THE ROLE OF FOREST DEBRIS IN A SOUTHEASTERN STREAM AND THE EFFECTS OF ITS REMOVAL ON TROUT POPULATIONS

by

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INTRODUCTION

Forest debris in streams can be either beneficial or detrimental. Logs, stumps, branches and similiar forest debris may accumulate in streams to the point that damage can be done to the watershed. Accumulations of debris either of natural origin or as the result of human activities such as logging can lodge against bridges and culverts in times of flood, and cause severe damage to these structures. When accumulations of debris completely block the stream channel unnecessary flooding and bank erosion can occur. For these and other reasons the United States Forest Service (U.S.D.A.) commonly removes debris from streams flowing through lands under their jurisdiction (Richard Pennington, Pers. Comm.)

Various salmonids often inhabit these mountain streams from which debris is removed. Consequently, debris removal is designed to minimize the impact on resident trout populations. The concern for the effects of debris removal on trout populations is based on the recognition that trout populations can be greatly effected by the morphology of their physical habitat and that the amount and configuration of forest debris in streams effects flow, substrate, depth and cover characteristics (i.e. morphology) of the stream. These factors in turn effect the food supply and general suitability of the stream for trout populations.

Trout show a preference for areas with suitable cover, depth, and flow. Confirmation of this idea has come from studies by Tarzewell (1937), Shetter, Clark, and Hazzard (1946) and Gard (1961). These studies documented increases in biomass and numbers (standing crops) of trout in stream sections containing stream improvements such as low dams and deflectors. Whether the increase in numbers and size result from increases in food supply or increased stream depth or the simple presence of the improvement structures was not determined. However, Shetter, Clark, and Hazzard (1946) hypothesized that an increase in actual carrying capacity had occurred. Based on this earlier work Saunders and Smith (1962) concluded that a lack of suitable "hiding places" might be limiting the standing crops of yearling and older brook trout (Salvelinus fontinalis) in a small Prince Edward Island stream. The placement in this stream of deflectors, dams, and covers increased the standing crop of fingerlings, yearling, and older trout but decreased the proportion of fingerlings in the population. Growth rates were not noticeably effected.

Boussu (1954) and Hunt (1971) attempted to quantify changes in trout populations correlated with removal or additions of specific cover types. The addition of cover (willow branches woven in wooden frames) resulted in increases in both biomass and numbers (Boussu, 1954). Conversely, the removal of overhead brush and undercut banks was followed by apparent decreases in biomass and numbers of large trout. Smaller trout, particularly fingerlings, noticeably increased in numbers and biomass. Boussu used simple inventories rather than statistical estimators to establish numbers and biomass. Inventories can be greatly affected by changes in habitat and has no error term associated with it for making valid comparisons. Hunt (1971) corroborated Boussu, when he demonstrated that dramatic increases in standing crops of brook trout in a Wisconsin stream occurred when a section of stream was restructured to provide additional cover, flow, and depth.

General ecological studies have supported the observations on trout habitat preferences from stream improvement studies. Lewis (1969) sought to determine, using multiple regression techniques, important physical parameters influencing the standing crops of trout in a Montana stream. Cover was the most important factor in determining brown trout (Salmo trutta) densities although coincidental current improved the value of the cover. Rainbow trout (Salmo gairdneri) densities were most affected by current velocity. Pools with the greatest amounts of cover exhibited the most stable populations.

Laboratory studies have attempted to define more precisely the reasons why trout react the way they do to the morphology of their habitat. MacCrimmon and Kwain (1966) and Kwain and MacCrimmon (1969a, 1969b) found that overhead light intensity greatly effected bottom color selection by rainbow trout. Yearling trout under illumination preferred darker backgrounds whereas fingerlings did not. Blinded fish on the other hand showed no background color preferences. Both brown and rainbow trout chose areas with dark backgrounds (such as would occur under cover) when frightened. The selective advantage of choosing a dark background under a fright situation has obvious advantages (Ritter and MacCrimmon 1973). Studies which have dealt with the behavioral responses of individual trout to their physical surroundings support the findings of field studies concerned with trout on the population level. The reaction of individual dominant trout to changes in overhead cover provided by three different sized artificial plywood structures was studied by Butler and Hawthorne (1968). Brown, brook and rainbow trout all showed a preference for the larger cover even when the position of the structures was changed. Brook and brown trout showed the greatest affinity for overhead cover respectively and the least inclination to depart from it. The choice of dark backgrounds and areas under cover by individual fish in experimental situations provides a clear behavioral explanation for the field observation of greater trout densities in areas with cover.

Baldes and Vincent (1969) referred to the habitat immediately surrounding an organism as its microhabitat. They investigated the preferred microhabitat of brown trout in an experimental raceway equipped with various types of cover structures. Fish preferred areas with flow just in front of cover structures or near raceway walls. This finding supports Lewis's (1969) findings that brown trout occur in the greatest densities in pools with cover and flow. Dependence on channel irregularities and structures increases with increasing velocity.

Jenkins (1969) further documented the importance of physical habitat in determining the extent and distribution of trout populations. By extensive observation of brown trout in their natural environment he determined that defended positions in the current were not held by locally dominant fish if the position was far from cover. Refuge areas, he concluded, were focal points for social hierarchies.

The foregoing discussion emphasizes that the physical makeup of the surrounding stream is very important to resident trout populations. The question remains, however, as to what roles forest debris plays in the physical habitat.

Limited research relating in-stream forest debris to stream ecology has been performed. Most of the documented work has been concerned with the effects of massive introductions of logging debris into small western streams (Bishop and Shapely 1962, Narver 1971). Logging debris of this type often blocks anadromous salmonid migrations, thus the need for removal is obvious. In the Southeast debris removal efforts are more often directed at debris of natural origin, in streams with resident trout populations. The role that forest debris plays in this situation is not clearly understood.

Large debris when in the proper configuration is likely to provide cover or hiding places as described by Tarzewell (1936) and Boussu (1954). Log jams have been shown to concentrate young of the year steelhead trout and salmon (Hartman 1965, Bustard and Narver 1975). The presence of forest debris may also effect flow characteristics of the stream which in turn effects fish distributions (Baldes and Vincent 1969). Stream flow will of course determine substrate characteristics which will in turn effect spawning areas and food supply (Cordone and Kelly 1961). A myrid of possible roles for stream forest debris exists.

Evaluating whether debris should be removed from southeastern trout streams requires a great deal of information not currently available. It is for this reason this study was initiated. The goal was to evaluate the role of debris in southeastern streams and evaluate the impact of debris removal of these streams with respect to trout populations. The four questions addressed were as follows: 1) Are trout concentrated in and around debris accumulations? 2) How will debris removal change the flow and substrate characteristics within the stream? 3) How will debris removal change the amount of available cover? 4) Can changes in fish populations within sections be explained by changes in the physical characteristics of the stream. The overall objective then was to evaluate changes which occur as the result of the removal of debris from several sites.

MATERIALS AND METHODS

The Study Area

The study was conducted on Poplar Creek and South Fork Mills River above its confluence with Poplar Creek in Transylvania county, North Carolina (Figure 1). Both streams originate in the Pisgah National Forest on the eastern side of the Blue Ridge and flow through an area known as the Pink Beds at an elevation of about 3200 feet. Both streams have generally low velocities with a gradient of less than 20 feet per mile through the study area. South Fork Mills River is typically 3 - 5 meters wide and .5 - 1.0 meters deep during normal summer flows. Poplar Creek is smaller being 3 - 4 meters wide and .3 - .7 meters deep. The surrounding forest is mixed pine and hardwoods with numerous hemlocks growing directly on the stream. These streams have similiar chemical characteristics as indicated by measurements taken in June 1975 (Table 1). Both streams tend to be quite unproductive as indicated by very low levels of hardness and alkalinity.

Criteria of Site Selection

Five criteria were used in selecting stream areas for this study. The areas had to: 1) have several discrete areas of debris accumulation around which study sections could be established, 2) contain resident or naturalized

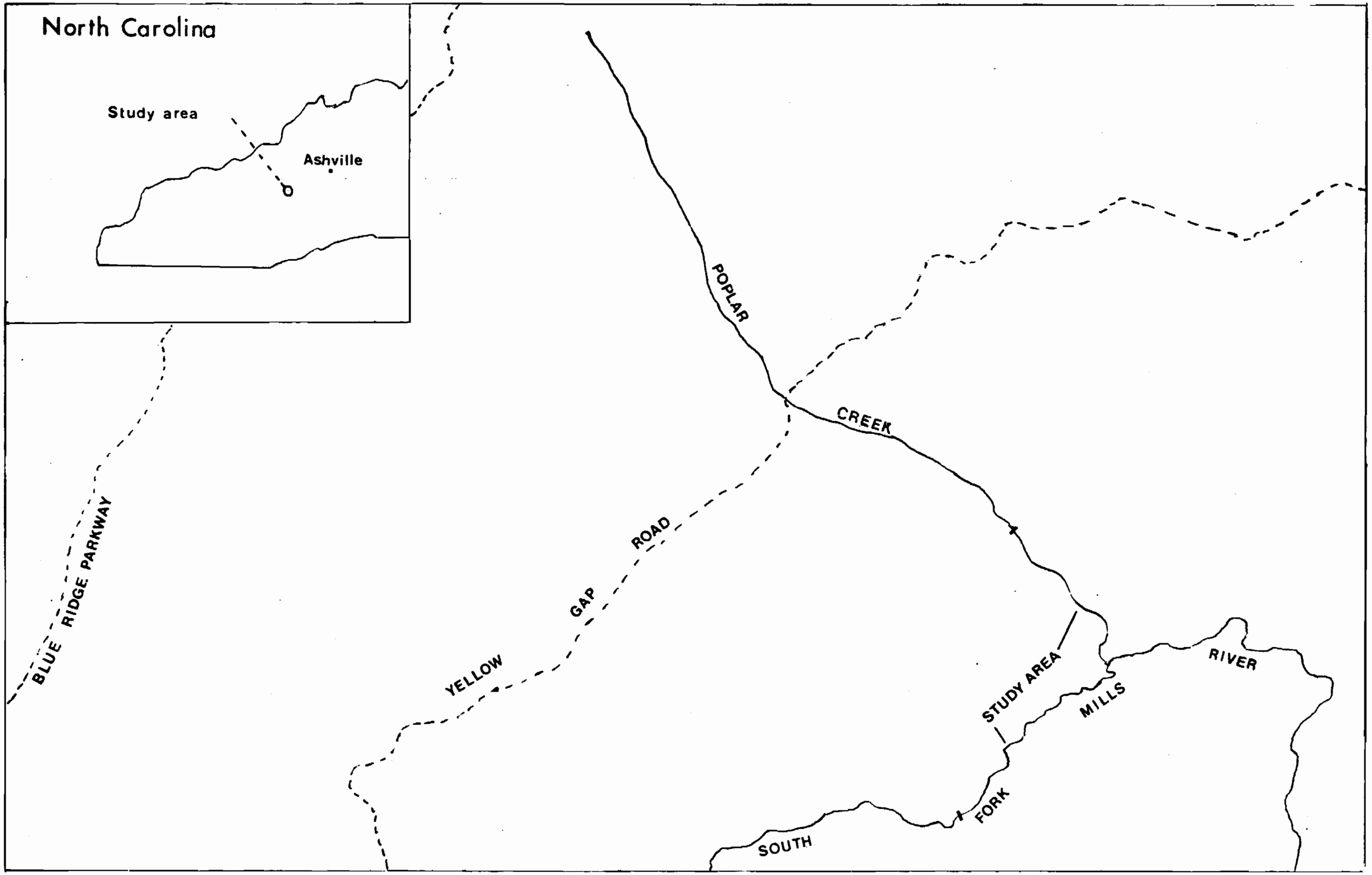

Fig 1. Location of study area, upper South Fork Mills River and Poplar Creek, North Carolina.

Table 1. Water chemistry measurements taken in the the study streams, June 1976.

Stream	pH	Alkalinity (ppm)	Hardness (ppm)
S.F. Mills River	7.2	5	6
Poplar Creek	7.7	4	8

populations of trout, 3) not be stocked, 4) not contain stream improvement structures and 5) be small enough to be sampled efficiently for precise estimates. Numerous streams in George Washington and Jefferson National Forests in Virginia were surveyed but all fell short in one or more of the above stated criteria. Usually they contained little or no debris or were stocked regularly. Poplar Creek and South Fork Mills River are generally lower gradient than the other streams surveyed which may account for the larger amounts debris. The North Carolina Wildlife Resources Commission manages both these streams as "native" trout streams i.e. no stocking, fishing with artificials only, and a daily limit of four fish over 10 inches.

Four 30 - 40 meter sections of stream containing debris accumulations on each stream were chosen as study sites. Additionally one 30 - 40 meter section of stream containing little or no debris on each stream was selected for study. Debris was removed from three sections on each stream. The remaining two sections with debris and the two without were intended as reference stations.

Physical Environment

In May 1975 and June 1976 (pre- and post-treatment) each of the 30 - 40 meter stream sections were mapped for substrate and cover characteristics. Before mapping, the upstream and downstream borders of each section were marked by spraying a painted mark on a rock or tree adjacent to the stream. The mapping of each station was done once in May 1975 prior to the debris removal treatment and once again in June 1976. Mapping was accomplished with the use of a measuring tape and measuring rod both marked in feet and tenths of feet. The perimeter of a station was measured, outlined on a sheet of graph paper, and the scale to be used recorded. Areas comprising different substrate types were then measured and drawn in position on the map. Substrate categories used were those developed by Whitworth, Berrien and Keller (1968). Depths were measured at numerous points throughout the section and recorded. Mapping of cover was performed by measuring the dimensions of an area affected by a given cover type or combination of types. The four cover designations used were overhanging banks (including vegetation), instream debris, overstream debris, and overstream vegetation. Arbitrary standards were devised to determine areas affected by various cover types. The area affected by a single log was considered to be the area under the log plus one foot on all sides of the log. The area affected by an accumulation of debris was considered to be the area covered by debris plus a foot out from the perimeter of the accumulation. If two logs were within three feet of each other they were counted as a single cover unit and the area between them included in the measure of cover area afforded. The cover and substrate areas on these maps were measured by a planimeter after which all measurements were converted to metric units.

Debris Removal Procedures

Debris removal treatment was performed in August 1975. The criteria used in determining what objects should be removed from the stream were those used by the forest service and described by Cloward (1973). This included: (1) log jams blocking the natural channel; (2) logs and timbers spanning the stream; (3) loose logs and slash which appeared to be unstable; and (4) trees or snags on the stream bank or in the channel which may be focal points for collecting debris. Debris removal was accomplished in six days by a 2 or 3 man crew using a chainsaw, hand winch and bow saws and was done in 3 randomly selected debris containing sections in each stream. Debris removed from the stream was hauled 20 - 30 feet up on the bank.

Fish Populations

Population estimates were made on the fish in the study sections once prior to the debris removal treatment in early summer 1975 and three times after the debris removal treatment. Post debris removal samples were made in the late summer of 1975 and in the spring and early summer of 1976.

Population estimates were made on the fish in the study sections using a depletion method (Johnson 1965, Zippen 1956, 1958, Carle 1976). A section was blocked off simultaneously at each end with 7.6 meter 9.5 mm mesh seines. The seines were secured at the banks and sealed along the bottom with rocks To set the nets the stream was entered at the point where the net was to be set. This standardization minimized the "herding" of fish into or out of the study section. Fish were collected using a Georator electro-fishing unit which was operated at 230 volts D.C. The use of continuous D.C. current has the advantages of: (1) attracting the fish to the postive electrode; (2) posing the least danger to the shocking crew; and (3) causing the least damage to the fish (Vincent 1971). Depletions were made in runs or units of fishing effort that consisted of shocking throughout the section from the downstream net to the upstream net and back. At the end of each run the downstream net was checked for net captured fish and reset. The fish captured in each run were kept in separate cages or buckets until all runs had been completed. Fish from each run were enesthesized with Tricaine Methanosulfonate (MS-222), weighed to the nearest gram on a 500 gram capacity spring scale, and measured by total and fork lengths to the nearest milimeter.

Zippen's (1956, 1958) depletion estimator and Carle's (1976) modification were used to estimate populations. These estimators have important assumptions associated with them. One of these assumptions is that the population be stationary with no deaths, recruitment, or emmigration during the time period in which the estimate is made. By blocking the stream section with nets the validity of this assumption was assured. A second assumption is that all individuals in the population have the same probability of being captured. In this study small fish under 10.0 cm were found to have a much lower probability of capture and thus were excluded from the estimates. The third assumption associated with the estimator is that the probability of capture and effort of capture remain the same in all runs. No effort was made to time each run; rather consistancy was accomplished by making each run thorough and of a similiar pattern.

Biomass estimates at each station were computed from the following formula:

$$W = \frac{W_s}{S} \quad N$$

where W = biomass in grams, W_S = weight in grams of the fish captured in all runs, S = the number of fish captured in all runs, and N = the estimated number of fish in the section.

Age and Growth

Scale samples were taken from the area just ahead of and below the dorsal fin of fish collected during population estimates. The scales were mounted between two microscope slides with a drop of water to aid light transmission and projected on the screen of a scale reading projector. Ages of fish were determined independently by two persons as a count of the number of annuli. Measurements were taken on the projected image of two normally shaped scales from each fish from the focus of the scale to the outside edge each annulus in an anterior direction. From these measurements the lengths of each fish at the formation of each annulus could be calculated (Carlander 1966, Nicholls 1957). A correction factor for length at scale formation was determined by a plot of scale radius against fish length (Lagler 1956) and incorporated into calculated lengths at each annulus.

Logarithmic transformations of weights and lengths were used to derive a linear regression for these two parameters from fish collected in early summer 1975. All calculations were based on information for both sexes combined because fish had to be returned to the stream alive and sexing via external characteristics is unreliable especially for small fish (Gruchy and Vladykov 1968). This procedure probably caused little bias in the calculations as both species have been shown to have similiar growth characteristics between sexes (Ball and Jones 1960, Hansen 1952).

RESULTS AND DISCUSSION

Physical Characteristics

The effect of debris removal on a given section of stream will be influenced by the initial physical makeup of the area. A brief description of the morphology of each station and significant changes which occurred during the study either due to natural causes or the debris removal process are given below.

South Fork Mills River Station 1

This study section was selected to act as a non-debris control. The station was primarily a long run flowing swiftly in a long arch approximately 25 meters in length. The flow of water was concentrated against the right bank where the maximum depths of .75 - 1.0 meters occurred. The substrate was primarily stone (60% of the stream bottom) and graded to gravel (23%) and sand (18%) towards the areas of lower stream velocity. Cover was provided entirely by the undercut right bank which affected 7.4% of the bottom area.

South Fork Mills River Station 2

This study section was selected as a treatment section. Prior to debris removal the section was an approximately .6 meter deep run flowing into a quiet pool with depths to 1.2 meters. Water left the pool through a short swift run with a stone bottom. The pool contained a large accumulation of logs and other forest debris which restricted flow and resulted in a sand bottom. Sand made up 60% of the substrate prior to debris removal, gravel 23%, and stone 16%.

Dramatic substrate changes occurred following debris removal probably as the overall stream velocity increased through the section. Sand was reduced to 16% of the bottom area and stone was increased to 60%. The area of the stream affected by cover was decreased from 43.2% to 24.1% almost wholly due to the removal of debris. The remaining cover was provided by undercut banks (5.3% of the stream bottom affected) and overhead vegetation (8.9%).

South Fork Mills River Station 3

This L-shaped station was selected as a debris containing control. Approximately 1/2 of the station was a long .3 - .5 meter deep gravel and stone bottom riffle, which entered a pool with depths ranging from .6 - 1.0 meters. A large amount of debris had accumulated against the right bank where the stream made a 90° turn. This accumulation forced the flow of water along the left bank and produced a quiet pool downstream from the debris. Initially the bottom had been 45% sand, 12% gravel and 38% gravel mixed with sand. During the course of the study part of the debris accumulation broke up and moved downstream out of the section. The breakup allowed a flow of water over a larger area of the stream which probably accounts for the decrease in sand substrate and the increase in gravel substrate in 1976. Undercut banks provided 4.4% of the bottom area with cover, overhead vegetation 4.6% and instream debris 9.1% in 1975 and 8.1% in 1976.

South Fork Mills River Station 4

This u-shaped treatment station was a shallow riffle entering a continuous sand bottom run containing concentrations of debris. The bottom 20 meters of the station was a run free of debris except for a small amount trapped in streamside vegetation. The stream bottom was 69% sand and 17% gravel. Prior to debris removal a large part of the cover was provided by instream debris. This percentage was reduced from 12.6% to 2.6% of the bottom area following treatment. Removal of debris jams apparently resulted in an increase in the amount of gravel substrate and a decrease in the amount of sand substrate.

South Fork Mills River Station 5

This treatment station was primarily a long s-shaped run with a small island midway through station. The bottom of the station was constricted, had a swift current and a stone and gravel bottom. Average depth was .8 meter. Part of the flow was directed around the left side of the island by an accumulation of debris. This action apparently created the island. Following debris removal the flow of water was confined to the right channel. Undercut banks provided 5.2% of the stream cover and accompaning overstream vegetation provided cover for 8.2% of the section. A log trapped between the island and the right bank caused an accumulation of debris which accounted for most of the 9.7% of the area affected by that type of cover. Overall the substrate characteristics of the section changed little after treatment. Some debris was added to the station after debris removal when a large log was trapped in the upper part of the section and debris accumulated behind it.

Poplar Creek Station 1

This L-shaped non-debris control station had primarily swift flowing water and rock substrates. Cover was provided primarily by undercut banks cut by heavy flows in the upper left side of the station.

Poplar Creek Station 2

This treatment station is a fast riffle flowing into a small pool. The pool is created by debris accumulated behind a log spanning over the stream. After briefly flowing through a shallow riffle the stream forms a large .5 - 1.0 meter deep pool which prior to debris removal contained a large number of logs. These logs had in turn caused the accumulation of smaller debris. Nearly a fifth of the section bottom was silt and 37% was sand. Debris removal caused a reduction in small substrates and reduced the area provided with cover by more than one-half.

Poplar Creek Station 3

This treatment station has generally swift flow throughout. In 1975 debris was trapped along the edges of the stream at several locations. Removal of this debris eliminated most silt and decreased the amount of sand. Substantial cover remained in the form of undercut banks.

Poplar Creek Station 4

This treatment station had a short shallow riffle grading into a long deep run. A large tree had fallen into the stream and forest debris had accumulated in the branches. The effect was primarily to force water around the accumulation. Debris removal apparently resulted in a more even but less intense flow through the section. Silt accumulation with the debris was eliminated but much of the gravel around the debris was replaced by sand. Nearly 75% of the available cover was eliminated by debris removal.

Poplar Creek Station 5

This debris containing control station had a short swift riffle flowing into a log jam under which the stream formed a .1 - 1.2 deep meter pool with large amounts of overstream vegetation and scattered small logs. Sand made up 55% of the substrate in 1975 and 45% in 1976 whereas gravel and stone made up 25% in 1975 and 45% in 1976. These changes may have resulted from the loss of part of the main log jam during the winter. The physical characteristics measured pre- and post-treatment are summarized in Tables 2 and 3 and Figures 2 through 5.

Fish Populations

During this study 233 brown trout and 121 rainbow trout over 10 cm were captured in the ten study sections over four sampling periods. Numerous smaller trout, 6 swannanoa darters (*Etheostoma swannanoa*), and 1 longnose (*Rhynicthyes cataractae*) were also captured. Swannanoa darters were caught only in stations 1 through 3 of South Fork Mills River and the one dace was collected in station 3 of Poplar Creek in April 1976.

Multiple regression techniques (Barr and Goodnight 1973) were employed to evaluate the importance of eight physical characteristics to trout populations. The percent of stream section area affected by the following eight parameters: instream debris, overstream, undercut banks, overstream vegetation, total cover, large substrates (gravel and stone), medium substrates (gravel), and small substrates (sand and silt) were used as independent variables against the two dependent variables, trout biomass /ha and trout numbers /ha.

Overstream debris contributed nothing to the variation in biomass/ha. The other seven variables together accounted for 90% of the variation in biomass

Table 2. Percentage of stream bottom area affected by each substrate type in the ten study sections pre- and posttreatment.

Stream	Poplar Creek									
Station	1		2		3		4		5	
Substrate Type	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Silt	0	0	18	13	12	1	8	0	10	4
Sand	19	19	37	31	25	32	15	40	55	43
Sand/Gravel	0	0	0	0	0	0	0	0	0	0
Gravel	5	5	24	41	25	11	0	9	0	0
Gravel/Stone	55	55	18	5	16	44	73	29	30	45
Stone	18	18	2	10	21	12	5	20	7	9
Total Area (m^2)	220.4		204.9		192.2		182.0		183.2	

Stream	South Fork Mills River									
Station	1		2		3		4		5	
Substrate Type	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Silt	0	0	0	0	6	0	8	0	7	0
Sand	18	18	60	16	45	30	69	32	41	52
Sand/Gravel	0	0	0	0	0	0	0	0	12	0
Gravel	23	23	23	31	12	39	17	38	20	8
Gravel/Stone	0	0	2	0	33	31	0	4	17	26
Stone	60	60	16	53	0	0	7	26	3	13
Total Area (m^2)	155.1		187.8		200.8		324.0		267.6	

Table 3. Percentage of stream bottom area effected by each cover type in the ten study sections, pre- and posttreatment.

Stream	Poplar Creek									
Station	1		2		3		4		5	
Cover Type	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Undercut Bank	4	4	3	3	8	8	1	1	4	4
Overstream Veg.	1	1	4	1	0	0	6	4	0	0
Instream Debris	2	3	19	3	13	2	6	0	15	12
Overstream Debris	0	0	3	3	0	0	9	0	0	0
Total Cover	7	8	29	10	21	11	21	5	19	16
Total Area (m^2)	220.4		204.9		192.2		182.2		183.2	

Stream	South Fork Mills River									
Station	1		2		3		4		5	
Cover Type	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Undercut Bank	7	7	5	5	4	4	2	2	6	5
Overstream Veg.	0	0	9	9	5	4	2	4	8	8
Instream Debris	0	0	29	5	9	9	13	3	10	4
Overstream Debris	0	0	1	4	0	0	2	0	0	0
Total Cover	7	7	43	8	18	17	19	9	23	17
Total Area (m^2)	155.1		187.8		200.8		324.0		267.6	

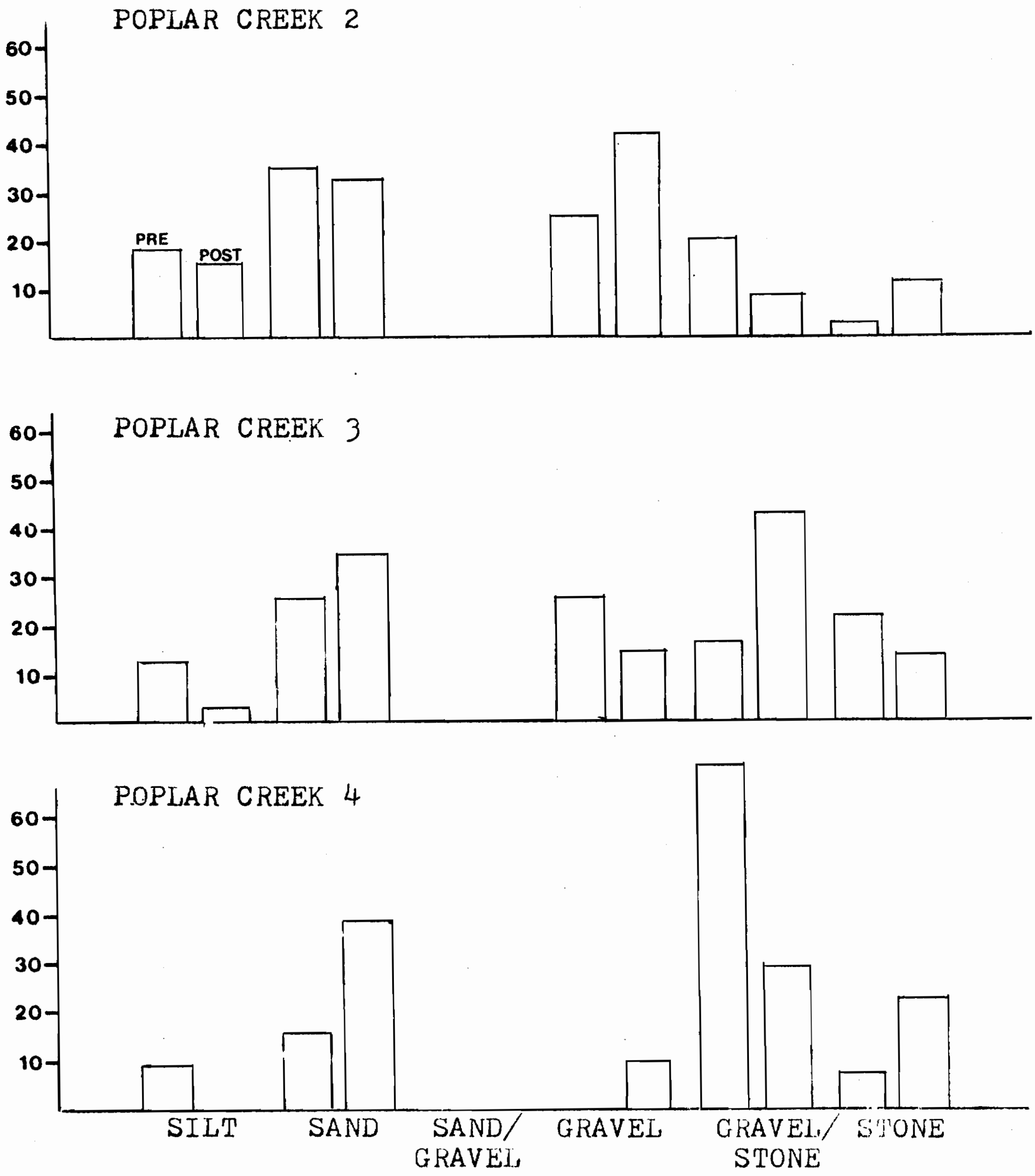

Fig. 2. Percentage of stream bottom area affected by each substrate type in the three Poplar Creek treatment stations, pre- and posttreatment.

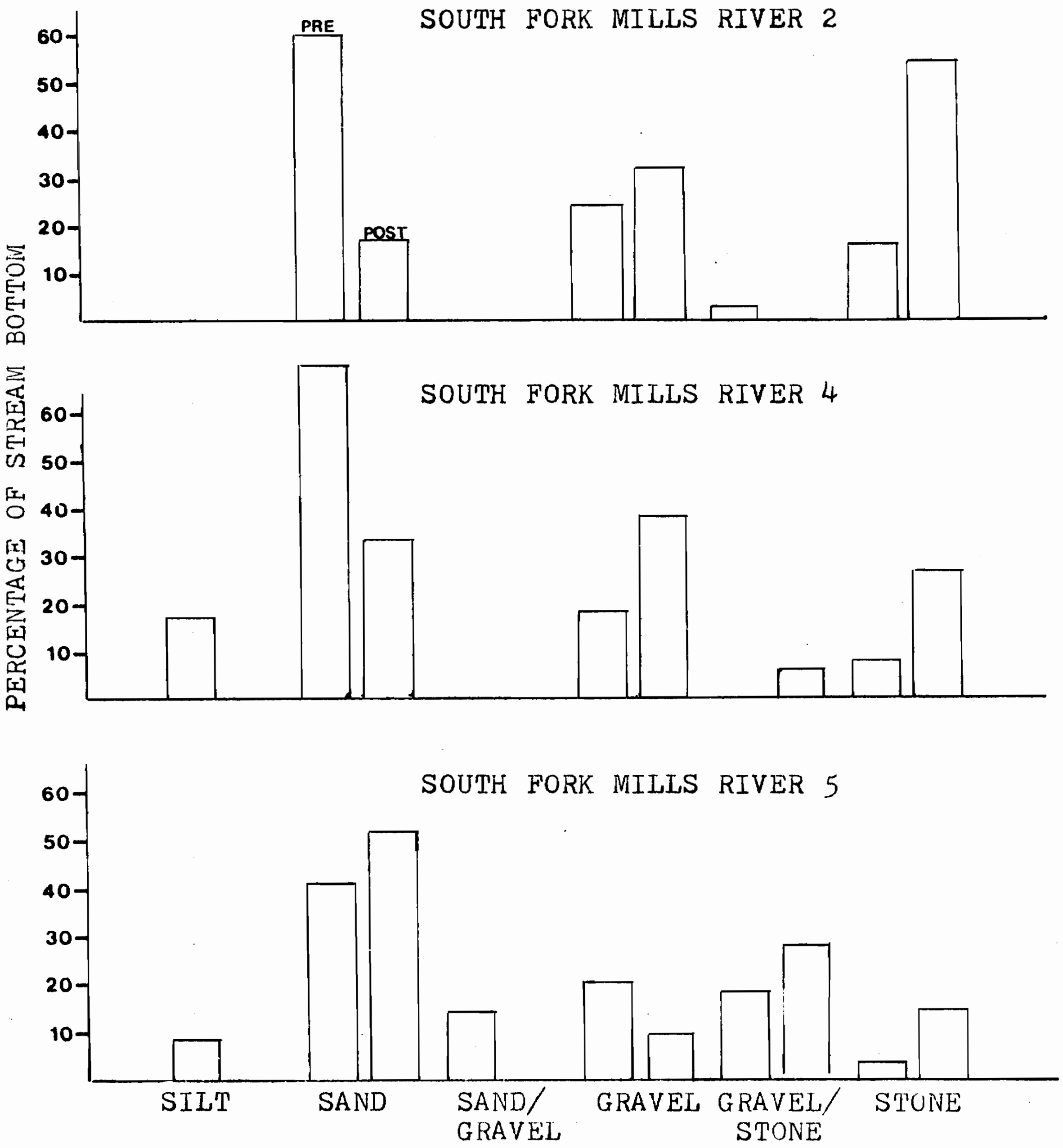

Fig. 3. Percentage of stream bottom area affected by each substrate type in the three South Fork Mills River treatment stations, pre- and posttreatment.

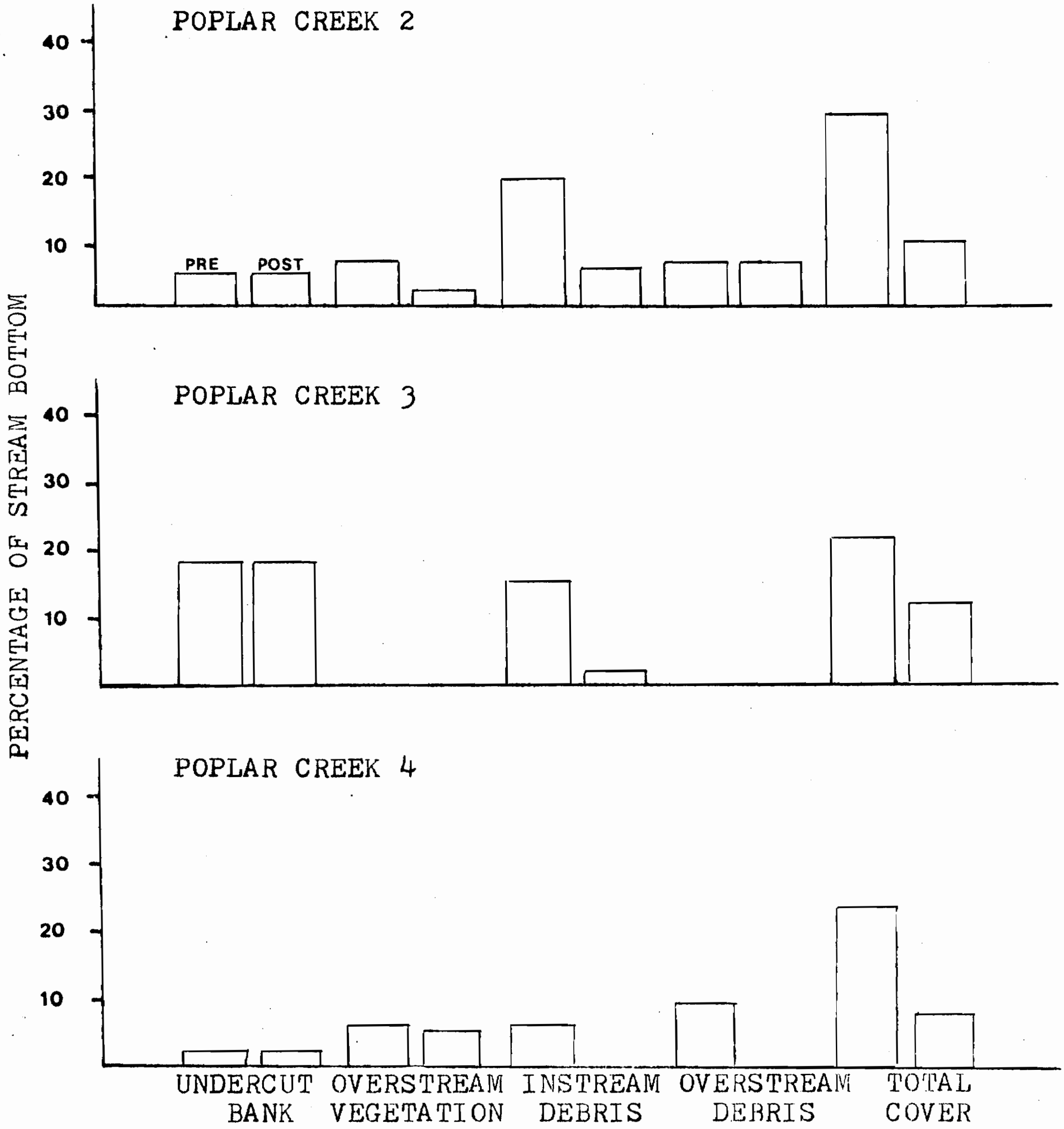

Fig. 4. Percentage of stream bottom area affected by each cover type in the three Poplar Creek treatment stations, pre- and posttreatment.

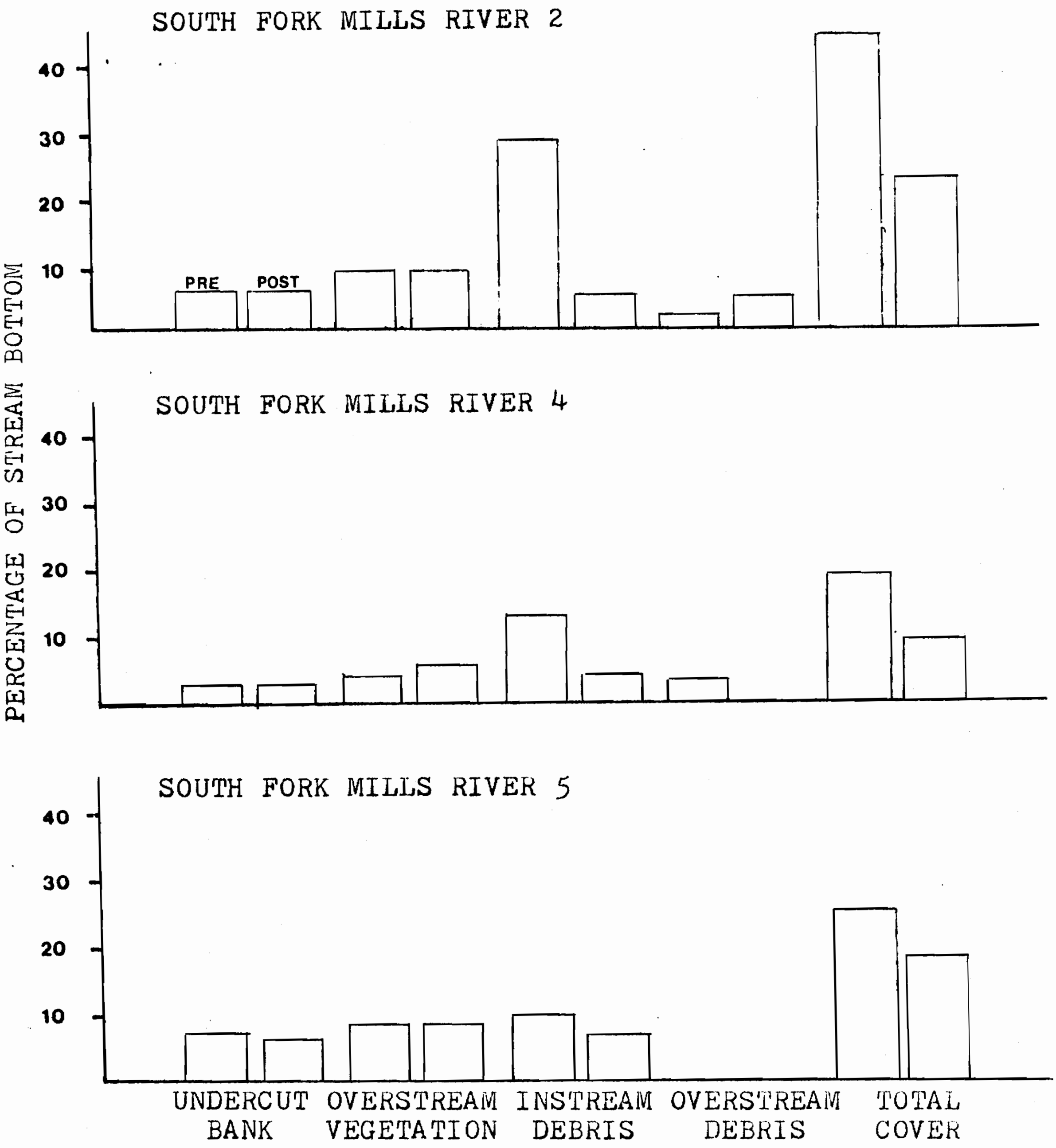

Fig. 5. Percentage of stream bottom area affected by each cover type in the three South Fork Mills River treatment stations, pre- and posttreatment.

between stations. The presence of large substrate (interpreted here as the result of higher velocity water flow) and instream debris accounted for 58% of the variation in trout biomass /ha. Regression models comprising these two variables were the only ones significant at the $\alpha = .1$ level (Table 4). In contrast to the above relationship, instream debris could account for none of the variation in trout number /ha. The seven remaining physical parameters accounted for 92% of the variation in numbers, while the presence of gravel substrate (interpreted to indicate intermediate water velocity) and overstream vegetation alone accounted for 73% of the variation in fish numbers. Regression models for these two variables were significant at the $\alpha = .1$ level (Table 5).

The regression analyses used does not assure that there is a direct biological relationship between the significant independant variables and the dependant variables used here. However, the fact that instream debris and greater substrate size resulting from higher stream velocities can account for much of the variation in trout biomass is evidence that instream debris is an important component of the streams physical environment especially for larger fish. It would also seem likely debris is acting directly as cover or "hiding places" for large trout since it functions much like the

TABLE 4. Results of multiple regression analyses with trout biomass as the dependent variable and instream debris and large substrate as the independent variables.

Source	DF	Sum of Squares	Mean Square	F	Prob>F	R^2[1]
Regression	2	1011430091.39	505715045.70	4.87**	0.0472	.582
Error	7	726458046.71	103779720.96			
Total	9	1737888138.10				

** Significant at 0.05 level.

[1] R^2 is amount of variance explained by the independent variables

TABLE 5. Results of multiple regression analyses with trout numbers as the dependent variable and median size substrates and overhead vegetation as the independent variables.

Source	DF	Sum of Squares	Mean Square	F	Prob > F	R^2[1]
Regression	2	38633.58	19316.79	9.45**	0.0103	0.730
Error	7	14311.33	2044.48			
Total	9	52944.90				

[1] R^2 is amount of variance explained by the independent variable.

** Significant at 0.05 level.

experimental cover used in studies by Kwain and MacCrimmon (1966, 1969a), Butler and Hawthorne (1968) and Baldes and Vincent (1969), that is by providing areas without overhead exposure and with current deflection.

Debris removal did not decrease numbers of total fish but did decrease numbers of large fish. Jenkins (1969) showed that smaller fish did not require cover but did require flow, and food supply. Debris thus acts to provide cover for larger fish who provide biomass in greater proportion than numbers.

Wilcoxons distribution-free Rank Sum Test, modified for ties among populations (Hollander and Wolfe, 1973), was used to test the hypothesis that trout populations in stations with debris accumulations tended to be made up of larger individuals than the populations in areas without debris. This test was significant at the $\alpha = .1$ level ($w^{*} \geq z\ (.08)$). Indicating that debris accumulations are important especially to larger trout.

The relationships between physical characteristics and trout populations established by the regression analysis provided a basis for predicting the effect of debris removal. Debris removal was expected to reduce the available cover, thereby reducing the habitat of large trout. A reduction in the numbers of large trout should reduce biomass. Fewer large trout and greater flow velocity was expected to make the area more attractive to smaller trout. The expected overall result would be a reduction in biomass with perhaps an increase in numbers.

Tables 6 and 7 contain estimates of numbers and biomass for the ten study sections from 1975 and 1976. In the following discussion the early summer 1976 sample will be used for comparison with pretreatment (early summer 1975) levels. Only these two samples are directly comparable because of possible seasonal differences. The two debris containing reference sections (South Fork Mills River Station 3 and Poplar Creek Station 5) exhibited either no significant change or increased trout numbers and biomass between 1975 and 1976. The two non-debris control stations (Poplar Creek Station 1 and South Fork Mills River Station 1) both had significant decreases in trout numbers and biomass between 1975 and 1976. These two stations in fact had very unstable populations of trout based on the four samples taken during the course of the study.

This instability may be explained perhaps by the fact that these stations had relatively low numbers of comparatively small trout which tend to move more than larger trout (Jenkins 1969). For this reason it is preferable to compare stations where debris was removed to the debris containing references which had more stable populations.

Table 6. Estimated numbers of trout over 10 cm in length in each station for each sampling period.

Station	7/75	9/75	4/76	6/76
Poplar Creek				
1	5 (5-6)	9 (9-11)	3 (3-3)	8 (8-9)
2	12 (12-14)	18 (18-20)	4 (4-5)	6 (6-7)
3	14 (13-18)	15 (15-16)	8 (8-9)	15 (15-16)
4	5 (5-7)	6 (6-7)	4 (4-4)	7 (7-9)
5	9 (9-10)	14 (12-22)	13 (12-18)	12 (12-13)
South Fork Mills River				
1	12 (12-13)	6 (6-7)	3 (3-4)	2 (2-3)
2	7 (7-9)	7 (7-7)	5 (5-6)	9 (9-10)
3	6 (6-7)	7 (7-8)	5 (5-7)	9 (9-10)
4	19 (17-26)	14 (12-22)	10 (10-12)	15 (13-23)
5	14 (14-15)	6 (6-7)	9 (9-10)	8 (8-9)

Table 7. Estimated biomass in grams of trout over 10 cm in length in the ten study sections during all sampling periods.

Station	7/75	9/75	4/76	6/76
Poplar Creek				
1	323	238	236	158
2	754	1076	422	807
3	1045	1544	1315	1204
4	392	784	598	879
5	1272	1469	1773	967
South Fork Mills River				
1	452	217	333	26
2	374	301	220	364
3	458	428	395	463
4	3349	2065	848	424
5	2477	370	622	929

Significant decreases (3) or no change (1) in biomass occurred in four of the six treatment stations. A fourth would have exhibited a large decrease in biomass except for the presence of a very large brown trout (over 70% of the biomass taken in this section) in summer 1976 sample. The remaining station showed an increase in biomass following debris removal (Figure 6).

No clear trend was evident in numbers of fish. Two stations showed no change, 2 showed increases and 2 showed decreases in fish numbers. Clearly any explanation of the effects of debris observed in this study must be based on a station by station discussion of the relationship between physical habitat changes and the accompaning changes in trout populations (Figure 7).

South Fork Mills River #2

This station exhibited a slight but significant increase in numbers of fish but no increase in biomass following debris removal. The removal of debris decreased the amount of small substrates and increased the amount of large substrates (indicating generally greater water velocity through the station). Since small fish have been shown to be associated with areas of high flow, an increase in numbers without an increase in biomass could be expected. It was expected that since the area affected by debris cover was reduced from 28.5% of the stream area to 9.9% of the stream area and total cover

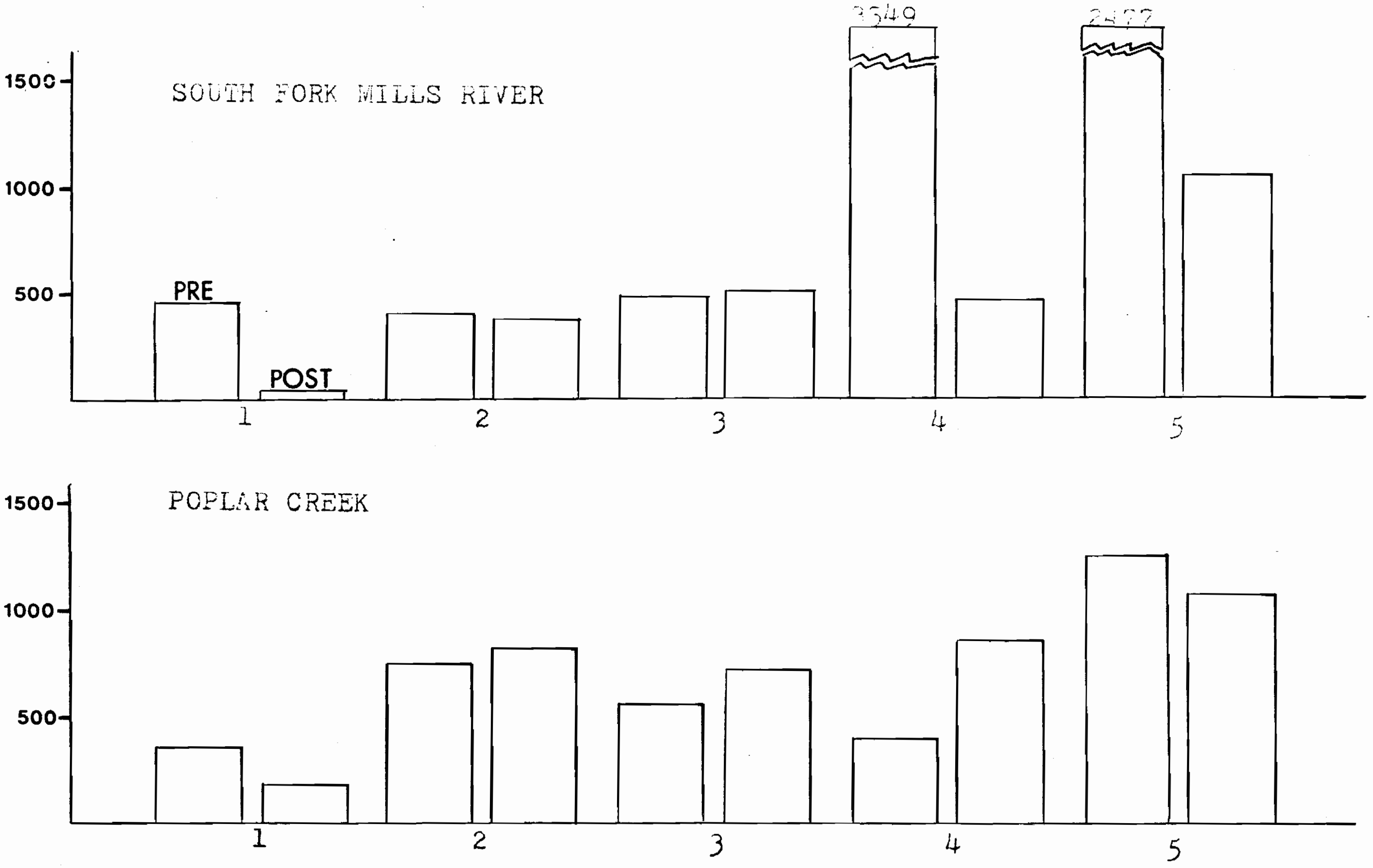

Fig. 6. Changes in the ten study sections from June 1975 to June 1976.

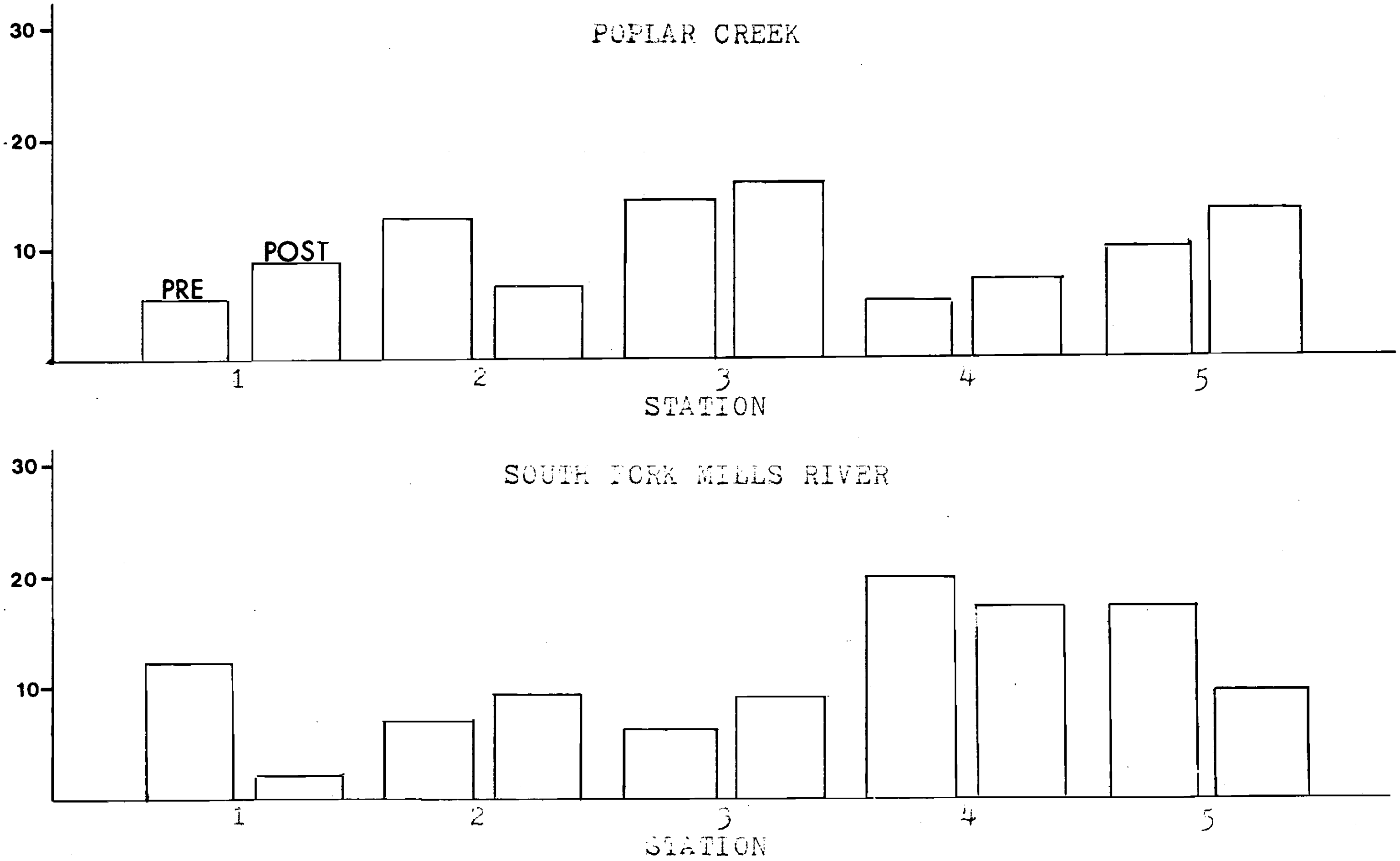

Fig. 7. Changes in numbers in the ten study sections from June 1975 to June 1976.

reduced from 43.2% to 24.1% that biomass would be much reduced. However, this station had the largest area affected by instream debris cover and the lowest initial trout biomass for a debris containing station. Therefore the cover was probably of low quality with respect to trout populations. Thus removal seemed to have had a minimal effect on trout.

South Fork Mills River #4

Numbers of fish did not change significantly in this station, but a large reduction in biomass did occur following debris removal. This response could be expected because of the removal of over half the available cover. A shift towards larger substrates indicating greater flow was accompanied by larger trout being replaced by smaller ones.

South Fork Mills River #5

Both biomass and numbers of trout were reduced in the summer following debris removal in this station. The average size of the fish was reduced from 177 to 117 grams. Total cover was reduced by about 1/3 and debris cover reduced by 2/3. General flow characteristics as indicated by substrate did change drastically.

Poplar Creek #2

Removal of debris in this station reduced available total cover from 29.3 to 10.4% of the stream area. There was no overall affects on flow as indicated by substrate.

The effect on trout populations was a significant reduction in numbers of fish (approximately 1/2). There was an apparent increase in biomass following debris removal. However, one very large brown trout accounted for 70% of the biomass in the posttreatment sample. Without this one fish there would have been a substantial decrease in biomass in the station.

Poplar Creek #3

This station exhibited a shift towards larger substrates (indicating higher flow velocity) and reduction of available cover accompaning debris removal. The summer following debris removal fish numbers had increased but biomass decreased. Jenkins (1969) found smaller fish tend to be found in flowing water and large fish particularly brown trout tend to be associated with cover.

Poplar Creek #4

Following debris removal there was a noticeable increase in biomass without an increase in numbers. This station was unusual in that debris removal caused a shift towards smaller substrates and thus indicated generally slower flows. Available cover was reduced from 21.4 to 5.6% of the bottom area. One possible explanation of these data is that there was a reduction of flow velocity through the deepest part of the station making the pool more favorable for larger trout.

Forest debris accumulations are an important component of the stream physical environment for large trout by providing suitable refuge areas as described by Jenkins (1969). Current velocity, another important factor is altered and controlled in some areas by the amount and configuration of debris present. As shown by Lewis (1969) and confirmed here these two physical factors cover and flow can account for much of the variation in trout numbers and biomass. Debris removal should then effect trout populations. The nature of this effect, of course, depends on the role debris plays in a given section of stream prior to its removal. My findings indicate that if the debris is providing cover but also sluggish flow then its removal may make the area less favorable to large trout but improve conditions for small trout. This finding is consistant with work by Boussu (1954). The increase flow and resulting trend to larger substrate types may increase the densities of small trout by providing greater supplies of drifting food organisms (Champman 1966). As shown here the result is a shift to less biomass but not necessarily fewer numbers of fish inhabiting the area. In some cases debris does play roles other than those mentioned. In cases where debris is concentrating the flow, removal can result in lower water velocities as well as less cover (as in Poplar Creek Station 4). In this situation a trend to less small fish and less large fish could be expected. The roles that forest debris can play and thus the specific effect of its removal are effectively infinite, but the situations described here are probably the most common.

Age and Growth

Scales adequate for age determinations were taken from 65 brown trout and 21 rainbow trout in September 1975 and April 1976 from Poplar Creek.

The length-weight relationship for each species is plotted in Figures 8 and 9. The lengths at each annulus were back-calculated for each fish by the following formula:

$$L_n = a + \frac{Sn}{Sc}(Lc - a)$$

where L_n = the length of the fish at time of annulus, Sn = scale measurement from focus to annulus, Sc = scale measurement from focus to edge, Lc = length of fish at capture, and a = the correction factor based on a plot of fish length versus scale length with a taken as the intercept of this plot where scale radius would be zero. This intercept was determined to be 5.92 cm for rainbow trout and 3.82 cm for brown trout. Total length (Carlander 1969) was used for all calculations. The calculated lengths for each species are shown in Tables 8 and 9.

Brown trout grew faster and lived longer than did rainbow trout. Growth for both species was somewhat slow in comparison to that of other streams (Sigler, 1952) probably due to the relative infertility of the water as evidenced by the water chemistry measurements and lack of forage fish.

The growth rates have important ramifications for the sports fishery on the stream. Rarely do rainbow trout reach the legal size and then only in their fourth or fifth year. Brown trout commonly reach the legal size but not until their third or fourth year. A reduction of the size limit to eight inches from ten would allow many more fish to be creeled while still allowing most fish to spawn.

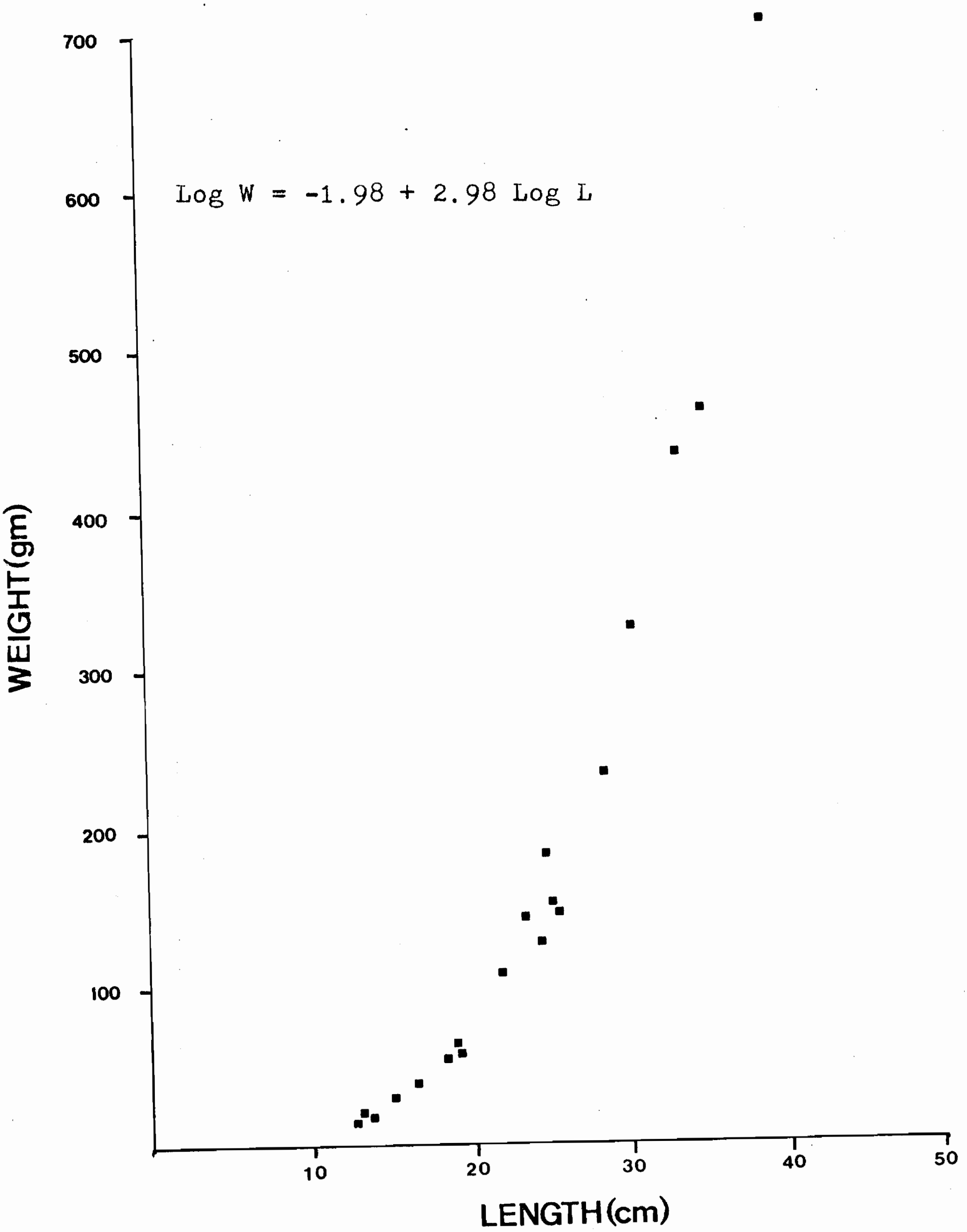

Fig. 8. Length-weight plot for brown trout captured in Poplar Creek in June 1976. Length-weight formula is based on logarithmic transformations of data.

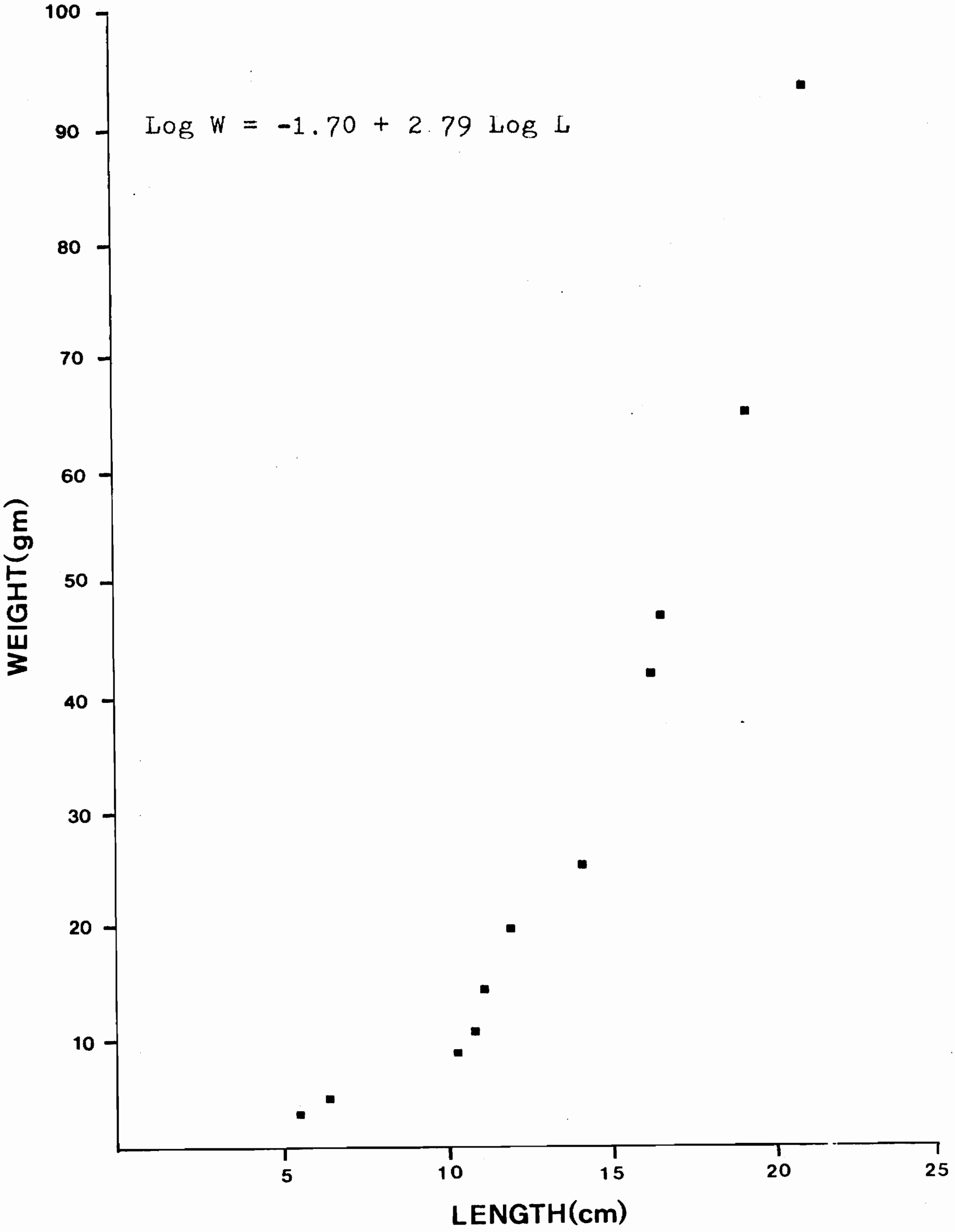

Fig. 9. Length-weight plot for rainbow trout captured in Poplar Creek in June 1976. Length-weight formula is based on logarithmic transformation of data.

Table 8. Calculated length of brown trout at each annulus, Poplar Creek.

Age group	n	Calculated length at each annulus 1	2	3	4	5
I	26	10.0				
II	21	10.6	17.5			
III	9	10.6	17.9	23.1		
IV	8	11.0	19.7	24.4	29.4	
V	1	13.3	22.8	28.6	32.4	34.9
Grand mean calculated length		10.5	18.2	24.0	29.7	34.9
Mean growth increment		10.5	7.7	5.8	5.7	5.2

Table 9. Calculated length of rainbow trout at each annulus, Poplar Creek.

Age group	n	Calculated length at each annulus 1	2	3	4
I	13	9.9			
II	3	10.2	14.7		
III	4	11.2	16.2	19.4	
IV	1	10.1	13.5	16.9	20.7
Grand mean calculated length		10.2	15.3	18.9	20.7
Mean growth increment		10.2	5.1	3.5	1.9

SUMMARY AND CONCLUSIONS

Earlier authors have provided ample evidence to support the conclusion that trout populations are determined to a great extent by the morphology of their physical environment. Flow, depth, and cover characteristics are parameters commonly mentioned as factors influencing trout populations.

Accumulations of forest debris influence the morphology of the stream, besides providing cover. Generally the effect is to decrease flow velocity (as incidated by increased substrate size following removal) through the effected area. However, debris can also concentrate flow around the accumulation, thereby increasing velocity.

The multiple regression analyses used in this study indicates that biomass is most influenced by the presence of debris and moderate to rapid flows. On the other hand the presence of debris accounts for none of the variation in numbers The best interpretation of these facts is that large fish, which provide most of the biomass in the study streams are apparently attracted by the debris, especially where there is coincidental flow. Smaller fish which predominate in numbers prefer areas with flow, irrespective of cover, perhaps to avoid large fish. Further evidence for this interpretation comes from tests which show that the populations in areas with debris are made up of larger individuals than in areas without debris accumulations.

The likely result of the removal of a debris accumulation in an area with very little flow would be a reduction in biomass and numbers. An area with flow would likely exhibit an increase in smaller trout and reduction in larger trout. An area where rapid flow resulted from concentration by a debris accumulation would likely exhibit decreases in small and large trout, because cover and flow have been reduced by debris removal.

The trout populations of Poplar Creek can be described as slow growing and short lived in comparison to those of other streams. Present size limits allow very few rainbow trout and few brown trout to be creeled. A reduction of the size limit from 10 to 8 inches would allow many more fish to be creeled while still allowing most to spawn.

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VITA

Patrick J. Coulston was born on February 28, 1952, in Riverside, California, to John Bishop and Ardis Jane Coulston. He attended high school at La Serna High School in Whittier, California, the family home since 1964. Following graduation he enrolled at Humboldt State University in Arcata, California, in Fisheries and graduated with honors in 1974. In the summer of 1974 he married Sheryl M. Slutzi and began his Master's program at Virginia Polytechnic Institute and State University where he served as a Graduate Research Assistant until June 1976. From June 1976 through the completion of his degree requirements for the Master of Science degree in Fisheries and Wildlife Science he worked as a Research Biologist for Ichthyological Associates in Pottstown, Pennsylvania.

Patrick J. Coulston

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THE ROLE OF FOREST DEBRIS IN A SOUTHEASTERN STREAM AND THE EFFECTS OF ITS REMOVAL ON TROUT POPULATIONS

by

Patrick J. Coulston

(ABSTRACT)

Measurements of substrate composition, cover characteristics, and trout populations and biomass were made at a total of ten sites on South Fork Mills River and one of its tributaries, Poplar Creek, in 1975 and 1976.

Besides providing cover debris accumulations generally caused a reduction in stream velocity with accompaning deposition of smaller substrate types. Removal of debris caused a shift to larger substrates.

A multiple regression treatment of the physical characteristics and trout populations indicated that regression models relating the presence of debris and large substrates (interpreted here as increasing water flow) to trout populations were the only ones significant at the .1 level and accounted for 58% of the variation in trout biomass. The presence of debris could account for none of the variation in trout numbers. Areas containing debris were found to contain populations made up of larger fish than areas without debris.

The effects of debris removal were not clear cut, however, there was a trend towards reduced biomass but not necessarily reduced number of trout. This was probably due to decreases in cover, which made the areas less desirable for large trout, but increased flows which favored smaller trout.