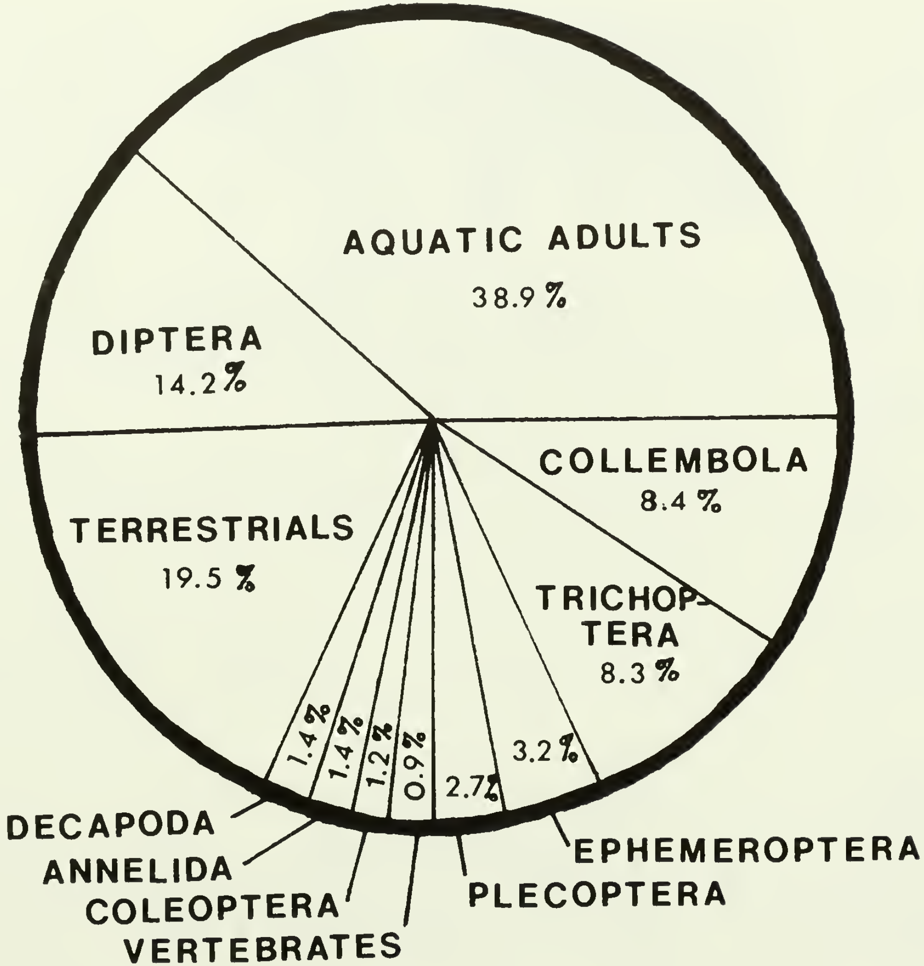

Figure 16. Diet of 22 brook trout stomachs.

TABLE IX

TOTAL NUMBER AND FREQUENCY OF OCCURRENCE OF ORGANISMS IN STOMACH CONTENTS OF 57 BLACKNOSE DACE COLLECTED IN SPRUCE FLATS BRANCH DURING JULY-NOVEMBER, 1975[a]

Organism	No. in Stomach	Percent of Total	Frequency of Occurrence
Trichoptera			
Lepidostoma	38	15.0	10
Diplectrona	4	1.6	4
Glossosoma	6	2.4	4
Cyrnellus	2	0.8	2
Parapsyche	3	1.2	3
Neophylax	11	4.4	4
Rhyacophila	1	0.4	1
Sortosa	1	0.4	1
Undetermined	2	0.8	2
Total	68	27.0	
Ephemeroptera			
Heptageniidae	21	8.3	15
Stenonema	1	0.4	1
Ephemera	16	6.3	13
Baetidae	1	0.4	1
Isonychia	1	0.4	1
Paraleptophlebia	1	0.4	1
Epeorus complex	1	0.4	1
Undetermined	0	0.0	0
Total	42	16.6	
Diptera			
Dixidae	7	2.8	7
Chironomidae	31	12.3	17
Simulium	12	4.7	7
Tipula	1	0.4	1
Heleidae	5	2.0	5
Blepharocera	1	0.4	1
Undetermined	1	0.4	1
Total	58	23.0	

TABLE IX (continued)

Organism	No. in Stomach	Percent of Total	Frequency of Occurrence
Plecoptera			
Peltoperla	6	2.4	6
Nemoura	8	3.2	6
Chloroperlidae	2	0.8	2
Acroneuria sp.	1	0.4	1
Undetermined	1	0.4	1
Total	18	7.2	
Coleoptera			
Psephenus	1	0.4	1
Elmidae	4	1.6	3
Undetermined	0	0.0	0
Total	5	2.0	
Odonata			
Lanthus	1	0.4	1
Hydracarina	2	0.8	2
Decapoda	5	2.0	4
Collembola	3	1.2	3
Copepoda	2	0.8	1
Aquatic adults			
Diptera	15	5.9	10
Total	15	5.9	
Terrestrials			
Homoptera and Hemiptera	15	5.9	10
Lepidoptera	1	0.4	1
Arachnida	3	1.2	3
Coleoptera	5	2.0	4

TABLE IX (continued)

Organism	No. in Stomach	Percent of Total	Frequency of Occurrence
Orthoptera	5	2.0	3
Hymenoptera	3	1.2	2
Total	32	12.7	
Annelida	2	0.8	2
Total	253		

[a]Mean length of 78 millimeters; range 40-91 millimeters. Taken during months of July, August, October, and November, 1975.

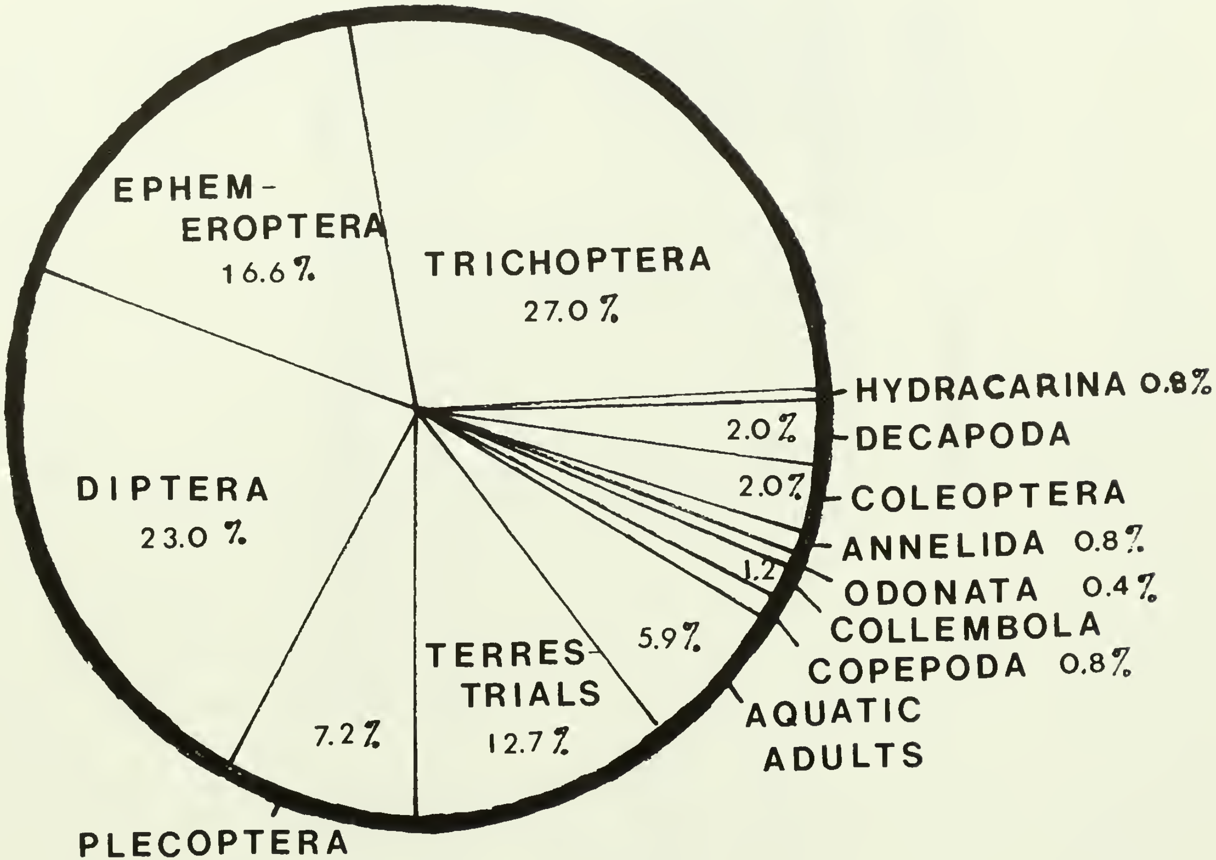

Figure 17. Diet of 57 blacknose dace stomachs.

greatest percentage of their diet by number. Ephemeroptera accounted for 16.6 percent of the dace diet, while terrestrial insects accounted for 12.7 percent.

Of all stomachs examined, Chironomidae immatures were the most frequent in occurrence (17) followed by Heptageniidae nymphs (15). *Ephemera* nymphs were obtained from 13 stomachs, while *Lepidostoma* and terrestrial Homoptera and Hemiptera were found in 10. Five stomachs were empty. The 52 stomachs contained 253 organisms.

Number and Volume of Organisms

The mean number and mean volume of organisms found in brook trout and dace stomachs were compared statistically; the results are given in Table X. A significant difference (.05) in mean number of organisms was found with the blacknose dace having a smaller mean number of organisms per stomach than the brook trout. No significant difference was found, however, when mean volume of organisms was compared.

Recovery of Fingerlings

The monthly recoveries of the two strains of fingerlings are compared in Figure 18. Throughout the study, the F_1 wild strain fingerlings were collected in greater numbers than hatchery fish. Comparison of

TABLE X

COMPARISON OF MEAN NUMBER AND VOLUME OF ORGANISMS IN 52 BLACKNOSE DACE AND 21 BROOK TROUT STOMACHS[a]

Species	Mean[b] No. of Organisms	Standard Error	Mean[c] Volume (ml)	Standard Error
Blacknose dace	4.92	0.7	.11	1.1
Brook trout	20.90	2.3	.31	8.8

[a]Empty stomachs not counted in these calculations. H_o: $u_1 = u_2$, D.F. = 71(52+21-2).

[b]C.I. = 95 percent, T_{table} = 1.996, Calculated "t" = -5.37 - Reject H_o.

[c]C.I. = 99.9 percent, T_{table} = 3.410, Calculated "t" = +3.38 - Accept H_o.

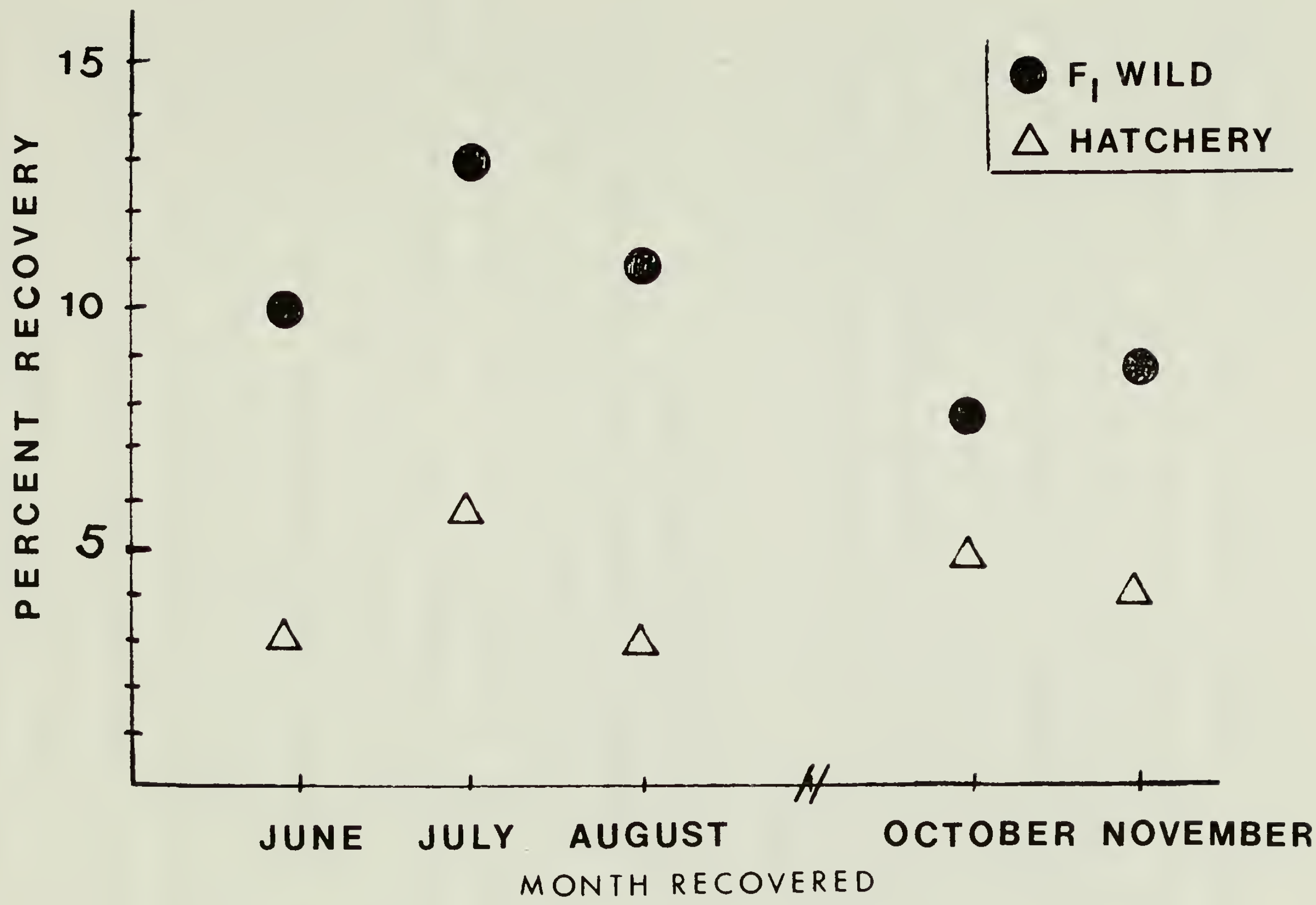

Figure 18. Monthly percent recovery of hatchery and F_1 wild fingerlings in Spruce Flats Branch.

fingerlings planted in Sections A and B revealed consistently higher recovery percentages in Section B (Figure 19).

At the conclusion of the study, a simple mark-recapture (Chapman, 1948) was done to estimate populations of the brook trout remaining in the stream. Results indicated that 38 fingerlings survived in Section B (18-H brand and 20-7 brand), while only 7 fish survived in Section A (7-X brand). This would indicate a mortality rate of 93 percent in hatchery fish and 88 percent in F_1 wild fingerling, and a total mortality of 90 percent.

Movement of Planted Fingerlings

Movement of fingerlings within subsections of Section A and B appeared insignificant. Generally, fingerlings remained in the stream section where planted or were not recovered at all. No fingerlings, either F_1 wild or hatchery planted in Section A, were found to have emigrated below the section. Only one fish was found to have emigrated above the last subsection of Section B. During the study movement between Sections A and B was limited. There were only 8 recoveries of Section B fish (7 and H brands) found in Section A; similarly, only 7 fish from Section A (J and X brands) were recovered in Section B.

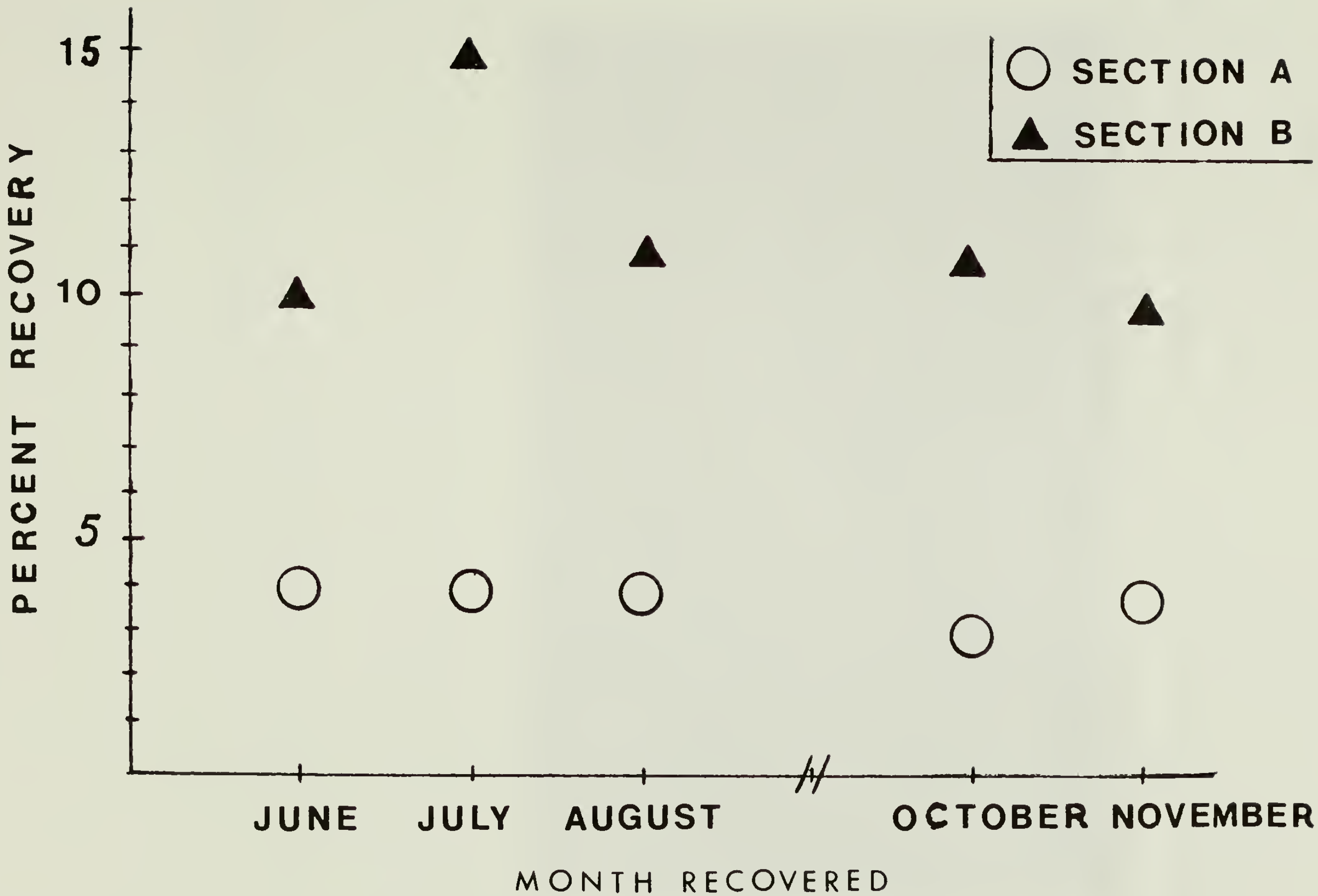

Figure 19. Monthly percent recovery of fingerlings by section in Spruce Flats Branch.

Duration of Cold-Brand Marking

The duration of the cold branding after the fish had been in the stream for six months is indicated by Figure 20. At the end of the study, at least two brands on the majority of fish were visible. The ventral brands were harder to identify than the dorsal and lateral brands. It should be noted that brands on other hatchery-reared F_1 wild fingerlings that were kept at the Buffalo Springs Hatchery were not visible after the six-month study period.

Figure 20. Cold brand after six months in Spruce Flats Branch.

CHAPTER V

DISCUSSION

Optimum environmental conditions of the brook trout are not entirely known; however, water temperature tolerance has probably received the most attention concerning its role in the success of the species in streams. Fry (1951) and Needham (1969) gave 19° C (66° F) as ideal or optimum summer temperature for brook trout. Water temperatures in SFB were near optimum in both sections during much of the study. Although the temperatures appeared favorable for the fingerlings, small mountain streams respond rapidly to changes in microclimate, particularly solar radiation, and temperatures intolerable for trout could result (Swift and Messer, 1971).

Chemical analyses of the stream indicated favorable conditions for survival of trout fingerlings; however, observation of the stream during periods of rainfall revealed increased turbidity. This could be a result of the second-growth forest being unable to control heavy runoff. Also an increase in stream turbidity might be associated with streamside rooting activities of wild boar (*Sus scrofa*).

Siltation of pools in Section A appeared to be greater than the pools in Section B. A lesser silt load in the upstream section was probably due to the steeper gradients and swifter water. Tebo (1955) and Saunders and Smith (1965) observed reduction of stream invertebrates and summer standing crops of brook trout in areas where silting occurred. Within limits of space and reproductive capacity, the available food in a stream can certainly be regarded as a factor limiting the production and survival of trout (Tebo, 1955). Leonard (1948) and Henry (1949) stated that food supply is the most limiting factor in trout production.

In an effort to determine if bottom fauna might have been a limiting factor to survival and growth of the brook trout fingerlings in either Section A or Section B, quantitative sampling was done. The sampling revealed no significant differences in mean numbers of organisms; however, caution is emphasized. Needham and Usinger (1956) showed that at least 194 samples per unit area would be required to obtain a 95 percent confidence value for weight, and 73 percent value for numbers. Furthermore, Hynes (1970) stated that all quantitative estimates of the numbers or biomass of animals on stream beds are, at best, only very rough estimates.

Both hatchery and F_1 wild strains of brook trout were included together in a study of food habits since the recoveries in Section A were low. Because blacknose dace appeared to be numerous in the lower section, a study of their food habits was undertaken to determine if interspecific competition was involved. A comparison of mean dace numbers in subsections of Section A and Section B revealed significantly more dace in the lower section. Saunders and Smith (1962) determined that transplanted trout fared better in partially depopulated habitats.

A comparison of food habits of the two species suggested that interspecific competition might have been involved. The blacknose dace fed on a wide variety of bottom fauna and terrestrial organisms. Five crayfish were found in stomachs of four dace, even though Traver (1929) stated that crustaceans were rarely found in their stomachs. As Miller (1958) pointed out, when trout are introduced into a stream containing resident fish, they must compete with the residents for food and a home. Competition was lessened by the fact that the trout fed more on surface organisms such as aquatic adults and terrestrials. Competition may increase during winter months when the feeding habits of the brook trout will be limited to the bottom fauna.

Mean number of organisms and volume in both dace and brook trout stomachs were compared. It was found that brook trout fingerling stomachs contained more organisms than did dace stomachs; however, no significant difference was found in mean volume of organisms in brook trout and dace stomachs. Therefore, brook trout fingerlings probably expend more energy acquiring food than the dace, which eat fewer and larger food items.

Growth of brook trout fingerlings varied in the stream. The hatchery brook trout in Section B (H brands) had a mean total length of 70.53 mm at planting. At final recovery, mean length was 106.18 mm or a 50 percent increase in length. Lennon and Parker (1960) concluded that brook trout fingerlings grew well in GSMNP with a length increase of 25 percent from June to September. The mean weight gain of the H-brand fingerlings was 373 percent at the conclusion of the study. Growth and condition of hatchery fingerlings in Section A could not be properly assessed due to low recovery rates.

The F_1 wild fingerlings in Section A (X-brand) and Section B (7-brand) increased in total length but not as significantly as the hatchery fish (H-brand) in Section B. The F_1 wild fish in Section A (X-brand) grew better than those (7-brand) in Section B; however, their growth advantage might be explained by the absence of (J-brand) hatchery fingerlings.

The mean coefficient of condition of the H-brand hatchery strain increased greater than the other three branded groups. The increase might be explained genetically, due to select breeding of hatchery strains for rapid growth and heavy body condition. The H-hatchery and both F_1 wild groups revealed a significant decline in condition between August and October recoveries. Their increase in mean length without a comparable increase in mean weight during this period might be explained by less available food or more competition. The trout fingerlings were all on a regular feeding schedule in the hatchery before being planted and food and competition were not limiting factors.

Movement of the two strains of fingerlings in SFB was slight. Emigration of planted fingerlings from Sections A and B was minimal. No fingerlings were sampled below Section A; however, deep pools between the first subsection and the barrier waterfalls made recovery attempts difficult. Only one brook trout fingerling had emigrated above the upper subsection (34) of Section B.

During the study several fingerlings were recovered from the same pools month after month. Mills (1971) found that transplanted trout movement was minimal and upstream only for short distances in summer. The seven fingerlings that emigrated from the lower section to the upper section might have done so due to competition from both trout and dace, or to seek more cover to elude predators. The eight fish which were originally planted in Section B and were recovered in Section A might have been displaced when flooding occurred.

Recoveries of F_1 wild fingerling (7-brand) and hatchery fingerling (H-brand) strains originally planted in Section B were consistently greater in percent returns than the F_1 wild (X-brand) and hatchery (J-brand) fish planted in Section A. November 9 was the last sampling of fingerlings for growth determinations. Section B showed 10 percent recovery of fingerlings, while Section A only had a 4 percent recovery. The greater percent recovery of fingerlings in the upper section can probably be attributed to several factors. Among these are less competition from dace and greater cover in the majority of the subsections. Mills (1967) found that the population density of trout was higher in that part of the stream which flowed through a section of forest where there was abundant vegetation and cover, as opposed to a section immediately downstream which had no undergrowth and little cover.

The F_1 wild fingerlings combined recovery was 9 percent at last sampling for growth and movement in November; hatchery strain recovery was 4 percent.

Vincent (1960) observed similar results and attributed higher recovery percentage of wild fish to their larger size at planting and to a certain degree, genetic adaptability.

The cold brands applied to both strains of fingerlings made it possible to determine growth, movement, and recovery during the study. The stream sections where trout were recovered appeared to have an influence on brand clarity. Fingerlings taken in the areas where stream cover was abundant were darker in body pigment than those fish recovered in areas of abundant light (Section A). The melanophores of the darker-hued fingerlings contracted after the fish were placed in light-colored plastic buckets. This resulted in lightened skin pigment of the fingerlings, making the subdued brand easier to identify. Fingerlings in Section A were easier to identify due to their lighter skin pigmentation.

It was hoped that as a result of the planting in SFB, the surviving fingerlings would populate the drainage through natural reproduction. The fish in Section B were given a better chance due to their greater numbers, better habitat, and lesser competition with the blacknose dace.

CHAPTER VI

SUMMARY

1. Water temperature and stream chemistry of Spruce Flats Branch were analyzed and found to be satisfactory for the planting and subsequent survival of brook trout fingerlings in both sections.

2. Although siltation was a factor which might be limiting to bottom fauna biomass in the stream, there was no significant difference in mean numbers of organisms in the two study sections.

3. Numbers of dace were significantly higher in Section A than Section B.

4. Both strains of brook trout fingerlings were compared in a food habits study with resident blacknose dace, and it appeared that interspecific competition was involved. Statistical analysis of mean numbers of organisms in brook trout and blacknose dace stomachs revealed trout stomachs contained significantly greater numbers of organisms; no difference was found in mean volume of organisms.

5. Hatchery brook trout in Section B had the best growth and body condition during the study. Genetic and environmental selectivity can be attributed to their performance. Slight decline in condition of F_1 wild

fingerlings can be attributed to larger size at planting and possibly competition.

6. Recovery of F_1 wild fish was superior to the hatchery strain; recovery of both strains was better in Section B than Section A.

7. Movement of fingerling brook trout in Spruce Flats Branch was minimal between sections and out of the study area.

8. Cold brands on fingerlings were recognizable after six months in the stream; however, the brook trout's environment influenced brand clarity.

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