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THE EFFECT OF STREAM IMPROVEMENT UPON THE CATCH AND POST-SEASON STANDING CROP OF TROUT IN THE PIGEON RIVER

By

Thomas F. Waters

The purpose of this project was to evaluate the effects of stream improvement upon the density of wild trout populations and upon the anglers' catch. Section A of the Pigeon River, included in the Pigeon River Trout Research Area, was selected for the study. All fishing in this area is controlled by a permit system of creel census, and annual fall population estimates of the standing crop of trout are made at the end of each fishing season. Data on the anglers' catch and fall standing crop are available since 1949 when the trout research area was established.

Section A is one of five experimental stream sections in the Area (see Fig. 1). Records previous to 1953 showed that, relative to the other four sections, Section A had been consistently low in contributing wild trout to the anglers' catch and also in fall standing crop. The section is 1.31 miles long, and has an area of 7.16 acres (Cooper, 1952). Much of Section A was of a character considered poor for trout production: wide, shallow areas of shifting sand, low gradient, and little ground water.

During the fall of 1953, stream improvement work was done in Section A, consisting of the construction of rock and sheet piling deflectors, log

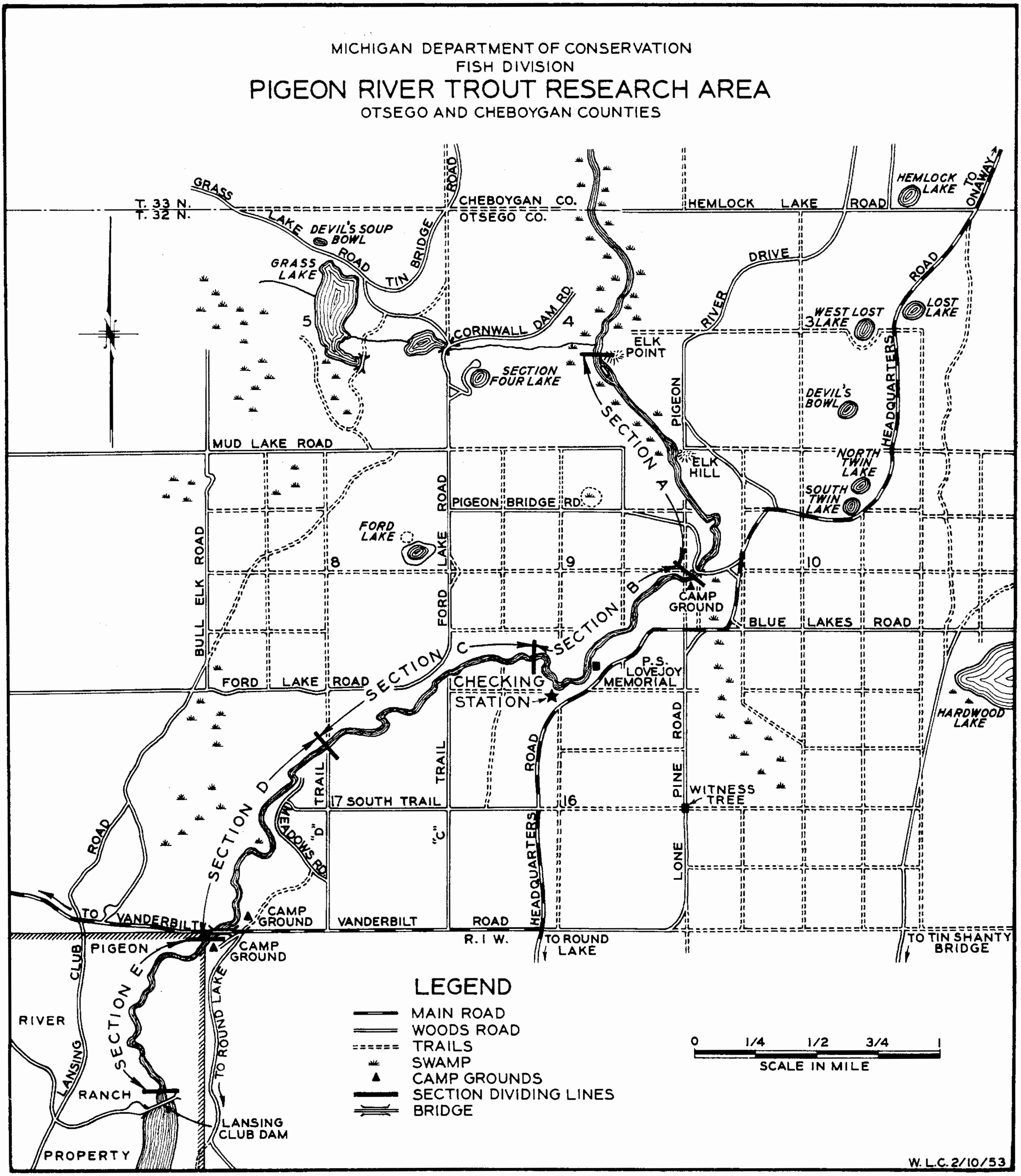
MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION
PIGEON RIVER TROUT RESEARCH AREA
OTSEGO AND CHEBOYGAN COUNTIES
T. 33 N.
T. 32 N.
GRASS LAKE ROAD
DEVIL'S SOUP BOWL
GRASS LAKE
TIN BRIDGE ROAD
CHEBOYGAN CO.
OTSEGO CO.
HEMLOCK LAKE ROAD
HEMLOCK LAKE
TO ONAWAY
RIVER DRIVE
ROAD
WEST LOST LAKE
LOST LAKE
CORNWALL DAM RD.
SECTION FOUR LAKE
ELK POINT
SECTION A
PIGEON
DEVIL'S BOWL
HEADQUARTERS
MUD LAKE ROAD
ELK HILL
NORTH TWIN LAKE
SOUTH TWIN LAKE
PIGEON BRIDGE RD.
FORD LAKE
BULL ELK ROAD
FORD LAKE ROAD
CAMP GROUND
SECTION B
BLUE LAKES ROAD
SECTION C
P.S. LOVEJOY MEMORIAL
CHECKING STATION
HARDWOOD LAKE
SECTION D
TRAIL
17 SOUTH TRAIL
WITNESS TREE
LONE PINE ROAD
HEADQUARTERS ROAD
MEADOWS RD
"D"
"C"
TO VANDERBILT
VANDERBILT ROAD
R. 1 W.
TO ROUND LAKE
TO TIN SHANTY BRIDGE
CLUB
PIGEON
RIVER
LANSING
RANCH
PROPERTY
SECTION E
TO ROUND LAKE
LANSING CLUB DAM
LEGEND
MAIN ROAD
WOODS ROAD
TRAILS
SWAMP
CAMP GROUNDS
SECTION DIVIDING LINES
BRIDGE
0 1/4 1/2 3/4 1
SCALE IN MILE
W.L.C. 2/10/53

Figure 1

THE PIGEON RIVER TROUT RESEARCH AREA

This research and experimental area is located in the northeastern corner of Otsego County and in a small portion of Cheboygan County in the Pigeon River State Forest. Here six miles of the Pigeon River and seven trout lakes have been designated as experimental waters for studies on brook, brown, and rainbow trout. This program, as is also true with other functions of the Fish Division, is financed solely from the sale of fishing licenses and trout stamps. Its success depends to a large extent on the cooperation of the fishing public in supplying the information needed to maintain and improve trout fishing.

The Pigeon River in this experimental area is divided into five convenient fishing sections as indicated on the reverse side of this sheet. Seven trout lakes of unusual character are included in the trout research program. These lakes are believed to have been formed geologically through the solution of underlying limestone by ground water, and a settling of the surface layer of sand and gravel, producing cone-shaped pot holes, some with nearly vertical banks 50 to 60 feet high.

In order to obtain a complete record of the fishing in this area, each fisherman is required to register daily at the checking station, obtain a free permit to fish in any lake or portion of the stream and report back to the checking station before fishing in another lake or stream section or before leaving the area. Some experimental changes in the usual regulations governing trout fishing in Michigan are made from time to time in order to learn how necessary such restrictions are and whether changes may improve the angling quality. The special regulations will be stated on the fishing permit.

In addition to the information on fishing success collected from persons in the area, many other research projects are being followed by department personnel. Periodic estimates are made of the trout populations and information on rate of growth of the fish and their success in spawning is obtained. Studies of the returns from hatchery plantings are being made to determine their value and need.

The correct stocking programs for lakes of the type found in the Pigeon River Research Area, which lack natural spawning facilities, are being determined by plantings of different species of varying size and at different seasons of the year.

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rafts, stump covers, and channel clearing (see Fig. 2 and Table 1). To evaluate this improvement work, creel census data and fall population estimates for the years 1954-56 (since stream improvement) were compared with data for the years 1949-53 (before stream improvement).

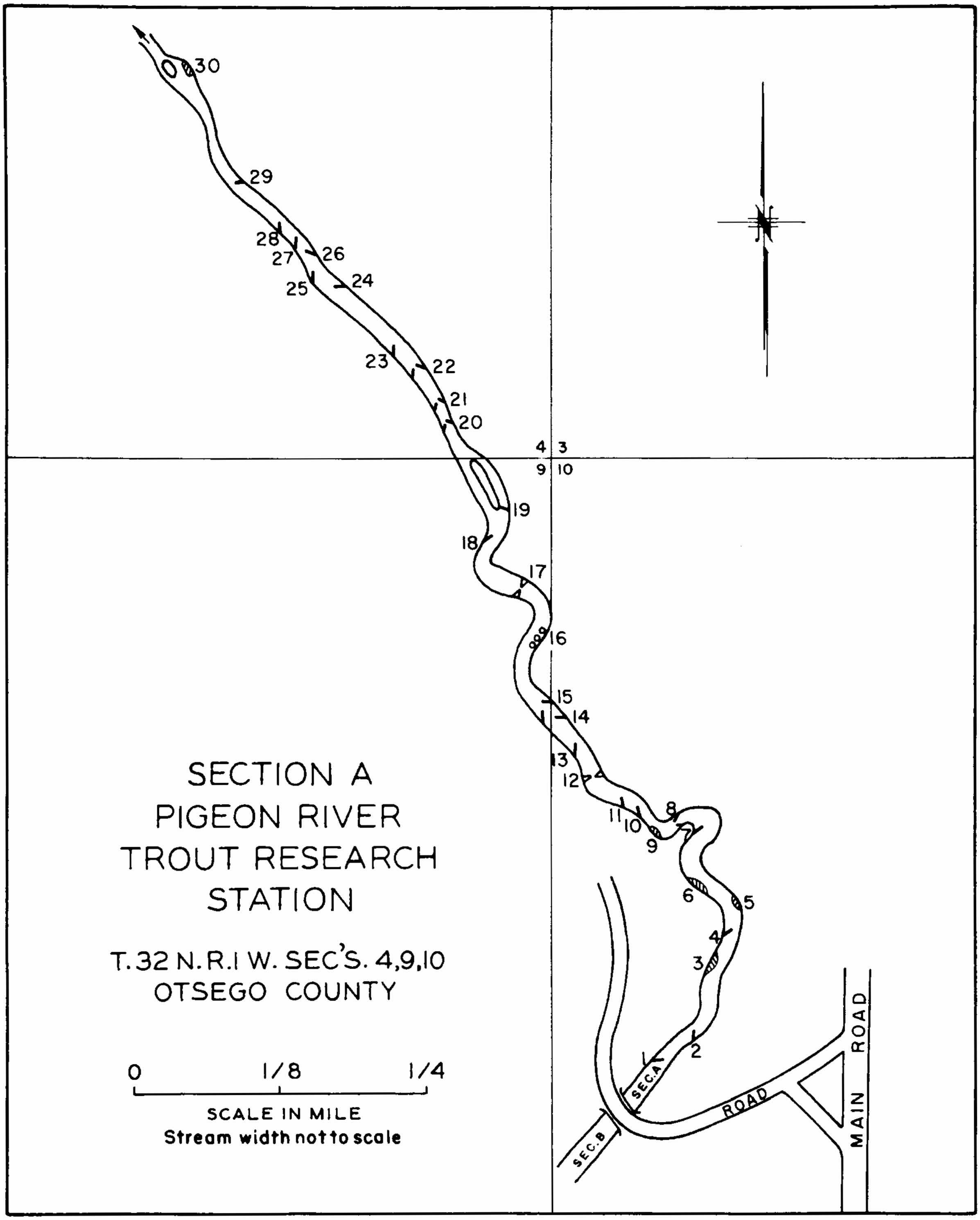
The stream improvement work in Section A was done by the Lake and Stream Improvement Section of the Fish Division, while creel census data and population estimates were obtained by the staff of the Pigeon River Trout Research Station. The project was under the general supervision of A. S. Hazzard, G. P. Cooper and D. S. Shetter. Many of the data included in this report are taken from the annual reports of the Pigeon River Trout Research Station appearing as Institute for Fisheries Research reports, numbers 1250, 1288 (Cooper, 1950, 1951), 1512, 1521, and 1527 (Waters, 1957a, b, c). Thanks are due especially to D. W. Hayne for assistance with statistical treatment of data.

Method of evaluation

In a preliminary study of the data on catch and standing crop of trout in the experimental sections, it was obvious that year-to-year variations were of such proportions as to mask, to the casual eye at least, any changes effected by the stream improvement in Section A. It became necessary, therefore, to evaluate the effects of the stream improvement by some other means than a direct comparison of the catch and standing crop in Section A alone between the groups of years before stream improvement and the years following stream improvement. The method used in the following sections was followed.

Section B (1.19 miles in length, 5.90 acres), in which stream improvement was not made, and in which fishing regulations were identical to those

Figure 2.--Locations of channel improvement structures put in Section A of the Pigeon River during 1953. Individual structures are described in Table 1.


SECTION A
PIGEON RIVER
TROUT RESEARCH
STATION
T.32 N.R.1 W. SEC'S. 4,9,10
OTSEGO COUNTY
0
1/8
1/4
SCALE IN MILE
Stream width not to scale
N
4
3
9
10
MAIN ROAD
ROAD
SEC. A
SEC. B
1
2
3
4
5
6
7
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30

Figure 2

Table 1.--Descriptions of stream improvement structures placed in Section A (location of numbered structures are shown in Fig. 2)

Number	Structure description
1	Single wing deflector, sheet piling
2	Single wing deflector, rock and sheet piling
3	Sodded log cover
4	Single wing deflector, sheet piling
5	Sodded log cover
6	Sodded log cover
7	Single wing deflector, sheet piling
8	Double wing off-set deflector, sheet piling
9	Sodded log cover
10	Single wing deflector, sheet piling
11	Single wing deflector, sheet piling
12	Double wing deflector
13	Single wing deflector, sheet piling
14	Single wing deflector, sheet piling
15	Double wing off-set deflector
16	Stump cover
17	Double wing deflector
18	Single wing deflector, sheet piling
19	Barrier dam, to cut off channel
20	Double wing deflector, sheet piling
21	Double wing deflector, sheet piling
22	Double wing deflector, sheet piling
23	Single wing deflector, sheet piling
24	Single wing deflector, sheet piling
25	Single wing deflector, sheet piling
26	Single wing deflector, sheet piling
27	Single wing deflector, sheet piling
28	Single wing deflector, sheet piling
29	Single wing deflector, sheet piling
30	Channel clearing, log jams removed

in Section A, was used as a control. The ratio A:B for the statistic tested (such as catch, standing crop, etc.) was computed for each year (1949-56), and the mean of these ratios for the years prior to stream improvement (1949-53) was compared to the mean for the years after stream improvement (1954-56). A *t* test was used to determine whether the ratio under consideration changed significantly after stream improvement. Using a control in this manner, the effects of natural factors affecting the catch and standing crop were essentially removed, since presumably such natural factors would be operative in both Sections A and B to a similar degree.

It might be more appropriate, theoretically, to consider the logarithms of the ratios A:B (i.e., logarithm of A minus logarithm of B) rather than the ratios. Or, to avoid any assumptions concerning the statistical distribution of the ratios, the non-parametric Mann-Whitney *U* test may be used (Siegel, 1956). In the present instance, computation by either of these alternative methods leads to the same over-all conclusions, differing in details of the probabilities involved.

Anglers' catch

In Table 2 are presented data on the total catch by anglers of wild, legal-size trout of all species (brook, brown and rainbow), in Sections A and B, for all years from 1949 to 1956, in terms of numbers and, in Table 3, in terms of weight. The ratios A:B for numbers and weight are also given, as well as the average ratio for these statistics for the years before, and the years after, stream improvement. For catch in numbers, the ratio A:B increased from an average of 0.566 before stream improvement (1949-53) to an average of 0.805 after stream improvement (1954-56), an increase of 42 percent (*t* value 3.94, 6 degrees of freedom, significant at less than the 1 percent level). For catch in weight (pounds), the

Table 2.--Numbers of wild trout of legal size (7 inches and larger) taken by anglers in Sections A and B, Pigeon River, 1949-56

Year	Section A				Section B				Ratio, A:B	Mean ratio, A:B
	Brook	Brown	Rainbow	Total	Brook	Brown	Rainbow	Total		
1949	93	22	12	127	141	59	17	217	0.585	
1950	87	26	3	116	139	85	7	231	0.502	
1951	174	27	2	203	214	161	6	381	0.533	0.566
1952	168	27	14	209	221	72	18	311	0.672	
1953	116	22	13	151	164	60	57	281	0.537	
	Stream improvement in Section A									
1954	244	42	5	291	279	121	16	416	0.700	
1955	163	25	6	194	163	47	13	223	0.870	0.805
1956	114	39	4	157	101	79	6	186	0.844	

Table 3.--Pounds of wild trout of legal size (7 inches and larger) taken by anglers in Sections A and B, Pigeon River, 1949-56

Year	Section A				Section B				Ratio, A:B	Mean ratio, A:B
	Brook	Brown	Rainbow	Total	Brook	Brown	Rainbow	Total		
1949	15.8	5.6	2.3	26.7	24.5	14.7	3.9	43.1	0.618	
1950	14.6	6.7	0.6	21.9	24.5	20.7	1.3	46.5	0.471	
1951	31.7	7.4	0.5	39.6	43.0	35.6	2.1	80.7	0.491	0.564
1952	28.6	7.3	3.2	39.1	36.1	17.8	4.2	58.1	0.672	
1953	23.7	6.8	2.9	33.4	31.3	17.1	10.6	59.0	0.567	
	Stream improvement in Section A									
1954	48.7	13.5	1.5	63.7	46.2	41.8	5.6	93.6	0.681	
1955	31.4	7.7	1.0	40.1	30.4	19.7	2.9	53.0	0.758	0.739
1956	17.6	17.6	1.4	36.6	17.4	26.9	2.9	47.2	0.778	

ratio A:B increased similarly from 0.564 to 0.739, an increase of 31 percent (*t* value 3.67, 6 degrees of freedom, significant at slightly above the 1 percent level).

Fall standing crop

In Table 4 are presented the post-trout-season population estimates, in terms of weight, for all three species, for the years from 1949 to 1956. The ratios A:B are also given, as well as the average ratios for the years before and after stream improvement. Although the average ratio A:B increased from 0.595 (before, 1949-53) to 0.661 (after, 1954-56), the increase was not statistically significant (*t* value 0.41, 6 degrees of freedom, significant at over the 50 percent level).

To determine whether the stream improvement had any effect upon the spawning and reproductive activities of trout in Section A, another *t* test was made separately for the fall population estimates of the young-of-year fish. Estimates for the various age groups were not available for all of the years concerned; for purposes of this test, all wild trout up to 4.9 inches in total length were assumed to be young-of-year (age group 0) and were used in the test. Table 5 presents the numbers of young-of-year trout (up to 4.9 inches), of all three species, estimated to be present in the fall of the year in Sections A and B. The ratios A:B are also given, as well as the average ratios for the years before and after stream improvement. The average ratio increased from 0.426 (before, 1949-53) to 0.676 (after, 1954-56); this difference was significant at between the 1 and 2 percent levels (*t* value 3.46, 6 degrees of freedom).

Table 4.--Post-trout-season standing crop (pounds) of trout of all sizes in Sections A and B, Pigeon River, 1949-56

Year	Section A				Section B				Ratio, A:B	Mean ratio, A:B
	Brook	Brown	Rainbow	Total	Brook	Brown	Rainbow	Total		
1949	13.3	33.6	1.3	48.2	24.0	66.8	0.9	91.7	0.526	
1950	30.5	30.0	0.6	61.1	50.8	88.4	1.7	140.9	0.434	
1951	41.0	28.9	4.8	74.7	63.6	68.0	3.2	134.8	0.554	0.595
1952	45.1	36.9	3.3	85.3	62.3	50.9	4.7	117.9	0.724	
1953	71.7	53.6	2.1	127.4	77.6	90.2	5.4	173.2	0.735	
	Stream improvement in Section A									
1954	54.7	34.6	1.0	90.3	101.7	113.7	2.8	218.2	0.414	
1955	41.6	57.0	2.0	100.6	40.6	66.1	0.6	107.3	0.938	0.661
1956	25.7	32.4	0.2	58.3	24.7	67.1	0.5	92.3	0.632	

Table 5.--Post-trout-season standing crop of wild young-of-year trout (numbers) in Sections A and B, Pigeon River, 1949-56 (trout up to 4.9 inches in length assumed Age Group 0)

Year	Section A				Section B				Ratio, A:B	Mean ratio, A:B
	Brook	Brown	Rainbow	Total	Brook	Brown	Rainbow	Total		
1949	189	173	0	362	547	454	7	1,008	0.359	
1950	465	167	9	641	995	686	0	1,681	0.381	
1951	798	204	57	1,059	1,992	387	131	2,510	0.422	0.426
1952	905	208	12	1,125	2,365	813	157	3,335	0.337	
1953	1,230	236	15	1,481	2,032	283	30	2,345	0.632	
	Stream improvement in Section A									
1954	1,578	230	7	1,815	2,503	469	40	3,012	0.603	
1955	760	236	9	1,005	841	458	10	1,309	0.768	0.676
1956	502	219	6	727	707	365	35	1,107	0.657	

Relation of stream improvement to catch and production

As pointed out above, the increase in catch was statistically significant while the increase in fall standing crop was not. If it was true that the production of wild trout did not increase, then an increase in the anglers' catch probably was due to increased exploitation. Rates of exploitation, as presented in Table 6, were computed by Cooper's (1952) method (comparing the catch with the sum of catch and legal trout remaining after the trout season). It was determined that, in Section A, the rate of exploitation increased from an average of 49.6 percent before stream improvement to an average of 63.1 percent after stream improvement (t value 2.35, 6 degrees of freedom, significant at slightly above the 5 percent level); in Section B, the rate of exploitation increased from 54.9 percent to 61.5 percent in the same years, a change much smaller than in Section A (t value 1.63, 6 degrees of freedom, significant at somewhat above the 10 percent level). The relative increase in exploitation in A as compared to B (examined as the ratio A:B) was not of a statistically significant magnitude (t value 1.05, 6 degrees of freedom, significant above the 30 percent level. The writer believes the more appropriate test is the one which compares exploitation in Section A alone before and after improvement, rather than the test which relates A to B; the former test shows the higher exploitation in Section A to be significant at slightly above the usually accepted 5 percent significance level.

When the anglers' catch and the estimated fall standing crop are summed for each year, giving a total figure in pounds of trout available in each section for the year, and the ratios A:B computed and compared, there again does not appear to be a statistically significant increase;

Table 6.--Rate of exploitation of wild, legal-size trout (brook, brown, and rainbow in Sections A and B, Pigeon River, 1949-56)

Section	Year	Number of trout in anglers' catch	Number of legal trout in fall population	Percentage exploitation	
				Annual	Mean
	1949	127	123	50.8	
	1950	116	142	44.9	
	1951	203	220	48.0	49.6
	1952	209	194	51.9	
A	1953	151	137	52.4	
		Stream improvement in Section A			
	1954	291	111	72.4	
	1955	194	171	53.2	63.1
	1956	157	90	63.6	
	1949	217	212	50.6	
	1950	231	264	46.7	
	1951	381	323	56.9	54.9
	1952	311	125	71.3	
B	1953	281	290	49.2	
		Stream improvement in Section A			
	1954	416	319	56.6	
	1955	223	100	69.0	61.5
	1956	186	129	59.0	

the average ratio before stream improvement was 0.586, while the average ratio after stream improvement, was 0.685 (t value 0.81, 6 degrees of freedom, significant at slightly below the 50 percent level). There is thus no reliable evidence from this test that there was any increase in production.

If there was in fact no relative change in production, but a relative increase in catch, then logically there must have been a relative increase in exploitation, even though the relative increase in exploitation rate was not statistically significant. In other words, it appears that the stream improvement may have been responsible for the greater rate of exploitation while having no effect upon production, an effect which certainly is still of value to the angler since it adds to the creel at least certain fish which otherwise would fall prey to natural mortality factors during the open trout season. In fact, a greater rate of exploitation might result in a greater survival of fish which otherwise would be lost to natural mortality, since as the season progresses and anglers remove more trout, the population density will decrease, and density-dependent natural mortality factors may affect the population to a lesser degree.

The question remains: What was the cause of the greater exploitation? One possibility is that the stream improvement in Section A attracted a greater fishing pressure resulting in a greater catch. Another is that the stream improvement, with its more abundant cover and pools resulting from deflectors, permitted the anglers to harvest the fish more easily.

Table 7 presents the fishing pressure in hours in Sections A and B, and also the ratios A:B for each year. There appears to have been two principal changes in the A:B ratio during the years 1949-56: one of from an average of 0.377 during 1949-52 to an average of 0.634 during 1953-54, and the other change was to an average of 0.855 during 1955-56.

Table 7.--Fishing pressure (hours) in Sections A and B, Pigeon River, 1949-56

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
1949	861.0	2,385.0	0.361	
1950	898.0	2,130.5	0.421	
1951	950.5	3,148.0	0.302	0.419
1952	660.0	1,563.0	0.422	
1953	965.0	1,535.0	0.629	
	Stream improvement in Section A			
1954	1,119.5	1,756.0	0.638	
1955	977.0	1,125.0	0.868	0.783
1956	882.0	1,046.5	0.842	

Two factors may have been responsible for these changes in the A:B ratio. The first is that during 1949-51, heavy plantings of legal-sized hatchery trout were made in Section B, which apparently attracted a heavy fishing pressure in that section, and which would cause a low A:B ratio. The low A:B ratio, however, persisted through 1952, a year in which there was not a heavy planting of legal-sized hatchery trout. In 1953, the A:B ratio increased substantially; the one-year lag may have been due to the failure of the anglers to adjust immediately to the cessation of the legal plantings in Section B.

The second change in A:B ratio, from 1954 to 1955, may have been due to an attraction of fishing pressure by the stream improvement in Section A, producing a higher A:B ratio, but, again, with a one-year lag.

Proceeding with the hypothesis that the total wild catch is a function of total fishing pressure, it would be expected that the A:B ratio for anglers' catch would have increased from 1952 to 1953 corresponding with the increase in A:B ratio for fishing pressure. However, this was not the case; the A:B ratio for anglers' catch increased only after stream improvement was placed in Section A, indicating that the increased exploitation in Section A may have been due to an increased catchability of the wild trout in that section, rather than to an increased fishing pressure, and also that fishing pressure may be a function (with obvious limits) of total catch. Perhaps the increased pressure in Section A in 1955-56 (that is, relative to Section B) was attracted by the better fishing (relative to Section B).

In analyzing the population estimates of the young-of-year trout, a statistically significant increase in the ratio A:B was observed, as pointed out in an earlier section. The reason for this increase may, of course, be assigned to the stream improvement; in other words, more young trout may have been produced (up to the fall of the first year of life, at least), but these increases are not reflected in the estimates of total fall standing crop in terms of weight, perhaps due to an increased mortality in the second or third year of life effected by density-dependent mortality factors. Another confounding factor to be considered in the question of the causality which may be inferred between stream improvement and the increased production of young-of-year, however, is the fact that, beginning in the fall of 1952, and continuing in each succeeding fall through that of 1955, plantings of sublegal hatchery brook and brown trout were made in Section A (project 27k, planting of hatchery fingerlings in the fall to compensate for lack of natural spawning). The possibility exists that the increased production of young-of-year was due to the additional spawning by these hatchery fish. In Table 5, which includes the A:B ratios for numbers of young-of-year trout estimated in Sections A and B in the fall, it can be noted that the A:B ratios were larger in 1953 and following years. An examination of the numbers present of the various species indicates that a relative increase in the number of young-of-year brook trout in Section A was principally responsible for the increase in the A:B ratio. Since the plantings of hatchery trout began in the fall of 1952 and continued through the fall of 1955, it is possible that the trout when planted contributed to the spawning of the same fall as planted and to the young-of-year crop of the following fall; particularly this may have been the case with brook trout since this species may spawn at a small size, while brown trout usually are larger when mature. Fall population studies indicated that in the case of those hatchery trout which survived to the following fall, however, there were not substantially larger numbers in Section A than in Section B (because of migration into Section B) and most of the one-year survivors were brown trout. The brook trout planted possibly included mature fish, since the average size of fish planted was reported to be about 5 inches in 1952 (probably these fish were larger, since weight records indicated an average size of about 6 inches); 4.9 inches in 1953; 5.2 inches in 1954; and 4.3 inches in 1955. (All hatchery trout were marked, and the recoveries of marked fish, of course, were not included in the anglers' catch of wild trout.) Whatever the cause of the increased production of young-of-year trout, the increase does not appear to be reflected in the total estimate of fall standing crop, presumably because of increased mortality.

It might of course be argued that the increased anglers' catch was the result of the increased production of young-of-year trout; if this were true, the increased anglers' catch of wild trout may reasonably be assigned as an indirect effect either of the planting program or of stream improvement in raising reproductive success, or as the direct result of stream improvement in increasing the rate of exploitation. Since neither the estimated fall standing crop nor the sum of the fall standing crop and anglers' catch indicated an increase in production, it was concluded that the latter effect was the one observed.

In summary, it appears that the effects of the stream improvement in Section A were to increase the anglers' catch by effecting an increase in the rate of exploitation, while production of trout was not affected. The increased fall standing crop of young-of-year trout may have been an indirect effect of the planting program conducted concurrently in Section A.

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