Original: Fish Division
cc: Educ.-Game
Inst. for Fish. Research
Pigeon River Station
Hunt Creek Station
Region II, Fish
Vic Beresford
W. C. Latta

INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN DEPARTMENT OF CONSERVATION
COOPERATING WITH THE
UNIVERSITY OF MICHIGAN

GERALD P. COOPER PH.D.
DIRECTOR

ADDRESS
UNIVERSITY MUSEUMS ANNEX
ANN ARBOR, MICHIGAN

September 28, 1960

Report No. 1608

THE EFFECTS OF STREAM IMPROVEMENT UPON THE ANGLERS' CATCH AND STANDING CROP OF TROUT IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN

By

William C. Latta

The purpose of this study was to evaluate the effects of improvement of the stream habitat upon the anglers' catch and the standing crop of brook and brown trout[1] in the Pigeon River, Otsego County, Michigan. Most previous attempts to evaluate stream habitat improvement have either concentrated upon the physical and bottom fauna changes and barely considered the trout populations (Tarzwell, 1937; Hunter, Thorpe and Grosvenor, 1941; Madsen, 1938) or else the streams studied were not typical of Michigan streams (Tarzwell, 1938). The exception was the study of Shetter, Clark and Hazzard (1949) which considered the physical changes as well as the changes in the bottom fauna, fish population and catch brought about by deflectors in a small Michigan brook trout stream (Hunt Creek). The present study considers brown trout as well as brook trout in a larger stream of poorer quality than Hunt Creek.

Six miles of the Pigeon River, divided into five almost equal experimental sections, are under the control of the Pigeon River Trout Research Station of the Michigan Department of Conservation (Fig. 1). Fishing is allowed only by permit, thus guaranteeing a nearly complete record of the catch. In addition to the catch

---

[1] Although rainbow trout are present in the Pigeon River, they contribute so little to the catch (about 5 percent) and standing crop (about 2 percent) that they are not considered in this report.

Figure 1.--Map of Pigeon River, showing experimental **sections.**

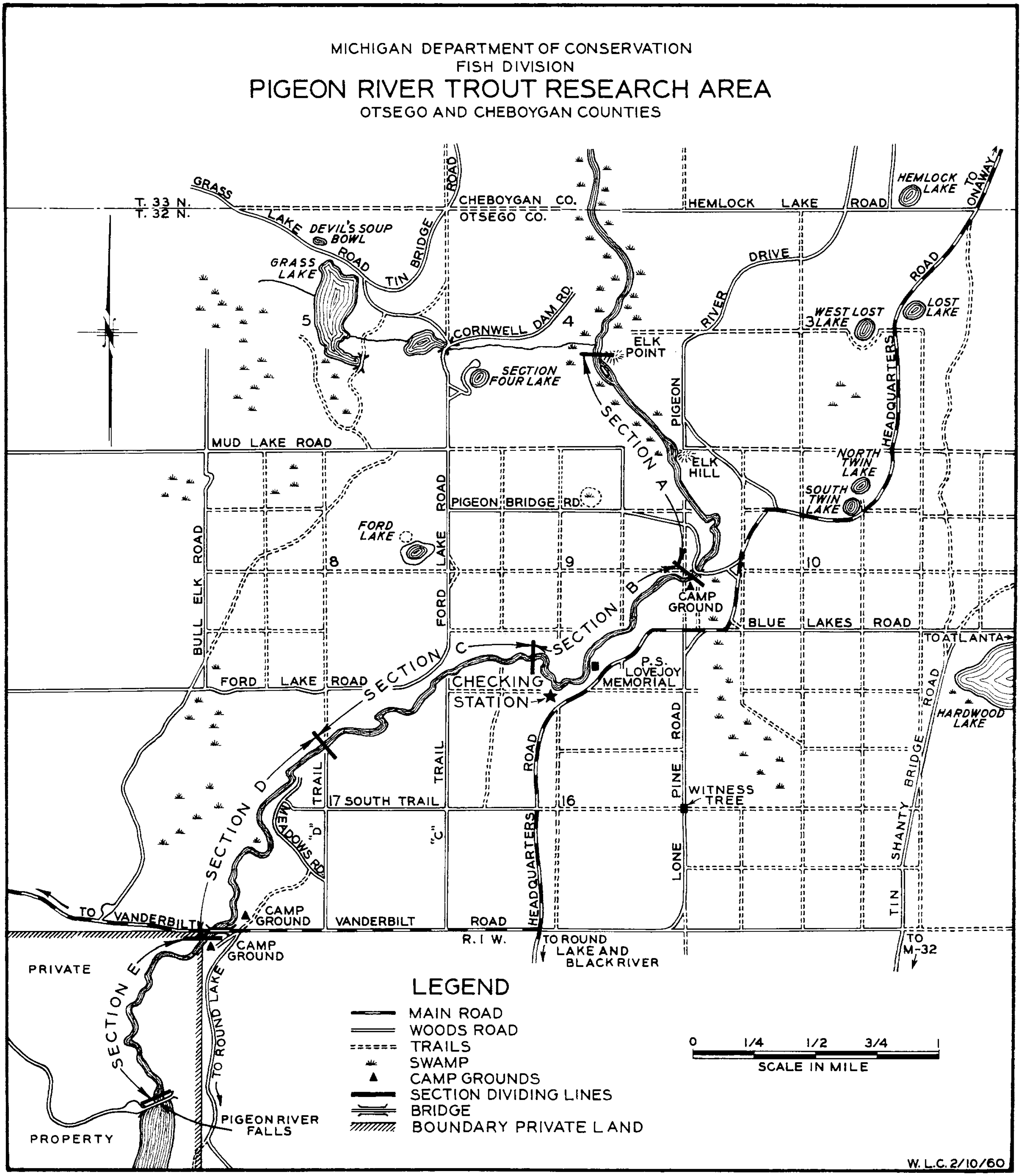

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION
PIGEON RIVER TROUT RESEARCH AREA
OTSEGO AND CHEBOYGAN COUNTIES
T. 33 N.
T. 32 N.
CHEBOYGAN CO.
OTSEGO CO.
GRASS LAKE ROAD
DEVIL'S SOUP BOWL
GRASS LAKE
TIN BRIDGE ROAD
HEMLOCK LAKE ROAD
HEMLOCK LAKE
TO ONAWAY
PIGEON RIVER DRIVE
HEADQUARTERS ROAD
WEST LOST LAKE
LOST LAKE
CORNWELL DAM RD.
SECTION FOUR LAKE
ELK POINT
MUD LAKE ROAD
SECTION A
ELK HILL
NORTH TWIN LAKE
SOUTH TWIN LAKE
PIGEON BRIDGE RD.
FORD LAKE
FORD LAKE ROAD
BULL ELK ROAD
SECTION B
CAMP GROUND
BLUE LAKES ROAD
TO ATLANTA
SECTION C
CHECKING STATION
P.S. LOVEJOY MEMORIAL
HARDWOOD LAKE
TIN SHANTY BRIDGE ROAD
SECTION D
17 SOUTH TRAIL
TRAIL "D"
TRAIL "C"
MEADOWS RD.
HEADQUARTERS ROAD
LONE PINE ROAD
WITNESS TREE
5
4
3
8
9
10
16
TO VANDERBILT
VANDERBILT ROAD
CAMP GROUND
R. I W.
TO ROUND LAKE AND BLACK RIVER
TO M-32
PRIVATE PROPERTY
SECTION E
TO ROUND LAKE
PIGEON RIVER FALLS
LEGEND
MAIN ROAD
WOODS ROAD
TRAILS
SWAMP
CAMP GROUNDS
SECTION DIVIDING LINES
BRIDGE
BOUNDARY PRIVATE LAND
0 1/4 1/2 3/4 1
SCALE IN MILE
W. L. C. 2/10/60

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 are stated on the fishing permit.

In addition to the information on fishing success collected from anglers using the area, periodic estimates are made of the size of the trout populations and the rates of growth and mortality of the fish are determined. All of these factors—fishing success, total catch, population size, growth, mortality and any others that are pertinent—are used in the evaluation of research projects.

Research projects include the evaluation of various changes in the fishing regulations, the correct stocking programs for the lakes and stream, and the effects of stream improvement, as well as studies of the basic biology of trout.

The research station also provides a base for studies on waters outside of the experimental area.

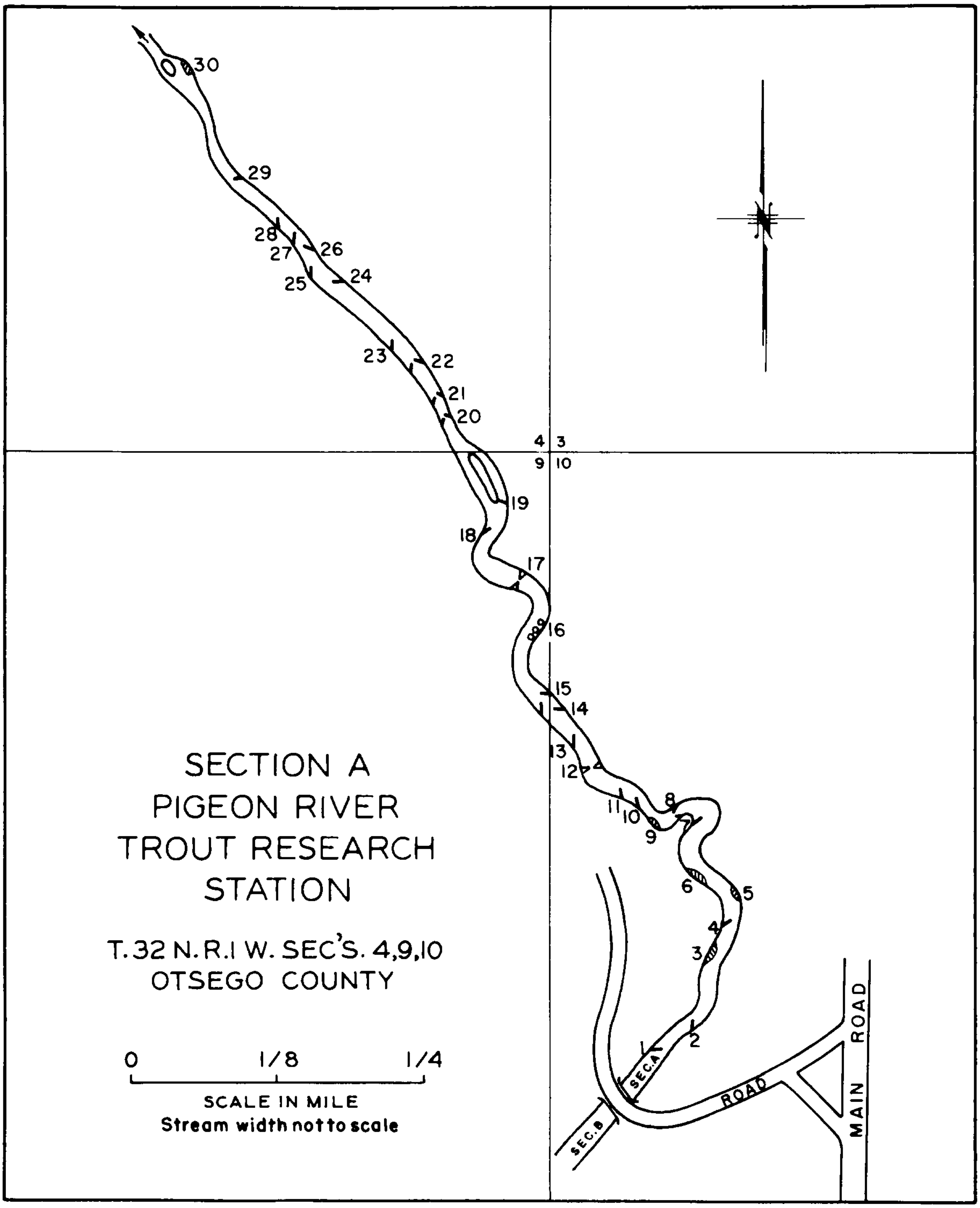
records, an estimate is made each fall, at the close of the fishing season, of the standing crop of fish in the river. These data have been recorded since the establishment of the Station in 1949.

Section A, at the downstream end of the experimental water, was selected for the present study. Records previous to 1953 showed that, relative to the other sections, Section A had been consistently low in contributing trout to the anglers' catch and also low in fall standing crop. Most of Section A consisted of wide, shallow areas of shifting sand. The gradient was low and there was little ground water. Section A is 1.31 miles long and has an area of 7.16 acres (Cooper, 1952). Fishing regulations for the ten years of the experiment were 5 fish per day, and a minimum size of 7 inches.

During the fall of 1953, at the end of the fishing season, stumps, sodded logs, a barrier dam and sheet-piling deflectors were installed, and a channel was cleared, to improve the trout habitat in Section A (see Fig. 2 and Table 1). In the years that followed, the action of the deflectors exposed numerous logs (remnants from the lumbering era) which had been buried in the sand of the stream bed. These half-buried logs, many of which were anchored to the banks, created much additional cover for trout, particularly in the lower half of the section. To evaluate the improvement work, creel census data and fall population estimates for the years 1949-53 (before stream improvement) were compared with data for the years 1954-58 (after stream improvement).

The improvement work in Section A was done by the Lake and Stream Improvement Section of the Fish Division, while creel census data and estimates of the standing crop 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. The data included in this report are taken from the Station's files or from the annual reports of the Pigeon River Trout Research Station appearing as Institute for Fisheries Research Reports, Numbers 1250, 1288 (Cooper, 1950, 1951),

Figure 2.--Section A of the Pigeon River, showing locations of thirty stream improvement structures installed during 1953. The individual structures are described in Table 1.



30
29
28
27
26
25
24
23
22
21
20
4 3
9 10
19
18
17
16
15
14
13
12
11
10
9
8
6
5
4
3
2
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
SEC.A
SEC.B
ROAD
MAIN ROAD

Figure 2

Table 1.--Descriptions of stream improvement structures placed in Section A (Locations 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, sheet piling
13	Single wing deflector, sheet piling
14	Single wing deflector, sheet piling
15	Double wing off-set deflector, sheet piling
16	Stump cover
17	Double wing deflector, sheet piling
18	Single wing deflector, sheet piling
19	Barrier dam, to cut off channel, sheet piling
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

1512, 1521, 1527 (Waters, 1957a, b, c), 1544 (Bacon, Shetter and Cooper, 1958), 1560 and 1568 (Latta, 1959a, b). D. W. Hayne suggested many of the methods for statistical treatment of the data.

A progress report on the effects of stream improvement in Section A was prepared by T. F. Waters in 1958 (Inst. Fish. Res., Rept. No. 1541). Waters' report combined the three species of trout and compared catch records and fall population figures for five years (1949-53) prior to improvement with data for three years (1954-56) following improvement. Waters found large year-to-year variations in the catch records and population figures for Section A, and because such variations might have been caused by time-related factors other than improvement, he used catch and population figures for Section B of the Pigeon River as a control. His method was to relate catch figures for Section A to corresponding yearly catch figures for B, and to relate fall population figures in the same way; his conclusions on the effects of improvement in A were based on an analysis of these ratios.

In the present report (referred to by Waters in Rept. No. 1541 as the forthcoming "final report"), the catch and population figures are again examined by relating data for Section A to data for B. However, there is an important complication in the use of Section B as a control for time due to the fact that fishing pressure in B was unusually high during the years 1949-51 when this section was planted with legal-size hatchery trout. The large drop in fishing pressure in B following 1951 (obviously due to the cessation of hatchery plantings) limits the value of Section B as a control (for A) in the present study. Thus in the present report, the effects of improvement of Section A are also judged on the basis of actual changes in catch and population data for A, before and after improvement, independent of the relationship of data for A and B. The data for Section B, before and after, are also considered alone.

In Waters' progress report the three species of trout (brook, brown and rainbow) present in the Pigeon River were considered as a group in the analysis of the catch and population data, whereas in the present report the brook and brown trout are considered separately. Further, the method of calculating the fall population size has been changed. In the previous report, the population size was calculated (by the mark-and-recapture method) for four size categories: (1) 0 to 3.9 inches, (2) 4.0 to 6.9 inches, (3) 7.0 to 9.9 inches, and (4) 10.0 inches and larger, for all species combined and for the entire 6 miles of experimental water as a unit. Then, the estimate for each size category was proportioned, on the basis of number of fish caught in two trips through the experimental water with the direct-current shocker (one trip to mark, the second to recapture), into number of fish in each section of stream, and then further broken down into number of each species and number in each inch group (Waters, 1957a). This method does not give enough weight to the difference in catchability between species and the difference in catchability of fish between sections.

For the present report the mark-and-recapture method was again used, but the calculations were made separately for each inch group of each species for each section.

In order to compute the pounds of trout in the standing crop, the average weight of each inch group of each species (based on the calculated weight at each tenth of an inch) was found, utilizing the published length-weight relationships of Pigeon River trout (Cooper and Benson, 1951).

Although in the original experimental outline no allowance was made for the exclusion of the year 1954, a logical argument can be made that this year was a period of transition, in which the stream was changing both physically and biologically after installation of the improvement structures, and should not be included in the analysis. J. W. Leonard (quoted in Shetter, Clark and Hazzard, 1949) indicated that it took more than a year for the bottom fauna to attain anything approaching normal abundance after the physical changes brought about by the construction of deflectors in Hunt Creek. The present analysis considers the post-improvement data, both with and without the year 1954.

Hatchery fish were excluded from the present tabulations.

Anglers' catch

Table 2 gives the mean values for catch and fall population data in Sections A and B, for the brook and brown trout, before (1949-53) and after (1954-58) stream improvement. These means were calculated from the data given in Tables 3-10, 12 and 13. The figures in parentheses are mean values with 1954 excluded. Figures 3 and 4 present graphically some aspects of the fall trout population and the anglers' catch in Sections A and B. Figure 5 shows the fishing pressure and catch per hour per trip in each section.

Section A.--The mean number per year of brook trout in the anglers' catch in Section A was 131 for the 5-year period before stream improvement, and 179 for the 5-year period after stream improvement, an increase of 37 percent. Similarly, the mean annual catch of brown trout was 26 before improvement, and 33 after improvement, an increase of 27 percent. However, the annual variation in catch was large, both before and after improvement (Table 3, Fig. 3), so that an appropriate statistical test is needed to determine whether the observed difference could have occurred purely by chance from a series of annual records with this much variation. Using the standard t test for significant difference in catch before and after improvement, the t value for brook trout was 1.55 with 8 d.f., and the t value for brown trout was 1.75 with 8 d.f. For this t test for brook trout, the statistical probability value is approximately 0.17, and for brown trout approximately 0.12; which means that there is one chance out of six for brook trout, and one chance out of eight for brown trout that the increases of 37 percent for brook trout and 27 percent for brown trout were the result of chance variation rather than being due to stream improvement. The usual standard set for this type of test is to require a P value of less than 0.05 to give 19 to 1 odds that the difference is statistically significant. Thus, although the average increases in catch of brook and brown trout were appreciable percentagewise, the 10 years of records

Table 2.--Mean values for the catch and fall population of brook and brown trout before (1949-53) and after (1954-58) stream improvement, Sections A and B, Pigeon River

Section, species of trout, and period	Trout in catch: Number	Trout in catch: Pounds	Fall standing crop (pounds)	Catch plus standing crop (pounds)	Number of trout in fall population: Young of year	Number of trout in fall population: Trout 7 inches and larger	Rate of exploi-tation	Natural mortality rate
SECTION A								
Brook								
Before	131	23.1	45.6	68.8	746	85	0.18	0.44
After[1]	179 (163)	32.9 (29.2)	40.3 (30.6)	73.2 (59.8)	730 (482)	58 (52)	0.20 (0.21)	0.57 (0.58)
Brown								
Before	26	6.9	41.7	48.6	217	105	0.10	0.45
After[1]	33 (30)	14.0* (14.0)*	52.0 (53.4)	66.0* (67.4)*	509 (564)	111 (104)	0.07 (0.06)	0.63 (0.66)
SECTION B								
Brook								
Before	186	31.6	56.5	88.1	1,553	53	0.14	0.63
After[1]	180 (154)	31.9 (28.2)	45.3 (32.5)*	77.1 (60.7)*	1,246 (897)	50 (39)	0.12 (0.12)	0.70 (0.72)
Brown								
Before	91	21.8	79.4	101.3	662	196	0.10	0.62
After[1]	69 (55)	25.2 (21.1)	73.4 (64.7)	98.7 (85.8)	735 (810)	150 (128)	0.09 (0.07)	0.63 (0.68)

	Total fishing pressure (hours)	Catch per hour per trip (brook plus brown trout)
SECTION A		
Before	866.9	0.20
After[1]	963.6 (924.6)	0.21 (0.20)
SECTION B		
Before	2,152.3	0.14
After[1]	1,233.5* (1,102.9)*	0.20* (0.18)

[1] Mean values after exclusion of 1954, are in parentheses.

* Significant at 0.050 level or lower in comparison with mean ratio for years 1949-53.

Figure 3.--Fall trout populations and anglers' catch, Section A, Pigeon River, 1949-58.

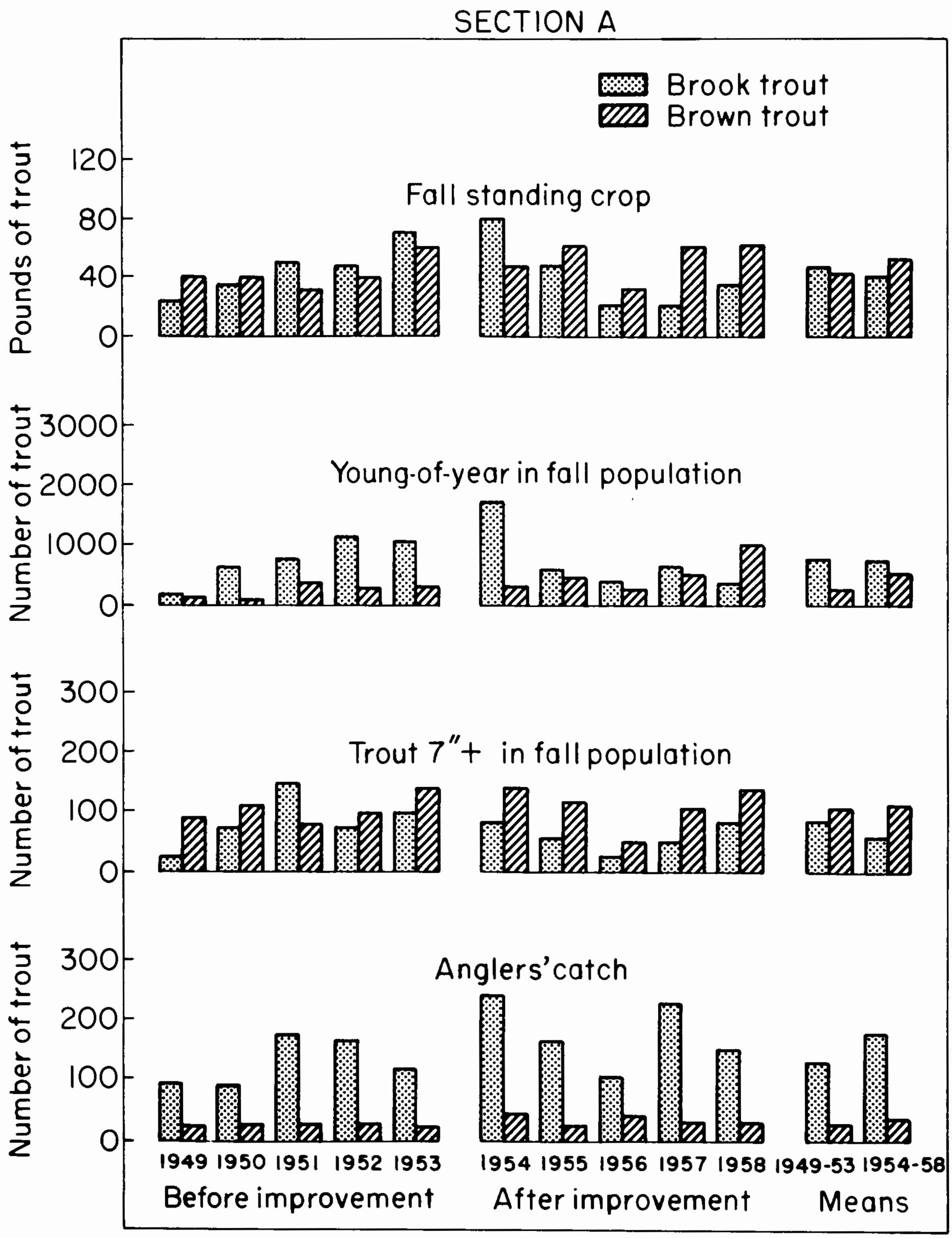

SECTION A
Brook trout
Brown trout
Pounds of trout
120
80
40
0
Fall standing crop
Number of trout
3000
2000
1000
0
Young-of-year in fall population
Number of trout
300
200
100
0
Trout 7"+ in fall population
Number of trout
300
200
100
0
Anglers' catch
1949 1950 1951 1952 1953
1954 1955 1956 1957 1958
1949-53 1954-58
Before improvement
After improvement
Means

Figure 3

Figure 4.--Fall trout populations and anglers' catch, Section B, Pigeon River, 1949-58.

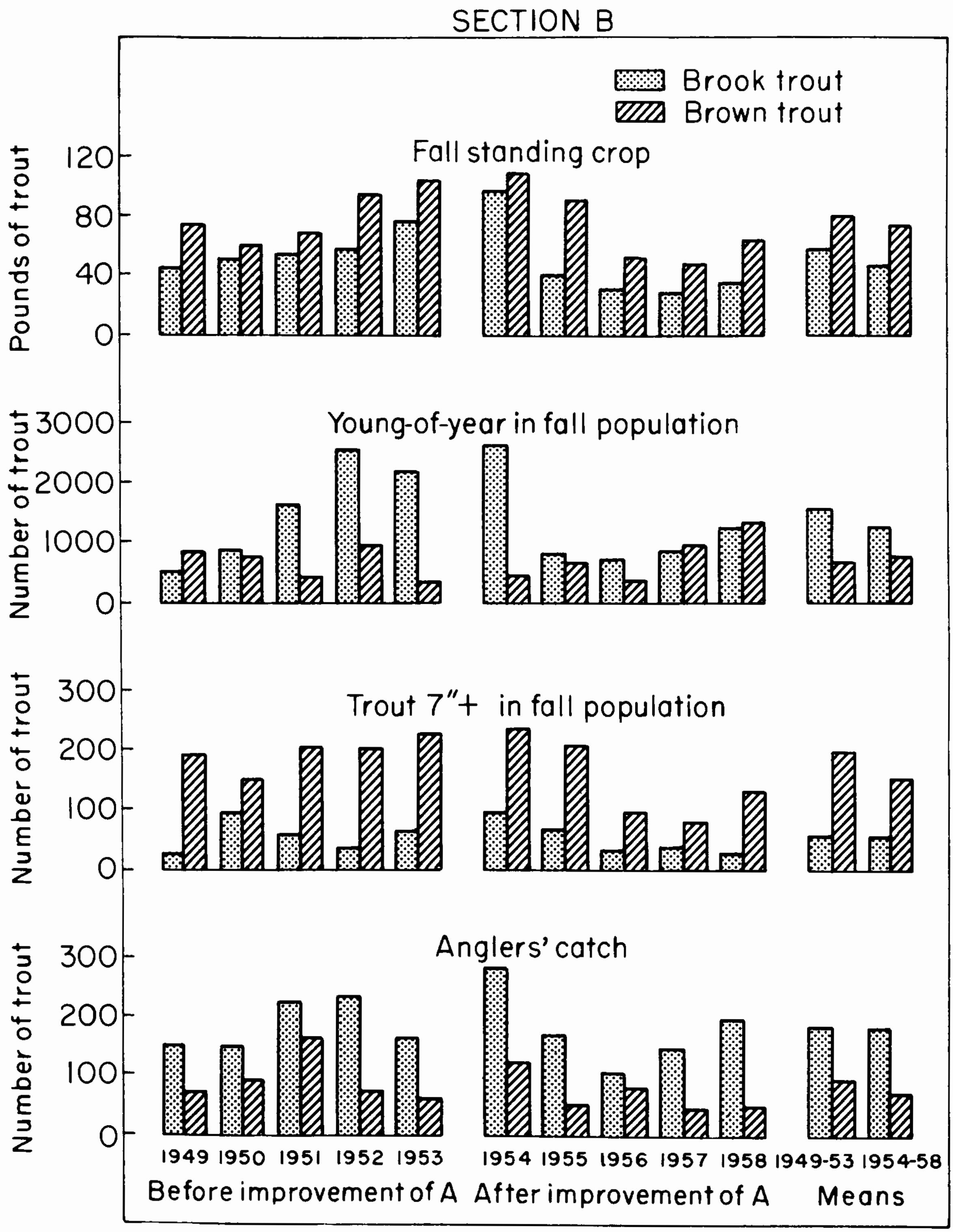

SECTION B
Brook trout
Brown trout
Fall standing crop
Pounds of trout
120
80
40
0
Young-of-year in fall population
Number of trout
3000
2000
1000
0
Trout 7"+ in fall population
Number of trout
300
200
100
0
Anglers' catch
Number of trout
300
200
100
0
1949 1950 1951 1952 1953
1954 1955 1956 1957 1958
1949-53 1954-58
Before improvement of A
After improvement of A
Means

Figure 4

Table 3.--Numbers of brook and brown trout taken by anglers in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
		BROOK TROUT		
1949	97	150	0.65	
1950	93	151	0.62	
1951	177	227	0.78	0.70
1952	168	234	0.72	
1953	118	166	0.71	
	Stream improvement in Section A			
1954	243	283	0.86	
1955	165	169	0.98	
1956	107	103	1.04	1.04*
1957	228	147	1.55	(1.09)*[1]
1958	152	196	0.78	
		BROWN TROUT		
1949	23	70	0.33	
1950	27	92	0.29	
1951	28	162	0.17	0.31
1952	28	72	0.39	
1953	22	61	0.36	
	Stream improvement in Section A			
1954	45	122	0.37	
1955	24	48	0.50	
1956	40	79	0.51	0.52*
1957	30	46	0.65	(0.56)*
1958	28	48	0.58	

[1] Mean ratios after exclusion of 1954 are in parentheses.

* Significant at 0.050 level or lower in comparison with mean ratio for years 1949-53.

277
248.2

are not sufficient (because of their variability) to prove that the stream improvement work done on Section A of the Pigeon would increase the annual numerical catch of brook trout or brown trout. The results are "suggestive" but not adequate statistical proof.[2]

The mean annual catch of brook trout increased from 23.1 pounds before, to 32.9 pounds after improvement, an increase of 42 percent. The pounds of brown trout increased from 6.9 to 14.0, an increase of 103 percent. The annual variations in the pounds of fish caught were again great (Table 4). The increase in pounds of brook trout caught was not statistically significant ($\underline{t}$ = 1.58, 8 d.f., P, the probability, was above the 0.10 level). However, the increase in pounds of brown trout caught was significant ($\underline{t}$ = 3.64, 8 d.f., P less than 0.01). The discrepancy between a non-significant increase in number, and a statistically significant increase in weight of brown trout caught by anglers is explainable; after improvement, these fish were larger, on the average, as well as more numerous. The brown trout from Section B were also larger, on the average, after improvement but the number of fish decreased rather than increased (see below).

Section B.--This experimental section of the Pigeon River, in which stream improvement was not made, is 1.19 miles in length and has an area of 5.90 acres (Cooper, 1952). Fishing regulations for the ten years of the experiment were the same as in Section A (5 fish per day, minimum size of 7 inches). Section B is designated as the control for variation with time in the data examined.

The mean annual number of brook trout in the anglers' catch in Section B decreased slightly from 186, before stream improvement, to 180, after stream

---

[2] One might take the point of view that the annual catch figures for brook and brown trout should be combined in a statistical test of anglers' catch before and after improvement, because the two species are at least somewhat competitive for space, food, and other factors affecting survival. For the two species combined, the $\underline{t}$ value is 1.75, and the conclusion is essentially the same as for each species separately.

Table 4.--Pounds of brook and brown trout taken by anglers in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
		BROOK TROUT		
1949	16.0	25.3	0.63	
1950	15.3	25.9	0.59	
1951	32.0	37.6	0.85	0.72
1952	28.5	37.7	0.76	
1953	23.9	31.5	0.76	
		Stream improvement in Section A		
1954	48.1	46.6	1.03	
1955	31.3	31.1	1.01	
1956	17.9	17.6	1.02	1.05*
1957	40.5	28.3	1.43	(1.05)*[1]
1958	26.9	35.7	0.75	
		BROWN TROUT		
1949	5.7	16.9	0.34	
1950	6.8	21.4	0.32	
1951	7.7	35.7	0.22	0.34
1952	7.5	18.0	0.42	
1953	6.8	17.1	0.40	
		Stream improvement in Section A		
1954	14.2	41.7	0.34	
1955	7.4	19.8	0.37	
1956	19.4	26.9	0.72	0.59*
1957	14.0	19.2	0.73	(0.66)*
1958	15.0	18.6	0.81	

[1] Mean ratios after exclusion of 1954 are in parentheses.

* Significant at 0.050 level or lower in comparison with mean ratio for years 1949-53.

improvement, a decrease of 3 percent. Likewise, the brown trout decreased from an average of 91, before, to 69, after, a decrease of 24 percent. The *t* test failed to demonstrate a statistically significant difference between before and after in either the brook or brown trout catch. (The *t* value for the brook trout was 0.17, 8 d.f., P greater than 0.50; *t* value for the brown trout was 0.92, 8 d.f., P greater than 0.20).

The mean pounds of brook trout in the catch increased from 31.6, before, to 31.9, after, an increase of slightly less than one percent. The pounds of brown trout increased from 21.8 to 25.2, an increase of 16 percent. Neither difference was statistically significant. (For the brook trout, the *t* value was 0.06, 8 d.f., P greater than 0.50, and for the brown trout, the *t* was 0.61, 8 d.f., P greater than 0.50).

Ratio, Section A to Section B.--In Tables 3 and 4 are presented the numbers and pounds of trout, respectively, taken by anglers in Sections A and B of the Pigeon River in 1949-58. The ratios (of catch figures) of Section A to Section B for each year, and the mean ratios, before and after stream improvement, are given also.

The mean ratio, A:B, for the number of brook trout in the catch, increased from 0.70, before stream improvement, to 1.04, after stream improvement. Similarly, the mean ratio for the brown trout increased from 0.31 to 0.52. The *t* test indicated that both of these differences were significant. (The *t* value for the brook trout was 2.43, 8 d.f., P less than 0.05, and for the brown trout the *t* value was 3.50, 8 d.f., P less than 0.01).

The mean ratio for the pounds of brook trout in the catch increased from 0.72 to 1.05, and the mean ratio for the pounds of brown trout increased from 0.34 to 0.59. Again, both of these increases were statistically significant. (The *t* value for the brook trout was 2.75, 8 d.f., P about equal to 0.025; for the brown trout, *t* equalled 2.50, 8 d.f., P less than 0.05).

If the number or pounds of trout caught by the anglers in 1954 are excluded from the calculations, the over-all results are not changed (Tables 2, 3 and 4). The average pounds of brown trout caught in Section A, after stream improvement, remained significantly greater than the average pounds caught before. Likewise, the mean ratios, A:B, for the number and pounds of trout caught after stream improvement, remained statistically significant from the before ratios. For both species, the mean ratio for the years 1955-58 was greater than it had been for the years 1954-58.

As stated previously in this report, the use of Section B as a control for time-related factors is subject to question because a big drop in fishing pressure in B occurred after 1951 when planting of legal-size hatchery trout in B was discontinued. Thus the tests of A:B ratios which show a statistically significant increase in the numbers and pounds of brook and brown trout caught after improvement are in doubt, and, if the comparison of the data for before and after in Section A is considered more appropriate, there remains the single conclusion (of a favorable result) that there was a statistically significant increase in the weight of brown trout caught by anglers.

Fall standing crop

Section A.--The mean fall standing crop (in pounds) of brook trout of all sizes decreased from 45.6 pounds, before stream improvement, to 40.3 pounds, after stream improvement (Table 2). The mean standing crop of brown trout increased from 41.7 pounds to 52.0 24.7 pounds. However, for both species the annual variations were so great (Fig. 3, Table 5) that the *t* tests failed to demonstrate a significant decrease (for the brook trout) or a significant increase (for the brown trout). (For the brook trout the *t* value was 0.40, 8 d.f., P greater than 0.50; for the brown trout the *t* value was 1.36, 8 d.f., P greater than 0.20).

If the pounds of trout in anglers' catch is added to the pounds of trout in the fall standing crop for each year, the means for before and after stream

Table 5.--Post-fishing-season standing crop (pounds) of brook and brown trout of all sizes in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
		BROOK TROUT		
1949	23.9	44.7	0.54	
1950	35.3	49.9	0.71	
1951	51.0	53.6	0.95	0.79
1952	47.2	58.3	0.81	
1953	70.7	76.2	0.93	
	Stream improvement in Section A			
1954	79.1	96.3	0.82	
1955	47.1	39.0	1.21	
1956	20.6	29.6	0.70	0.90
1957	21.1	26.2	0.80	(0.92)[1]
1958	33.6	35.3	0.95	
		BROWN TROUT		
1949	40.9	73.7	0.56	
1950	38.8	59.3	0.65	
1951	29.7	67.8	0.44	0.53
1952	39.2	93.8	0.42	
1953	60.1	102.6	0.59	
	Stream improvement in Section A			
1954	46.5	108.4	0.43	
1955	60.9	90.4	0.67	
1956	31.5	56.9	0.55	0.77
1957	60.7	47.9	1.27	(0.86)
1958	60.6	63.5	0.95	

[1] Mean ratios after exclusion of 1954 are in parentheses.

improvement are as follows: the brook trout increased from 68.8 pounds, before, to 73.2 pounds, after; and the brown trout increased from 48.6 pounds to 66.0 pounds (Tables 2 and 6). The brook trout increase was not significant (t = 0.24, 8 d.f., P greater than 0.50), but the brown trout increase was statistically significant (t = 2.60, 8 d.f., P less than 0.05).

In the fall populations of trout, most of the fish less than 4.9 inches in length were young-of-year (or Age-group 0). In order to obtain a better approximation of the number of young-of-year in the fall populations, the age of 4- and 5-inch trout, some of which were scale sampled at the time of the fall population estimates in 1953, 1956-58, was determined. The percentages of 0's and I's in the 4-inch group and in the 5-inch group were calculated for each year in which scale samples were taken. The average of these percentages, for each inch group, was used to determine the proportion of young-of-year in the fall populations. The resulting estimates of young-of-year trout for Sections A and B, 1949-58, are given in Table 7 (Figs. 3 and 4). Each Section was considered separately in the sampling and calculations.

In Section A, the mean number of young-of-year brook trout decreased from 746, before stream improvement, to 730, after stream improvement (Table 2). The brown trout number increased from 217 to 509. Neither of these changes proved to be statistically significant, even though the brown trout number increased 135 percent. Again, the annual variation in numbers was such that the increase could be attributed to chance (Table 7, Fig. 3). (For the brook trout, t = 0.05, 8 d.f., P greater than 0.50; for the brown trout, t = 2.04, 8 d.f., P greater than 0.05.)

The last aspect of the fall standing crop to be considered is the number of trout 7 inches and larger remaining in the population at the close of the fishing season (Table 8, Fig. 3). The mean number of brook trout in this category decreased from 85, before stream improvement, to 58, after stream improvement (Table 2).

Table 6.--Anglers' catch plus standing crop (pounds) of brook and brown trout in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
		BROOK TROUT		
1949	39.9	70.0	0.57	
1950	50.6	75.8	0.67	
1951	83.0	91.2	0.91	0.76
1952	75.7	96.0	0.79	
1953	94.6	107.7	0.88	
		Stream improvement in Section A		
1954	127.2	142.9	0.89	
1955	78.4	70.1	1.12	
1956	38.5	47.2	0.82	0.96
1957	61.6	54.5	1.13	(0.98)[1]
1958	60.5	71.0	0.85	
		BROWN TROUT		
1949	46.6	90.6	0.51	
1950	45.6	80.7	0.56	
1951	37.4	103.5	0.36	0.48
1952	46.7	111.8	0.42	
1953	66.9	119.7	0.56	
		Stream improvement in Section A		
1954	60.7	150.1	0.40	
1955	68.3	110.2	0.62	
1956	50.9	83.8	0.61	0.73
1957	74.7	67.1	1.11	(0.82)*
1958	75.6	82.1	0.92	

[1] Mean ratios after exclusion of 1954 are in parentheses.

* Significant at 0.050 level or lower in comparison with mean ratio for years 1949-53.

Table 7.--Post-fishing-season standing crop (numbers) of young-of-year brook and brown trout in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
		BROOK TROUT		
1949	156	492	0.32	
1950	611	881	0.69	
1951	753	1,643	0.46	0.48
1952	1,140	2,550	0.45	
1953	1,071	2,199	0.49	
	Stream improvement in Section A			
1954	1,722	2,644	0.65	
1955	583	796	0.73	
1956	376	704	0.53	0.58
1957	625	854	0.73	(0.57)[1]
1958	344	1,233	0.28	
		BROWN TROUT		
1949	139	834	0.17	
1950	56	758	0.07	
1951	364	410	0.89	0.44
1952	247	965	0.26	
1953	281	345	0.81	
	Stream improvement in Section A			
1954	290	439	0.66	
1955	487	635	0.77	
1956	257	381	0.68	0.69
1957	513	915	0.56	(0.69)
1958	997	1,307	0.76	

[1] Mean ratios after exclusion of 1954 are in parentheses.

Table 8.--Post-fishing-season standing crop (numbers) of brook and brown trout, 7 inches and larger, in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
		BROOK TROUT		
1949	26	22	1.18	
1950	72	94	0.77	
1951	150	57	2.63	1.70
1952	76	33	2.30	
1953	99	61	1.62	
		Stream improvement in Section A		
1954	83	94	0.88	
1955	55	66	0.83	
1956	22	30	0.73	1.44
1957	50	34	1.47	(1.58)[1]
1958	82	25	3.28	
		BROWN TROUT		
1949	92	193	0.48	
1950	113	152	0.74	
1951	80	205	0.39	0.55
1952	99	203	0.49	
1953	142	227	0.63	
		Stream improvement in Section A		
1954	142	238	0.60	
1955	118	207	0.57	
1956	50	96	0.52	0.83
1957	108	79	1.37	(0.88)
1958	139	129	1.08	

[1] Mean ratios after exclusion of 1954 are in parentheses.

The mean number of brown trout increased slightly, from 105, before, to 111, after. Neither of the changes was statistically significant. (For the brook trout, $\underline{t}$ = 1.17, 8 d.f., P greater than 0.20; for the brown trout, $\underline{t}$ = 0.30, 8 d.f., P greater than 0.50).

Section B.--The mean standing crop (in pounds) of brook trout of all sizes decreased from 56.5 pounds, before stream improvement, to 45.3 pounds, after stream improvement (Table 2). The mean standing crop of brown trout decreased from 79.4 pounds, before, to 73.4 pounds, after. Neither of the decreases was statistically significant. (For brook trout, $\underline{t}$ = 0.80, 8 d.f., P greater than 0.40; for brown trout, $\underline{t}$ = 0.44, 8 d.f., P greater than 0.50).

The mean pounds of brook trout, for the summation of the catch and standing crop in Section B, decreased from 88.1, before, to 77.1, after; the brown trout mean decreased from 101.3, before, to 98.7, after (Table 2). The decrease was not statistically significant for either species, as indicated by the $\underline{t}$ test (brook trout, $\underline{t}$ = 0.60, 8 d.f., P greater than 0.50; brown trout, $\underline{t}$ = 0.16, 8 d.f., P greater than 0.50).

The mean number of young-of-year brook trout decreased from 1,553, before, to 1,246, after stream improvement, while the number of brown trout increased from 662 to 735 (Table 2). The changes were not statistically significant (brook trout, $\underline{t}$ = 0.58, 8 d.f., P greater than 0.50; brown trout, $\underline{t}$ = 0.35, 8 d.f., P greater than 0.50).

Finally, in Section B, the mean number of brook trout 7 inches and larger in the fall population decreased from 53, before, to 50, after; and the mean number of brown trout decreased from 196, before, to 150, after. Neither decrease was significant (brook trout, $\underline{t}$ = 0.17, 8 d.f., P greater than 0.50; brown trout, $\underline{t}$ = 1.39, 8 d.f., P about equal to 0.20).

Ratio, Section A to Section B.--In Table 5 is presented the fall standing crop (in pounds) of brook and brown trout of all sizes in Sections A and B, for the years 1949-58, and the ratio of Section A to Section B for each year. The mean ratio for the brook trout standing crop increased from 0.79, before stream improvement, to 0.90, after stream improvement, but the increase was not statistically significant. Likewise, the brown trout ratio increased from 0.53 to 0.77, but this was not a significant change either (brook trout, $\underline{t}$ = 0.92, 8 d.f., P greater than 0.20; brown trout, $\underline{t}$ = 1.50, 8 d.f., P greater than 0.10).

The catch plus standing crop (in pounds) for each year, 1949-58, and accompanying ratios of Section A to B are given in Table 6. For the brook trout, the mean ratio, A:B, before stream improvement, was 0.76, and after stream improvement, 0.96. For the brown trout, the mean ratio increased from 0.48 to 0.73. Neither of the increases was statistically significant (brook trout, $\underline{t}$ = 2.22, 8 d.f., P greater than 0.05; brown trout, $\underline{t}$ = 1.92, 8 d.f., P greater than 0.05).

The mean ratio, A:B, for the number of young-of-year brook trout increased from 0.48, before stream improvement, to 0.58, after stream improvement (Table 7). The mean ratio for the brown trout increased from 0.44 to 0.69. These increases were not significant (brook trout, $\underline{t}$ = 1.00, 8 d.f., P greater than 0.20; brown trout, $\underline{t}$ = 1.47, 8 d.f., P greater than 0.10).

The mean ratio, A:B, for the number of brook trout 7 inches and larger, remaining in the fall populations, decreased from 1.70, before, to 1.44, after (Table 8). The mean ratio for the brown trout increased from 0.55, before, to 0.83, after. Neither the decrease of the brook nor the increase of the brown trout ratio was statistically significant (brook trout, $\underline{t}$ = 0.44, 8 d.f., P greater than 0.50; brown trout, $\underline{t}$ = 1.56, 8 d.f., P greater than 0.10).

When the data for the year 1954 were excluded from the figures for fall standing crop, the over-all pattern of differences did not change materially (Table 2). There were no changes in the analysis for Section A. In Section B, there was a significant decrease in the standing crop (pounds) of brook trout, after stream improvement (of A), and also a significant decrease in catch plus standing crop (pounds), after stream improvement. The only other exception was the mean ratio, A:B, of catch plus standing crop (pounds) for the brown trout, which increased significantly from 0.48, before stream improvement, to 0.82, after stream improvement (t = 2.83, 7 d.f., P less than 0.05) (Table 6).

Rates of mortality and exploitation

Annual expectations of death, expressed in terms of total mortality, rate of exploitation (fishing mortality) and natural mortality, were determined for the brook and brown trout in Sections A and B (Tables 9 and 10). The symbols and methods used in these calculations follow Ricker, 1958. The annual total mortality rate $\underline{a}$ was calculated on the basis that:

$$\underline{s} \text{ (survival rate)} = (1 - \underline{a}) = \frac{\text{Age-group I + II + ...}}{\text{Age-group 0 + I + ...}}$$

For example, from Table 9, the total fall population in 1949 was 378 brook trout, composed of age-group 0 + I + ... , and in 1950 the population remaining was 222. The population remaining, or Age-group I + II + ... , is the total fall population of trout minus the young-of-year (Age-group 0). The method of determining the number of young-of-year fish was described above. The rate of exploitation, $\underline{u}$, is the number caught during the year divided by the total population available the previous fall. Natural mortality, $\underline{v}$, is the difference between $\underline{a}$ and $\underline{u}$; $\underline{a} = \underline{u} + \underline{v}$.

Section A.--The mean rate of exploitation for the brook trout increased slightly from 0.18, before stream improvement, to 0.20, after stream improvement, while the brown trout mean rate decreased slightly from 0.10, before, to 0.07, after (Table 2). Neither of the changes was statistically significant (brook trout, $\underline{t}$ = 0.25, 7 d.f., P greater than 0.50; brown trout, $\underline{t}$ = 1.50, 7 d.f., P greater than 0.10).

The mean natural mortality rate for the brook trout increased from 0.44 before, to 0.57, after; the mean for brown trout increased from 0.45, before, to 0.63, after (Table 2). Neither change proved significant (brook trout, $\underline{t}$ = 1.08, 7 d.f., P greater than 0.20; brown trout, $\underline{t}$ = 1.80, 7 d.f., P greater than 0.10).

Section B.--The mean rate of exploitation for the brook trout decreased slightly from 0.14, before stream improvement, to 0.12, after stream improvement (Table 2). The brown trout rate of exploitation also decreased from 0.10 to 0.09.

Table 9.--Annual expectations of death for the brook trout, Sections A and B, Pigeon River, 1950-58

Population		Catch		Population remaining	Total mortality a	Rate of exploitation u	Natural mortality v
Year	Number	Year	Number				
SECTION A							
1949	378	1950	93	222	0.41	0.25	0.16
1950	833	1951	177	244	0.71	0.21	0.50
1951	997	1952	168	221	0.78	0.17	0.61
1952	1,361	1953	118	572	0.58	0.09	0.49
1953	1,643	1954	243	563	0.66	0.15	0.51
1954	2,285	1955	165	421	0.82	0.07	0.75
1955	1,004	1956	107	141	0.86	0.11	0.75
1956	517	1957	228	97	0.81	0.44	0.37
1957	722	1958	152	230	0.68	0.21	0.47
1958	574						
SECTION B							
1949	906	1950	151	328	0.64	0.17	0.47
1950	1,209	1951	227	291	0.76	0.19	0.57
1951	1,934	1952	234	242	0.88	0.12	0.76
1952	2,792	1953	166	591	0.79	0.06	0.73
1953	2,790	1954	283	703	0.75	0.10	0.65
1954	3,347	1955	169	343	0.90	0.05	0.85
1955	1,139	1956	103	200	0.82	0.09	0.73
1956	904	1957	147	113	0.88	0.16	0.72
1957	967	1958	196	219	0.77	0.20	0.57
1958	1,452						

Table 10.--Annual expectations of death for the brown trout, Sections A and B, Pigeon River, 1950-58

Population		Catch		Population remaining	Total mortality	Rate of exploitation	Natural mortality
Year	Number	Year	Number		a	u	v
				SECTION A			
1949	252	1950	27	123	0.51	0.11	0.40
1950	179	1951	28	100	0.44	0.16	0.28
1951	464	1952	28	118	0.75	0.06	0.69
1952	365	1953	22	189	0.48	0.06	0.42
1953	470	1954	45	178	0.62	0.10	0.52
1954	468	1955	24	179	0.62	0.05	0.57
1955	666	1956	40	68	0.90	0.06	0.84
1956	325	1957	30	120	0.63	0.09	0.54
1957	633	1958	28	167	0.74	0.04	0.70
1958	1,164						
				SECTION B			
1949	1,102	1950	92	222	0.80	0.08	0.72
1950	980	1951	162	261	0.73	0.16	0.57
1951	671	1952	72	220	0.67	0.11	0.56
1952	1,185	1953	61	390	0.67	0.05	0.62
1953	735	1954	122	287	0.61	0.17	0.44
1954	726	1955	48	370	0.49	0.07	0.42
1955	1,005	1956	79	112	0.89	0.08	0.81
1956	493	1957	46	93	0.81	0.09	0.72
1957	1,008	1958	48	172	0.83	0.05	0.78
1958	1,479						

Both decreases were slight and not statistically significant (brook trout, $\underline{t}$ = 0.50, 7 d.f., P greater than 0.50; brown trout, $\underline{t}$ = 0.33, 7 d.f., P greater than 0.50).

The mean natural mortality rate for the brook trout increased from 0.63, before, to 0.70, after; the brown trout rate increased from 0.62, before, to 0.63, after (Table 2). Neither of these changes was significant (brook trout, $\underline{t}$ = 0.88, 7 d.f., P greater than 0.40; brown trout, $\underline{t}$ = 0.10, 7 d.f., P greater than 0.50).

Ratio, Section A to Section B.--In Table 11 are presented the ratios of Section A to Section B for the annual rates of exploitation and natural mortality. The mean ratio, A:B, for the rate of exploitation of the brook trout increased from 1.38, before stream improvement, to 1.58, after stream improvement; the brown trout mean ratio decreased from 1.03, before, to 0.77, after. The $\underline{t}$ test did not show a significant difference existed in either case (brook trout, $\underline{t}$ = 0.57, 7 d.f., P greater than 0.50; brown trout, $\underline{t}$ = 1.53, 7 d.f., P greater than 0.10).

The mean ratio for the natural mortality rate of the brook trout increased from 0.67, before, to 0.80, after; and the mean ratio for the brown trout increased from 0.74, before, to 1.05, after. Again, neither change was significant (brook trout, $\underline{t}$ = 0.93, 7 d.f., P greater than 0.20; brown trout, $\underline{t}$ = 1.63, 7 d.f., P greater than 0.10).

Exclusion of the data for 1954 did not change the over-all pattern of rates of exploitation and natural mortality cited above.

Fishing pressure and success

Total annual fishing pressure, in hours, and fishing success, as measured by catch per hour per trip (number of trout), for Sections A and B, 1949-58, are given in Tables 12 and 13, and Figure 5.

Table 11.--Ratios of Section A to Section B for rates of exploitation and annual expectations of natural mortality, Pigeon River, 1950-58

Year	Rate of exploitation		Natural mortality	
	Ratio, A:B	Mean ratio, A:B	Ratio, A:B	Mean ratio, A:B
		BROOK TROUT		
1950	1.47		0.34	
1951	1.11	1.38	0.88	0.67
1952	1.42		0.80	
1953	1.50		0.67	
		Stream improvement in Section A		
1954	1.50		0.78	
1955	1.40		0.88	
1956	1.22	1.58	1.03	0.80
1957	2.75	(1.60)[1]	0.51	(0.81)
1958	1.05		0.82	
		BROWN TROUT		
1950	1.38		0.56	
1951	1.00	1.03	0.49	0.74
1952	0.55		1.23	
1953	1.20		0.68	
		Stream improvement in Section A		
1954	0.59		1.18	
1955	0.71		1.36	
1956	0.75	0.77	1.04	1.05
1957	1.00	(0.82)	0.75	(1.01)
1958	0.80		0.90	

[1] Mean ratios after exclusion of 1954 are in parentheses.

Table 12.--Total fishing pressure in hours in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
1949	861.0	2,385.0	0.36	
1950	898.0	2,130.5	0.42	
1951	950.5	3,148.0	0.30	0.43
1952	660.0	1,563.0	0.42	
1953	965.0	1,535.0	0.63	
	Stream improvement in Section A			
1954	1,119.5	1,756.0	0.64	
1955	977.0	1,125.0	0.87	
1956	882.0	1,046.5	0.84	0.80*
1957	848.5	931.5	0.91	(0.84)*[1]
1958	991.0	1,308.5	0.76	

* Significant at 0.050 level or lower in comparison with mean ratio for years 1949-53.

[1] Mean ratio after exclusion of 1954.

Table 13.--Catch per hour per trip (number of trout) in Sections A and B, Pigeon River, 1949-58

Year	Section A	Section B	Ratio, A:B	Mean ratio, A:B
1949	0.16	0.10	1.60	
1950	0.13	0.12	1.08	
1951	0.26	0.12	2.17	1.48
1952	0.31	0.20	1.55	
1953	0.16	0.16	1.00	
	Stream improvement in Section A			
1954	0.26	0.26	1.00	
1955	0.17	0.18	0.94	
1956	0.17	0.17	1.00	1.07
1957	0.28	0.19	1.47	(1.09)[1]
1958	0.17	0.18	0.94	

[1] Mean ratio after exclusion of 1954.

Figure 5.--Total fishing pressure (hours) and catch per hour per trip (number of fish), Sections A and B, Pigeon River, 1949-58.

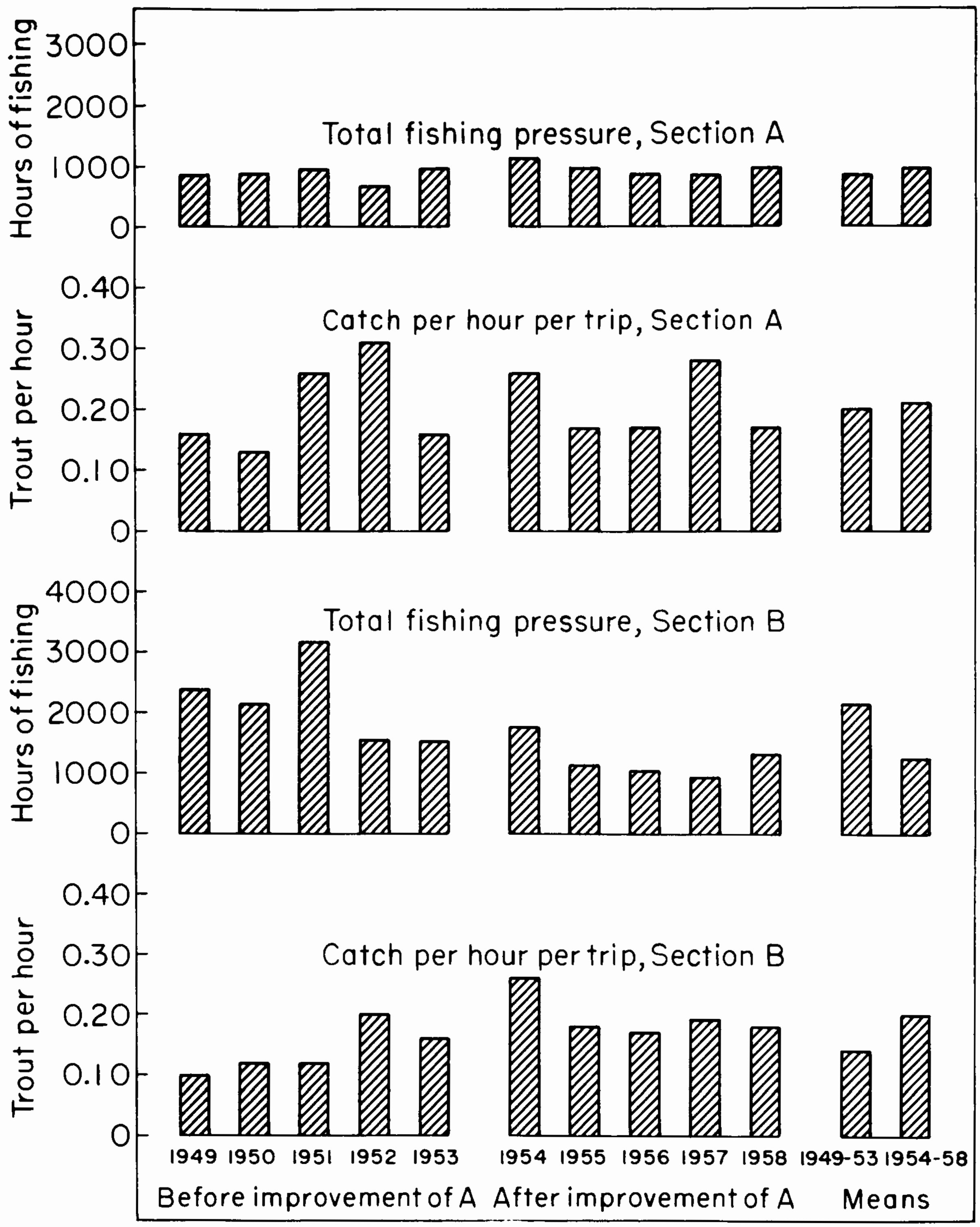

Hours of fishing
3000
2000
1000
0
Total fishing pressure, Section A
Trout per hour
0.40
0.30
0.20
0.10
0
Catch per hour per trip, Section A
Hours of fishing
4000
3000
2000
1000
0
Total fishing pressure, Section B
Trout per hour
0.40
0.30
0.20
0.10
0
Catch per hour per trip, Section B
1949 1950 1951 1952 1953
1954 1955 1956 1957 1958
1949-53 1954-58
Before improvement of A
After improvement of A
Means

Figure 5

Section A.--The mean number of hours fished per year in Section A, before stream improvement, was 866.9 and, after stream improvement, 963.6 (Table 2). The increase was not statistically significant (t = 1.33, 8 d.f., P greater than 0.20).

The catch per hour per trip increased slightly from 0.20 trout to 0.21 trout (Table 2). The increase was not significant (t = 0.24, 8 d.f., P greater than 0.50).

Section B.--The mean number of hours fished per year in Section B, before stream improvement, was 2,152.3 and, after stream improvement, 1,233.5 (Table 2). The decrease was statistically significant (t = 2.78, 8 d.f., P less than 0.025).

The catch per hour per trip increased from 0.14 trout, before, to 0.20 trout, after (Table 2). This increase was statistically significant (t = 2.50, 8 d.f., P less than 0.05).

During the years 1949-51, Section B was planted heavily with legal-size hatchery trout. The fishing pressure during these years was considerably greater than in the following years (Table 12, Fig. 5). It was this greater fishing pressure that caused the significant difference in Section B, between before and after stream improvement. Also, it was probably greater fishing pressure that caused a lower catch per hour per trip for the years before stream improvement (Table 13, Fig. 5); the number of wild trout in the population was spread among a greater number of trips (or anglers).

Ratio, Section A to Section B.--The mean ratio, A:B, for the fishing pressure in hours, increased from 0.43, before stream improvement, to 0.80, after stream improvement (Table 12). This was a statistically significant increase, which would be expected with the slight increase in pressure in Section A and the large decrease in pressure in Section B, after stream improvement (t = 5.29, 8 d.f., P less than 0.001).

However, the mean ratios, A:B, for the catch per hour per trip were not statistically different (Table 13). The mean ratio was 1.48, before stream improvement, and 1.07, after (*t* = 1.78, 8 d.f., P greater than 0.10).

The omission of the data for 1954 only changed the results in that the difference between before (0.14 trout) and after (0.18 trout) in catch per hour per trip in Section B was no longer significant.

Factors affecting the evaluation of stream improvement

The catch and population data from Section A and Section B have in common a large variation between years. Further, the brook trout population in both sections, during the years of the experiment, 1949-58, increased gradually to a peak in 1954, in numbers (Table 9) and pounds (Table 5, Figs. 3 and 4), and then declined. The brown trout population did not show this pattern in numbers (Table 10), but it did have a peak in pounds of fish in Section B in 1954, and the pattern for Section A differed only in that 1954 was somewhat low and 1957 was high in pounds of standing crop (Table 5, Figs. 3 and 4). The patterns of variation for the young-of-year trout, trout 7 inches and larger in the standing crop, and the anglers' catch, in Sections A and B were also similar (Figs. 3 and 4). These facts indicate that probably the better evaluation of the effects of stream improvement is obtained by relating data for Section A to that for Section B. The mean ratios, A:B, for the various categories of the catch and population, before and after stream improvement, are summarized in Table 14. The number and pounds of trout (both brook and brown) in the catch increased significantly after stream improvement, but no aspect of the standing crop, the rate of exploitation or the natural mortality rate showed a statistically significant change. The fishing pressure in hours showed a statistically significant change, but the catch per hour per trip did not.

Table 14.--Summary of mean ratios, Section A to Section B of the catch and fall population, before (1949-53) and after (1954-58) stream improvement, Pigeon River

Species of trout, and period	Trout in catch: Number	Trout in catch: Pounds	Fall standing crop (pounds)	Catch plus standing crop (pounds)	Number of trout in fall population: Young of year	Number of trout in fall population: Trout 7 inches and larger	Rate of exploitation	Natural mortality rate
Brook								
Before	0.70	0.72	0.79	0.76	0.48	1.70	1.38	0.67
After	1.04* (1.09)*[1]	1.05* (1.05)*	0.90 (0.92)	0.96 (0.98)	0.58 (0.57)	1.44 (1.58)	1.58 (1.60)	0.80 (0.81)
Brown								
Before	0.31	0.34	0.53	0.48	0.44	0.55	1.03	0.74
After	0.52* (0.56)*	0.59* (0.66)*	0.77 (0.86)	0.73 (0.82)*	0.69 (0.69)	0.83 (0.88)	0.77 (0.82)	1.05 (1.01)

	Total fishing pressure (hours)	Catch per hour per trip
Brook plus brown		
Before	0.43	1.48
After	0.80* (0.84)*	1.07 (1.09)

* Significant at 0.050 level or lower in comparison with mean ratio for years 1949-53.

[1] Mean values after exclusion of 1954 are in parentheses.

Because no aspect of the population showed a significant change while the catch and fishing pressure did show a significant change, the question arises: Was the increase in catch real or was it a function of fishing pressure? It would seem probable that the heavy fishing pressure in Section B, for the before years, could have resulted in a greater catch (or rate of exploitation). This would create low A:B ratios for these years and the appearance of a significant change in the catch after stream improvement.

In order to test the hypothesis that with an increase in fishing pressure there was an increase in rate of exploitation, the annual rate of exploitation was plotted against the annual fishing pressure (hours), for Sections A and B, for the brook and brown trout (Figs. 6 and 7). Obviously, there was little or no relationship between fishing pressure and rate of exploitation in Section A (Fig. 6), but in Section B, it appears there might have been some relationship (Fig. 7). The coefficient of correlation, $\underline{r}$, for the brook trout in Section B, was 0.41; for the brown trout $\underline{r}$ was 0.64. Following Snedecor (1956), these correlation coefficients were tested to determine if they were significantly different from zero. Neither proved to be significant (brook trout, $\underline{t} = 1.20$, 7 d.f., P greater than 0.20; brown trout, $\underline{t} = 2.23$, 7 d.f., P greater than 0.05). Thus, the conclusion was that no significant relationship could be demonstrated to exist between fishing pressure (hours) and rate of exploitation. But the increased catch after stream improvement, as shown by the significant increase in the A:B ratios is still in doubt, for although an increase in rate of exploitation with an increase in fishing pressure in Section B could not be proven, neither could it be disproved that a relationship of this type existed.

Another factor to consider in the evaluation of stream improvement was the fall planting of fingerling brook trout (2,500 per year) and brown trout (500 per year) in Section A from 1952 through 1955. Waters, in his preliminary report in 1958, suggested that the significant increase he found in numbers of young-of-year fish after stream improvement might be attributed to the spawning of these

Figure 6.--Relationship between annual fishing pressure (hours) and annual rate of exploitation, Section A, Pigeon River, 1950-58.

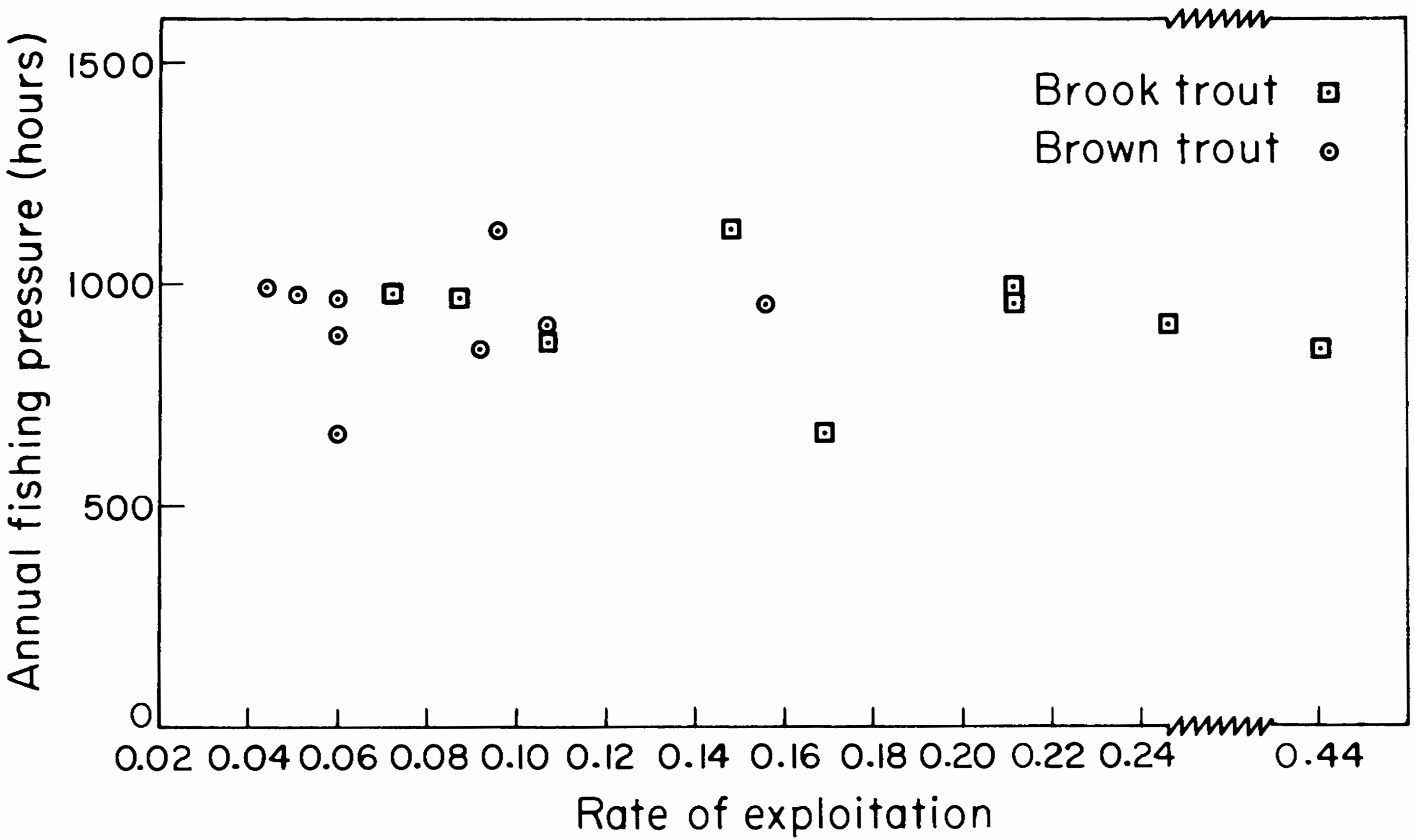

Brook trout
Brown trout
Annual fishing pressure (hours)
0
500
1000
1500
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.44
Rate of exploitation

Figure 6

Figure 7.--Relationship between annual fishing pressure (hours) and annual rate of exploitation, Section B, Pigeon River, 1950-58.

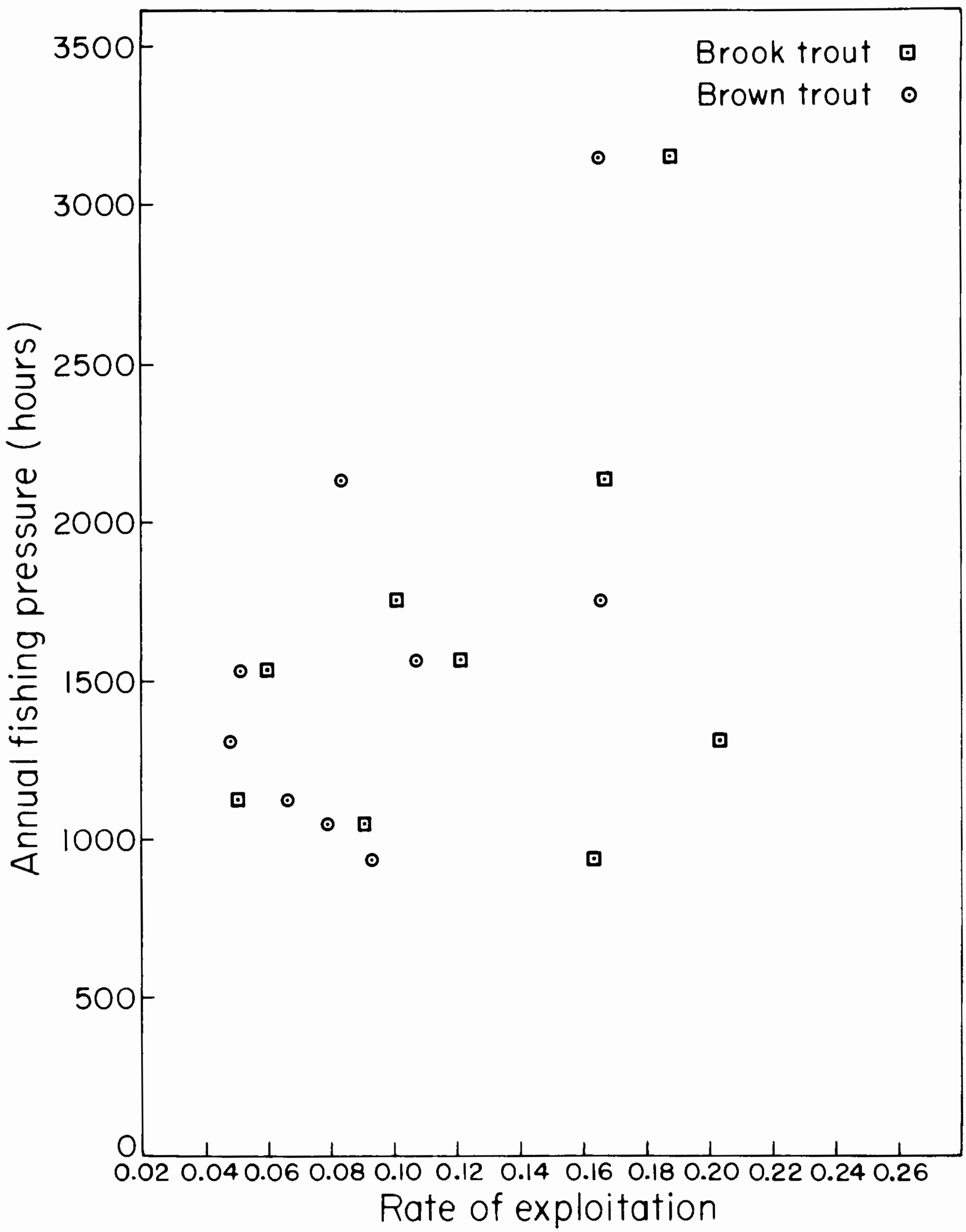

Brook trout
Brown trout
Annual fishing pressure (hours)
3500
3000
2500
2000
1500
1000
500
0
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26
Rate of exploitation

Figure 7

hatchery fish, particularly the brook trout which spawns at a smaller size than the brown trout. In the present analysis, the numbers of young-of-year fish did not show a significant increase after stream improvement, but the planting of these fish might have had some effect and their presence should be considered.

The hatchery fingerlings were planted in Section A, near the A-B dividing line. Almost as many fish moved upstream into Section B as went downstream in Section A. The total numbers of planted fish counted in the fall population studies in the experimental sections of the river, in the years 1953-58, were as follows: brook trout, Section A--30, Section B--20, Section C--41, Section D--16, Section E--16; brown trout, Section A--94, Section B--67, Section C--28, Section D--17, Section E--30. The total catch in Sections A and B, over the six-year period these fish were in the stream, was as follows: brook trout, Section A--72, Section B--36; brown trout Section A--33, Section B--40. Thus some of these hatchery fingerling trout distributed themselves widely through the experimental waters; but apparently only a few of them survived for more than a year and they contributed relatively little to the catch. Even though the total number of fingerling trout planted in Section A during the years 1952-55 was large (10,000 brook trout and 2,000 brown trout), it is doubtful that these hatchery plantings had much effect on the population or catch of wild trout in Section A; or if there was a marked effect, it probably was similar in the two sections.

A third factor to consider was the flood of the experimental water which occurred in the spring of 1957. At the upstream end of the experimental sections, on private property, there was (and again is) a dam which creates a 65-acre impoundment. On May 15, 1957, after a heavy rainfall the preceding day, the dam was washed out. A large amount of sand from the impoundment was released into the river. It covered most of the bottom of Section E, the experimental section furthest upstream. The sand, which probably has an adverse effect on the bottom organisms and on success of reproduction of the trout, has been moving slowly through the experimental sections. However, at the close of the stream improvement experiment, in the fall of 1958, this sand had not yet reached Section B, which is 3.5 miles below the dam. The fall estimates in 1957 and 1958 did not indicate any pronounced changes in the trout population except a decrease in young-of-year fish in Section E in 1957 (Latta, 1959). There was no evidence that the flood caused any large mortality or movement of the fish which would have affected Section A or Section B. In all probability, the flood had little effect on the experiment or what effect it did have was operative in both Section A and B.

The final factor to consider is the possible disproportionate movement of fish between sections. The shocker returns, from a group of wild fingerlings (2,423 brook, 202 brown) marked in 1951 as part of another experiment in Section C of the Pigeon River, indicated some upstream movement. Although the evidence available is not sufficient to apply in the present evaluation, the possibility of movement influencing the fish population of Section A exists, and in the present study it was not checked.

Conclusions

In a comparison of the mean values for the brook and brown trout in various aspects of the catch and population, before (1949-53) and after (1954-58) stream improvement, in Section A alone, only the pounds of brown trout in the catch and the catch plus standing crop (pounds) of brown trout showed a statistically significant increase (Table 2). The annual variations limit the value of a before and after comparison for Section A alone. The annual variations, though great, were similar to the variations in Section B; thus it was judged that a comparison of Section A with Section B (ratio A:B) would provide the better evaluation.

The mean ratios, A:B, for the catch, in number and pounds, showed a statistically significant increase after stream improvement (Table 14). The mean ratios for the fall population data were not statistically different.

Because of the heavy fishing pressure on Section B, before stream improvement, which could have been responsible for the appearance of an increased catch in the ratios A:B, the relationship between fishing pressure and rate of exploitation was sought. It could not be shown that a relationship existed between fishing pressure and rate of exploitation in Section B, but neither could it be shown that a relationship did not exist.

If no relationship existed, and the increased catch shown by the A:B ratio was real, the question of the source of the additional fish in the catch arises because no significant change in any aspect of the standing crop could be shown. It would seem logical to expect that with an increase in the catch there would be an increase in production, with more young-of-year fish, greater numbers of trout 7 inches and larger remaining in the fall and/or more pounds in the fall standing crop, but no significant increase was found. Another possibility would be that the stream improvement structures increased the chances of catching trout and the increased catch resulted without an increase in the standing crop. However, the rate of exploitation did not show a significant increase. If there was an increased catchability, one would expect a significant decrease in natural mortality rate and/or decrease in the fall population of fish 7 inches and larger, but such decreases did not appear either.

The exclusion of the data for the year 1954 did not change the results. The A:B ratio for catch plus standing crop (pounds) for the brown trout, after stream improvement, was significantly different from the ratio before (Table 14).

The fishing pressure in hours and the catch per hour per trip in Section A alone did not change significantly after stream improvement. However, in Section B, both catch per hour and fishing pressure showed a significant change after stream improvement in Section A. In 1949-51, Section B was planted heavily with legal-size hatchery trout. In the following years, fishing pressure decreased substantially while the catch per hour per trip increased; both changes were statistically significant. The ratio, A:B, for fishing pressure showed a statistically significant decrease after stream improvement, caused by the heavy fishing pressure in Section B in 1949-51 for hatchery trout. The ratio, A:B, for the catch per hour per trip did not change significantly after stream improvement.

Because of the inconclusive results, the experiment in the evaluation of the effects of stream improvement will be continued through 1960-65. During the summer of 1959, most natural cover and all man-made cover and current deflectors were removed from Section A. In addition, the deep holes which had resulted from the deflectors were filled with sand. A large log-jam at the downstream end of Section A was re-created to slow the flow of the stream, allow the accumulation of sand upstream behind the jam, and decrease the stream gradient. The object was to create conditions similar to those that existed before the stream improvement of 1953, but with a minimum of cover. In 1958, before the natural cover and stream structures were removed from Section A, 100-foot sample segments of Section A and B were mapped to record water depths, bottom soil types and cover. These segments will be mapped again in 1960 and 1964, in order to note the physical changes in the stream during the years of the experiment. More exacting population statistics will be provided by an estimate of the trout population each spring as well as in the fall, a sampling of the age structure of the spring and fall populations, and a check on the possibility of disproportionate movement between sections. No hatchery fish will be planted. It is anticipated that a comparison of the catch and population figures for the next five years (1960-64), without stream improvement in Section A, with the figures for the previous five years with stream improvement (1954-58) will provide more conclusive results.

Literature cited

Bacon, E. H., D. S. Shetter and G. P. Cooper

1958. Third, fourth and fifth annual reports of the Pigeon River Trout Research Station for 1951, 1952 and 1953. Mich. Inst. for Fish. Res., Rept. No. 1544, unpublished, 45 pp.

Cooper, Edwin L.

1950. Pigeon River Trout Research Area initial report of fishing, 1949. Mich. Inst. Fish. Res., Rept. No. 1250, unpublished, 53 pp.

1951. Pigeon River Trout Research Area second annual report of fishing, 1950. Mich. Inst. Fish. Res., Rept. No. 1288, unpublished, 81 pp.

1952. Rate of exploitation of wild eastern brook trout and brown trout populations in the Pigeon River, Otsego County, Michigan. Trans. Am. Fish. Soc., 81 (1951): 224-234.

Cooper, Edwin L. and Norman G. Benson

1951. The coefficient of condition of brook, brown and rainbow trout in the Pigeon River, Otsego County, Michigan. Prog. Fish-Cult., Vol. 13, No. 4, pp. 181-192.

Hunter, George W., III, Lyle M. Thorpe and David E. Grosvenor

1941. An attempt to evaluate the effect of stream improvement in Connecticut. Trans. Fifth N. Am. Wildl. Conf., 1940, pp. 276-291.

Latta, William C.

1959a. The ninth annual creel census, Pigeon River Trout Research Station, 1957. Mich. Inst. Fish. Res., Rept. No. 1560, unpublished, 29 pp.

1959b. The tenth annual creel census, Pigeon River Trout Research Station, 1958. Mich. Inst. Fish. Res., Rept. No. 1568, unpublished, 30 pp.

Madsen, M. J.

1938. A preliminary investigation into the results of stream improvement in the intermountain forest region. Trans. Third N. Am. Wildl. Conf. pp. 497-503.

Ricker, W. E.

1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. No. 119, 300 pp.

Shetter, David S., O. H. Clark and Albert S. Hazzard

1949. The effects of deflectors in a section of a Michigan trout stream. Trans. Am. Fish. Soc., 76 (1946): 248-278.

Snedecor, George W.

1956. Statistical methods. Iowa State College Press, Ames, ix + 534 pp.

Tarzwell, Clarence M.

1937. Experimental evidence on the value of trout stream improvement in Michigan. Trans. Am. Fish. Soc., 66 (1936): 177-187.

1938. An evaluation of the methods and results of stream improvement in the southwest. Trans. Third N. Am. Wildl. Conf., pp. 339-364.

Waters, Thomas F.

1957a. Report of sixth annual creel census, Pigeon River Trout Research Station, 1954. Mich. Inst. Fish. Res., Rept. No. 1512, unpublished, 33 pp.

1957b. The seventh annual creel census, Pigeon River Trout Research Station, 1955. Mich. Inst. Fish. Res., Rept. No. 1521, unpublished, 27 pp.

1957c. The eighth annual creel census, Pigeon River Trout Research Station, 1956. Mich. Inst. Fish. Res., Rept. No. 1527, unpublished, 28 pp.

1958. The effect of stream improvement upon the catch and post-season standing crop of trout in the Pigeon River. Mich. Inst. Fish. Res., Rept. No. 1541, unpublished, 20 pp.

INSTITUTE FOR FISHERIES RESEARCH

William C. Latta

Report approved by G. P. Cooper

Typed by M. S. McClure