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Hunt, Robert L.
Madison, Wisconsin: Wisconsin Department of Natural Resources, 1971

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Technical Bulletin Number 48
DEPARTMENT OF NATURAL RESOURCES
Madison, Wisconsin
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By
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ACKNOWLEDGMENTS

During this 7-year study and subsequent period of report preparation, supervisory assistance was generously supplied by Lyle Christenson and Oscar Brynildson. Fellow project leaders in the trout research unit during this period, Robert Carline, Eddie Avery, Gerald Lowry, and John Mason, provided assistance with field work and the essential day–to–day exchange of research ideas and interpretations that constitute much of the final report that is published. Clarence Todd, Truman Sannes, and Harry Sheldon, project technicians, assisted with many phases of field work and the tedious preliminary analyses of data. Their interest in the study and faithfulness in carrying out assigned duties is gratefully acknowledged.

John Fotor of the DNR and Prof. William Kirby, Wisconsin State University–Stevens Point, contributed their special technical competence in statistical analyses of study data.

Lester Peters supervised the habitat development crew of DNR personnel.

Robert Heding was responsible for the technical planning of the development. I dedicate this report to him on behalf of the thousands of trout fishermen who have or will benefit from the results of his public service as a habitat manager to purchase, protect, and improve many miles of trout streams in central Wisconsin. His exemplary record is a reflection of his professional competence, exceptional rapport with the public, and a high degree of personal motivation to preserve for future generations the valuable and irreplaceable trout stream resource of Wisconsin.

Supported in part by funds from the Federal Aid in Wildlife Restoration Act under Dingell–Johnson Project F–83–R.

Edited by Ruth L. Hine

ABSTRACT

Man–made modifications of trout habitat in the upper mile (section A) of Lawrence Creek were followed by significant increases in standing crops of wild brook trout (*Salvelinus fontinalis*), angler use, and yield. During the 3 years (1965-67) after completion of development, average annual biomass of age 0 and older trout was 41% greater than the average for the 3-year predevelopment period (1961-63). Biomass of age I and older trout increased by an average of 57% and biomass of age II+ trout increased by an average of 141%. An obvious stockpiling effect was evident, a result primarily of improved overwinter survival after development.

Trout production (total growth) also increased after development, especially in age II+ stocks. A greater proportion of the increased annual production was also tied up in the standing crop, and as a result of increased angler harvest, more of the trout flesh produced annually was harvested. Both angler use and yield in developed section A increased nearly 200%. Prior to development in section A, it received less fishing pressure than any of the other 3 study sections (18% of total). After development, section A received nearly as much fishing pressure (46% of total) as the other 3 sections combined.

Comparisons of trout population and fishery parameters involving all 4 study sections strongly supported the conclusion that the consistently greater improvements in these parameters in section A during the latter 3-year period of study were attributable to changes in trout habitat resulting from development.

Multiple and partial correlation analyses involving 6 environmental variables and 4 trout population variables measured in each of 17 stations in section A indicated that trout carrying capacity of undeveloped section A was limited by the physical quality of the habitat, especially the amount of pool area and permanent bank cover. Both of these environmental components were greatly increased by the development and the trout population increased in response.

Trout carrying capacity was poorly correlated with surface area, both before and after development. Expressions such as number of trout/acre or pounds/acre would have been ecologically meaningless.

Estimated cost of development was $26,200 or $1,050/year prorated over a functional period of 25 years. On the basis of increased angler use which averaged 300 more trips/season after development, and a theoretical recreational value of $5.00/trip, only 17 years would be required to redeem the expenditure for development. Annual cost of development did not compare favorably with the annual cost of stocking legal–sized domestic trout ($1,050 vs. $132) in numbers sufficient to supply an increased harvest of 200 trout over 8 inches, the average observed increase for the postdevelopment period of study. Pragmatic and philosophic reasons for rejecting the latter cost–benefit criterion are discussed.

CONTENTS

INTRODUCTION

Trout habitat development, man's attempts to improve living conditions for trout, is one of the four major procedures used to manage the valuable trout resource of Wisconsin. This management technique, aimed at improving survival, growth, and reproduction of trout, is also one which has widespread endorsement by Wisconsin's trout fishermen as a worthwhile expenditure of public monies. Yet, despite such public backing, and despite its prominent place in the management program of the Department of Natural Resources, there have been few detailed studies in Wisconsin, or elsewhere, to document quantitative changes in trout populations and their environment produced by habitat development.

The urgent need for such scientific documentation led to implementation of the study I am reporting here, a study which is, to my knowledge, the most detailed long–term evaluation of trout habitat development which has been reported on to date.

This report has two major objectives:

(1) To present completed results of an evaluation of trout habitat development previously reported on in part (Hunt, 1969).

(2) To present a new series of analyses that have provided additional insights into the mechanisms of trout population responses to habitat development, and at a broader level (independent of evaluating habitat improvement) to utilize these same analyses for investigating the question of why some stretches of a trout stream hold more trout than other stretches.

Lawrence Creek, located near Westfield in central Wisconsin, has been used for many years as a site for conducting research on the ecology and management of brook trout (*Salvelinus fontinalis*). The Wisconsin Department of Natural Resources (DNR) operated a year–round research station there from 1955 through 1967. Several cooperative projects were also carried out by graduate students from the University of Wisconsin, most notably the doctoral studies of White (1967) and Miller (1970).

Major investigations by DNR personnel have been reported on by McFadden (1961), Hunt, Brynildson and McFadden (1962) and Hunt (1966, 1969, 1970).

The study discussed in this paper encompassed a 7-year period, 1961-67. Physical and biological data were collected for 3 years (1961-63) prior to habitat development and for 3 years (1965-67) after completion of the development effort. The improvement work was done in 1964 by DNR personnel in the Fish Management Bureau. It was entirely confined to the upper 1.1 miles of stream, designated as study section A. Study sections B,C, and D, comprising the remaining 2.3 miles of Lawrence Creek, were used as reference sections. A road bridge constituted the boundary between sections A and B.

In my 1969 paper (Hunt 1969, prepared for a special assignment), information spanning all but 6 months of the 7-year study was included. However, only data for sections A and B were reported on. Now, in this paper, data for all 4 study sections are considered, including the missing 6 months of data for sections A and B.

The second objective of this paper involved only section A. Throughout the many years of conducting trout research at Lawrence Creek, electrofishing data for making population estimates were routinely collected by 100-yard segments of stream within each study section. Section A consisted of 17 such "stations," numbered 0 through 16 proceeding downstream. These stations were also utilized for preparing field maps of stream morphometry in 1963 and 1966, before and after habitat improvement. Station-by-station data for 6 environmental factors and 4 parameters of the trout populations in section A were analyzed by multiple regression and correlation. These analyses revealed several relationships between environmental quality and trout carrying capacity that were not apparent from previous analyses at the section level of data classification.

METHODS

Most of the field data were obtained through three procedures:

1. Electrofishing gear (variable voltage, 100-300 volt D–C) was used to obtain information on the trout population. Petersen mark and recapture estimates by inch groupings were made each April, June, and September (Tables 11-13, Appendix). Captured trout were measured to the nearest 0.1 inch and weighed to the nearest gram. Age structure within inch–group estimates was determined primarily on the basis of relative proportions of known–age (fin–clipped) individuals captured. Known–age stocks were established by permanently marking age 0 trout collected each year during June and September censuses. Age 0 trout could be readily detected by their length. There was no size overlap with age I trout in June and very little in September.

Additional age specific growth data for production calculations were collected monthly during 1963 and 1966 in sections A and B. Production was calculated as the product of the monthly instantaneous growth rate and the average monthly biomass (Ivlev, 1945).

2. A compulsory, registration–type, creel census was operated throughout each fishing season. A free daily permit was issued for each angling trip to each stream section. All creeled trout were presented for examination at the census station at the end of each fishing trip. Length, weight, age, and sex data were recorded for each trout. Information on fishing method, hours of fishing per trip, and number of trout released was recorded for each angler.

3. Detailed morphometric measurements were made of section A before and after development. Section B was also mapped prior to development in section A and a portion of Section B was remapped after development. Surface area, channel volume, gradient, pool area, bottom types (sand, silt, or gravel), and overhanging permanent bank cover were determined for each 100-yard station in sections A and B. Pools were subjectively defined as abrupt depressions in the bottom profile. Permanent bank cover was arbitrarily defined as all streambank providing at least 6 inches of overhang having at least 12 inches of water beneath it. Examples of field maps are illustrated in Figure 21a and b, Appendix. Less precise

measurements of sections C and D were made in 1963 to determine only section length, average width, and surface area. Mapping was done in the spring before streamflow was confined by the rich growth of aquatic plants characteristic of Lawrence Creek during the summer and fall.

Computer programs were used to summarize most of the angler harvest data, to calculate trout production, for some tabulations of population estimate data and for the various statistical treatments employed.

Statistical differences between 3-year mean values involving both intrasectional and intersectional comparisons of trout populations and harvest were tested with the non–parametric Mann–Whitney U test. It is designed to test the null hypothesis that the two samples of data being compared come from identical continuous populations. Three predevelopment and three postdevelopment observations of a given population parameter were ranked by order of magnitude and assigned a score from 1 to 6. The difference between the rank sum for the postdevelopment scores and the rank sum for the predevelopment scores was then tested for significance with the Mann–Whitney U test. Because only 3 observations were included per set, the 0.05 level of significance was the best that could be detected. To detect a significance level of 0.01 or better, at least 4 observations per set were required.

Relationships between environmental factors and several of the trout population parameters within section A before and after development were tested with conventional multiple and partial regression techniques. Six environmental factors (surface area, average depth, channel volume, pool area, overhanging bank cover, average pool depth) were considered to be independent variables; 4 parameters of the trout stock in each station (number of trout, pounds of trout, number less than 6 inches long, number more than 6 inches long) were classified as dependent variables. These station-by-station analyses differ the most from any reported in my 1969 symposium paper.

During the 1961-67 fishing seasons, an experimental 8-inch minimum size limit and a bag limit of 5/day applied to the fishery in Lawrence Creek. In addition, fly–fishing was the only legal method allowed in sections C and D. Fly–fishermen could also fish in sections A and B, although in practice nearly all of them chose to fish in the "flies–only" water (Hunt, 1970). Because the normal statewide size limit for trout is 6 inches not 8 inches, a distinction will be made in the following "Results" and "Discussion" portions of this paper between numbers of trout/section over 6 inches long and numbers/section over 8 inches long. Discussion of numbers of trout over 6 inches long will be given more emphasis than discussion of trout over 8 inches since the broader statewide implications of the impact of habitat development are more important in this paper than those specifically concerned with the dynamics of only the trout population and fishery in Lawrence Creek under the special regulations in effect there.

Most of the habitat improvement work in section A consisted of installation of a series of bank covers and current deflectors placed alternately on each streambank (Appendix, Fig. 21c). These paired structures narrowed the stream by approximately 50%. The confined flow scoured pools beneath the bank covers as the flow was guided in a meandering pattern down the channel. Additional details on construction of such devices and the resulting physical alterations of the stream are given by White and Brynildson (1967) and Hunt (1969).

For ease of presentation and discussion of the data, the 1961-63 period will be referred to as the "predevelopment" period and the 1965-67 period as the "postdevelopment" period when discussing various changes from one period to the next in all four sections even though development was done only in section A.

Habitat development produced major changes in several of the physical characteristics of section A. These physical changes were accompanied by substantial positive changes in several parameters of the trout population and in the fishery. Percentage changes for 8 of these physical characteristics and 9 parameters of the trout population and fishery are summarized in Figure 1. Surface area of section A and the amounts of silt and sand bottom were greatly reduced by the development effort. The amount of gravel bottom was slightly increased. Pool area and permanent bank cover were markedly increased, especially bank cover. Mean depth of the section was also increased substantially.

Average biomass of age I and older trout present in April, prior to the opening of the fishing season, increased by 78%. The number of trout present over 6 inches long increased by an average of 101%, and the number over 8 inches increased by an average of 156%. Average catch and angler use of altered section A both increased almost 200%.

Intrasectional Comparisons

Within each section 30 sets of 6 observations of various characteristics of the trout population and fishery were tested to determine statistical differences between predevelopment and postdevelopment means. For section A, 19 of the 30 comparisons were significantly different at the 0.05 level of detection. By contrast, only 4 of 30, 3 of 30, and 0 of 30 intrasectional comparisons differed significantly at that level for sections B, C, and D, respectively (Table 7). Especially noteworthy differences between postdevelopment and predevelopment means for section A include: increased number of trout creeled, increased angling trips and the increased numbers of trout over 6 inches long both in April and September.

In only one instance did a tested parameter of the trout population or fishery improve more in unaltered sections B, C, or D than in altered section A. The single exception was the postdevelopment increase in number of trout over 8 inches long in section C in September.

The average number of age I and older trout/section in April increased during the postdevelopment period by 65% in section A, by 38% in section B, by 19% in section C, and decreased by 28% in section D. For sections B, C, and D combined (that is, the entire portion of Lawrence Creek not altered) there was a modest 4% increase in the average number of trout present in April during the postdevelopment period (Table 1). Of the 4 intrasectional comparisons of changes in April stocks, only the average 65% increase for section A was statistically significant at the 0.05 level (Fig. 2).

September stocks of trout (including age 0) decreased on the average during the postdevelopment period in sections B, C, and D–by 10%, 11%, and 56%, respectively. By contrast, section A showed an average increase of 14%–significant at only the 0.35 level, but nonetheless a positive change. Sections B, C, and D combined had an average numerical decline of 21% from the predevelopment level (Fig. 3).

The average number of age I and older trout present in September increased in sections A, B, and C during the post-development years (by 53%, 12%, and 39% respectively), but only the average increase in section A was statistically significant at the 0.05 level.

Only section A had an average increase in the number of age 0 trout present in September during the postdevelopment period, and in September, 1967, the third year after development, section A contained more age 0 trout than any other section (Table 1). During the previous 12 years section B had always been the section containing the most young–of–the–year (Appendix, Table 14, lines 2, 16, 30, 44).

The average annual biomass of age 0 and older trout in section A increased from a predevelopment average of 165 pounds/section to a postdevelopment average of 232 pounds/section, an improvement of 41%, significant at the 0.05 level. In sections B and C average biomass increased by 7% and 13%, respectively. In section D the post-development average was 32% lower than the predevelopment average (Fig. 4). Also noteworthy in Figure 4 is the fact that both sections B and D had higher average standing crops than section A during the predevelopment period, but altered section A led all

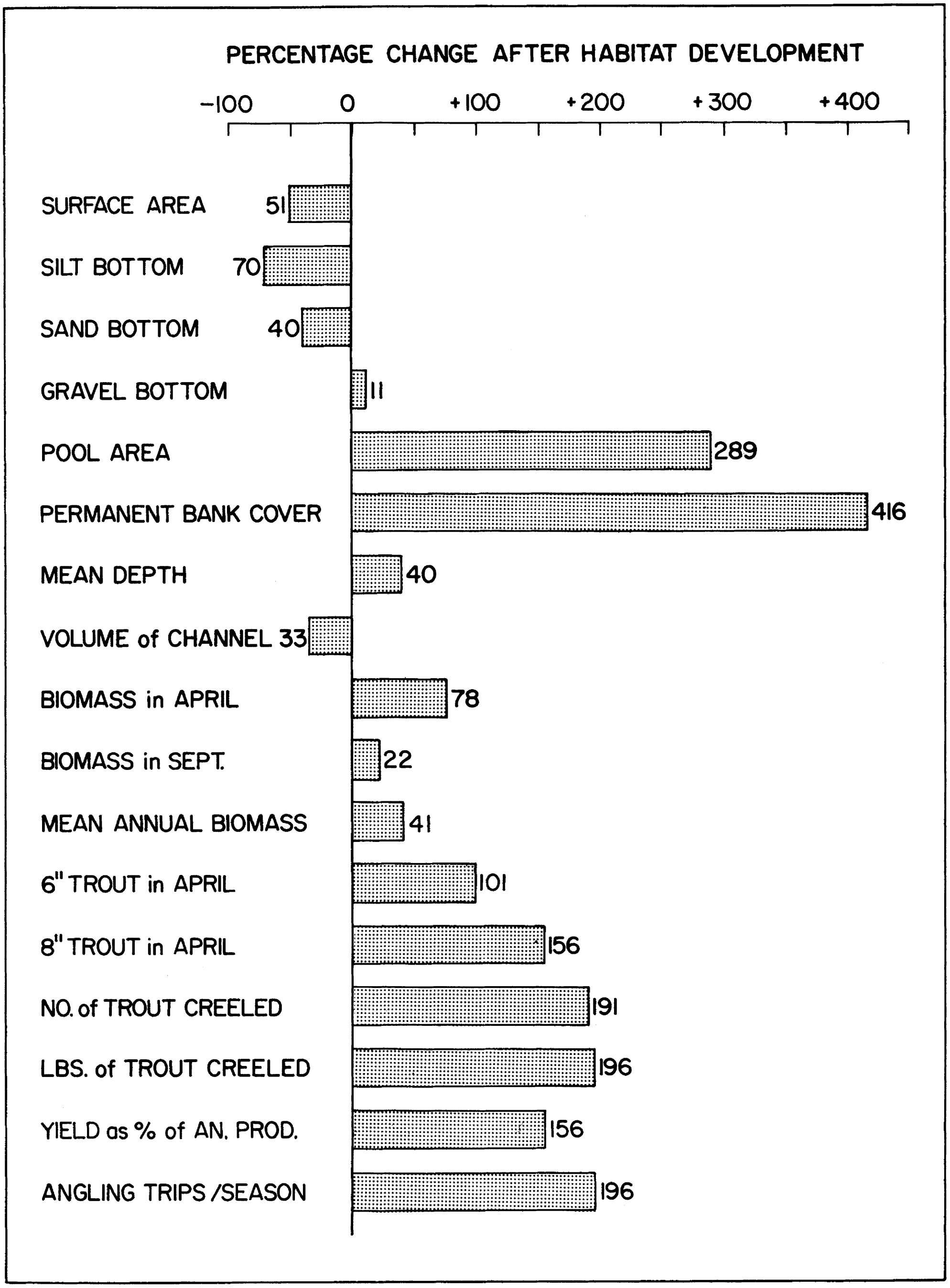


Figure 1. *Average changes in several physical characteristics, trout population parameters, and the fishery in section A during the 3 years following completion of habitat development.*

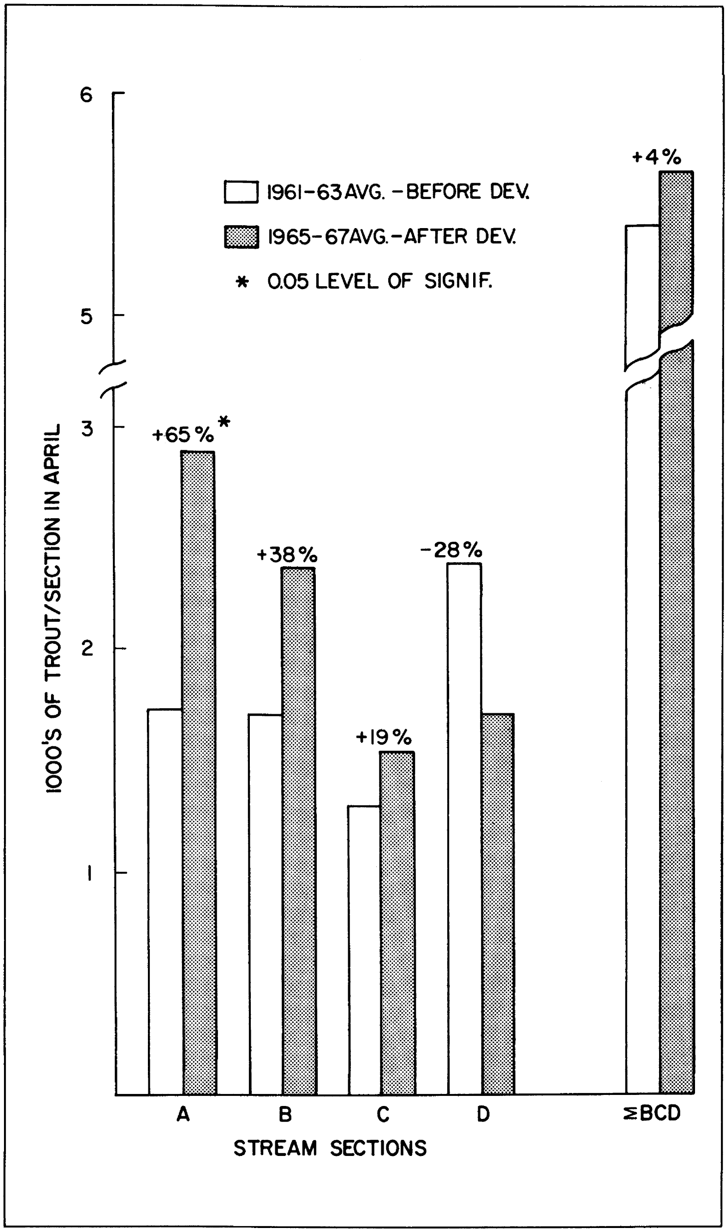


Figure 2. *Average number of brook trout in the study sections of Lawrence Creek in April, before and after habitat development in section A only.*

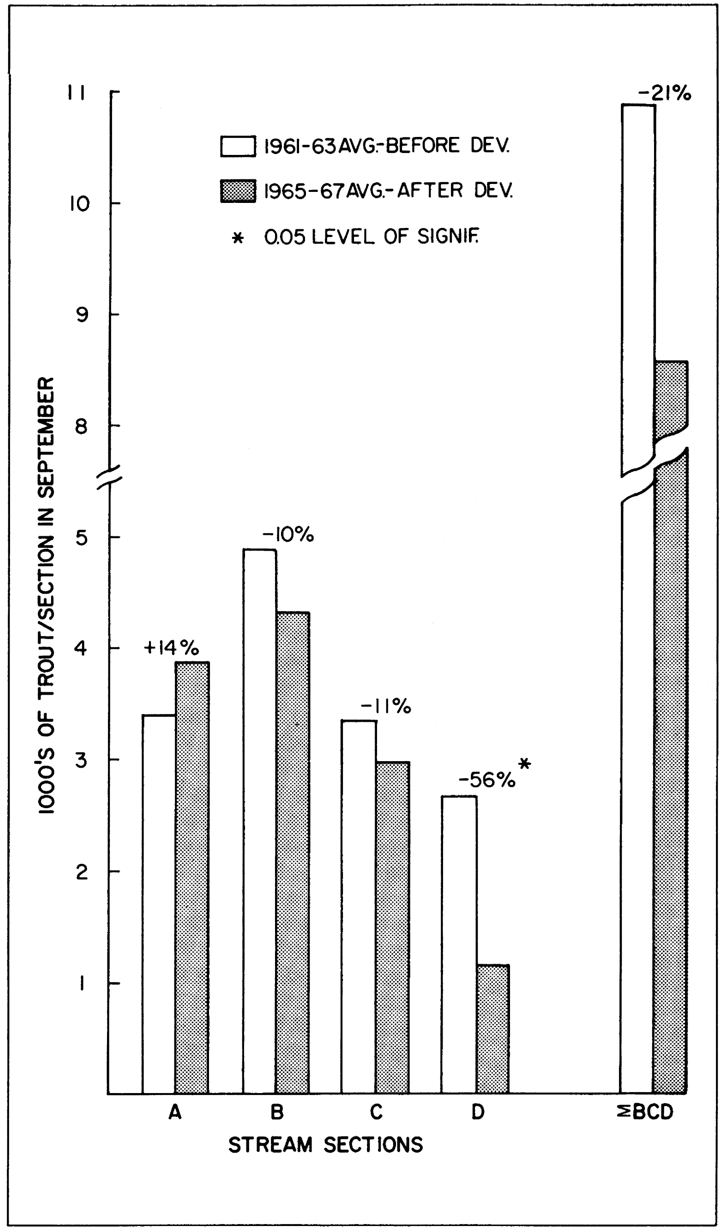


Figure 3. *Average number of brook trout in the study sections of Lawrence Creek in September, before and after habitat development in section A only.*

sections in average biomass during the postdevelopment period.

Average biomasses of age I and older trout increased by 57%, 24%, and 27% in sections A, B, and C but decreased by 27% in section D during the postdevelopment period (Table 2). The section A increase was significant at the 0.05 level, the section B increase at the 0.10 level, and the section C increase at the 0.20 level (Table 7).

During both the predevelopment and postdevelopment years there were usually more trout over 6 inches long in sections A, B, and C when the fishing season closed (September estimate) than were present when it opened (April estimate). In all three sections, April and September stocks of trout over 6 inches increased after development (Fig. 5).

Postdevelopment changes in trout/section over 6 inches were significant at the 0.05 level for preseason and postseason gains in section A, for the preseason gain in section B, and the postseason gain in section C (Table 7).

During the three predevelopment years, section D held more trout over 6 inches in April than any other section and it also had more such trout/section in September of 1962 and 1963. However, after habitat development was completed in section A, that section held more trout over 6 inches in both April and September than any other section in 1965, 1966 and 1967 (Table 3).

Numbers of trout over 8 inches long in April increased in all sections during the postdevelopment period, but again the largest relative gain was in section A–a 157% increase compared to 78% for section B, 81% for section C, and 9% for section D. These increases were significant at the 0.05, 0.20, 0.20 and 0.35 levels for sections A through D, respectively (Table 7).

Despite the impressively large relative increase in harvestable trout in section A, it did not contain the highest number of 8 inch+ trout/section as was the case for trout over 6 inches long. Section D, the lowermost section, held more trout over 8 inches long in April during all 3 predevelopment years and 2 of the 3 postdevelopment years (Table 4).

Angler harvests of trout in section A after development increased by an average of

TABLE 1. Number of Brook Trout in Lawrence Creek

	Sec-	Predevelopment Period			Postdevelopment Period			1961-63	1965-67	Percent
Age	tion	1961	1962	1963	1965	1966	1967	Avg.	Avg.	Change
NUMBER OF TROUT IN APRIL										
I	A	961	2029	1520	1989	2556	1705	1503	2083	+ 39
	B	1065	2044	1137	1391	1992	1955	1415	1779	+ 26
	C	595	1543	645	816	897	1149	928	954	+ 3
	D	981	2951	1342	806	1470	1123	1758	1133	- 36
II	A	67	192	444	627	640	836	234	701	+ 200
	B	153	275	449	483	345	752	292	527	+ 80
	C	200	264	591	392	397	693	352	494	+ 40
	D	407	382	925	387	382	679	571	482	- 16
III	A	0	8	16	50	126	98	8	91	+1038
	B	3	14	15	32	57	82	11	57	+ 418
	C	2	28	24	56	96	119	18	90	+ 400
	D	5	58	59	61	76	108	41	82	+ 100
IV	A	1	0	2	5	3	9	1	6	
	B	0	0	1	7	2	8	0	6	
	C	3	0	1	14	7	2	0	8	
	D	4	0	13	20	17	6	6	18	
I-IV	A	1029	2229	1982	2671	3325	2648	1746	2881	+ 65
	B	1221	2333	1602	1913	2396	2797	1718	2369	+ 38
	C	794	1835	1261	1278	1397	1963	1298	1546	+ 19
	D	1397	3391	2339	1274	1945	1926	2376	1715	- 28
NUMBER OF TROUT IN SEPTEMBER										
0	A	3591	1968	2077	2834	1368	3513	2545	2572	+ 1
	B	5784	2414	3676	2945	4542	2645	3959	3377	- 15
	C	3106	1589	2601	1873	1974	1329	2432	1725	- 29
	D	1832	1640	2013	800	308	408	1828	505	- 72
I	A	673	1036	606	1060	1328	881	772	1090	+ 41
	B	748	1150	650	623	1286	761	849	890	+ 5
	C	538	1197	589	1006	878	1045	775	976	+ 26
	D	401	1140	543	449	623	475	695	516	- 26
II	A	48	54	149	156	212	250	84	206	+ 145
	B	45	43	129	92	131	174	72	132	+ 83
	C	75	47	249	168	219	320	124	236	+ 90
	D	93	59	223	71	138	122	125	110	- 12
III	A	2	1	6	19	14	24	3	19	+ 533
	B	0	4	5	8	19	6	3	11	+ 266
	C	0	8	6	14	37	67	4	39	+ 875
	D	1	9	21	19	19	31	10	23	+ 130
IV	A	0	0	0	1	0	0	0	0	
	B	2	0	0	1	1	2	0	1	
	C	0	0	4	2	2	8	1	5	
	D	0	0	0	2	4	5	0	4	
0-IV	A	4314	3059	2838	4070	2922	4668	3404	3887	+ 14
	B	6577	3611	4460	3669	5979	3588	4883	4411	- 10
	C	3719	2841	3449	3063	3110	2769	3336	2981	- 11
	D	2327	2848	2800	1341	1092	1041	2658	1158	- 57

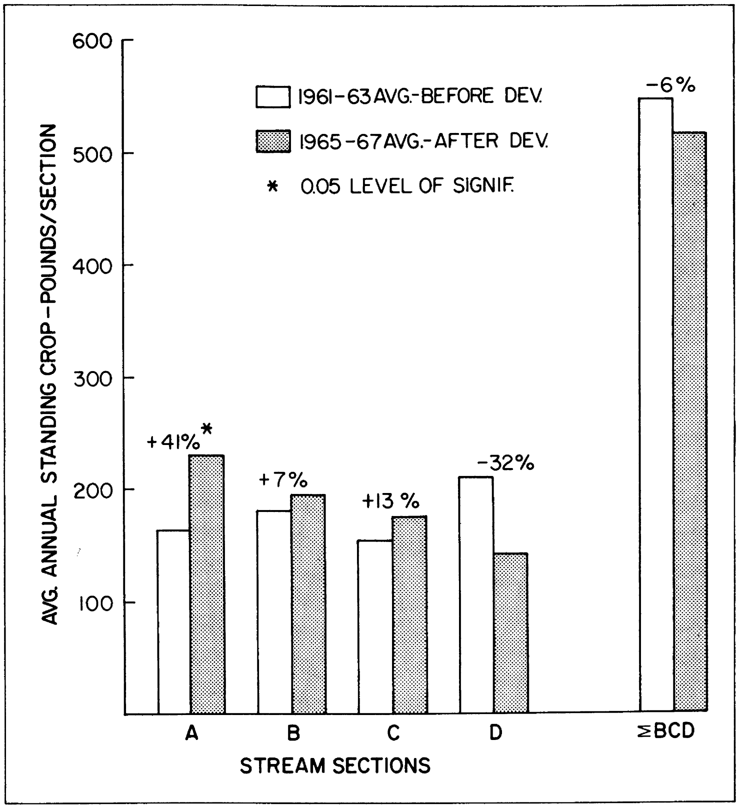


Figure 4. *Average annual biomass of brook trout in the study sections of Lawrence Creek, before and after habitat development in section A only.*

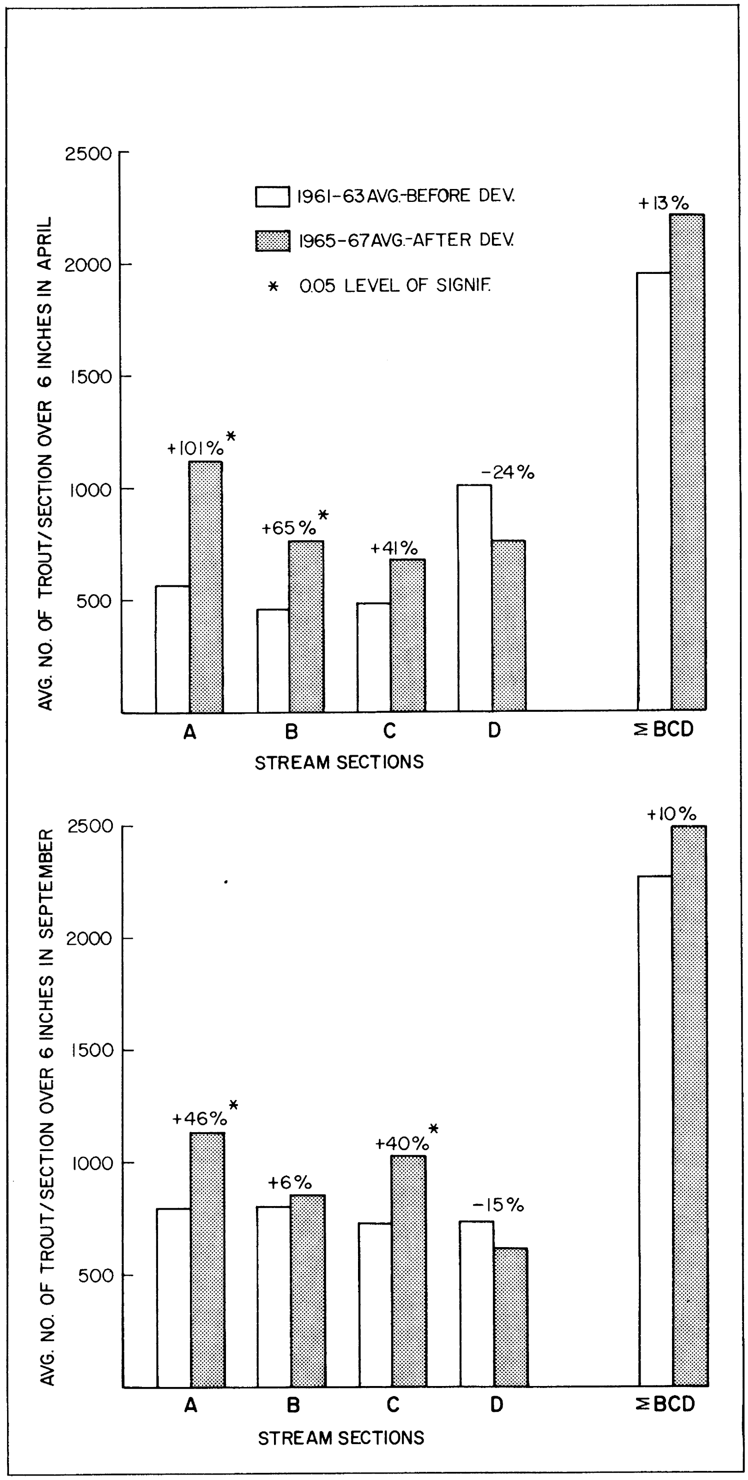


Figure 5. *Average number of brook trout over 6 inches long in the study sections of Lawrence Creek, before and after habitat development in section A only (April averages in upper diagram; September averages in lower diagram).*

191%/season. Catches/section also improved in B, C, and D but by much less in comparison to predevelopment levels. For sections B, C, and D combined the average catch/season was 22% better during the postdevelopment period. Only the section A change was significant at the 0.05 level (Fig. 6).

Angling effort (both trips and hours) also increased substantially in section A following habitat development there. The average number of trips/season increased by 196% (from 149 to 441) and hours of effort/season by 187% (from 371 to 1066). In the other three sections, however, the average number of trips/season declined during the postdevelopment years—by an average of 32% in B, 5% in C, 13% in D (Fig. 7) and the hours of fishing effort/season declined by 28% in B, by 13% in C, and 8% in D (Table 5).

During the predevelopment years section A was the least fished section and section B the heaviest fished section. After improvement of the trout habitat in section A, it was the heaviest fished section. It received only 18% of the total hours of angling effort during the 3 predevelopment seasons but 46% of the total hours during the 3 postdevelopment seasons, or nearly as much fishing pressure as the combined effort in the 3 undeveloped sections (Table 5).

The increased harvests in section A during the postdevelopment period were more than a simple result of increased angling effort. Harvests of 355 trout such as was made in 1966 or 348 trout taken in 1967 could not have been attained in 1962 and 1963 even if anglers had taken every legal trout. Harvests in section A in 1962 and 1963 plus the numbers of legal trout remaining at the end of the season totalled only 232 and 314 respectively (Tables 4 & 5).

Annual production (total growth) during the postdevelopment period exceeded annual production during the predevelopment period in only 1 of the 4 sections—section A, where the habitat improvement was done (Fig. 8). Annual production declined by averages of 11%, 7%, and 39% during the postdevelopment period in sections B, C, and D, respectively, but it increased by an average of 17% in improved section A. Production in section A by all age groups combined (including age 0) was significantly

TABLE 2. Standing Crops of Brook Trout in Lawrence Creek

		Average Monthly Biomass in Pounds								
		Predevelopment Period			Postdevelopment Period					
Age	Section	1961	1962	1963	1965	1966	1967	1961-63 Avg.	1965-67 Avg.	Percent Change
0	A	53	28	38	39	17	52	40	36	- 10
	B	80	34	61	41	48	35	58	41	- 29
	C	39	19	38	24	19	15	32	19	- 41
	D	23	20	31	12	5	6	25	8	- 68
I	A	81	115	77	116	129	93	91	113	+ 24
	B	82	120	70	78	132	80	91	97	+ 7
	C	53	116	50	79	76	78	73	78	+ 7
	D	58	156	75	46	87	57	96	63	- 34
II	A	15	26	55	60	65	86	32	70	+ 119
	B	21	28	46	45	38	68	32	50	+ 56
	C	28	32	77	48	53	83	46	61	+ 33
	D	64	50	113	43	47	74	76	55	- 28
III	A	1	2	4	8	14	15	2	12	+ 500
	B	1	3	4	4	8	8	2	7	+ 250
	C	1	9	4	8	16	21	4	15	+ 275
	D	1	18	14	10	12	17	11	13	+ 18
IV	A	1	0	0	2	1	0	0	1	
	B	1	0	0	1	1	2	0	1	
	C	1	0	0	2	1	4	0	2	
	D	0	0	4	4	4	4	2	4	
I-IV	A	96	143	136	186	209	194	125	196	+ 57
	B	103	151	120	128	179	158	125	155	+ 24
	C	81	157	131	137	146	186	123	156	+ 27
	D	123	224	206	103	150	152	185	135	- 27
O-IV	A	149	171	174	225	226	246	165	232	+ 41
	B	183	185	181	169	227	193	183	196	+ 7
	C	120	176	169	161	165	201	155	175	+ 13
	D	146	244	237	115	155	158	210	143	- 32

TABLE 3. Number of Brook Trout Over 6 Inches Long in Lawrence Creek

		Predevelopment Period			Postdevelopment Period					
	Section	1961	1962	1963	1965	1966	1967	1961-63 Avg.	1965-67 Avg.	Percent Change
April (before fishing season)	A	280	683	724	953	1176	1261	562	1130	+101
	B	279	579	546	610	611	1093	468	771	+ 65
	C	258	545	623	534	599	882	475	672	+ 41
	D	607	1226	1192	587	943	769	1008	766	- 24
Sept. (after fishing season)	A	705	954	695	1100	1316	1011	785	1142	+ 45
	B	759	965	689	620	1260	677	804	852	+ 6
	C	547	942	697	943	996	1120	729	1020	+ 40
	D	460	1012	719	506	772	576	730	618	- 15

TABLE 4. Number of Brook Trout Over 8 Inches Long in Lawrence Creek

	Section	Predevelopment Period 1961	1962	1963	Postdevelopment Period 1965	1966	1967	1961-63 Avg.	1965-67 Avg.	Percent Change
April (before fishing season)	A	35	130	189	230	393	285	118	303	+157
	B	45	154	111	107	165	276	103	183	+ 78
	C	59	169	168	163	209	281	132	218	+ 65
	D	239	299	551	249	315	622	363	395	+ 9
Sept. (after fishing season)	A	296	112	190	224	217	232	200	223	+ 12
	B	200	76	159	94	207	110	145	137	- 6
	C	141	109	172	169	247	300	141	239	+ 70
	D	245	229	294	189	342	263	356	265	+ 4

TABLE 5. Sport Fishing Statistics for Lawrence Creek

	Section	Predevelopment Period 1961	1962	1963	Postdevelopment Period 1965	1966	1967	1961-63 Avg.	1965-67 Avg.	Percent Change
No. of trout creeled	A	64	120	124	196	355	348	103	300	+191
	B	123	180	224	224	156	266	176	215	+ 22
	C	125	99	174	115	164	176	133	152	+ 14
	D	130	141	231	136	186	321	167	214	+ 28
Lbs. of trout creeled	A	14	27	27	44	82	79	23	68	+196
	B	29	41	49	50	36	60	37	49	+ 32
	C	30	24	39	27	38	41	31	35	+ 13
	D	34	39	54	36	48	86	42	57	+ 36
No. of angling trips	A	80	161	205	387	391	544	149	441	+196
	B	230	338	276	182	160	227	281	190	- 32
	C	143	188	166	152	140	179	166	157	- 5
	D	139	209	227	137	135	228	192	167	- 13
No. of angling hours	A	164	406	542	922	1013	1263	371	1066	+187
	B	534	856	764	505	442	606	718	518	- 28
	C	336	522	484	384	339	446	447	390	- 13
	D	245	389	535	312	294	470	390	359	- 8

greater at only the 0.20 level of detection, but production by age groups I-IV combined was significantly higher at the 0.05 level in comparison to predevelopment production by these age groups (Table 7). Production/year in section A increased from an average of 264 pounds during 1961-63 to 309 pounds annually during 1965-67. Annual production was highest in 1967 when it reached 355 pounds, or 34% more than the predevelopment average. Age I-IV trout accounted for 53% of annual production during the predevelopment period but 64% of annual production during the postdevelopment period. Increased production by age II and age III stocks in improved section A was especially impressive. Age II annual production increased by an average of 133%, and age III annual production increased by an average of 700% (Table 6).

Intersectional Comparisons

As a further means of evaluating the impact of habitat improvement on the trout population and fishery in section A, a series of *intersectional* ratios were derived and postdevelopment vs. predevelopment ratios were tested with the same non–parametric rank–sum test as was used for the 30 intrasectional comparisons. U-values for these intersectional comparisons are listed on the right–half side of Table 7, columns A/B, A/C, A/D, A/BC, and A/BCD. For example, A/B ratios of age I trout in April, 1965, 1966, and 1967 had a probability of only 0.50 of being statistically different from the predevelopment A/B ratios of age I trout in April, 1961, 1962, and 1963. The A/C postdevelopment ratios for April yearlings differed significantly from A/C predevelopment ratios at the 0.20 level. Even more favorable was the difference between A/D ratios which had a 0.05 probability of being representative of different populations–a difference that could be ascribed to the habitat improvement done in section A, but not in section D.

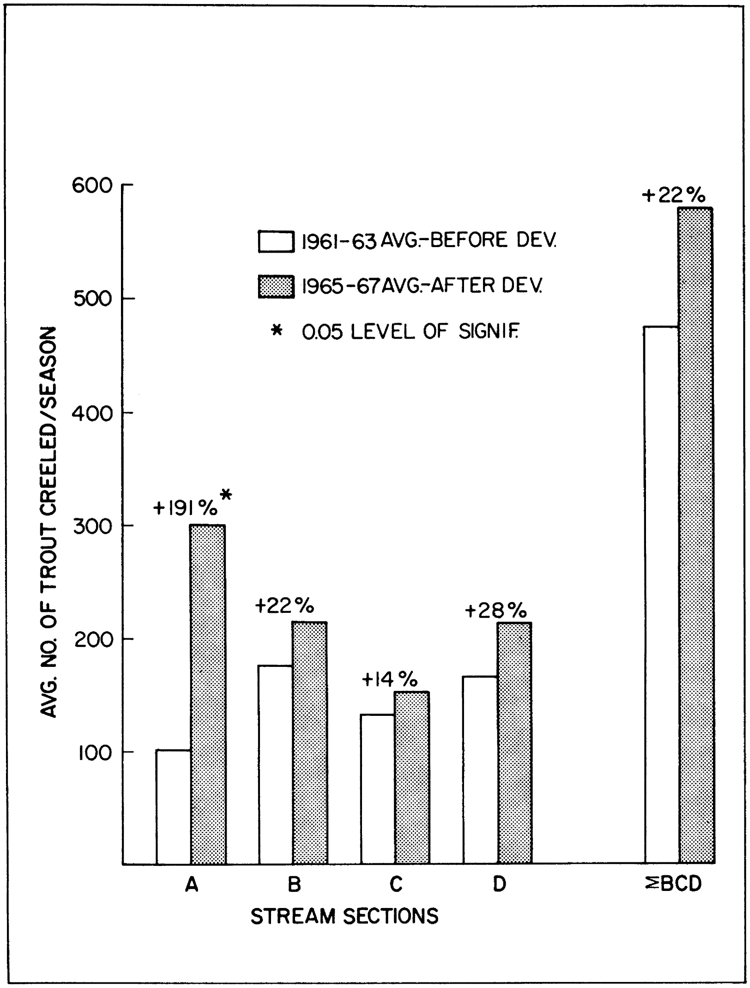


Figure 6. *Average yield of brook trout from the study sections of Lawrence Creek, before and after habitat development in section A only.*

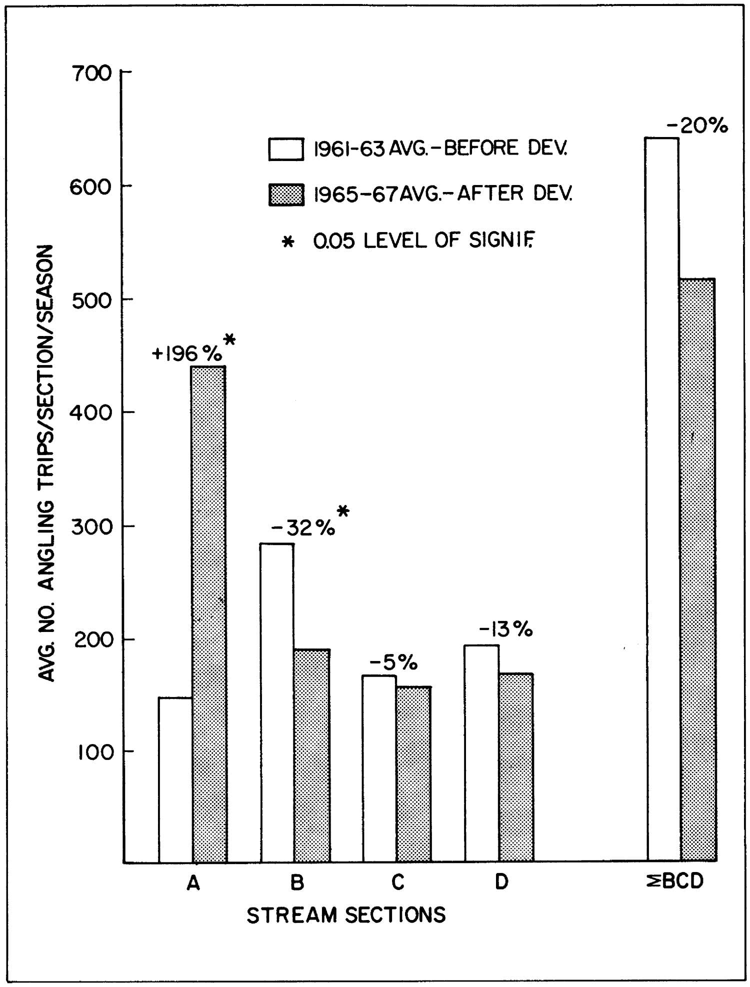


Figure 7. *Average number of angler trips in the study sections of Lawrence Creek, before and after habitat development in section A only.*

Post development vs. predevelopment ratios of age II and age III trout in section A versus any other section or combination of sections were generally more impressive than the age I ratio differences. Significant differences were detectable at the 0.05 level for all ratio comparisons involving intersectional changes in April stocks of age groups II and III. All intersectional ratios for angler harvest and fishing effort were also significantly favorable at the 0.05 level for altered section A.

Of the 30 such series of intersectional comparisons tested, A/B postdevelopment ratios differed from A/B predevelopment ratios 16 times at the 0.05 level, 17 times at the 0.10 level and 21 times at the 0.20 level. Data ratios for A/C differed 10 of 30 times at the 0.05 level and A/D postdevelopment ratios differed from A/D predevelopment ratios 27 of 30 times at the 0.05 level, the highest level of detection possible (Table 7).

TABLE 6. Annual Production by Brook Trout in Lawrence Creek (in Pounds)

Age	Section	Predevelopment Period 1961	1962	1963	Postdevelopment Period 1965	1966	1967	1961-63 Avg.	1965-67 Avg.	Percent Change
0	A	161	88	124	128	50	159	124	112	- 10
	B	263	124	215	139	157	114	201	137	- 32
	C	123	70	136	80	61	50	110	64	- 70
	D	71	63	102	39	14	19	79	24	- 70
I	A	110	129	103	131	151	118	114	133	+ 17
	B	100	133	88	97	168	108	107	124	+ 16
	C	63	128	71	99	96	106	87	100	+ 15
	D	79	172	99	52	102	72	117	75	- 36
II	A	13	14	47	60	40	69	24	56	+133
	B	16	21	30	37	23	36	22	32	+ 45
	C	23	22	51	42	32	49	32	41	+ 28
	D	48	25	74	38	29	60	49	42	- 14
III	A	1	1	2	4	11	9	1	8	+700
	B	1	2	3	2	5	6	2	4	+100
	C	1	5	5	4	10	17	3	10	+233
	D	1	9	8	5	9	14	6	9	+ 50
IV	A	1	0	0	1	0	0	1	0	
	B	1	0	0	0	0	0	0	0	
	C	1	0	0	0	0	0	0	0	
	D	1	0	4	2	4	0	1	3	
I-IV	A	123	144	152	196	202	196	140	197	+ 41
	B	116	156	121	136	196	150	131	160	+ 22
	C	86	155	127	145	138	172	122	151	+ 24
	D	128	206	185	97	144	146	173	129	- 25
0-IV	A	284	232	274	324	252	355	264	309	+ 17
	B	379	280	336	275	353	264	332	297	- 11
	C	209	225	263	225	199	222	232	215	- 7
	D	199	269	287	136	158	165	252	153	- 39

TABLE 7. Summary of Levels of Statistical Significance of Whitney-Mann "U" Tests of 1965-67/1961-63 Ratios of Data Involving Both Intrasectional and Intersectional Comparisons

Ratio Tested	Intrasectional Comparisons				Intersectional Comparisons				
	A/A	B/B	C/C	D/D	A/B	A/C	A/D	A/BC	A/BCD
No. of Trout in April									
Age I	.20	.35	.35	-.35	.50	.20	.05	.35	.10
II	.05	.10	.20	-.42	.05	.05	.05	.05	.05
III	.05	.05	.05	.20	.05	.05	.05	.05	.05
I-IV	.05	.10	.20	-.20	.20	.10	.05	.10	.05
No. of Trout in Sept.									
Age 0	.65	-.65	-.20	-.05	.35	.35	.05	.35	.35
I	.10	.50	.35	.65	.05	.50	.05	.20	.10
II	.05	.10	.20	.50	.05	.35	.05	.15	.05
III	.05	.05	.05	.35	.50	.65	.20	.65	.50
I-IV	.05	.50	.20	-.35	.05	.50	.05	.10	.05
0-IV	.35	-.35	-.20	-.05	.35	.20	.05	.35	.20
Avg. Monthly Biomass									
Age 0	.65	-.35	-.15	-.05	.35	.35	.05	.35	.35
I	.10	.50	.35	-.20	.20	.50	.05	.35	.05
II	.05	.20	.20	-.20	.05	.05	.05	.05	.05
III	.05	.05	.10	.65	.05	.35	.05	.10	.05
I-IV	.05	.10	.20	-.20	.05	.10	.05	.05	.05
0-IV	.05	.35	.50	-.20	.05	.10	.05	.05	.05
Annual Production									
Age 0	.65	-.20	-.10	-.05	.35	.35	.05	.35	.35
I	.10	.35	.35	-.20	.65	.65	.05	.65	.20
II	.10	.10	.35	.65	.05	.05	.05	.05	.05
III	.05	.10	.20	.20	.05	.35	.35	.20	.35
I-IV	.05	.20	.20	-.20	.20	.35	.05	.35	.05
0-IV	.20	-.20	-.28	-.05	.35	.10	.05	.35	.10
No. of Trout Creeled	.05	.28	.35	.35	.05	.05	.05	.05	.05
Lbs. of Trout Creeled	.05	.20	.35	.35	.05	.05	.05	.05	.05
No. of Angling Trips	.05	-.05	-.35	-.35	.05	.05	.05	.05	.05
No. of Angling Hours	.05	-.10	-.35	.65	.05	.05	.05	.05	.05
No. of Trout Over 6 Inches in April	.05	.05	.35	-.20	.20	.05	.05	.05	.05
No. of Trout Over 6 Inches in Sept.	.05	.35	.05	.65	.05	.50	.05	.05	.05
No. of Trout Over 8 Inches in April	.05	.20	.20	.35	.10	.10	.05	.10	.05
No. of Trout Over 8 Inches in Sept.	.35	.50	.10	.50	.35	-.20	.50	-.20	.50
Significance Level Totals:									
.05 or less:	19	4	3	0	16	10	27	12	19
.10 or less:	23	10	5	0	17	15	27	16	22
.20 or less:	25	14	14	2	21	17	28	18	24

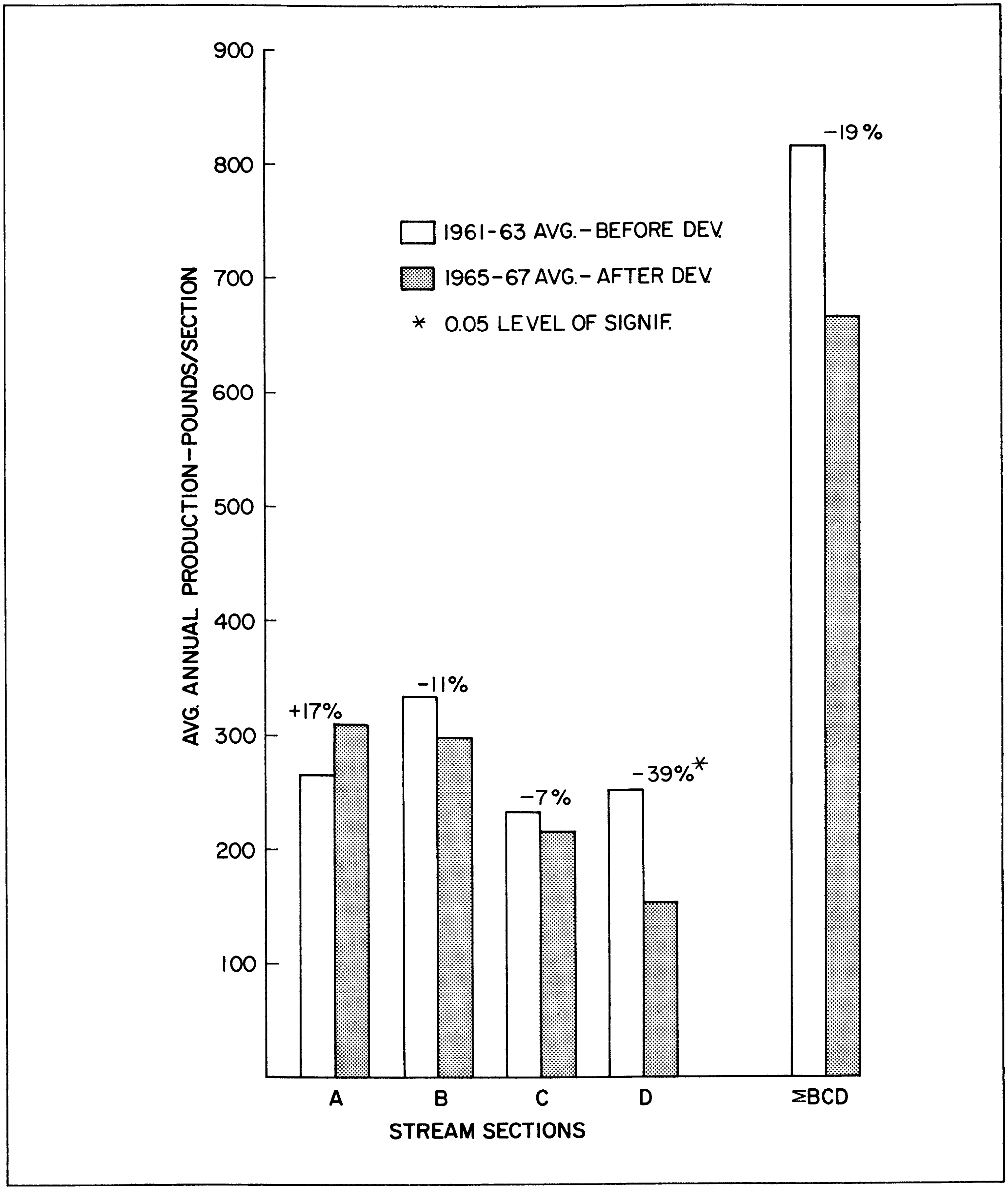


Figure 8. *Average annual production by brook trout stocks in the study sections of Lawrence Creek, before and after habitat development in section A only.*

Station-by-Station Comparisons Within Section A.

Although the type of habitat development done in section A was quite similar throughout the section, the intensity of development varied from station to station. For example, the surface areas of all 17 stations were reduced by the construction of streambank covers and wings but the amount of reduction/station varied from 15% for station 11 to 73% for station 6 (Fig. 9).

Through the stretch comprising stations 11, 12, and 13 narrowing of the channel was much less than the average for the section. It was felt that this shallow, gravelly stretch, constituting the main spawning area in the section, needed little streambank alteration.

Confinement of the streamflow caused considerable scouring of the predominantly sand–silt bottom. Consequently, mean depth of all stations increased after development, by amounts ranging from 9% for station 12 to 100% for station 2, and mean depth of the section increased by 65%, from 4.9 inches to 8.1 inches (Fig. 10).

Such scouring action was especially important in creating 98 new pools and greatly enlarging the area of the existing 188 pools. Development increased the amount of pool area in all 17 stations. Increases in pool area/station of 100% or more were achieved in 15 of the 17 stations and increases of 500% or more were produced in 4 of the 17 stations. The greatest amount of pool area/station prior to habitat development was in station 16 which contained 1,316 sq. ft. of pool area. After completion of the habitat development work this amount of pool area/station was exceeded in 11 other stations and the amount in station 16 was increased by 94% (Fig. 11).

Prior to habitat development, pool area accounted for a minimum/station of only 0.5% of the stream bottom in station 9 and a maximum/station of 9.4% of the stream bottom in station 14. Following development pool area accounted for a minimum value of 3.9% of the bottom area in station 0 and a maximum value of 69.7% of the bottom area of station 15. In 5 of the 17

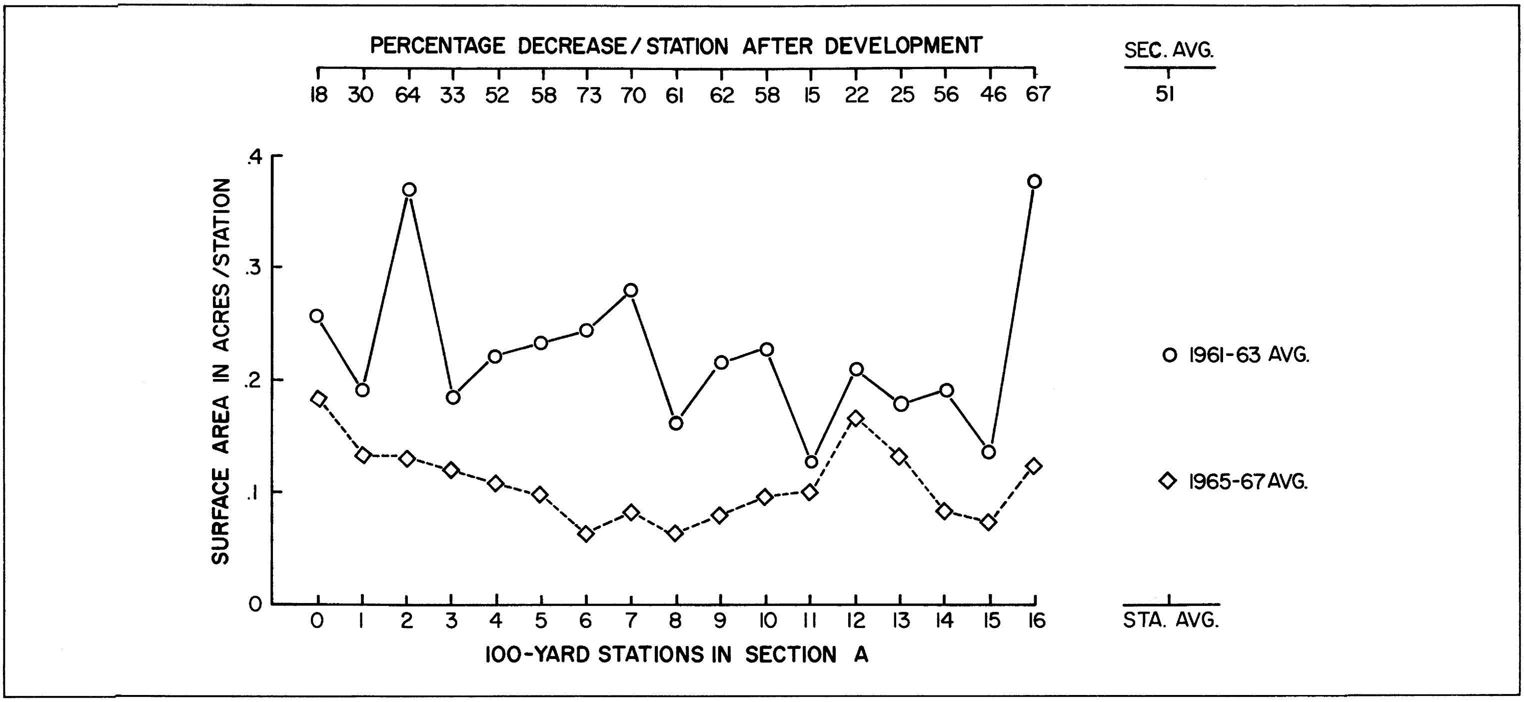


Figure 9. *Station–by–station changes in surface area in section A, before and after habitat development.*

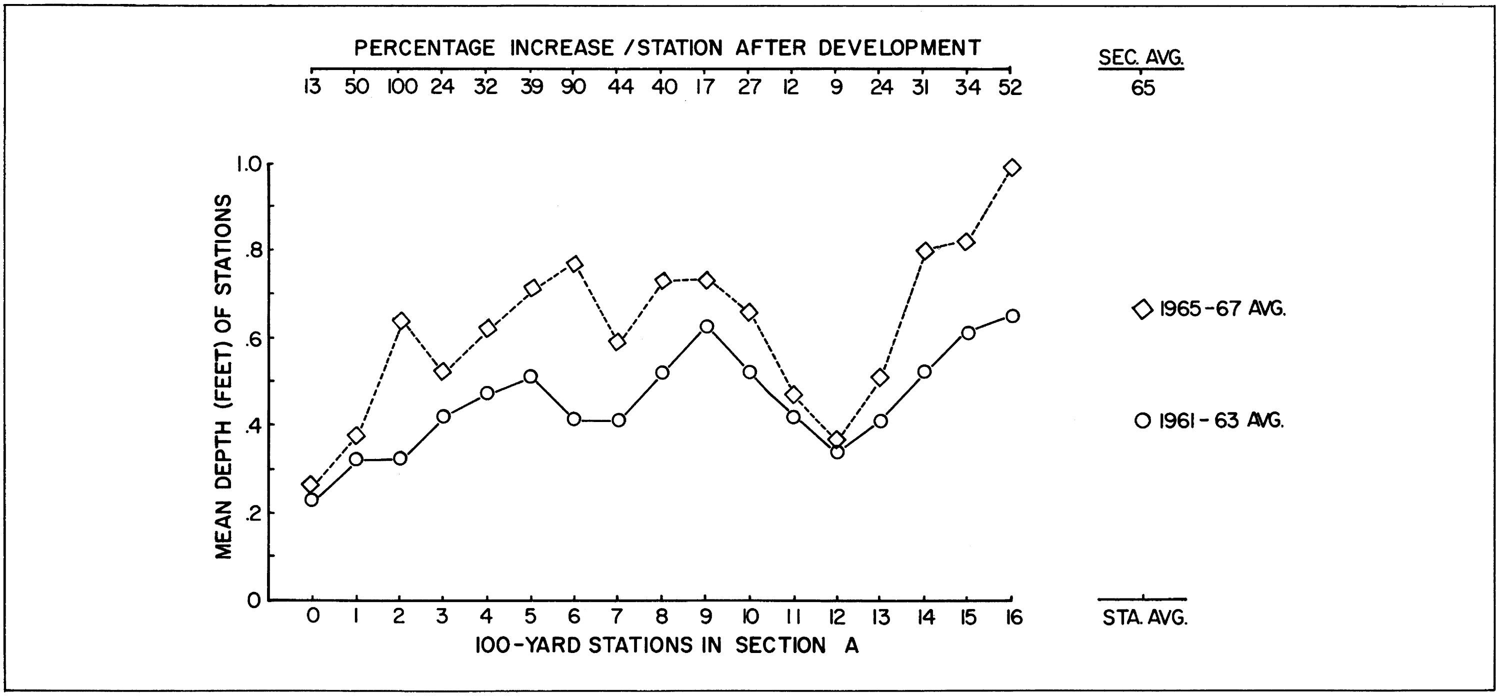


Figure 10. *Station–by–station changes in mean depth of water in section A, before and after habitat development.*

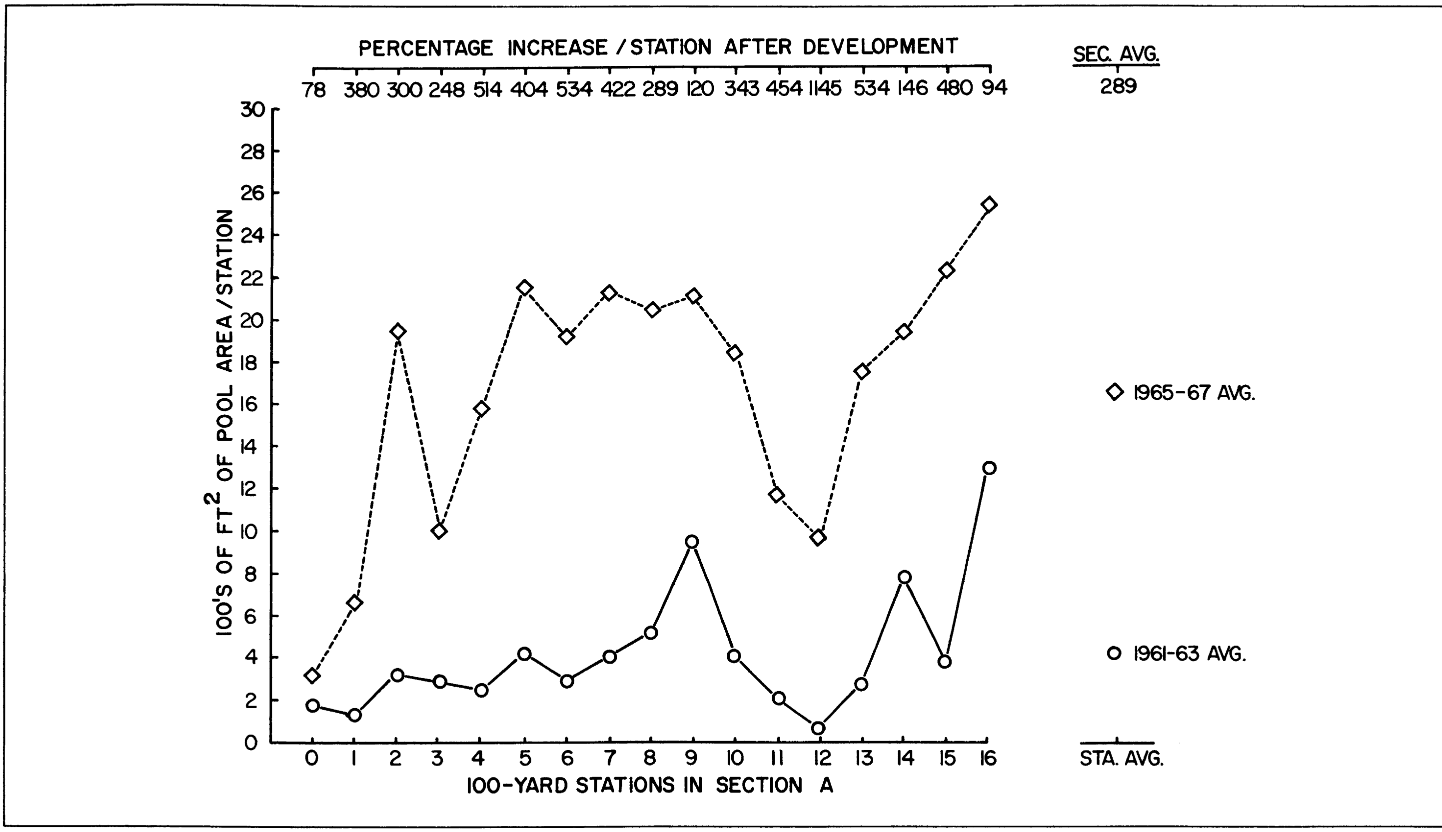


Figure 11. *Station–by–station changes in pool area in section A, before and after habitat development.*

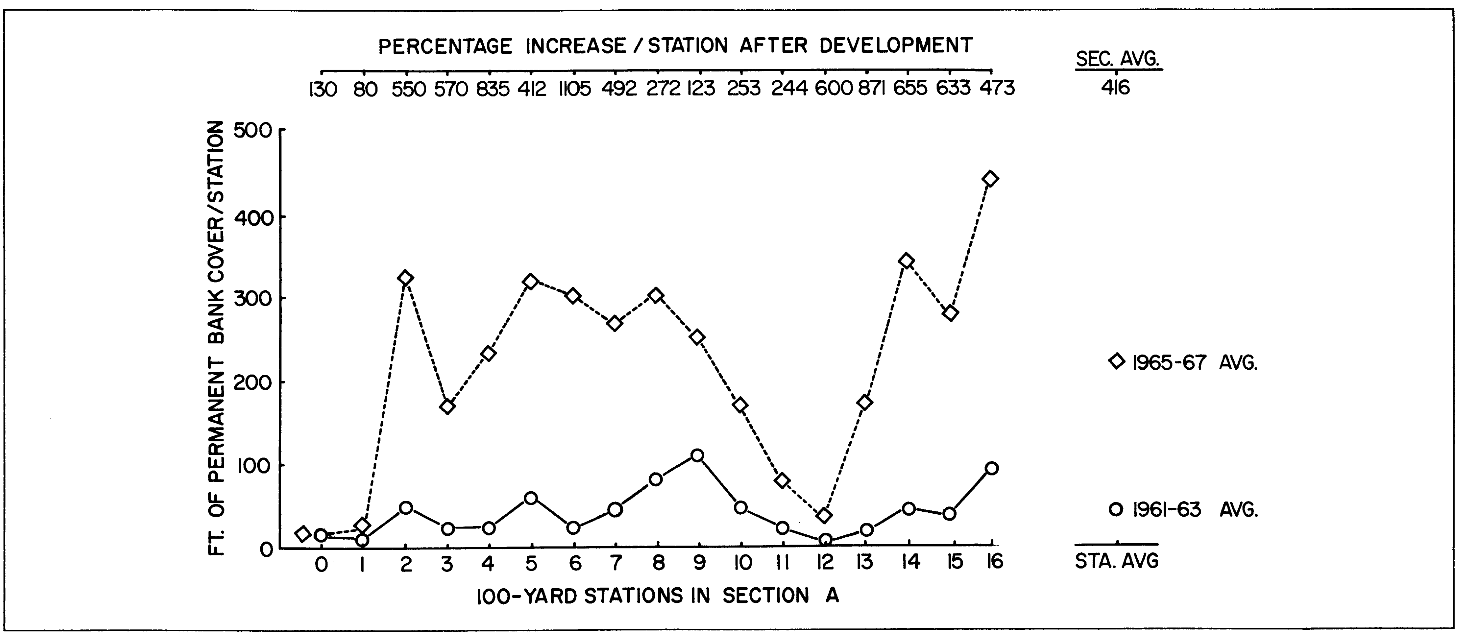


Figure 12. *Station–by–station changes in the number of brook trout in section A, before and after habitat development.*

stations postdevelopment pool area accounted for at least 50% of the stream bottom. For section A as a whole, the area of stream bottom in pools increased from 4.4% before development to 24.3% after development (Table 8).

Permanent streambank cover was the measured physical characteristic improved the most by development. It was increased by 416% for the section with a minimum increase of 80% in station 1 and a maximum increase of 1,105% in station 6 (Fig. 12). The maximum amount of bank cover/station before development was found in station 9 where 112 feet of cover accounted for 12% of the total amount of streambank. Bank cover in greater amounts than this was present in 13 of the 17 stations after development. The greatest amount of bank cover added was in station 16 which contained 438 feet of stream edge having at least 6 inches of permanent overhang and 12 inches of water beneath it. Prior to development, bank cover/station represented as little as 0.7% of the total streambank/station and only a maximum of 12.0%. After development the proportion of streambank/station consisting of permanent cover varied from 1.5% to 46.5% and in 12 of the 17 stations at least 25.0% of the streambank provided year–round cover for trout. For section A as a whole, the proportion of stream edge providing permanent cover increased from 4.4% for predevelopment conditions to 24.3% for postdevelopment conditions (Table 8).

The average number of trout present in April increased after development in 15 of the 17 stations. In stations 8 and 16, April stocks declined by 19% and 32%, respectively, but in the other 15 stations April stocks improved by at least 15% and by as much as 238%. Numerical increases of at least 100% occurred in 8 of the 17 stations, and the section as a whole showed an average increase of 64% (Fig. 13).

Postdevelopment declines in the number of trout/station present in April represented trout less than 6 inches long, nearly all of which were yearlings. Trout in this size range were less numerous in 4 of the 17 stations after development. Substantial increases in the number of such trout in the other 13 stations, however, more than offset the declines, such that the average number for the section as a whole increased by 46% after development, and in 6 stations, the average increase exceeded 100% (Fig. 14).

April biomass of trout/station increased after development in 15 of the 17 stations. As might be expected the 2 stations showing decreased biomass were the same stations that showed numerical declines, namely stations 8 and 16. The maximum increase in average biomass/station was 266% in station 4 and improvements of at least 100% occurred in 8 of the 17 stations. The average increase in biomass of trout for all of section A was 78% (Fig. 15).

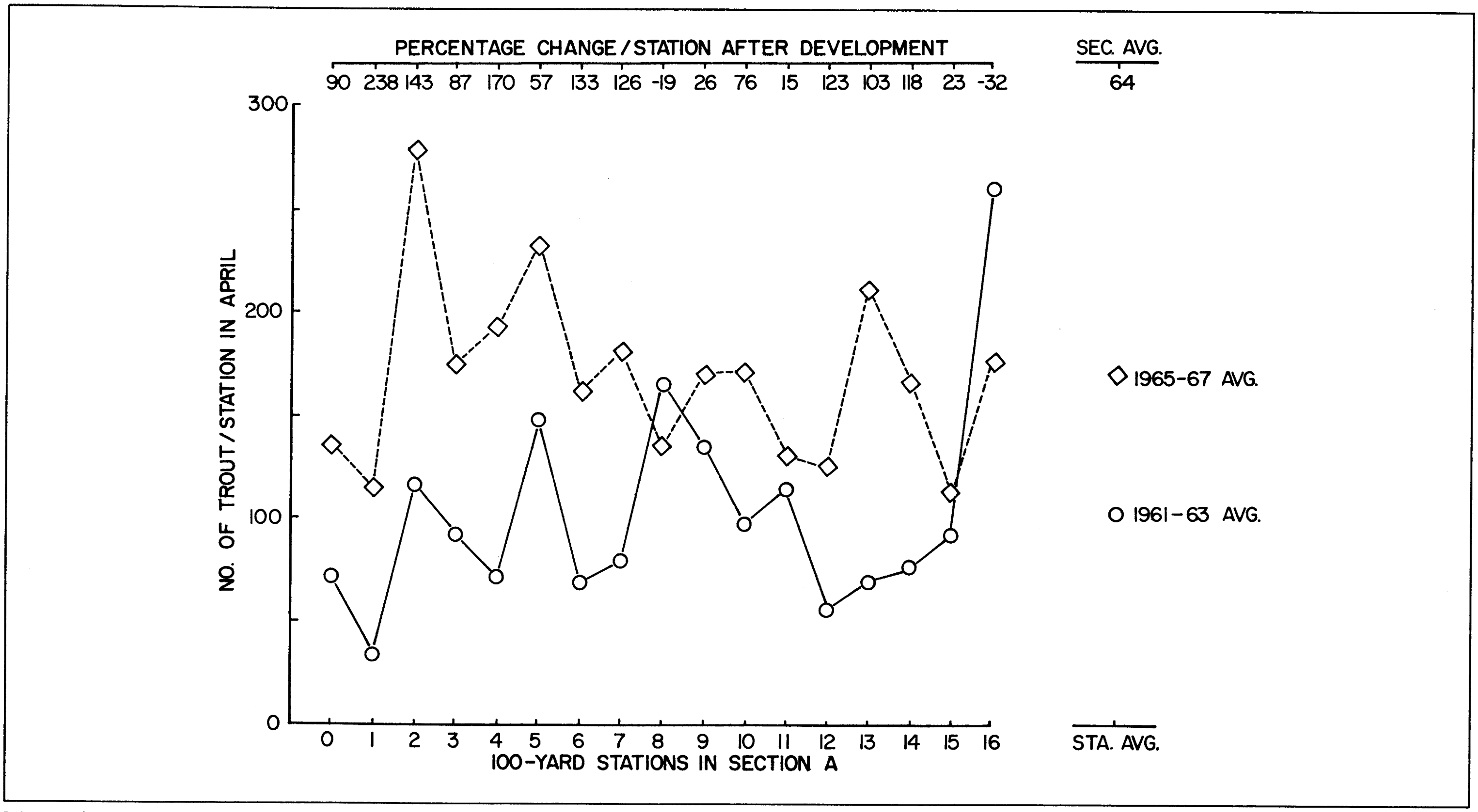
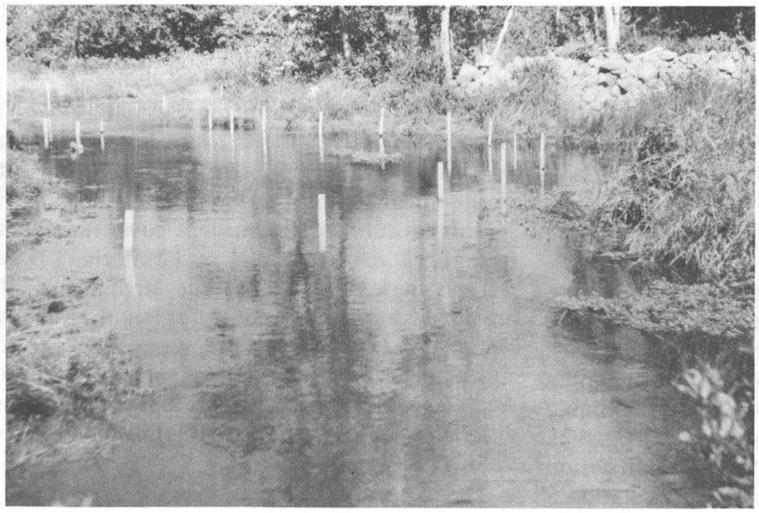
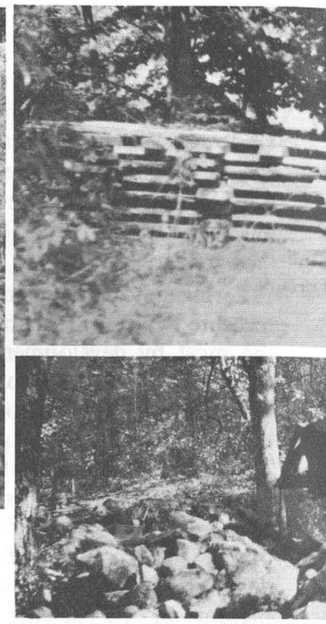


Figure 13. *Station–by–station changes in the number of brook trout in section A, before and after habitat development.*

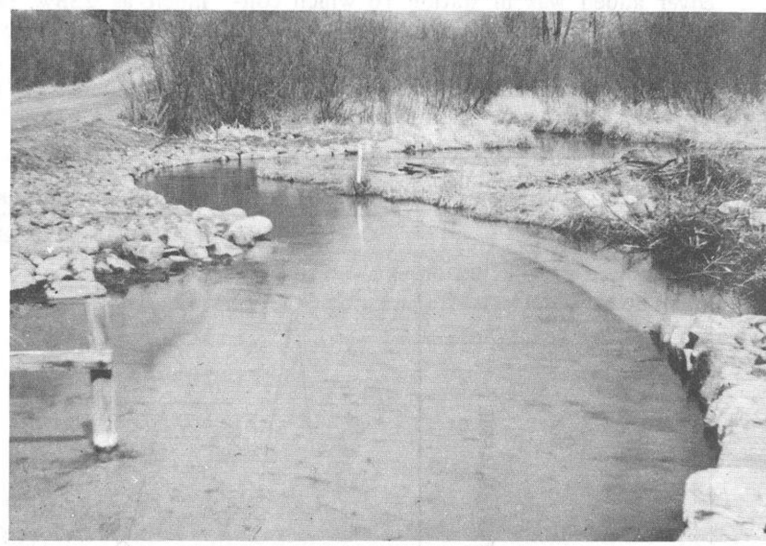
1 *Enhancing the trout carrying capacity of Lawrence Creek through habitat development requires careful field planning and consultation between the habitat management biologist and his construction crew foreman, . . .*

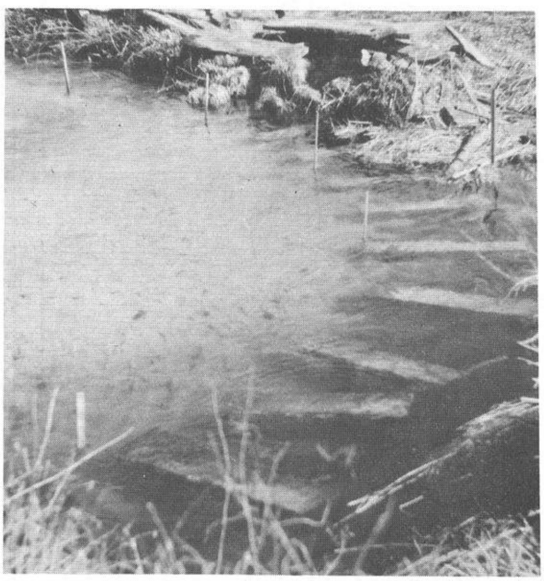


2 *. . . staking out a clear pattern of where instream structures are to be built, . . .*

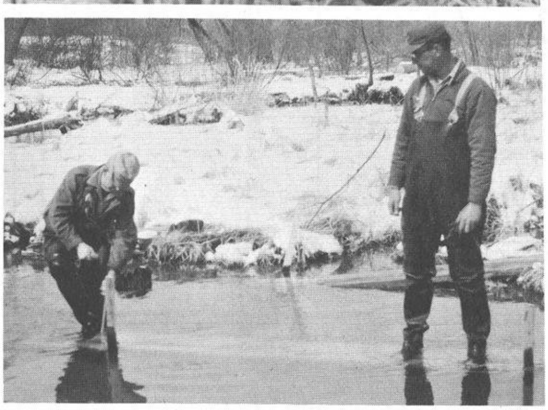


3 *. . . and stockpiling plenty stream.*



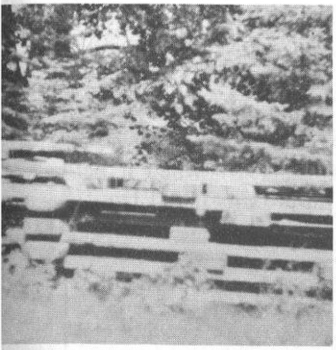


6 *On top of each pair of pilings, short "stringer planks" are nailed in place at right angles to the stream edge.*



7 *Longer planks are then nailed to the stringers to provide underwater platforms to support the rock, dirt, and sod bank built on top of it. The plank shown would constitute the outside edge of the new stream bank. Two or three more planks would be nailed in place behind the outside plank before rock is added.*

8 *Rock is place on top and behind the plant platform. All wood is kept under water to reduce decay. The outside row of rock is placed by hand; the remainder is often dumped by the bucket.*

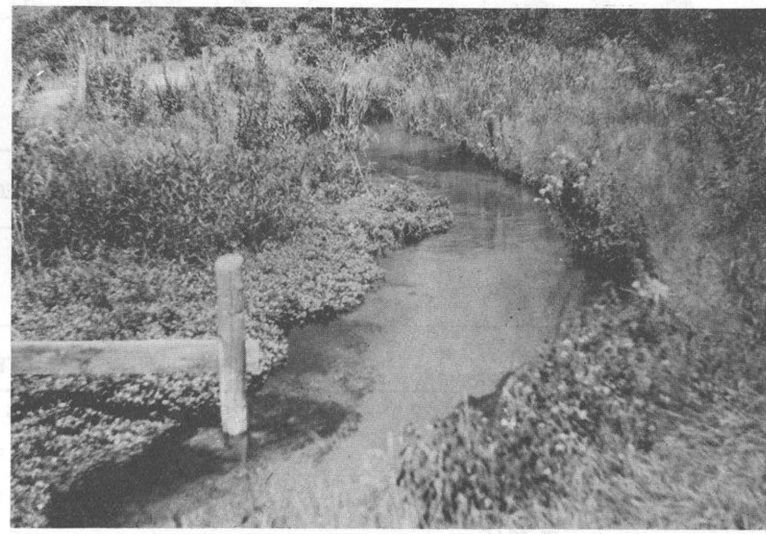


of working materials near the

4 *A crew of skilled technicians follow an orderly sequence of device construction. First, a powerful jet of water is emitted from the long pipe held by the man on the right. This jet stream is used to bore holes in the stream bottom into which oak pilings are placed.*

5 *These pilings, each about 5 feet long, are placed in pairs at 3- to 4-foot intervals parallel to the stream edge.*

9 *Dirt to cover the space between rocks and a covering of sod completes the combination bank-cover and wing. Note that the right-side, upstream device overlaps the next downstream device. The bulk of the flow is gently guided across the channel from one device to the next. In combination these pairs of devices cause the confined current to scour pools beneath the overhanging artificial streambanks.*



10 *Vegetational succession soon restores a natural, esthetic appearance—an important component of the trout fishing experience (above right).*

11 *Such development provides abundant hiding cover for trout, even during winter when much of the instream cover supplied by aquatic plants has largely disappeared (below right).*

In all 17 stations the number of trout over 6 inches long increased after development, by amounts ranging from 2% in station 9 to 500% in station 13, and by at least 100% in 10 of the 17 stations. The predevelopment average of 33/station was exceeded during the postdevelopment period in 15 stations, and for the section as a whole there was an average of 100% increase to 66/station (Fig. 16).

The maximum number of trout over 6 inches in section A during the 7-year study was recorded in April, 1967 when it held 1,261, a density of approximately 1 trout/5 feet of stream.

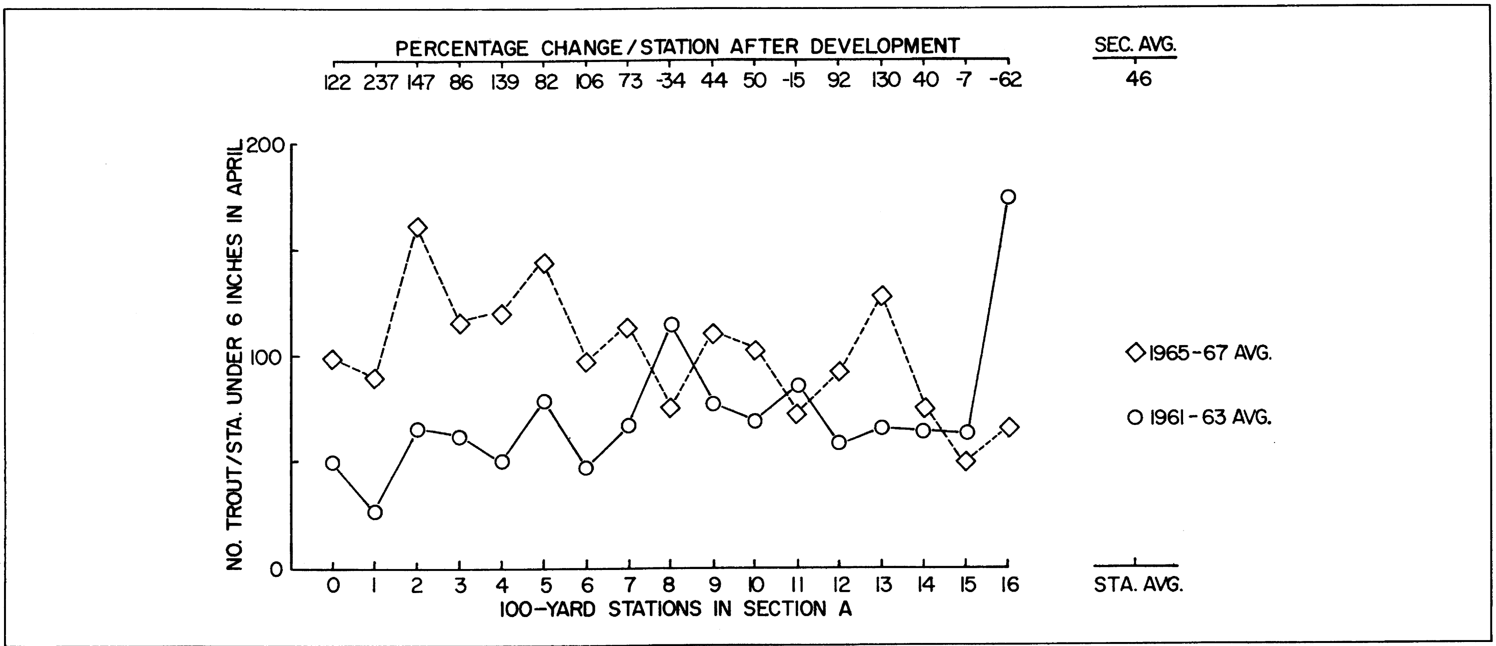


Figure 14. *Station–by–station changes in the number of brook trout less than 6 inches long in section A, before and after habitat development.*

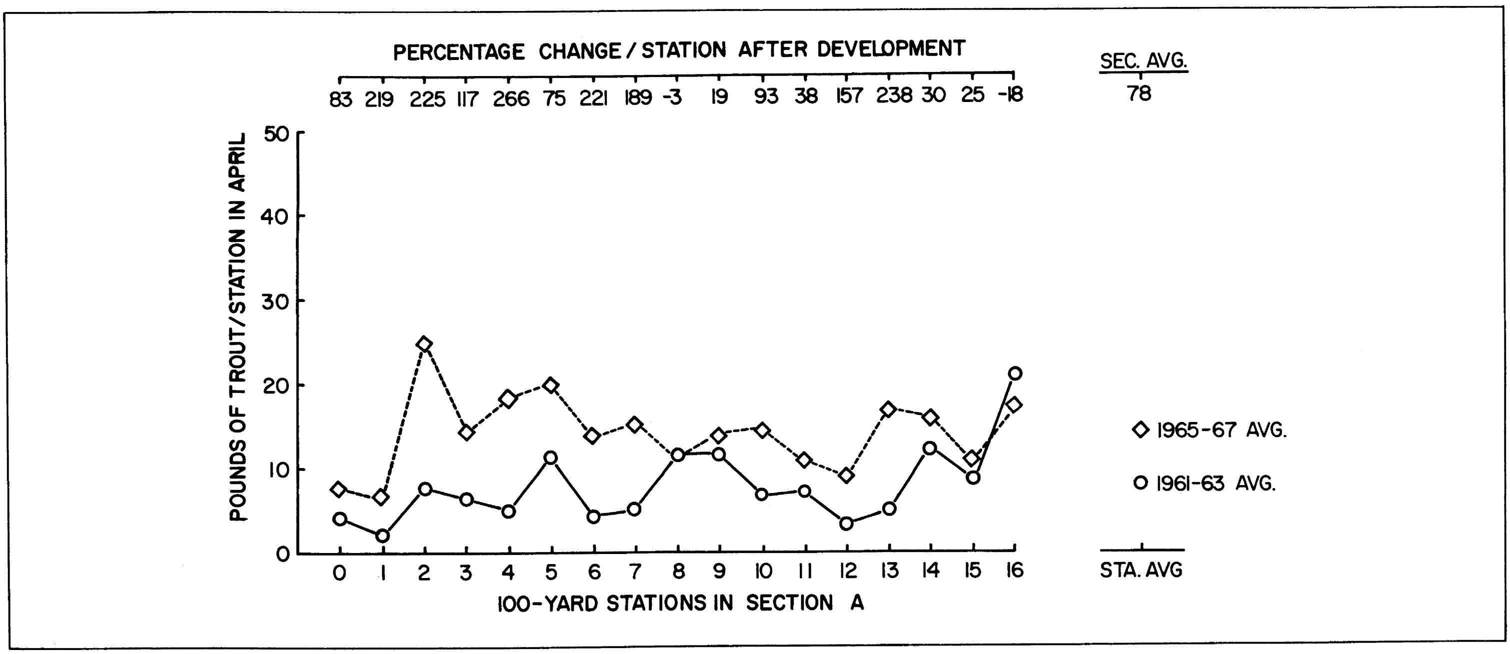


Figure 15. *Station–by–station changes in the biomass of brook trout in section A, before and after habitat development.*

TABLE 8. Physical Characteristics of the 17 Stations* in Station A Before (1963) and After (1966) Habitat Development.

Station Number	Surface Area (acres) Pre	Surface Area (acres) Post	Surface Area (acres) Percent Change	Mean Depth (inches) Pre	Mean Depth (inches) Post	Mean Depth (inches) Percent Change	Volume (feet^3) Pre	Volume (feet^3) Post	Volume (feet^3) Percent Change	Pool Area (feet^2) Pre	Pool Area (feet^2) Post	Pool Area (feet^2) Percent Change	Percent Bottom in Pools Pre	Percent Bottom in Pools Post	Bank Cover (feet) Pre	Bank Cover (feet) Post	Bank Cover (feet) Percent Change	Percent Streambank Providing Cover Pre	Percent Streambank Providing Cover Post
0	.26	.18	- 18	2.8	3.1	- 11	2,604.9	2,417.7	- 7	178.8	317.8	78	1.6	3.9	13.0	16.8	130	1.1	1.5
1	.19	.13	- 30	3.8	5.8	53	2,615.3	3,066.5	17	137.5	660.5	380	1.7	11.4	12.0	21.5	80	1.2	2.8
2	.37	.13	- 64	3.9	7.7	97	5,238.1	3,572.1	- 32	324.3	1,943.9	500	1.9	34.0	50.0	325.0	550	4.4	27.4
3	.18	.12	- 33	5.0	6.2	24	3,269.1	2,741.2	- 16	291.8	1,015.6	248	3.8	19.0	25.0	167.5	570	3.1	25.2
4	.22	.11	- 52	5.6	7.5	34	4,475.4	3,076.3	- 31	257.5	1,582.5	514	2.7	33.4	25.0	233.8	835	2.7	30.1
5	.23	.10	- 58	6.1	8.5	39	5,089.6	2,933.5	- 42	427.5	2,155.8	404	4.3	49.8	62.5	320.0	412	7.7	41.2
6	.24	.06	- 73	4.9	9.3	90	4,265.4	2,734.7	- 36	302.5	1,919.0	534	2.9	67.8	25.0	301.2	1,105	3.1	41.0
7	.28	.08	- 70	4.9	7.1	45	4,976.3	2,570.9	- 48	409.6	2,137.1	422	3.2	58.5	45.0	266.3	492	5.8	38.6
8	.16	.06	- 61	6.3	8.8	40	3,659.0	2,164.8	- 41	525.0	2,043.6	289	7.4	73.6	81.2	302.4	272	12.0	46.5
9	.22	.08	- 62	7.6	8.9	17	6,066.2	3,036.3	- 50	959.4	2,112.1	120	0.5	58.7	112.5	251.3	123	12.0	32.8
10	.23	.10	- 58	6.3	7.9	25	5,259.8	2,812.5	- 47	415.6	1,844.2	343	4.4	43.9	47.5	167.5	253	5.7	22.6
11	.12	.11	- 15	5.0	5.6	12	2,179.7	2,278.3	+ 5	212.5	1,177.5	454	4.0	25.4	22.5	77.5	244	3.2	11.4
12	.21	.17	- 22	4.1	4.4	7	3,128.5	3,029.8	- 3	78.1	972.0	1,145	1.0	13.1	5.0	35.0	600	0.7	4.8
13	.18	.13	- 25	4.9	6.1	24	3,199.0	3,124.0	- 2	278.1	1,763.4	534	3.3	29.7	17.5	170.0	871	2.5	26.8
14	.19	.08	- 56	6.2	9.6	55	4,278.9	2,980.7	- 30	790.6	1,943.9	146	9.4	53.1	45.0	340.0	655	6.2	44.7
15	.14	.07	- 46	7.3	9.8	34	3,707.8	2,657.2	- 28	384.4	2,230.6	480	6.6	69.7	37.5	275.0	633	4.7	42.0
16	.38	.12	- 67	7.8	11.9	53	10,759.3	5,297.0	- 51	1,315.6	2,554.5	94	7.9	47.8	92.5	437.5	473	7.0	36.5
Section Total or Average	3.82	1.86	- 51	4.9	8.1	65	74,772.3	50,493.5	- 32	7,288.8	28,374.0	171	4.4	24.3	718.7	3,708.3	416	4.9	27.4

* Each station is approximately 100 yards long.

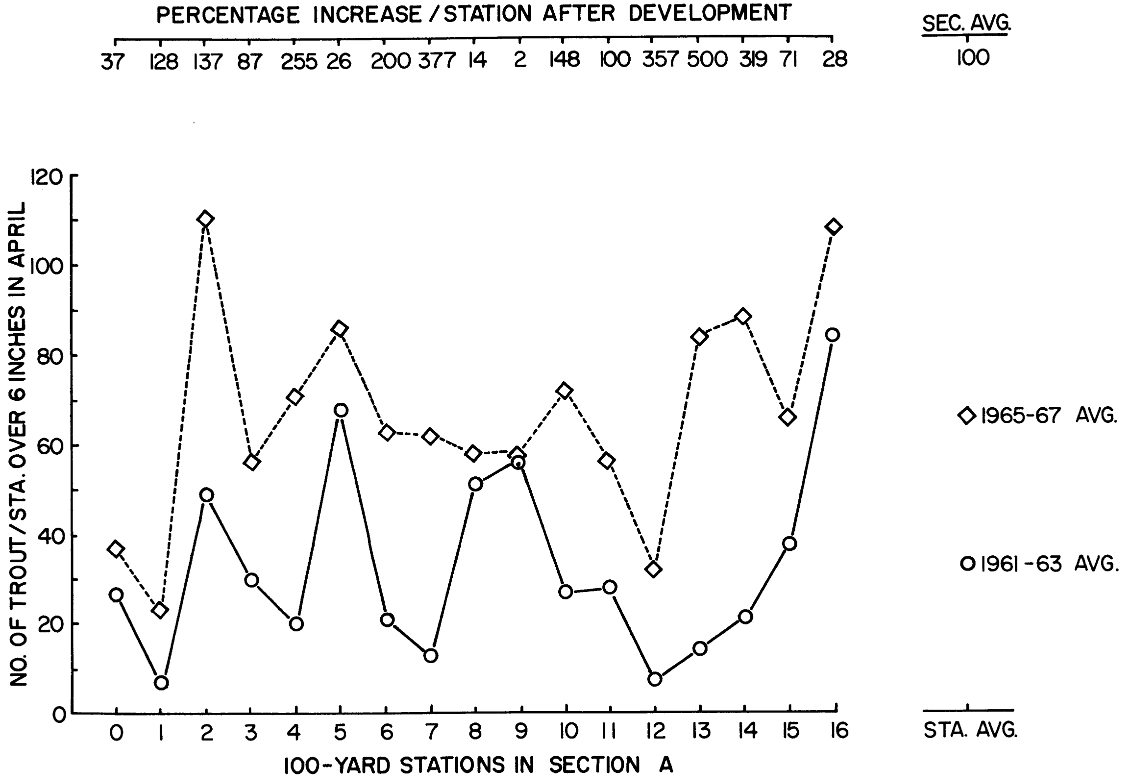


Figure 16. *Station–by–station changes in the number of brook trout over 6 inches long in section A, before and after habitat development.*

TABLE 9. Number, Pounds, and Number of Trout Over 6 Inches Long in Each of the 17 Stations* Within Section A for April 1961-63, the Predevelopment Period, and April 1965-67, the Postdevelopment Period.

Number of Trout

Station Number	1961	1962	1963	1961-63 Average	1965	1966	1967	1965-67 Average	Percent Change**
0	28	75	111	72	70	184	159	137	90
1	21	43	37	34	96	138	111	115	238
2	41	129	175	115	181	341	319	280	143
3	23	136	120	93	164	227	132	174	87
4	33	135	44	71	218	228	132	192	170
5	61	207	175	148	194	322	179	232	57
6	51	76	80	69	142	180	160	161	133
7	61	82	96	80	218	257	100	181	126
8	85	236	176	166	176	108	118	134	- 19
9	81	146	178	135	264	149	98	170	26
10	62	142	88	97	150	182	181	171	76
11	151	130	67	115	122	107	162	130	15
12	54	51	62	56	128	90	157	125	123
13	64	62	83	70	194	301	142	212	103
14	39	118	74	76	114	232	150	166	118
15	46	110	119	92	109	104	127	113	23
16	128	351	297	259	131	175	221	175	- 32
Section Total or Average	1,029	2,229	1,982	1,749	2,671	3,325	2,648	2,870	64

Pounds of Trout

Station Number	1961	1962	1963	1961-63 Average	1965	1966	1967	1965-67 Average	Percent Change**
0	1.5	4.5	6.5	4.2	3.5	10.2	9.5	7.7	83
1	1.1	2.6	2.5	2.1	5.0	7.5	7.4	6.7	219
2	2.4	8.3	12.6	7.7	13.3	28.8	32.7	25.0	225
3	1.4	8.7	9.8	6.6	12.0	17.5	13.4	14.3	117
4	1.9	9.5	3.7	5.0	18.4	23.3	13.5	18.3	226
5	3.5	13.9	16.9	11.5	16.4	27.3	16.6	20.1	75
6	2.7	5.2	5.2	4.3	11.0	15.6	14.6	13.8	221
7	3.6	5.1	7.2	5.3	15.9	20.2	9.8	15.3	189
8	5.0	15.8	14.4	11.7	13.5	9.1	11.3	11.4	- 3
9	5.6	11.9	17.6	11.7	21.0	12.3	8.6	13.9	19
10	4.3	11.1	7.3	7.5	10.9	15.4	17.2	14.5	93
11	8.7	8.6	6.2	7.8	9.3	8.9	14.1	10.8	38
12	2.9	3.5	4.0	3.5	8.8	5.0	13.1	9.0	157
13	3.9	4.0	6.6	5.0	14.8	22.9	12.8	16.9	238
14	2.5	9.3	7.3	12.2	10.0	21.1	16.5	15.9	30
15	3.6	10.0	12.5	8.7	10.0	9.7	12.9	10.9	25
16	9.2	26.6	27.6	21.1	14.4	16.9	21.0	17.4	- 18
Section Total or Average	63.8	158.6	167.9	135.9	208.2	271.7	245.0	241.9	78

Number of Trout Over 6 Inches

Station Number	1961	1962	1963	1961-63 Average	1965	1966	1967	1965-67 Average	Percent Change**
0	14	24	46	27	12	59	39	37	37
1	1	10	11	7	22	37	14	24	128
2	22	55	69	49	63	123	165	117	137
3	10	36	43	30	30	87	53	57	87
4	16	38	6	20	95	42	73	70	255
5	23	95	85	68	52	119	87	86	26
6	20	19	23	21	49	65	73	62	200
7	13	10	17	13	61	83	52	65	377
8	29	67	58	51	61	45	68	58	14
9	36	67	71	57	86	52	37	58	2
10	14	40	27	27	47	69	83	66	148
11	26	32	25	28	51	34	83	56	100
12	6	10	4	7	25	9	59	31	357
13	6	16	19	14	79	111	59	83	500
14	7	28	27	21	51	95	120	89	319
15	4	36	74	38	65	49	74	63	71
16	33	100	119	84	104	97	122	108	28
Section Total or Average	280	683	724	562	953	1,176	1,261	1,130	100

* Each station is approximately 100 yards long.
**1965-67 Avg. ÷ 1961-63 Ave.

DISCUSSION

None of the conclusions stated in my 1969 paper concerning the impact of habitat development on the trout population and fishery in section A of Lawrence Creek requires revision based on the additional data and analyses presented in this paper. In all instances, these additional analyses of complete data for the 7-year study strengthen the conclusions previously drawn. Habitat development in section A was a sound management procedure. More legal–sized trout were stockpiled, the section received much more angling pressure, harvest increased proportionately, and this harvest represented a better utilization of the increased annual production.

Increased standing crops of trout in section A after development were largely the result of increased rates of survival after the 9th month of life of the 1965-67 year classes and improved overwinter survival of age I–IV stocks. Postdevelopment populations were not larger simply because stronger year classes were born. The average number of age 0 trout in section A in September was about the same after development as before development. In April, however, section A held approximately 40% more age I trout during the postdevelopment period than it did during the predevelopment period. Similarly, age I trout in September were only 41% more numerous in altered section A, but by the following April, when the survivors were now age II, they were 200% more abundant during the postdevelopment period (Table 1).

The beneficial impact of development on overwinter survival was also reflected in the statistically significant increase in production by age I and older stocks in section A. Changes in age–specific growth rate components of production were not important (Appendix, Table V), but the increased numbers of "producing units" were. Because more trout simply lived longer, on the average, during the postdevelopment period, more production occurred despite slightly lower rates of growth for most age groups.

The addition of comparative data from sections C and D, none of which were included in my 1969 report, also strengthened earlier conclusions that habitat development was mainly responsible for the observed improvements in the trout population and fishery in section A. In nearly all of the 30 instances of testing intersectional ratios of postdevelopment vs. predevelopment data (Table 7), the A/C and A/D ratios had greater statistical significance favoring section A than did the A/B ratios.

The most important contributions of this paper, however, are not the additional data from sections A and B presented to substantiate previous conclusions, nor the new comparative data from sections C and D, but the insights derived from the station-by-station analyses of physical–biological relationships within section A before and after habitat development. These insights have provided increased understanding of how habitat development benefitted this specific trout population, why similar development work can be expected to benefit other trout populations, and why some stretches of a trout stream consistently hold more trout than other stretches (independent of any consideration of habitat development).

Effects of various physical components of a stream environment on trout carrying capacity have been reported by several investigators. Some of these studies have involved evaluations of trout habitat improvement (Shetter et al., 1946; Saunders and Smith, 1962; Hale, 1969). Other studies involved deleterious human alterations of trout habitat (Boussu, 1954; Whitney and Bailey, 1959; Elser, 1967; Gunderson, 1968). Relationships between habitat quality and carrying capacity have also been investigated in streams which have not been deliberately altered by man for either good or ill (Allen, 1951; Onodera, 1962, Chapman and Bjornn, 1962, Lewis, 1969; Stewart, 1970). The latter two studies by Lewis and Stewart contain results especially relevant to my own results since both investigators attempted, as I did, to measure the effects of single environmental variables and the combined effects of several environmental variables on carrying capacity by simple and multiple regression analyses.

Lewis (1969) measured several physical characteristics of 19 pools in a trout stream in Montana during the summer of 1966. Also measured was the number of brown trout (*Salmo trutta*) and rainbow trout (*Salmo gairdneri*) over 7 inches long inhabiting each pool. The 6 physical factors measured accounted for 77% and 70% of the variation in number of brown and rainbow trout, respectively. Cover was the most important single factor influencing distribution of brown trout and current velocity through the pools was the single factor most important for rainbow trout. Fast water pools were more attractive for rainbow trout.

Stewart (1970) determined 15 physical characteristics of 41 study sections of a small trout stream in Colorado. Weights of brook and rainbow trout/section were used as the dependent measures of carrying capacity. Only trout over 7 inches long were inventoried. For both species, mean depth was the single variable of first importance and the combination of several categories of hiding and protective cover proved to be highly correlated with the density distribution of brook trout but not rainbow trout.

In section A of Lawrence Creek physical differences among the 17 stations also influenced the distribution of brook trout, both before and after habitat development. Multiple correlation coefficients were significant at the 0.01 level for all trout population parameters tested. However, several of the physical variables became less important after development, especially in relation to their influence on carrying capacity of the stations for trout less than 6 inches long. Partial and multiple correlations for all 6 independent and 4 dependent variables are summarized in Table 10. Correlations involving the 3 independent variables surface area, pool area, and permanent bank cover are especially worthy of further consideration, those involving surface area because of the surprising lack of any strong impact on carrying capacity, and those for pool area and permanent bank cover because of their very important effects on carrying capacity.

Influence of Development on Trout Carrying Capacity

Surface Area. Fish populations are commonly compared on the basis of their densities per unit area of water surface; for example, number/acre or pounds/acre. Such unit area indexes are commonly used to compare seasonal changes in a fish population within a body of water as well as population density differences in different bodies of water. The validity of these kinds of comparisons have apparently seldom been questioned or tested. yet from the results I obtained, the need for such questioning and testing is certainly apparent. Indexes such as number of trout/acre and pounds/acre would not have been ecologically meaningful for comparing station-to-station differences in carrying capacity either before or after habitat development. None of the correlation coefficients derived to test the degree of association between surface area/station and population parameters were statistically significant at the 0.10 level, and in every instance postdevelopment correlations were lower than predevelopment correlations despite reductions in surface area of all stations and increases in standing crops of trout (Table 10).

TABLE 10. Correlation Coefficients and Coefficients of Determination for the 5 Dependent and 6 Independent Variables Measured in Each of the 17 Stations of Section A Before and After Habitat Development

	Partial Correlation Coefficients (15 df)							
Dependent Variables	Surface Area	Avg. Depth	Volume	Avg. Pool Depth	Pool Area	Bank Cover	Mult. Corr. (r)	Coef. of Determination
No. Trout/Sta. (April-Predev.)	.421	.643**	.785**	.718**	.779**	.789**	.880**	.774
No. Trout/Sta. (April-Postdev.)	.023	.190	.341	.273	.395	.479	.822**	.676
Lbs. Trout/Sta. (April-Predev.)	.328	.775**	.792**	.714**	.911**	.811**	.921**	.848
Lbs. Trout/Sta. (April-Postdev.)	-.186	.449	.434	.468	.608**	.692**	.860**	.740
No. 6 Inches/Sta. (April-Predev.)	.385	.604*	.761**	.597*	.754**	.706**	.882**	.778
No. 6 Inches/Sta. (April-Postdev.)	.224	-.247	.024	-.050	-.013	.034	.770**	.593
No. 6 Inches/Sta. (April-Predev.)	.423	.619**	.721**	.811**	.717**	.815**	.850**	.723
No. 6 Inches/Sta. (April-Postdev.)	-.223	.628**	.578*	.543*	.717**	.809**	.909**	.826

* Indicates significance at 5% level.

** Indicates significance at 1% level.

Scatter diagrams of number of trout less than 6 inches/station vs. surface area/station are shown in Figures 17a and 17b for the predevelopment and postdevelopment data respectively, and similar diagrams for trout/station more than 6 inches long vs. surface area/station are illustrated in Figures 17c and 17d.

Pool Area. During the predevelopment period of this study, the amount of pool area/station was an important factor in determining trout carrying capacity. Both number of trout less than 6 inches/station and number more than 6 inches/station were highly correlated with pool area/station (Figs. 18a and 18c). Correlation coefficients (0.761 and 0.717, respectively) were significant at the 0.01 level. After development, and the resulting average increase of nearly 300% in the amount of pool area/station, the number of trout/station less than 6 inches long was no longer limited by the amount of pool area/station (Fig. 18b). However, numbers of trout/station more than 6 inches long continued to be highly dependent upon the increased amounts of pool area that had been created by development (Fig. 18d). Pool area/station, therefore, was judged to be in short supply for both trout less than 6 inches and trout more than 6 inches prior to development. After development, however, the amount of pool area/station did not impinge upon the relative carrying capacities of the stations for trout less than 6 inches, but pool area continued to be a factor influencing the distribution of trout more than 6 inches long within section A.

Permanent Bank Cover. The amount of permanent bank cover also had a strong influence on trout carrying capacity. Of the 6 physical characteristics of each station that were measured, this one was altered the most by development. Prior to development, both the number of trout less than 6 inches long/station and the number more than 6 inches long/station were highly dependent upon the amount of permanent bank cover/station (Figs. 19a and 19c). Correlation coefficients were statistically significant at the 0.01 level. After development had increased the amount of bank cover by an average of more than 400%/station, trout less than 6 inches were no longer limited by this environmental factor (Fig. 19b), but trout more than 6 inches long continued to be distributed in relation to the amount of bank cover/station (Fig. 19d).

These data on relationships between pool area vs. carrying capacity and bank cover vs. carrying capacity before and after development suggest that the additional quantities of both pools and bank cover supplied by the development were more than adequate to meet the minimum needs of trout less than 6 inches long under the other conditions that existed as a part of their environment, but apparently for trout more than 6 inches long, even the greatly increased amounts of cover and pools added by development did not completely eliminate these components of the environment as "limiting factors."

Multiple Correlations. In combination, the 6 environmental factors measured accounted for approximately 78% of the station–to–station variation in number of trout less than 6 inches long before development. These trout constituted primarily the age I stocks, yearlings that had survived through their first winter of life. Nearly all mortality experienced by these stocks up to the time of April population estimates had been caused by natural factors. Mortality due to angling was negligible. These age groups in the spring normally constituted 60-65% of the total population by number and 40-50% of the total weight. After development, the same combination of physical components accounted for 60% of the station–to–station variation in number of trout less than 6 inches. Although none of the partial

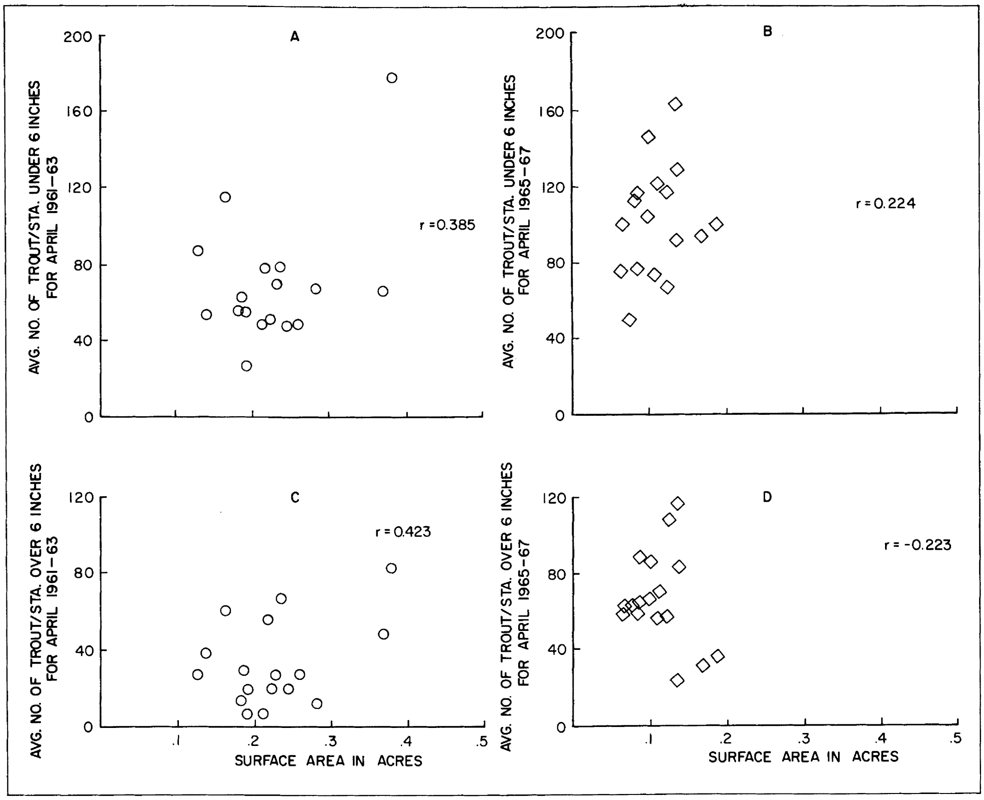


Figure 17. *Relations of surface area/station to trout carrying capacity in section A, before and after habitat development (predevelopment relations illustrated in 17a and 17c; postdevelopment relations illustrated in 17b and 17d).*

correlations were statistically significant at the 0.05 level, the multiple correlation coefficient was significant at the 0.01 level (Table 10), an indication that environmental quality *in toto* was still a factor limiting the number of yearling trout that survived through the winter.

For trout more than 6 inches long, multiple correlations were significant at the 0.01 level for the predevelopment (r=0.850) and the postdevelopment periods (r=0.909). In combination the 6 physical variables considered accounted for 72% of the station–to–station variation in trout over 6 inches prior to development and 83% of station–to–station variation in the density of such trout after development (Table 10). Distribution of trout over 6 inches was most highly correlated with bank cover/station before and after development.

It is important to emphasize again that the relationships discussed above between trout carrying capacity and physical factors are based on measures of standing crops and habitat in the early spring, a time when instream aquatic vegetation is sparse and trout have just come through the severe temperature stresses of winter and snow–melt flooding. Because of the lack of instream vegetation, streamflow is not as confined as when vegetation is more abundant in summer and fall. Average depth approximates the yearly low, as do also the area and depth of pools and availability of permanent bank cover. These environmentally poor springtime conditions were deliberately chosen so that respective trout carrying capacities could be tested when environmental conditions were most limiting.

Habitat development was successful in Lawrence Creek because it substantially increased the quantities of key environmental factors impinging upon survival of the trout population, most notably the amounts of pool area and bank cover for trout. Development was aimed especially at supplying more of these two components and supplying them in combination. Device construction was such that much of the additional pool area was created beneath the overhanging artificial banks of the devices. Pools and bank cover as they apply to trout carrying capacity of small streams like Lawrence Creek are perhaps best thought of not in terms of what each contributes to carrying capacity, but what both contribute in combination. Development was so successful at supplying both of these essential needs, that the carrying capacity of the section for trout less than 6 inches long was no longer dependent upon them, and the impact of both on carrying capacity of larger trout was greatly ameliorated. As a result the number of trout over 6 inches increased by an average of 101% during the 3 years following development. Together, these two factors accounted for 68% of the station–to–station variation in the postdevelopment number of such trout present in April. Increased amounts of either cover or pool tended to reinforce the beneficial impact of the other on carrying capacity, and stations with the highest amounts of both pool and cover held the highest numbers of trout over 6 inches (Fig. 20).

Cost-Benefits of Habitat Development

Economic analyses of trout habitat development have usually been based on estimating the cost of the development work plus periodic maintenance, determining the increased harvests of trout from the developed area, calculating the cost/trout creeled over a period of 20-25 years, and comparing this amortized cost with that of stocking the same reach of undeveloped stream with hatchery–reared trout in numbers sufficient to provide a similar harvest. An excellent example of this kind of analysis is provided by Hale (1969) in his evaluation of development of a portion of Split Rock Creek in Minnesota. He concluded that development provided a savings of approximately

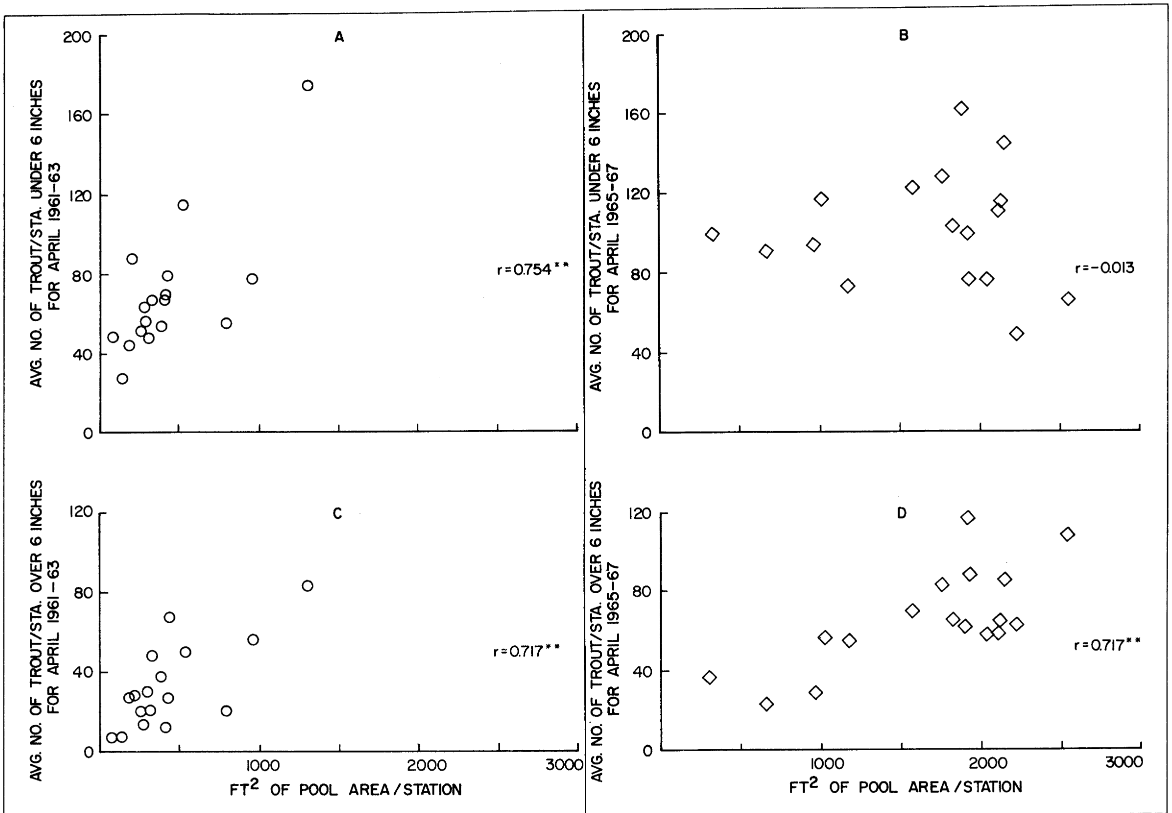


Figure 18. *Relations of pool area/station to trout carrying capacity in section A, before and after habitat development (predevelopment relations illustrated in 18a and 18c; postdevelopment relations illustrated in 18b and 18d).*

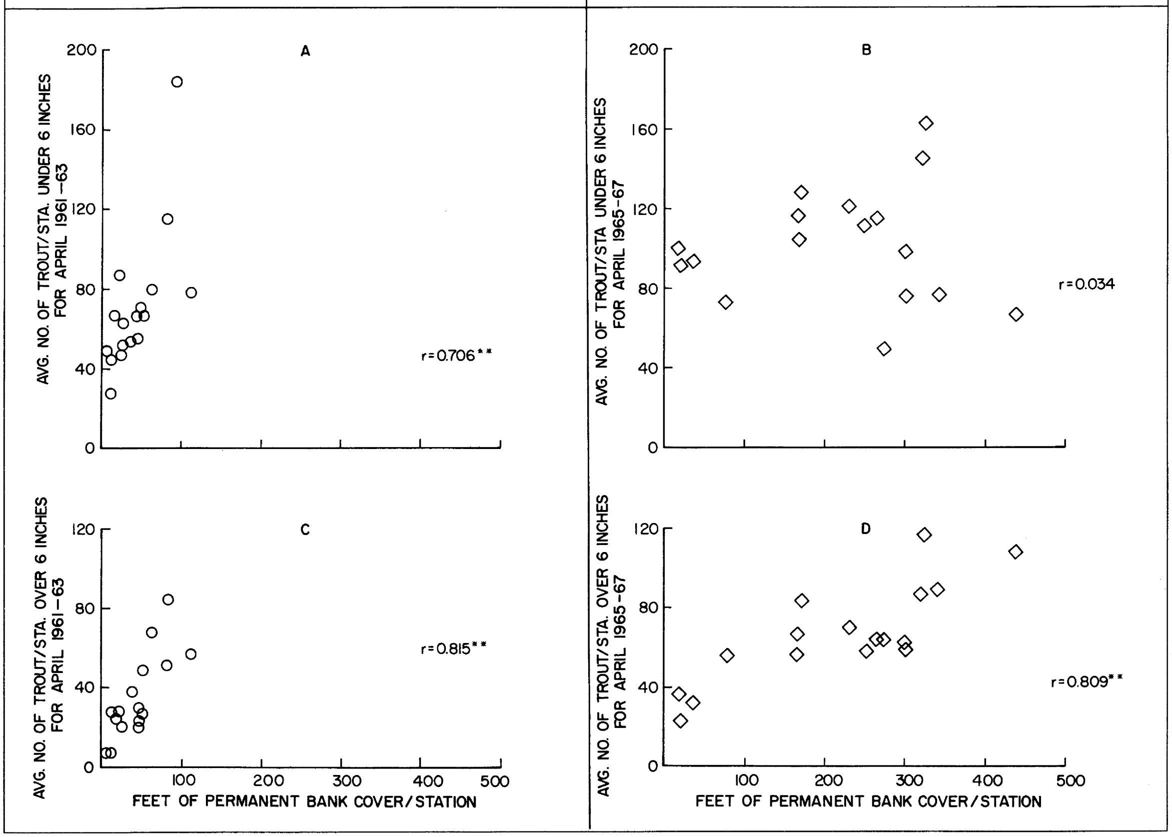


Figure 19. *Relations of permanent bank cover/station to trout carrying capacity in section A, before and after habitat development (predevelopment relations illustrated in 19a and 19c; postdevelopment relations illustrated in 19b and 19d).*

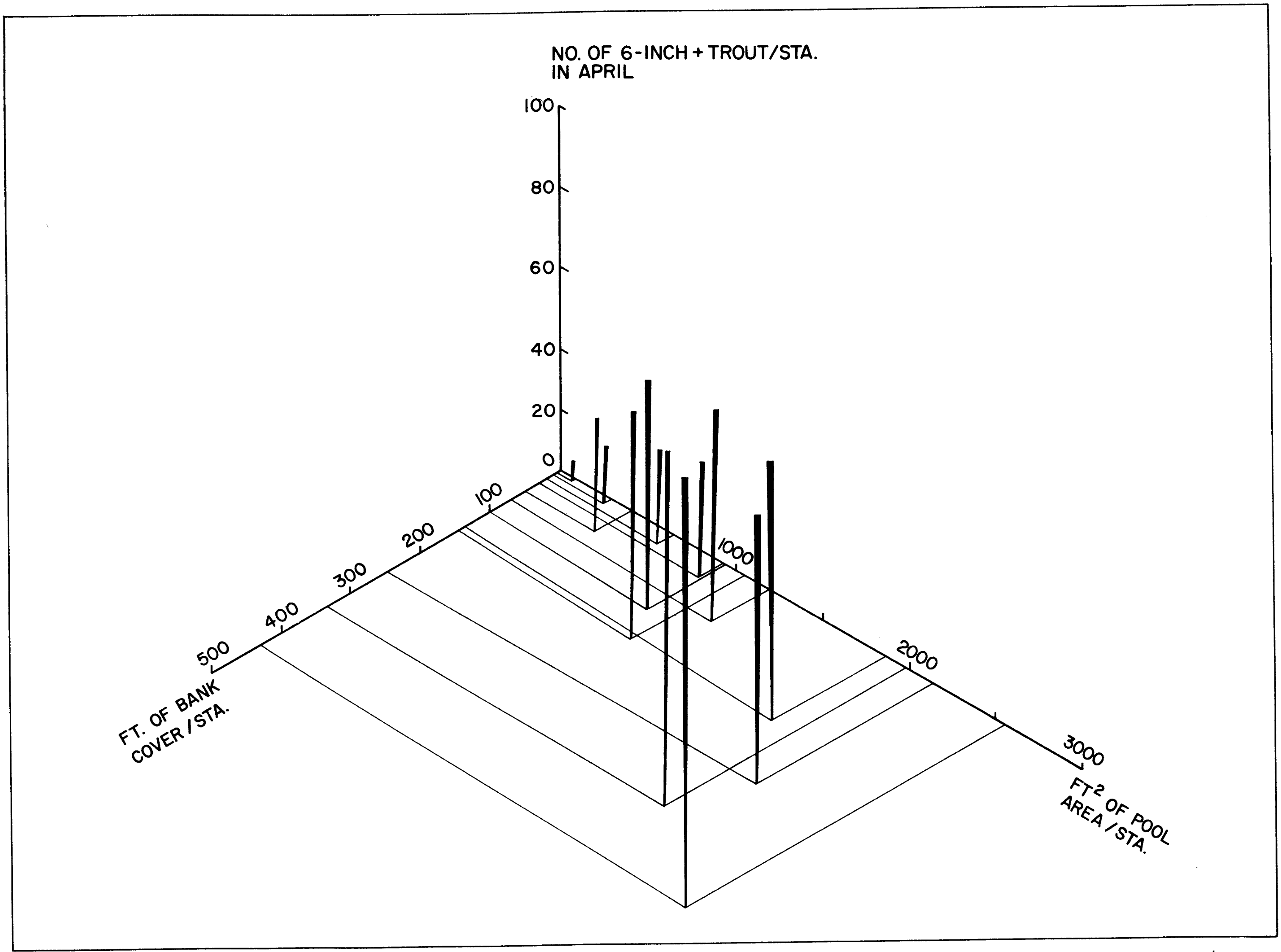


Figure 20. *Relation of permanent bank cover/station and pool area/station to trout carrying capacity in section A after habitat development.*

$220/year/mile of developed stream as compared to stocking hatchery trout. Total cost for developing one mile of stream was $13,146. The increase in harvest of wild brook trout averaged 807/year.

Precise records of financial expenditures were not kept for the development work on Lawrence Creek. However, based on the best estimate that could be obtained from the records for this project and other similar development projects a total cost of approximately $26,200 was derived based on installation of 6,550 feet of streambank structures at an average cost of $4.00/foot. Labor costs accounted for approximately 70%, vehicle operation accounted for 20% and materials for the structures (planks, rock, and sod) for the remaining 10% of the total expenditure. Based on results of development projects on other trout streams similar to Lawrence Creek, maintenance costs during the ensuing 20-25 years are expected to be negligible. Cost to date has been zero on several similarly developed streams over periods as long as 15 years. Amortization of total expense for development and maintenance over a 25-year functional period would therefore yield an average investment of approximately $1,050/year.

If the average observed increase of 200 trout over 8 inches long/season is the criterion to be used in assessing the fiscal soundness of such an expenditure, each additional trout creeled would represent an investment of $5.25. By comparison, the estimated cost in 1968 of stocking domestic trout of similar size was only $0.33/trout (including cost of personnel salaries, fish food, station maintenance, administration, and transportation). If anglers were able to harvest 50% of such trout stocked, cost of stocking the necessary 400 trout annually would be $132 and each trout creeled would represent a management investment of $0.66. Obviously, if the cost of developing section A is to be judged only by the standard of stocking vs. development, stocking is clearly the most economical procedure. A savings of approximately $918/year would be realized over a projected 25-year amortization period.

If, on the other hand, a recreational value of $5.00/angler trip is accepted as realistic (Freeman, et al., 1964), and the observed average increase of 300 trips/season is used as the measure of response, a period of only 17 years would be required to redeem the expense of developing and maintaining section A of Lawrence Creek as a purely wild brook trout fishery. Should both fishing pressure and the recreational value of angling continue to increase (as they are likely to do), this proration period would be reduced accordingly.

For several reasons, however, I hesitate to accept either of these prorations, especially the former, as fair procedures for a cost–benefit appraisal of habitat development. Before this management technique can be objectively appraised economically, it seems to me that several questions must be answered:

1. Would most trout fishermen equate the value of catching 1 hatchery trout with that of catching 1 wild trout of the same size? If not, what is a fair "trade–off" ratio–2:1, 3:1?

2. Is a functional period of 20-25 years for habitat development realistic? Unfortunately, little empirical evidence has been compiled. Based on personal observations over the past 10 years of development done in central Wisconsin, a period of 25 years would certainly appear to be highly conservative

3. What are the many other benefits worth that accrue from carrying out a project of habitat development? Shouldn't benefits such as more efficient utilization of inherent stream productivity, stockpiling of more larger trout, increased trout production, improved utilization of the greater trout production, and long–term enhancement of water quality and stream esthetics also be given monetary values and plugged into the cost–benefit equation along with the value for increased yield? As a fellow biologist, Ray J. White, has pointed out (pers. comm.), "It is unlikely that no (other management) activity outside of habitat management would achieve benefits expressible in equivalent terms. This has been the failing of comparisons of stream improvement against stocking of hatchery trout. Stocking . . . does nothing to insure that a deteriorating stream will provide fish habitat in the future." Improvement of trout habitat on streams having public access, then, could be considered as an obligation entrusted to a natural resources agency by the public. Such upkeep could be viewed as analogous to the homeowner who periodically repaints his home to maintain or enhance its market value, its livability and its contribution to community esthetics. The question of what a recently improved trout stream would bring on the open market as compared to the same stream in its former deteriorated condition also remains to be answered.

4. Finally, in evaluations of trout habitat development reported to date, measured changes in angler use and harvest have been subject to the vagaries of public response. In the case of section A of Lawrence Creek, for example, yield increased two–fold after development, but this increased yield could probably have been nearly doubled again if enough voluntary angling effort had been expended. Furthermore, if the size limit had been 6 inches instead of 8 inches, post-development yield would have been even greater. The increased yield that was measured, therefore, was not indicative of the potential increase but only that due to an uncontrolled input of additional angling effort. Should such empirical increases in fishery statistics be used as criteria for evaluating the economics of habitat development or should theoretical estimates such as maximum sustained yield be used?

Until there is a "meeting of the minds" among fish managers, research biologists, and resource economists on the kinds of questions cited above, a thorough, unbiased cost–benefit appraisal of trout habitat development will not be possible. However, it seems intuitively clear that any future economic appraisal which includes the kinds of factors cited above (especially those incorporating recreational values of fishing for wild trout) can only improve cost–benefit ratios over those presently available for judging the merits of this management technique. Moreover, if cost of labor, the major expense in development, continues to increase, one could argue that more emphasis should be given to habitat development now. The procedures for accomplishing the job have been worked out and the need for more development on many Wisconsin streams is undeniable. Only the necessary financial support from public or private funds, plus the management decisions to implement an expanded program of habitat development are needed to substantially improve the wild trout fishery resource of Wisconsin.

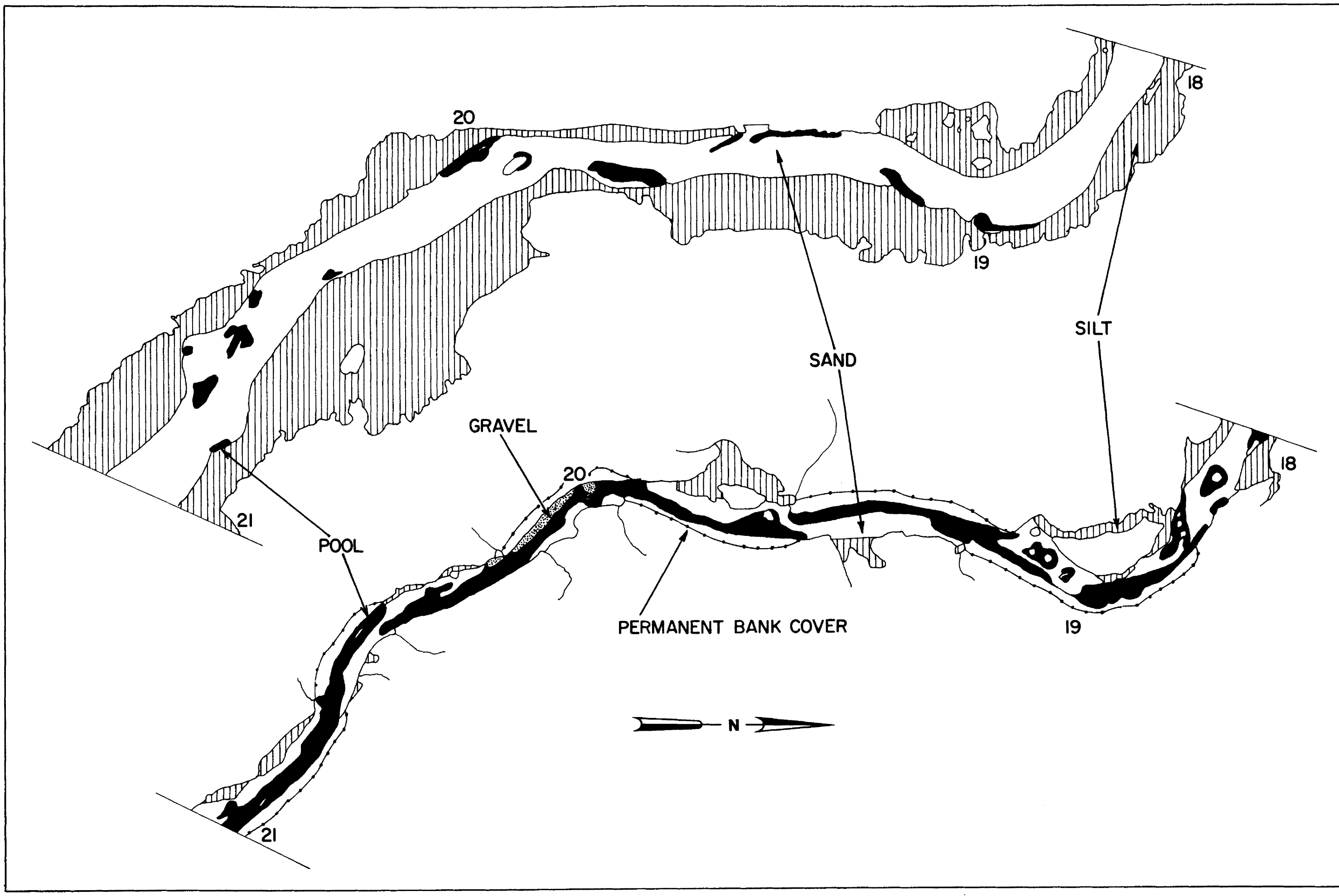


Figure 21. *Example of morphometric maps drawn of each 100-year station in section A before and after habitat development. Note by comparison of A (predevelopment) and B (postdevelopment), the small, scattered pools, lack of overhanging permanent bank cover, and lack of exposed gravel substrate in A vs. the long, large pools, extensive permanent cofer, and increased amounts of gravel substrate in B.*

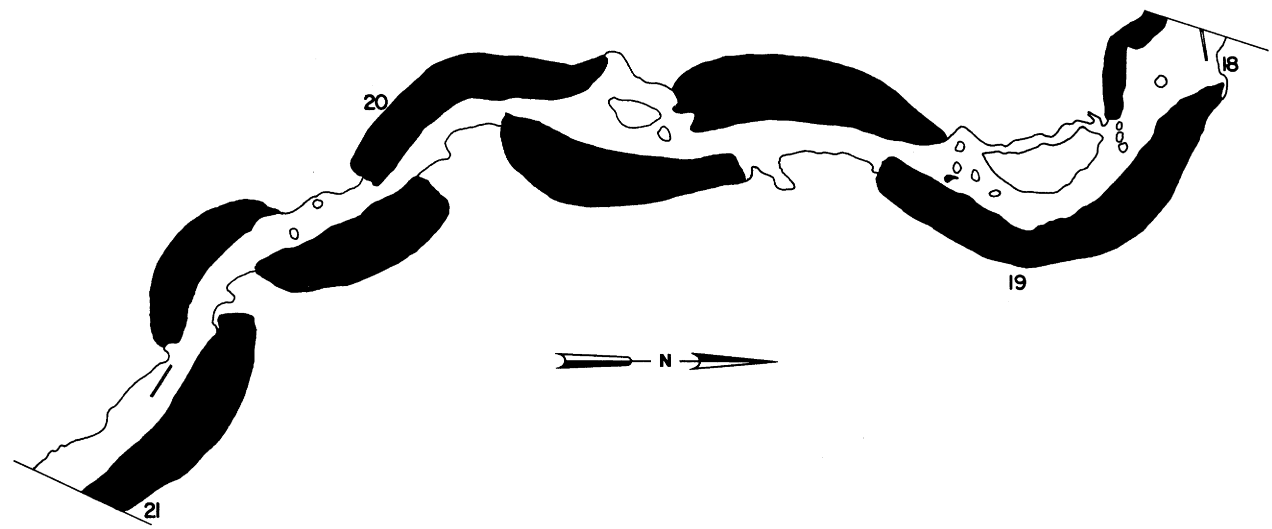


Figure 21 (continued) The typical pattern of device installation is illustrated in C.

TABLE 11. Estimated Number and Weight of Brook Trout in Lawrence Creek in September, 1966

Total Length (inches)	Stream Section A	B	C	D	Total Number	Total Weight (lbs.)
1.5-2.4	10	23	6	3	42	0.1
2.5-3.4	79	763	308	30	1180	16.6
3.5-4.4	899	2889	1443	213	5444	119.8
4.5-5.4	396	864	225	62	1547	92.8
5.5-6.4	443	359	265	25	1092	93.9
6.5-7.4	677	667	442	243	2029	253.5
7.5-8.4	330	320	294	306	1250	242.9
8.5-9.4	72	78	90	144	384	95.4
9.5-10.4	16	15	32	52	115	38.7
10.5-11.4		1	5	11	17	7.8
11.5-12.4				3	3	1.8
Total Number	2922	5979	3110	1092	13103	--
Total Weight	244.1	345.6	216.7	156.9	--	963.3
Percent of Total Number	22.3	45.6	23.7	8.4	100.0	--
Percent of Total Weight	25.3	35.9	22.5	16.3	--	100.0

TABLE 12. Estimated Size-Age Group Structure of the September, 1966 Population of Brook Trout in Lawrence Creek

Total Length (inches)	Number by Age Group 0	I	II	III	IV	Total Number	Total Weight (lbs.)
1.5-2.4	42					42	0.1
2.5-3.4	1180					1180	16.6
3.5-4.4	5444					5444	119.8
4.5-5.4	1495	52				1547	92.8
5.5-6.4	31	1056	5			1092	93.9
6.5-7.4		1937	92			2029	253.5
7.5-8.4		929	315	6		1250	242.9
8.5-9.4		138	207	39		384	95.4
9.5-10.4		3	76	34	2	115	38.7
10.5-11.4			5	8	4	17	7.8
11.5-12.4				2	1	3	1.8
Total Number	8192	4115	700	89	7	13103	--
Percentage	62.5	31.4	5.3	0.7	0.1	100.0	--
Total Weight	228.9	556.5	147.7	27.0	3.2	--	963.3
Percentage	23.8	57.8	15.3	2.8	0.3	--	100.0
Avg. Length	4.0	7.0	8.4	9.6	10.9	5.2	--
Avg. Weight	0.03	0.14	0.21	0.30	0.46	--	0.07

TABLE 13. Distribution of the Brook Trout Population in Lawrence Creek in September, 1966 According to Age Group and Stream Section

Stream Section	Age Group 0 No.	0 %	I No.	I %	II No.	II %	III No.	III %	IV No.	IV %	All Ages No.	All Ages %
A	1368	16.7	1328	32.3	212	30.3	14	15.7	0	0.0	2922	22.3
B	4542	55.4	1286	31.3	131	18.7	19	21.3	1	14.3	5979	45.6
C	1974	24.1	878	21.3	219	31.3	37	41.6	2	28.6	3110	23.7
D	308	3.8	623	15.1	138	19.7	19	21.3	4	57.1	1092	8.4
Totals	8192	100.0	4115	100.0	700	100.0	89	100.0	7	100.0	13103	100.0

TABLE 14. Number of Brook Trout of Each Age in Each of the 4 Study Sections of Laurence Creek in April and September, 1955-1967.

Line Number	Study Section	Age Group	Month	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
				Number of Brook Trout Per Section												
1	A	0	April	--	--	--	--	--	--	--	--	--	--	--	--	--
2			Sept.	1,007	3,251	4,383	1,012	5,775	2,384	3,591	1,968	2,077	2,451	2,834	1,368	3,513
3		I	April	2,651	587	2,951	3,716	675	1,658	961	2,029	1,520	2,401	1,989	2,556	1,705
4			Sept.	784	462	2,013	1,942	280	344	673	1,036	606	1,180	1,060	1,328	881
5		II	April	388	291	184	1,043	756	30	67	192	444	320	627	640	836
6			Sept.	83	95	84	154	170	9	48	54	149	117	156	212	250
7		III	April	27	36	75	75	175	9	0	8	16	67	50	126	98
8			Sept.	1	1	60	28	24	3	2	1	6	30	19	14	24
9		IV	April	3		1		1	1	1		2	2	5	3	9
10			Sept.				2							1		
11		V	April	1												
12			Sept.													
13		VI	April		1											
14			Sept.		1											
15	B	0	April	--	--	--	--	--	--	--	--	--	--	--	--	--
16			Sept.	3,236	4,040	4,756	1,425	8,787	3,216	5,784	2,414	3,676	4,523	2,945	4,542	2,645
17		I	April		738		2,293	844	1,730	1,065	2,044	1,137	1,929	1,391	1,922	1,955
18			Sept.	950	153	705	1,836	358	794	748	1,150	650	1,396	623	1,286	761
19		II	April		293		447	914	53	153	275	449	290	483	345	752
20			Sept.	71	12	19	224	167	14	45	43	129	81	92	131	174
21		III	April		27		13	40	23	3	14	15	58	32	57	82
22			Sept.			2	8	10	3		4	5	12	8	19	6
23		IV	April									1	1	7	2	8
24			Sept.											1	1	2
25		V	April													
26			Sept.													
27		VI	April													
28			Sept.													
29	C	0	April	--	--	--	--	--	--	--	--	--	--	--	--	--
30			Sept.	1,280	3,212	3,105	1,383	6,250	1,922	3,106	1,589	2,601	1,650	1,873	1,974	1,329
31		I	April		450		1,431	125	1,456	595	1,543	645	1,322	817	897	1,149
32			Sept.	711	138	377	277	285	1,202	538	1,197	589	1,023	1,006	878	1,045

TABLE 14. Number of Brook Trout of Each Age in Each of the 4 Study Sections of Laurence Creek in April and September, 1955-1967. (Cont.)

Line Number	Study Section	Age Group	Month	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
				Number of Brook Trout Per Section												
33		II	April		345		182	431	50	200	264	591	242	392	397	693
34			Sept.	122	12	9	108	196	6	75	47	249	115	168	219	320
35		III	April		16		7	28	56	2	28	24	107	56	96	119
36			Sept.	5		2	7	7	2		8	5	38	14	37	67
37		IV	April						1			1	1	14	7	2
38			Sept.	1								1		2	2	8
39		V	April										1			
40			Sept.													
41		VI	April													
42			Sept.													
43	D	0	April	--	--	--	--	--	--	--	--	--	--	--	--	--
44			Sept.	197	350	1,014	346	1,834	985	1,832	1,640	2,013	1,056	800	308	408
45		I	April		237		1,045	171	3,666	981	2,951	1,342	1,837	806	1,470	1,123
46			Sept.	309	63	298	338	121	984	401	1,140	543	783	449	623	475
47		II	April		159		283	379	77	407	382	925	417	387	382	679
48			Sept.	31	12	41	101	76	11	93	59	223	132	71	138	122
49		III	April		36		13	13	109	5	58	59	148	61	76	108
50			Sept.	9	1	11	3	4	3	1	9	21	37	19	19	31
51		IV	April		3		6			4		13	13	20	15	16
52			Sept.									4	7	2	4	5
53		V	April										2		2	
54			Sept.													
55		VI	April													
56			Sept.													

TABLE 15. Average Weights of Brook Trout in Lawrence Creek in April and September 1961-63 and 1965-67

Month	Age	Section	Avg. Weight (g) 1961	1962	1963	1965	1966	1967	1961-63 Avg.	1965-67 Avg.
April	I	A	19.1	21.2	20.0	17.3	18.4	19.1	20.1	18.3
		B	15.6	18.4	17.4	14.5	15.7	16.3	17.1	15.5
		C	16.0	19.0	16.5	15.1	17.4	14.3	17.2	15.6
		D	18.7	21.9	19.3	15.3	22.1	17.6	20.0	18.3
	II	A	61.9	64.6	61.8	55.9	60.4	55.1	62.5	57.1
		B	52.4	62.0	55.6	50.2	57.2	54.8	56.7	54.1
		C	50.7	64.1	55.6	55.7	54.8	59.2	56.8	56.6
		D	61.1	70.5	67.1	62.2	71.9	76.7	66.2	70.3
	III	A	-	102.0	95.3	77.3	81.9	76.3	98.7	78.5
		B	59.1	96.3	82.7	72.0	81.5	77.8	79.4	77.1
		C	70.9	96.3	81.3	78.5	83.9	76.0	82.8	79.5
		D	92.2	143.1	100.4	96.5	88.7	93.9	111.9	93.0
September	0	A	9.4	8.0	9.0	8.4	11.4	9.1	8.8	9.6
		B	8.5	6.9	8.2	8.3	9.9	8.2	7.9	8.8
		C	7.7	6.4	8.3	7.8	8.8	8.1	7.5	8.2
		D	8.6	7.1	9.3	8.5	10.1	9.1	8.3	9.2
	I	A	64.3	44.6	45.7	46.6	41.7	41.7	51.5	43.3
		B	56.8	41.7	44.5	43.3	51.5	37.7	47.7	44.2
		C	52.6	38.9	41.9	40.7	45.1	36.2	44.5	40.7
		D	64.6	46.8	49.2	44.4	58.2	53.3	53.5	52.0
	II	A	121.1	80.1	79.0	71.4	67.2	72.8	93.4	60.5
		B	94.6	70.9	72.0	65.5	72.0	66.0	79.2	67.8
		C	101.2	78.5	70.8	75.8	71.4	72.2	83.5	73.1
		D	125.8	87.2	80.8	87.9	94.6	95.3	97.9	92.6
	III	A	195.1	106.4	112.3	82.1	98.8	85.7	137.9	88.9
		B	-	133.0	106.4	75.4	89.6	53.2	119.7	72.7
		C	-	155.1	106.4	87.9	106.4	87.9	130.8	94.1
		D	177.3	141.8	126.6	91.5	134.4	125.8	148.6	117.2

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