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The effects of deflectors in a section of a Michigan trout stream[1]

[1] Contribution from the Michigan Institute for Fisheries Research

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Abstract

The changes in angling produced by current deflectors in a 1,605-foot section of a Michigan brook trout stream were studied over an 8-year period, 3 years before and 5 years after placement of the devices. Data on changes in the physical character of the stream, the fish population, and the bottom food supply also are presented for 1 year before and 3 years after deflector installation. The methods used to measure these various changes are given.

Installation of 24 pool-forming deflectors increased the number of good pools from 9 to 24, increased the average pool depth by 6 inches, and exposed additional gravel without significantly changing the average stream depth over the entire section. Preliminary and unpublished bottom food studies indicate a decrease in total number and volume of all organisms but an increase in forms found most frequently in trout stomachs. Fish population studies demonstrated slight increases in the number of smaller trout present after the addition of deflectors,

attended by a slight decrease in their average size. Average creel census figures for the 3 years prior to stream improvement and the 5 years after show an increase after improvement of 120 percent in the total catch and of 46 percent in pounds caught per hour coincident with a 64 percent increase in angling pressure. It was demonstrated that migration into the section improved was not responsible for the increases noted, also that bordering sections failed to have fishing comparably good to that produced in the improved section. It was concluded that the improvement in trout fishing in the experimental section was the result of an increase in number, size, and depth of pools created by installation of current deflectors.

Introduction

The purpose of this investigation was to determine as accurately as possible the effects of the addition of current deflectors upon the number and depth of pools, the fish-food supply, the fish population, and the yield to the angler in a section of a small Michigan trout stream.

The use of deflectors and other so-called stream improvement devices was advocated by Hubbs, Greeley, and Tarzwell (1932), on the theory that properly located structures would better the habitat for trout and thereby increase the fish yield. At the time their publication was issued there had been no experiments to measure the actual results of such work although several hundred devices had been installed and were then under observation to learn the permanence and effectiveness of the different types used. Tarzwell (1937) subsequently reported on

the physical and biological changes following improvement in portions of six Michigan trout streams where numbered structures had been installed 5 years previously. Tarzwell (1938) compared food production, fish yield, and growth rate in two Arizona streams which he considered very similar in character. One was improved by the placement of a number of dams and the other was the control. Madsen (1938) made a rather general survey of stream improvement structures installed in the intermountain region but lacked data for a critical evaluation of the work. Hunter et al. (1940) described the effects over a 2-1/2-year period of placing a single dam in a Connecticut stream, using the area above the influence of the structure for comparison.

Hunt Creek, where the present experiment was conducted, is a tributary of the Thunder Bay River in Montmorency County, Michigan. The stream is approximately 12 miles in length from source to mouth. It is relatively rapid in flow through much of its course. The surrounding country is hilly or swampy and the soil is generally of sand and gravel or peat. Streamside vegetation varies with the soil type, but aspen is probably predominant with some mixture of pines and hardwoods in the uplands and typical swamp conifers (white cedar, tamarack, balsam, and spruce) in the lowlands. Springs feed the stream at intervals from the source to near the mouth. A more detailed account of the ecology of Hunt Creek has been given by Shetter and Leonard (1943).

In 1939, approximately 2 miles of stream near the headwaters were selected (Hazzard, 1940) for intensive studies of the life history and management of the brook trout (Salvelinus fontinalis Mitchill). This portion of the stream has been kept under constant observation since that time by a resident staff of fisheries biologists. After preliminary

examination the stream was divided into sections based upon physical characteristics, and signs were erected marking the boundaries. The entire stream in the experimental area was mapped to show the stream channel, water depths, bottom types, and existing shelter for fish.

Description of the Experimental Section

One of the experimental sections, 1,605 feet in length, and designated as Section B, was selected for a study of the effects of pool-forming deflectors. In this part of its course Hunt Creek flows through a swamp and has a border of tamarack, balsam, spruce, and poplar. It is moderately rapid in flow (about 1.5 feet per second in mid-channel) and before improvement was shallow with few pools. Undercut banks and submerged logs (part of them old CCC stream improvement structures) provided rather scant shelter for fish. The bottom is largely of moderate to fine gravel and sand, with some muck in the quiet water along the edge.

Sparse growths of Chara and Veronica are found near the margins in a few places. The brook trout (Salvelinus fontinalis) and the muddler (Cottus cognatus) are the principal species of fish. Other fish occasionally taken are the mudminnow (Umbra limi), the brook stickleback (Eucalia inconstans), the bluntnosed minnow (Hyborhynchus notatus), the fathead minnow (Pimephales p. promelas), the northern redbelly dace (Chrosomus eos), and the black-nosed shiner (Notropis h. heterolepis).

Methods

Plans for the experiment were made by Dr. Justin W. Leonard (then in charge of the Hunt Creek Fisheries Experiment Station), and the authors. The senior author has been in immediate charge of the creel census at Hunt Creek and became acting director of the Station in February, 1943.

Mapping.--Three maps of the experimental area were made: one on May 23-24, 1939 when remains of nine log wing deflectors installed by Civilian Conservation Corps crews persisted; one in October, 1943 after 24 wing deflectors were installed; and one in 1944. Maps were constructed at a scale of 20 feet to the inch with plane table and alidade and all distances were chained or determined by stadia readings. Cross sections of the stream were made at regular intervals and intermediate soundings were taken where changes in profile or anticipated future needs made additional depth information desirable. Bottom soils, bars, logs, stream velocities, timber types, and log sizes were noted on maps. On October 30, 1943, ten days after the second mapping a stream gage was installed about a mile below the test section and a reading of 1.4 feet obtained. At 300-foot intervals along the test section permanent reference stakes were set.

Installation and costs of improvement structures.--In September, 1941, twenty-three wing deflectors and in 1943, one deflector, were installed in the test section, or one structure for each 70 feet of stream. They consisted of 22 single wing, 1 double wing, and 1 diversion deflector. The typical structure was a rectangular log crib 30 inches by 30 inches by 25 feet and two or more logs high (Figure 1). The logs were wired and stapled to posts placed with a hydraulic jet. Log spreaders were placed at intervals along the structure. The interior space was filled with gravel, sand, sods and earth and the top well sodded to prevent surface erosion and to improve the appearance. Wings were installed at an angle of 35 to 45 degrees to the center thread of the stream with the terminal end being downstream from the base.

Figure 1.--Two single-wing deflectors in Section B of Hunt Creek.

The total cost of the 24 deflectors together with maintenance to the end of 1946 amounted to $512.16. Of this amount, $130.00 constituted the maintenance costs for the 5-year period, leaving $382.16 as the original construction cost, or $15.50 as the average cost per unit. The average annual maintenance cost for each structure was $1.09, a figure we believe will decrease as the bars formed behind the wings become stabilized by vegetation. The highest water for the period 1938 to 1946 occurred on June 1, 1944, when a gage reading of 2.45 feet was recorded. This flood caused damage requiring more than average repair, in some cases necessitating the lifting of the sod to replace washed-out material.

Food and fish population studies.--The effect of the deflectors upon the food supply of trout was measured by comparison of square-foot samples of the bottom fauna taken from September 17 to October 15, 1941, prior to the improvement, with similar samples taken at approximately the same time of year in the three years after the structures were placed. Twenty sampling stations were selected in areas which presumably would be affected by the deflectors. The folding square-foot device described by Surber (1937) was used to secure the samples. Organisms were measured volumetrically by water displacement and identified to species in most instances. Stomach examinations and studies of the fauna in the other parts of the stream contributed to this investigation.

Sample counts of the fish population were made in August of 1941, 1942, 1943, and 1944. Theoretically, the 1941 count represents the fish population for an unimproved stream area, and the counts for succeeding years represent fluctuations in the population caused by the habitat changes resulting from the installation of pool-producing deflectors.

Five different stretches of Section B, varying in length from 60 to 83 feet and in width from 13 to 23 feet, considered to be representative of the stream conditions originally found there, were selected as sampling areas for the long-term study and marked with stakes. Each year during late August these sections were blocked off by fine-meshed seines (1/4 - and 3/8-inch bar measurement, 40 to 60 feet long and 6 feet deep) staked to the stream bottom. The fish populations of the blocked-off portions were then removed and counted, weighed, and measured by species. All brook trout captured were measured individually and all larger than 4 inches were weighed individually. The fingerling brook trout were weighed in groups of 10 fish. Scale samples have been preserved from all trout larger than seven inches, and from a good random series of those less than the legal length. All fish captured were returned alive to the stream except for a small number killed in the process of capture or handling and retained for stomach analysis. It is therefore believed that the sampling has had little if any influence on the final results.

Two methods of obtaining the fish populations from the sample sections have been used. In 1941, the sample areas within Section B were blocked off and the enclosed populations removed by intensive seining for 3 to 5 hours per section with common-sense seines and 8-foot by 6-foot by 3/8-inch mesh seines, the method described by Shetter and Hazzard (1939). In 1942, 1943 and 1944, the electric "shocker," modified somewhat from that described by Haskell (1940), was used in the collection of the fish from the blocked-off areas (Figures 2 and 3).

Shetter and Leonard (1943) demonstrated that by intensive seining it is possible to capture only about 90 percent of the total number of

Figure 2.--Portion of Section B prepared for population study by means of electric shocker. Blocking seines are placed at either end of sample area; shocker unit is at base of deflector in middle background.

Figure 3.--Use of electric shocker in trout stream population study.

trout present, even under the best conditions. The remaining 10 percent of the population consists mainly of fish belonging to the smaller size groups. Consequently, the actual counts of smaller fish obtained for 1941 are probably somewhat low and the observed results were corrected accordingly from data obtained by Shetter and Leonard (1943). However, the sample counts for 1942, 1943 and 1944, when the "shocker" was used, are probably very close to the actual number of fish present. Thirteen tests with from 12 to 40 marked fish introduced into the sample sections after they were blocked off indicate that the "shocker" has an efficiency of 100 percent for brook trout 7 inches or larger, 94.4 percent for brook trout 4 to 7 inches long, and 96.2 percent for fingerling brook trout under 4 inches in size, or an over-all average efficiency of 95.7 percent for all trout present.

Since the five sample areas studied were the same each year, the changes in the actual populations of the sample areas may be taken to indicate increases or decreases in the fish population of Section B. The actual numbers of fish given in the tables are the totals obtained from 366 lineal feet of Section B. An area of 7,360.8 square feet (0.169 acres) was sampled, or approximately one-fourth of the total area of Section B.

Creel census.--Starting with the trout fishing season of 1939, complete records of the catch were secured for the entire 2 miles of stream in the Hunt Creek experimental area. Creel census clerks employed and trained by the Institute interviewed fishermen and examined the fish taken by them. Almost all of the fish were measured and weighed individually and the catch and the time spent fishing in each section were recorded. The data secured represent the yield of the stream for

3 years prior to installation of the deflectors and for 5 years thereafter. Hence any major changes in the quality of fishing can be attributed to the modification in the environment produced by the deflectors. The trout season has varied from 129 to 136 days in the period 1939-1946, since it opens the last Saturday in April and extends through Labor Day. There was no change during the period in the regulations as to size, creel limit, or otherwise. The fishing pressure varied somewhat because of war-time travel restrictions and with the increased popularity of the improved section, but not enough to affect the experiment as it has been conducted.

Results of Deflector Installation

Physical changes.--In 1939, soundings were taken at locations where 13 structures were subsequently placed. The average maximum depth at these locations in 1939 was 1.52 feet (Table 1). The same locations in 1943 showed an average maximum depth of 2.07 feet, and in 1944 of 2.08 feet, representing an average increase of 0.55 foot per pool by 1943 and no significant difference the following year. Tarzwell (1937) found the average increase in pool depth in five Michigan streams resulting from deflector installation was 13.2 inches. In general, material was swept from the pool floors by the deflector-accelerated current which also tended to concentrate the coarser gravel over the pool bed area below the structure.

Tarzwell (1937) recorded an average area of gravel uncovered by deflectors of 266 square feet on the Little Manistee River; 144 square feet on the East Branch of the Black River; 122 square feet on Gamble Creek; 542 square feet on the Pigeon River; and 18 square feet on the

Table 1.--Change in stream pool depths of Hunt Creek, Section B, 1939, 1943, 1944. Structures were installed in the fall of 1942.

Pool and deflector number	Maximum depth in feet in 1939	Condition in 1939	Maximum depth in feet in 1943	Change in depth in feet over 1939	Maximum depth in feet in 1944	Change in depth in feet over 1939	Pool area in square feet, 1944
1	2.0	...	1.7	-0.3	1.9	-0.1	80
2	No record	No pool	2.5	...	2.4	...	600
3	No record	No pool	2.5	...	2.4	...	
4	1.6	...	1.9	+0.3	2.0	+0.4	200
5	1.6	...	1.5	-0.1	2.7	+1.1	60
6	0.6	No pool	2.0	+1.4	2.1	+1.5	100
7	2.0	...	3.3	+1.3	3.3	+1.3	160
8	No record	No pool	2.0	...	2.2	...	200
9	No record	No pool	1.4	...	1.8	...	160
10	2.0	...	2.1	+0.1	2.0	0	200
11	No record	No pool	2.0	...	1.4	...	80
12	1.0	No pool	2.0	+1.0	1.5	+0.5	120
13	No record	No pool	3.3	...	3.0	...	320
14	No record	No pool	2.5	...	2.4	...	240
15	2.0	...	2.2	+0.2	2.2	+0.2	440
16	1.8	...	1.9	+0.1	1.7	-0.1	120
17	0.7	No pool	1.8	+1.1	1.6	+0.9	280
18	No record	No pool	2.4	...	2.4	...	1,600
19	No record	No pool	3.0	...	2.8	...	
20	1.0	No pool	2.3	+1.3	2.3	+1.3	
21	No record	No pool	1.5	...	1.5	...	200
22	2.0	...	2.6	+0.6	2.2	+0.2	240
23	No record	No pool	1.9	...	1.6	...	240
24	1.5	...	1.6	+0.1	1.6	+0.1	80
Total	...	...	...	...	...	...	5,720
Average	1.52	...	2.07	...	2.08	...	238
Average change over 1939, in sites for which data are available for the 5-year period			...	+0.55	...	+0.56	...
Minimum total increase in pool area.[1]			...	...	...	...	4,140

[1] Based on gains over areas listed in Column 3 as containing no pools prior to improvement.

West Branch of the Sturgeon River. Little change is apparent in the bottom soil types in Section B of Hunt Creek, except increased deposition of silt behind the wing structures and sand bar formation downstream from the terminal end of several wings. At the time of the original survey there were nine pools that were judged to be capable of harboring legal trout. Two of these were excellent, but the others were shallow and of very limited extent. In 1944, there were 29 pools, all of considerable size. Two of the original nine pools had become reduced in depth to a point where they are not now classed as pools. New deflectors were installed at the sites of 5 of the old devices and 2 pools were undisturbed by new construction, leaving a total of 19 pools that have been added to the experimental area. Five of the original nine pools have been expanded considerably by the wing deflectors. The total pool area as computed in 1944 was 5,720 square feet, a ratio of pool area to total stream area of 1 to 5.2. Although the original pool area was not determined, the two best pools at the time of the 1939 survey, upon which no subsequent improvement was placed, have not significantly increased in area. The five pools near which new structures were installed have materially increased in both depth and area. The average area per pool, using the 1944 figures, was 238 square feet.

Using all soundings, the average depth in the section was 1.29 feet in 1939 and 1.30 feet in 1944. This change was too small to be significant assuming the water stage was approximately the same at the time of both surveys. No water stage was recorded in 1939, but there is considerable evidence that the water at that time was substantially at the same stage as in 1944. The maximum depth of the pool below the dam at the upper end of the section was 0.1 of a foot deeper in 1944 than in 1939.

This pool was unaffected by any of the improvement structures placed below. Several areas intermediate between structures retained approximately their same depths for the two periods, indicating but slight change in water stage for the 1939 and 1944 survey periods.

Considerable movement of sand and silt has occurred near the structure sites. Most of the finer sediments have been deposited in the back-water area behind the wings and smaller amounts at the angle where the upstream edge of the wing deflector intersects the bank. Coarser sediments (largely sand) have been deposited in bars paralleling the current and extending from a point near the outer end of the deflector downstream for variable distances depending on current velocity. Below the double-wing deflector and the diversion structure sand and gravel have been deposited at right angles to the current where the water velocity is sufficiently lessened to prevent further transport. The bar thus formed has emerged above normal water flow and on it some vegetation has become established. Removal of the finer sediments by current action has exposed additional gravel bottom in the stream area where more rapid flow predominates.

The character of the banks, the generally stable water level, and good marginal cover have eliminated the necessity for bank protectors. The sod placed on the deflectors has become well rooted, providing a stable cover for the deflectors and giving them a pleasing natural appearance. In a few cases undercutting and settling of the earth fill has occurred, mostly following the 1944 flood. Replacement of fill accounts for the major portion of the maintenance costs. Subsequently it has been found that sheet piling extending back 4 to 6 feet from the stream end of each deflector prevents undercutting and settling of the earth and sod.

The total area of the experimental section as measured from the maps by polar planimeter underwent little significant change. In 1939 the computed area was 30,124 square feet, or 0.69 acres. In 1943 and 1944, areas were 30,960 and 29,640 square feet, or 0.71 and 0.68 acres respectively. The 1943 and 1944 measurements included the area of the installed structures.

Judging by the average depth and area of the total section before and after improvement, cutting and deposition caused by the deflectors is local. Excavation to form pools has been equalized by deposition of sediment in bars below pools or on the upstream or downstream shoreward end of the deflectors. This process may be considered as controlled resedimentation, which directs the shifting bottom materials into areas where they may eventually become stablized by the growth of marginal vegetation.

Effects on aquatic insects.--Dr. Leonard's annual surveys of bottom fauna were interrupted by his entry upon military duty early in 1943. From the South Pacific, Captain Leonard wrote in 1944:

> "For some time after improvement devices were installed, a decrease in total number and volume of bottom organisms was noted. A decrease appeared logical in view of the considerable physical disturbance incident upon the work of construction. During the late fall and winter months of 1942-43, however, faunal recovery was apparent. It was gratifying to note that a favorable change in species occurrence ratios was taking place. Certain species of Trichoptera and Chironomidae, and the scud, Hyalella, apparently favored items of trout diet in Hunt Creek as evidenced by stomach analyses, were taken in greater quantity than before improvement. Nymphs of the stonefly Isogenus, and larvae of the snipe-fly, Atherix, both pre-

daceous forms seldom encountered in trout stomachs but locally dominating the bottom fauna in Section B prior to improvement, had shown but little tendency to invade the area. Thus, at the time the study was interrupted, while the total number and bulk of bottom organisms were still slightly less than prior to improvement, the number and bulk of organisms of proven value in trout nutrition were greater than before, the overall loss being largely at the expense of species of dubious value in the trout food cycle. This situation greatly encouraged me in my conviction that, with further knowledge of the trout food cycle and of the ecological requirements of its essential components, environmental control measures can be perfected to restrict a stream's basic productive capacity in very large measure to the support of organisms entering directly into the trout food cycle."

The collection of bottom fauna samples has been continued and the analyses will be made the subject of a separate publication.

Changes in the fish population.--Results of sample population counts taken the year prior to improvement and each year thereafter from the same five areas are presented in Table 2. Brook trout and muddlers were the predominant forms encountered. Small numbers of creek chubs, blunt-nosed minnows, black-nosed shiners, fat-head minnows, red-sided dace, mud minnows, and sticklebacks were also present. Crayfish varied in numbers, but have never been particularly abundant.

The total brook trout population of the sample areas has shown a slight increase since the installation of the pool-forming deflectors. In 1941, the sample counts revealed 453 brook trout. In 1942, after the

Table 2.--Actual number of fish found in the five population study areas of Section B, Hunt Creek, in August of 1941, 1942, 1943 and 1944.[1]

Item	1941		1942		1943		1944	
	Number	Weight (pounds)	Number	Weight (pounds)	Number	Weight (pounds)	Number	Weight (pounds)
Brook trout - legal	...	...	...	...	1 (1)	0.14 (0.14)	4 (4)	0.59 (0.59)
sublegal	84 (99)	3.26 (3.84)	71 (75)	3.02 (3.19)	99 (105)	4.56 (4.84)	133 (141)	4.94 (5.24)
fingerling	369 (430)	3.34 (3.89)	430 (447)	3.26 (3.39)	432 (449)	2.81 (2.92)	421 (438)	2.69 (2.80)
Total trout	453 (529)	6.60 (7.73)	501 (522)	6.28 (6.58)	532 (555)	7.51 (7.90)	558 (683)	8.22 (8.63)
Muddlers	17	0.05	9	0.09	19	0.22	33	0.27
Other fish	10	0.08	14	0.07	13	0.11	18	0.08
Crayfish	29	[2]0.78	4	0.10	10	0.32	9	0.36
Totals	509	7.51	528	6.54	574	8.16	618	8.93

[1] Legal trout are 7.00 inches total length or longer, sublegal trout are those between 4.00 and 6.99 inches, fingerling trout are less than 3.99 inches. Figures in parentheses were determined by applying corrections as outlined in text.

[2] Weight of 2 crayfish not included.

deflectors had been in place for 10 months, 501 brook trout were counted. In 1943 and 1944, the numbers of brook trout listed from the sample areas were 532 and 558 respectively. Except for a drop between 1941 and 1942, the total weight of the brook trout captured has also shown an increase, varying as follows: 6.60 pounds in 1941; 6.28 pounds in 1942; 7.51 pounds in 1943, and 8.22 pounds in 1944.

Seventeen muddlers which weighed 0.05 pound were encountered in 1941. In 1942, nine muddlers weighing 0.08 pound were taken, while in 1943 and 1944, the numbers taken were 19 and 33 with corresponding weight increases. Apparently the changing bottom conditions after the installation of the deflectors in 1941 had some influence on this species also. Only eight more minnows were taken in 1944 than in 1941. The total number captured has varied between 10 (1941 count) and 18 (1944 count). Their total weight has varied between 0.07 and 0.11 pound.

Crayfish appear to have been more abundant under stream conditions prevalent in 1941, when 29 individuals weighing 0.78 pound were captured. In 1942, four individuals weighing 0.10 pound were noted, and in 1942 and 1943, ten weighing 0.32 pound and nine weighing 0.36 pound were taken, respectively. After the bottom becomes more stabilized, however, the original numbers and weight of crayfish may again be reached.

In 1941 and 1942, no legal fish were captured in population studies in the sample sections. The explanation for failure to take any legal trout in Section B in these years is believed to be that legal trout were very scarce. However, in 1943 one legal fish (weight 0.14 pound) was captured, and in 1944 four legal fish (total weight 0.59 pound) were taken aside from those removed by angling. Although the evidence as regards legal-sized brook trout in the sample areas under consideration

is slight, it does indicate an increase in numbers of legal fish. Better evidence as to the increase in numbers of brook trout larger than 7 inches is available from the creel census data.

In Table 2, in parentheses, will be found the numbers of brook trout estimated to have been present in the various years. The actual numbers counted have been corrected as follows: 1941 data obtained by block-and-seine technique were emended in accordance with observed percentages of the total brook trout population obtained by Shetter and Leonard (1943) by seining; 1942, 1943, and 1944 data were corrected by percentages of efficiency observed during those years from 12 marking and recovery tests of a limited nature (see p. 00). No data on the efficiency of the shocking are available for muddlers, crayfish, and other fish, and the information on these forms has not been corrected. Except that the 1941 data were obtained by block-and-seine technique, and in subsequent years by use of the shocker, the samples are comparable.

With the exception of 1942, the sublegal brook trout (those from 4 to 6.99 inches total length) increased in the years following the placement of the deflectors. The numbers and weights of sublegal brook trout were 99 fish (weight 3.84 pounds)[2] in 1941, 75 fish (weight

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[2] The comparative figures given here are based on the data corrected as explained in the preceding paragraph.

3.19 pounds) in 1942, 105 fish (weight 4.84 pounds) in 1943, and 141 fish (5.24 pounds) in 1944. The fingerling brook trout (those less than 4 inches total length) have fluctuated in the yearly samples. From 430 fingerlings estimated in 1941, they have varied as follows: 447 in

1942; 449 in 1943; 438 in 1944. The average size of individuals of each group has undergone slight changes (Table 3). In 1941, fingerling brook trout averaged 2.97 inches in length and 0.14 ounces in weight. By 1943, however, this size group of fish averaged only 2.64 inches in length and 0.11 ounces in weight. A slight increase to an average length of 2.68 inches attended by a decrease in average weight to 0.10 ounces occurred in 1944.

The sublegal brook trout in 1941 were of an average size of 4.9 inches and 0.62 ounces. In 1942 and 1943, for all practical purposes they were the same average size (1942 - 4.99 inches and 0.68 ounces; 1943 - 4.97 inches and 0.74 ounces. A decrease in the average size of trout belonging to this size group took place in 1944, when the average length was only 4.71 inches and the average weight 0.60 ounces. The legal trout captured were too few to permit any comparison.

The reasons for the decreases in the average size of trout in some size groups may be more readily understood if the arbitrary size groups into which the brook trout were separated are broken down still further, as has been done in Table 4, where the number of trout in each inch grouping from 2 to 7 inches is given. It will be noted that there was an increase in the numbers of fish in the 0.0 - 1.9-inch, 2.0 - 2.9-inch, 4.0 - 4.9-inch, and 5.0 - 5.9-inch size groups and a decrease in the 3.0 - 3.9-inch size group. The 6.0 - 6.9-inch size group has fluctuated only slightly. These changes would tend to lower the average sizes of the arbitrary groupings.

The habitat changes produced by the deflectors apparently have made possible the survival of a larger number of brook trout between the sizes of 2 and 6 inches as well as an increase in the number of brook trout larger than 7 inches.

Table 3.--Average size of brook trout captured in the five sample areas of Section B for each year of the population studies. Lengths recorded in inches, weights in ounces.

Size group	Year			
	1941	1942	1943	1944
Fingerling brook trout				
Average length	2.97	2.78	2.64	2.68
Range in length	2.20-3.94	2.13-3.94	1.97-3.86	1.81-3.94
Average weight	0.14	0.12	0.11	0.10
Sublegal brook trout				
Average length	4.90	4.99	4.97	4.71
Range in length	3.98-6.93	3.98-6.81	3.98-6.89	3.98-6.89
Average weight	0.62	0.68	0.74	0.60
Legal brook trout				
Average length	...	...	7.05	7.41
Range in length	...	...	...	7.36-7.48
Average weight	...	...	2.22	2.37

Table 4.--Size-frequency distribution of brook trout captured in the population study areas of Section B, Hunt Creek, 1941-1944 inclusive.[1]

Size group	Size range (inches)	Number in size group in year			
		1941	1942	1943	1944
Fingerlings	0.0-1.9	...	...	1	3
	2.0-2.9	211	326	357	346
	3.0-3.9	158	102	74	72
Sublegals	4.0-4.9	58	38	57	94
	5.0-5.9	15	26	30	29
	6.0-6.9	10	6	12	8
Legals	7.0-7.9	...	...	1	4
Totals	All sizes	452(1)	498(3)	532	556(2)

[1] In parentheses are numbers of fingerlings which escaped measurement.

Similar increases in a stream fauna have been noted by other researchers but very little has been recorded in the literature concerning the changes in the fish population of an improved area after installation of improvement devices. Tarzwell (1937), in his original work on Michigan trout streams, considered the point, but was unable to conduct enough counts in sample areas before and after the installation of his experimental devices. He states (page 181): "It is significant, however, that in all tests made more legal trout were taken and the average size of the trout was greater after improvement."

The comparative figures in Table 2, obtained from five sample areas within Section B of Hunt Creek, provide evidence that the fish population of Section B was increased by the addition of pool-forming deflectors. Excluding the legal trout, because none were captured during the population studies in 1941 or 1942, the various elements of the Section B population study areas increased or decreased between 1941 and 1944 as follows:[3] Sublegal trout increased 42.4 percent in number, 36.4 percent

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[3] In calculating percentage increases or decreases, the corrected data of Table 2 were used.

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in weight; fingerling trout increased 1.9 percent in number but decreased 28 percent in weight; all trout combined increased 28.3 percent in number, 4 percent in weight; muddlers increased 94.1 percent in number, 388 percent in weight; minnows increased 80 percent in number, but showed no change in weight; crayfish decreased 69 percent in number, 54.7 percent in weight.

At the start of the intensive studies on Section B in the fall of 1941, the possibility was not overlooked that the brook trout resident upstream and downstream might be attracted into the improved area. In order that any such movement might be noted, numerous brook trout of all sizes were marked by fin-clipping in Section A (immediately downstream) and Section C (immediately upstream). The dorsal and right pectoral fins were removed from 261 wild brook trout seined in Section A, and the dorsal and left pectoral fins were clipped from 249 wild trout in Section C (Table 5). Both lots of fish were returned to the stream areas of Sections A and C from which they were originally seined.

These fish were marked in September, 1941. The experimental stream area was seined each month thereafter until November, 1942, except for the months of March and August, 1942. In the course of the seining operations records were kept of the number of seine hauls (made with an 8-foot by 6-foot by 3/8-inch mesh seine) conducted in each stream section (A, B, C, and D), and of the number and size of the various marked and unmarked brook trout captured (Tables 6, 7, 8). From these data it is possible to calculate the relative abundance of the two types of fin-clipped fish on the basis of the comparative numbers of differently marked fish caught per seine haul in the three stream sections of interest to us.

The results from these periodic seinings indicate that there was a small amount of movement into Section B from Sections A and C. However, if the catch per seine haul is compared by sections and months, it will be noted that for any month many more marked fish were captured per haul in the sections where they were marked than were taken in Section B.

Table 5.---Summary of marking data on wild brook trout seined and fin-clipped above and below Section B of Hunt Creek before deflectors were installed, September, 1941.

Stream section	Fins clipped	Number and average total length in inches of brook trout marked						Total fish marked
		Fingerlings	Average length	Sublegals	Average length	Legals	Average length	
Section A	Dorsal and right pectoral	147	3.3	113	5.1	1	8.2	261
Section C	Dorsal and left pectoral	154	3.3	93	5.0	2	7.0	249

Table 6.--Catch per seine haul of fin-clipped fish in Section A for the period October, 1941, to November, 1942, inclusive. Numbers and letters in parentheses show numbers and section of origin of fish marked and released outside of Section A; all other recoveries were marked and released in Section A.

Date of seining	Marked fish caught			Number of hauls	Catch per seine haul		
	Legal	Sublegal	Fingerling		Legal	Sublegal	Fingerling
1941							
October	0	13	2	27	0	0.48	0.07
November	0	3	0	44	0	0.07	0
December	0	5	0	45	0	0.11	0
1942							
January	0	1	0	20	0	0.05	0
February	0	0	0	30	0	0	0
April	0	0	1	37	0	0	0.03
April	0	2	0	24	0	0.08	0
May	0	11 (1-C)	2	40	0	0.27	0.05
June	1	4	0	38	0.03	0.11	0
July	4	3	0	30	0.13	0.10	0
August	1	3	0	33	0.03	0.09	0
September	2	6	0	28	0.07	0.21	0
October	4	7 (1-C)	0	34	0.12	0.21	0
November	0	2	0	28	0	0.07	0
Total	12	60 (2-C)	5	458	...	...	...
Average	...	...	...	...	0.03	0.13	0.01

Table 7.--Catch per seine haul of fin-clipped fish in Section B for the period October, 1941 to November, 1942, inclusive. (Numbers and letters in parentheses show numbers and section of origin of fish marked and released outside of Section B; all other recoveries were marked and released in Section B).

Date of seining	Marked fish caught			Number of hauls	Catch per seine haul		
	Legal	Sublegal	Fingerling		Legal	Sublegal	Fingerling
1941							
October	0	1 (1-A)	0	25	0	0.04	0
November	0	1 (1-A)	0	24	0	0.04	0
December	0	0	0	33	0	0	0
1942							
January	0	0	0	24	0	0	0
February	0	0	0	28	0	0	0
April	0	0	0	43	0	0	0
April	0	2 (1-A,1-C)	1 (1-C)	32	0	0.06	0.03
May	0	2 (1-A,1-C)	1 (1-C)	26	0	0.08	0.04
June	0	3 (2-A,1-C)	0	31	0	0.10	0
July	0	1 (1-C)	0	35	0	0.03	0
August[1]	...	...	...	...	...	...	...
September	0	0	0	34	0	0	0
October	0	3 (3-C)	0	41	0	0.07	0
November	0	2 (1-A,1-C)	0	28	0	0.07	0
Total	0	15 (6-A,9-C)	2 (2-C)	404	...	...	...
Average	...	...	...	...	0	0.04 (1.02-A,0.02-C)	[2]0.00

[1] Deflectors being installed in August; no seining done.

[2] Average less than 0.00.

Table 8.--Catch per seine haul of fin-clipped fish in Section C for the period October, 1941, to November, 1942, inclusive. Numbers and letters in parentheses show numbers and section of origin of fish marked and released outside of Section C; all other recoveries were marked and released in Section C.

Date of seining	Marked fish caught			Number of hauls	Catch per seine haul		
	Legal	Sublegal	Fingerling		Legal	Sublegal	Fingerling
1941							
October	0	20	9	37	0	0.54	0.26
November	0	12	12	58	0	0.21	0.21
December	0	13	8	84	0	0.15	0.10
1942							
January	0	14	5	54	0	0.26	0.09
February	0	7	4	54	0	0.13	0.07
April	1	8	3	78	0.01	0.10	0.03
April	2	26	7	59	0.03	0.44	0.12
May	0	19	1	52	0	0.37	0.02
June	1	11	0	43	0.02	0.25	0
July	0	4	0	57	0	0.07	0
August	0	4	0	42	0	0.10	0
September	0	7	0	40	0	0.18	0
October	0	4	0	54	0	0.07	0
November	0	5	0	30	0	0.16	0
Total	4	154	49	742	...	...	...
Average	...	...	...	...	[1]/0.00	0.21	0.07

[1]/Average less than 0.00.

At no time in the course of the seinings were any marked fish of legal size taken in Section B by seining, although marked legal fish were captured by seining (and also by angling) in Sections A and C. Sublegal fish were taken most frequently. Considering all the seining data, the catch per seine haul in Section C of sublegal fish marked in Section C was 0.21 fish, of the same marking recovered in Section B, 0.02 fish, or 10 times less. For sublegal fish marked in Section A, about nine times fewer fish of that marking were recovered per seine haul in Section B than were recovered in Section A (0.13 fish per seine haul in Section A; 0.014 fish per seine haul in Section B). No fish marked as fingerlings in Section A were recovered in Section B, and only two fingerlings marked in Section C were captured in Section B.

The fin-clipped fish marked in Section C which were captured in Sections B and A are regarded as passive migrants which were current-borne to the lower habitats. A small percentage of the Section B brook trout population was derived in this manner before the installation of the devices as well as afterward, as can be proven by the results of the seining prior to 1941 for other lots of wild experimental fish marked in Section C (unpublished data).

It is very likely that the migrants from Section A which were later caught in Section B are probably fish which were marked near the Section A-Section B border and whose normal ranges extended upstream into the lower course of Section B. The authors believe that the small amount of passive movement and sporadic wanderings by brook trout in the neighboring stream sections have not materially increased the Section B brook trout population since the deflectors were placed, and have influenced the anglers' catch only slightly.

Trout migration from tributary streams.--Two tributary streams enter Section B between its upper and lower limits. Tributary 3, which meets the main stream just above the lower end of Section B, is about 2-1/2 miles long, drains one natural lake and one artificial trout pond, and flows about 400-500 gallons a minute. Tributary 4 (Fuller Creek), which enters Section B at its extreme upper end, drains East Fish Lake (a trout lake) and is 2 miles in length. It flows about 5,000 gallons per minute (approximately equal to Hunt Creek where the two join). Both tributaries are trout streams but only Fuller Creek is fished.

Two-way fish traps were operated on both Fuller Creek and Tributary 3 during the course of the experiment. The records of fish capture have some bearing on the question of the source of the increased yield of Section B and some pertinent data are given in Tables 9 and 10.

From records of daily inspection over a five year period (Table 9) it would appear that population increases in Section B might have been the result of more downstream migration from Tributaries 3 and 4 and less movement out of B into those tributaries, if one assumes that all fish moving downstream out of those tributaries became residents of Section B. Untabulated data for 1945 and 1946 from weir records, tag recoveries and creel census indicated that no greater percentage of the anglers' catch in Section B in those years was composed of fish originating in the tributaries than for the previous years.

The influence of trout moving from the tributaries toward Section B can be estimated from the numbers of trout tagged in the period October, 1940 - October, 1944 and the location of ultimate recovery (Table 10).

From 548 brook trout marked moving downstream through the Tributary 3 weir, 78 have been recovered, 15 of them in Section B. The

Table 9.--Known numbers of brook trout of all sizes exchanged between Section B and Tributaries 3 and 4, as shown by trapping weirs at mouths of the tributaries.

Time period	Tributary 3		Tributary 4		Totals	
	Out of B	Into B	Out of B	Into B	Out of B	Into B
Aug. 15, 1939-Oct. 30, 1940	(No weir)	(No weir)	28	1,099	28	1,099
Oct. 1, 1940-Sept. 30, 1941	219	41	23	403	242	444
Oct. 1, 1941-Sept. 30, 1942	303	270	70 [1]	37 [1]	373	307
Oct. 1, 1942-Sept. 30, 1943	193	601	254	397	447	998
Oct. 1, 1943-Sept. 30, 1944	0	293	198	350	198	643
Totals	715	1,205	573	2,286	1,288	3,491

[1] Weir on Tributary 4 not operated for the period Nov. 16, 1941-Aug. 10, 1942.

Table 10.--Numbers of brook trout tagged moving toward Section B in Tributaries 3 and 4 in various years, and the number and locality of recovery of the tagged fish in subsequent years.[1]

Tributary where tagged	Date of tagging	Number of tagged trout moving toward Section B	Number of tagged brook trout recovered							
			1941		1942		1943		1944	
			In Section B	Elsewhere	In Section B	Elsewhere	In Section B	Elsewhere	In Section B	Elsewhere
Tributary 3	Oct. 1, 1941-Sept 30 1942	138	0	0	8	16	1	2	0	3
	Oct. 1, 1942-Sept 30, 1943	277	0	0	0	10	4	19	1	4
	Oct. 1, 1943-Sept 30, 1944	133	0	0	0	0	0	0	1	10
Tributary 4	Oct. 1, 1940-Sept 30, 1941	202	0	0	0	1	0	1	0	0
	Oct. 1, 1941-Sept 30, 1942	12	0	0	0	2	0	0	0	2
	Oct. 1, 1942-Sept 30, 1943	209	0	0	0	3	1	3	1	8
	Oct. 1, 1943-Sept 30, 1944	182	0	0	0	0	0	1	2	17

[1] Fish were recovered by means of angling, seining, weir traps, or electric shocker, and were of all sizes.

largest number was recaptured from the 138 fish marked during the 1941-1942 season in Tributary 3, with 9 recoveries made in Section B and 21 elsewhere. A smaller proportion of the fish tagged in 1942-1943 in Tributary 3 was recovered in Section B (5 out of 277 tagged were recovered in Section B, 33 out of 277 elsewhere), and a still smaller proportion of the 1943-1944 marking was taken in Section B (1 of 133 marked was taken in Section B, 10 of 133 were captured elsewhere).

Records for Tributary 4 show that none of the 214 brook trout tagged in 1940-1941 and 1941-1942 were captured in Section B. From the 1942-1943 tagging of 209 fish in Tributary 4, 2 were later recovered in Section B, while 14 were recovered elsewhere. The 1943-1944 markings at Tributary 4 included 182 fish, of which 2 have been recovered in Section B and 18 elsewhere.

Although Tributary 2 enters Hunt Creek about 80 yards downstream from the lower boundary of Section B, it also has had a slight influence on the population of the experimental section under consideration. From 289 brook trout of all sizes tagged between October, 1941, and October, 1944, a total of 59 fish was recovered. Three of these recoveries had moved upstream into Section B and 56 were recaptured elsewhere, chiefly in Section A or further downstream.

The evidence just presented indicates that only a small part of the increases in the Section B population have been the result of downstream movement from the tributaries. No valid method of estimating the extent of the increases ffom the downstream migrations of any year in any tributary appears possible, since the recoveries listed in Table 10 were obtained by various methods involving different units of fishing effort

(i.e., it would not be proper to compare the number of recoveries made by angling with those made by seining, shocking, or trap).

The data available from the fin-clipping and subsequent seinings of native brook trout in stream sections immediately above and immediately below the improved water, plus the weir records from Tributaries 2, 3, and 4, with the tag recoveries from fish marked at those weirs, suggest that a small but unknown percentage of the population increase of Section B noted in the population studies was due to migrations into Section B from neighboring waters (Sections A, C, Tributaries 3 and 4).

Although it would be desirable to evaluate accurately the contribution of the three tributaries and the neighboring stream areas to the population increases noted from 1941 through 1944, a lack of knowledge concerning the number of brook trout moving out of the tributaries and neighboring sections, and their subsequent residence previous to the improvement of Section B, makes it impossible to compare the known data (which pertain chiefly to the period after improvement) with previous conditions. However, if Section B has been improved so that its carrying capacity for brook trout has increased as our studies indicate, is the source of the increase of particular importance? It may be logically reasoned that if 10 trout leave Section A to reside in Section B, they have made space and food available for 10 other trout to survive in Section A. Similarly if one assumes that before improvement of Section B, 90 fish out of every 100 moving downstream out of Tributary 3 continued on downstream in Hunt Creek, and after the deflectors were placed only 80 out of 100 migrated out of Section B, then more space and food would be available for the fish populations of the lower waters. Although the

total increase of the Section B population did not originate entirely from within the improved section, it is evident that stream conditions there after improvement are now capable of supporting more trout. This fact appears to be demonstrated by the general increase in the number and poundage of the different size groups of brook trout taken in the population counts, and also by the increased numbers of legal trout in the anglers' catches.

Natural spawning was observed to occur each fall in Section B throughout the 6-year period of the study. Since there were no counts of nests prior to the installation of the stream improvement devices, no comparison with the 32 redds observed in the fall of 1944 can be made. In 1944, several redds were noted along the gravelly upstream faces of deflectors, or at their terminal ends where suitable bottom had been exposed by placement of the devices. All available data indicates that natural spawning has continued to be successful. The increases noted in the brook trout population probably result from better survival of young brook trout, a circumstance attributed to the habitat changes made by the deflectors.

Changes in angling.--A comparison of the returns to the angler from a water area before and after environmental improvement is the best measure of its value. Tarzwell (1937) reported angling results on an area of the East Branch of the Black River in Michigan before and after improvement. Although the number of seasons of fishing before and after improvement is not stated, Tarzwell's data indicated a 48 percent increase in angling quality, as measured by the number of trout caught per hour, following improvement.

The same author (Tarzwell, 1938) chose a different method to demonstrate the angling benefits to be derived from stream improvement in experimental work in the Southwest. Two Arizona streams of similar length and physical characteristics were placed under intensive creel census. Horton Creek was improved throughout its length, while Tonto Creek was left unimproved. The creel censuses conducted on these two streams during the 1936 and 1937 trout seasons show that the legal trout catch per acre on the Horton Creek improved water exceeded the per acre removal from the unimproved stream by 15 and 48 percent respectively.

Certain features of the Arizona experiment might be questioned, such as the fact that no creel census data are presented for either Tonto Creek or Horton Creek before Horton Creek was improved. It is also unfortunate that hatchery trout were introduced into these experimental streams during the course of the last season of creel census. Over one-third more legal and near-legal trout were placed in the improved stream than were released in the unimproved water. Although these trout were fin-clipped, Tarzwell states that the mark regenerated towards the end of the 1937 season, so that their influence on the 1937 catch could not be evaluated with accuracy. It is not impossible, in view of recovery results noted for plantings of legal-sized hatchery fish (Gee, 1942) in southwestern streams, that one-third to one-half of the 1,250 hatchery-reared fish released in Horton Creek in 1937 might have entered the 1937 anglers' catch for that stream.

In the course of the experimental work on the effect of stream improvement devices on angling quality in Section B of Hunt Creek, an attempt has been made to eliminate experimental practices which might confuse the interpretation of results or break down the validity of the

data. The creel census data for Section B of Hunt Creek are presented in Table 11.

All but two legal brook trout listed in the catches are probably naturally-spawned fish. Plantings of hatchery-reared brook trout fingerlings were made in other areas of Hunt Creek in 1939 and 1940, but in those years all fish released were marked by clipping different combinations of two fins. With the exception of a few experimental plantings of marked legal trout, no fish have been stocked in the Hunt Creek system since 1940. The only possible unmarked legal hatchery fish which might have entered the catches listed for Section B would have originated from fingerling plantings of 1938 or earlier, and probably would have been recorded in the 1939 or 1940 catch records (before improvement). In the light of what has been learned concerning the survival of fingerling plantings in this stream (unpublished data), it appears doubtful if any but wild brook trout were encountered in those years, but the possibility is not entirely excluded. Two marked legal-sized brook trout of hatchery origin, one of which escaped from an experimental raceway about 400 yards upstream from Section B, and another which migrated upstream about 1/2 mile from a small experimental planting of legal fish, were taken in the 1942 catch. Except for these two fish all others captured by anglers since the installation of the deflectors have been wild brook trout. The changes in the catch and the angling quality may therefore be regarded as reflecting changes in the natural population of legal brook trout of Section B brought about by the stream improvement.

Creel census data for the 3 years preceding improvement indicate that there was an average angling pressure of 64.91 hours per season

Table 11.--Summary of intensive creel census for Section B of Hunt Creek for 1939, 1940, and 1941, preceding improvement and 1942, 1943, 1944, 1945, and 1946 following improvement. Figures in parentheses show the number of legal brook trout caught and returned to the stream.

Year	Hours of angling	Number of legal brook trout taken	Catch per hour	Pounds of legal fish removed	Pounds per hour	Average size		Percent of unsuccessful angling days
						Length (inches)	Weight (ounces)	
1939	33.50	15(6)	0.45	1.11	0.033	7.4	2.47	70
1940	86.50	41	0.47	6.69	0.077	8.0	2.84	62
1941	74.75	32	0.43	5.23	0.069	7.7	2.68	64
Averages	64.91	29.3(2)	0.45	4.34	0.067	7.8	2.74	64
1942	126.50	65	0.51	11.04	0.087	7.8	2.85	54
1943	73.25	67(1)	0.91	10.96	0.149	7.6	2.70	38
1944	123.50	77(4)	0.62	11.81	0.096	7.6	2.57	43
1945	77.75	36	0.46	7.09	0.091	8.0+	3.00	54
1946	132.25	78	0.59	11.51	0.087	7.5-	2.36	61
Averages	106.65	64.6(1)	0.61	10.48	0.098	7.7	2.65	51
Percentage change in averages	+64.3	+120.4	+35.5	+141.5	+46.2	-1.2	-3.4	-20.3

on Section B (range 33.50 to 86.50 hours). After improvement, angling pressure increased to an average of 106.65 hours (range 73.25 to 132.25 hours), or a percentage increase of 64.3 (Table 11). Legal trout caught in the 1939-1941 period varied between 15 and 32, with an average of 29.3 legal fish per year. After improvement the legal catch ranged between 65 and 78 brook trout (average 64.6 fish), or a percentage increase of 120.4 after improvement.

The weight of legal fish removed by angling in the seasons prior to placement of deflectors varied between 1.11 and 6.69 pounds, with an average of 4.34 pounds. After the devices were installed, anglers removed from 7.09 to 11.81 pounds of legal brook trout each season, or an average of 10.48 pounds. The average percentage of increase was 141.5.

It will be noted that, despite the increase in angling pressure on Section B, the quality of the fishing, as measured either by the catch per hour of legal brook trout or more accurately (Shetter, 1944) by the pounds of legal brook trout removed per hour of angling, has improved. The average catch per hour for the five seasons following improvement was 35.5 percent greater than for the three seasons preceding improvement (0.61 legal fish per hour as compared with 0.45 legal fish per hour). Before improvement the average number of pounds of legal trout removed per hour of angling was 0.067. After improvement this figure was increased 46.2 percent, to 0.098 pounds per hour.

There occurred a very slight decrease in the average length and average weight of the legal brook trout taken by angling in the two periods. Before placement of the deflectors, the average size of the legal fish was 7.8 inches and 2.74 ounces. In the 5-year period after installation the average size has been 7.7 inches and 2.65 ounces, a

decrease in average length and average weight of 1.2 and 3.4 percent respectively.

There has been an encouraging decrease in the number of unsuccessful angling days (angling days in which no legal fish were taken) spent on Section B. In 1939, 1940, and 1941, from 62 to 70 percent (average 64 percent) of the angling days were unsuccessful. In 1942, 1943, 1944, 1945, and 1946, from 38 to 61 percent of the angling days were nonproductive of legal trout (average 51 percent). In other words, the number of unsuccessful angling days has decreased an average of 20.3 percent since the deflectors have been in place.

The question properly may be raised as to the source of the increase in the yield following installation of deflectors. From brook trout fin-clipped in Sections A and C, two legal fish were recovered in 1942 in Section B by angling, while 12 were captured by fishermen in other sections. The three recaptures since that season have been made in stream areas other than Section B (Table 12).

Of the tagged fish recaptured in Section B which originated in the tributaries (Table 13), one legal fish of the Section B catch in both 1942 and 1943 came from Tributary 3 or Tributary 4, while in 1944, two legal fish came from Tributary 4. No brook trout tagged moving downstream in Tributary 2 have as yet been recovered by Section B anglers. Twenty-six recoveries have been made in other stream areas from the tagging in the tributaries since 1941. Since October, 1941, almost all legal-sized brook trout moving down the tributaries have been tagged, and because about 68 percent of all sublegal fish have also been tagged, the unmarked legal trout in the Section B catch may be regarded as

Table 12.--Numbers of fin-clipped brook trout recovered as legal trout by angling, with the year and locality of recovery, from the September, 1941, markings in Sections A and C of Hunt Creek.

Section of Recovery	Brook trout fin-clipped in Section A recovered as legal fish in:			Brook trout fin-clipped in Section C recovered as legal fish in:			Total recoveries for each section
	1942	1943	1944	1942	1945	1944	
D	0	0	0	0	0	0	0
C	1	0	0	6	0	1	8
B	1	0	0	1	0	0	2
A	3	1	1	0	0	0	5
Below A	0	0	0	2	0	0	2
Total for year	5	1	1	9	0	1	17

Table 13.--Number of tagged brook trout, recovered as legal fish by angling, which originated in Tributaries 3 or 4.

Figures in parentheses show number of recoveries made in Tributary 4 (Fuller Creek).

Stream where tagged	Time of tagging	Total brook trout tagged moving downstream	Year and section of recovery												Total recoveries for all years by section			
			1942				1943				1944							
			C	B	A	Below A	C	B	A	Below A	C	B	A	Below A	C	B	A	Below A
Tributary 3	Oct. 1941-Sept. 1942	138	0	1	2	2	0	1	0	0	0	0	1	1	0	2	3	3
	Oct. 1942-Sept. 1943	277	0	0	0	0	0	0	4	3	0	0	1	0	0	0	5	3
	Oct. 1943-Sept. 1944	133	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4	0
Tributary 4	Oct. 1940-Sept. 1941	202	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct. 1941-Sept. 1942	12	0	0	0	0	0	0	0	0	0 (1)	0	0	0	0 (1)	0	0	0
	Oct. 1942-Sept. 1943	209	0	0	0	0	0	0	1	0	2 (1)	1	0	0	2 (1)	1	1	0
	Oct. 1943-Sept. 1944	182	0	0	0	0	0	0	0	0	0 (2)	1	0	1	0 (2)	1	0	1
Totals	...	1,153	0	1	2	2	0	1	5	3	2 (4)	2	6	2	2 (4)	4	13	7

originating for the most part from some portion of the main stream. Since there has apparently been only a small amount of trout movement into Section B from Sections A and C it seems logical to assume that the increases noted in the Section B catch are the result of a greater survival to legal size of young trout reared in this part of the stream. A general analysis of the probable origins of the components of the anglers' catch in Section B in the various years since improvement indicates that approximately 96 percent of the anglers' catch originates from within Section B, while Section A, Tributaries 3 and 4, and Section C contribute about 4 percent, (Table 14).

A comparison of the trends in the angling quality in Sections A and C, as well as in Section B, is also of some interest. The average number of legal trout taken in Section A has decreased 14.2 percent since the improvement of Section B, and 28.9 percent in Section C (Table 15). The catch per hour in Section A increased 41.1 percent but decreased 14.3 percent in Section C. Prior to improvement the quality of fishing in Section B was considerably poorer than in Section A and about the same as in Section C. Following improvement the catch per hour in Section B averaged much higher than in Section C but was still less than in Section A. In other words, fishing got better in Section A and poorer in Section C in spite of no environmental improvement until fall of 1945 when 16 deflectors were installed in Section A.

The effect of the war on fishing pressure is evident in the total angling hours recorded for each section. It will be noted, however, that while the average load decreased 39.5 percent in A and 17.5 percent in C, in the 5 years following improvement it increased 64.3 percent in B.

Table 14.--Marked fish recovered by anglers in Section B, 1942-1946, inclusive.

Percentages of marked fish in total catch are given in parentheses.

Year	Section of origin of marked fish caught in Section B				Hatchery fish	Presumably from Section B	Total catch of Section B
	Section A	Tributary 3	Tributary 4	Section C			
1942	1 (1.5)	1 (1.5)	0	1 (1.5)	2 (3.0)	6.0 (92.5)	65
1943	0	1 (1.5)	0	0	0	66 (98.5)	67
1944	0	0	2 (2.6)	0	0	75 (97.4)	77
1945	0	0	1 (2.8)	0	0	35 (97.2	36
1946	2 (2.6)	1 (1.3)	0	0	0	75 (96.1)	78
Totals	3 (0.9)	3 (0.9)	3 (0.9)	1 (0.3)	2 (0.6)	311 (96.4)	323

Table 15.--Number hours fished, number of trout caught, and catch per hour in Sections A, B, and C of Hunt Creek before and after installation of deflectors in Section B.

Year	Section A			Section B			Section C		
	Total angling hours	Total trout caught	Catch per hour	Total angling hours	Total trout caught	Catch per hour	Total angling hours	Total trout caught	Catch per hour
1939	199.00	143	0.72	33.50	15	0.45	262.75	112	0.43
1940	296.25	152	0.51	86.50	41	0.47	259.50	113	0.44
1941	315.75	126	0.40	74.75	32	0.43	443.00	180	0.41
Average	270.33	140.3	0.51	64.91	29.3	0.45	321.75	135.0	0.42
1942	189.75	136	0.72	126.50	65	0.51	391.50	117	0.30
1943	162.50	136	0.84	73.25	67	0.91	135.00	90	0.66
1944	151.50	154	1.02	123.50	77	0.62	163.75	62	0.38
1945	124.50	60	0.48	77.75	36	0.46	226.25	102	0.45
1946	203.00	116	0.57	132.25	78	0.59	411.25	109	0.27
Average	166.25	120.4	0.72	106.65	64.6	0.61	265.55	96.0	0.36
Percentage change in averages	-39.5	-14.2	+41.1	+64.3	+120.4	+35.5	-17.5	-28.9	-14.3

In the absence of information concerning the relationship between angling quality and angling pressure, the only explanation that can be offered for the percentage increases in average number of legal trout caught and average catch per hour following improvement for Section B is an increase in the stock of legal trout available in Section B. If the legal brook trout population had not increased in Section B after improvement, the percentage increase in Section B angling pressure noted would have resulted in a decline in average angling quality.

Although it might appear that the increases noted for Section B in Table 14 were drawn from Section C, the marking data previously discussed indicates that this influence was small.

Economic Considerations

Assuming that the average difference in the yield to the angler can be attributed to the addition of pool-forming structures one can calculate the cost of adding one trout to the catch. Installation and maintenance for the 5-year period has cost to date $512.16. The average difference in the number of trout caught and kept by anglers in the period before as compared with the period after improvement was 36.3, or a total of 181.5 for the 5 years. Hence there was an actual cost of $2.82 for each additional trout entering the catch during the entire period after improvement.

Properly maintained, the deflectors should function for at least 20 years. Maintenance costs have decreased as the structures have become stablized by the compacting of fill materials and by deposition of sediments behind the structure. Assuming, however, that the annual cost of maintenance will remain at $26 for the 20-year period and that the

average annual contribution to the catch of trout will remain at 36.3, the estimated cost per additional trout produced during the 20-year period would be $1.24.

In the light of our present knowledge of conditions on Section B it seems possible that a similar increase in yield might have been attained by using fewer structures more skillfully placed. As will be noted from Figure 1, some deflectors produced larger and deeper pools than others. Although individual records were not kept for each pool it was noted that some yielded more legal trout than others, and population studies have shown that some pools contained larger numbers of legal trout than did others.

Whether the cost figures for Hunt Creek would be directly applicable to other waters of the state is questionable, but they constitute the first reliable estimate of the expense involved in producing additional trout for the angler by stream improvement. Admittedly it is expensive, but perhaps not more so than planting legal-sized fish if all proper charges and the actual returns to the angler are considered; furthermore the results are not open to the same serious objections which apply to planting. Additional experiments are under way in other sections of Hunt Creek and similar investigations are contemplated for streams elsewhere in the state on which accurate yield data can be obtained.

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Summary and Conclusions

Data obtained by mapping, population and food studies, and by an intensive creel census for a 3-year period before and a 5-year period after the installation of 24 pool-forming deflectors in a 1,605-foot section of Hunt Creek, Montmorency County, Michigan, may be summarized as follows:

(1) The number of pools judged to be capable of supporting legal-sized trout rose from 9 to 29.

(2) The average pool depth was increased by approximately 6 inches.

(3) Additional gravel was exposed by local current acceleration, and shifting sand and silt were stablized adjacent to the structures.

(4) No significant change in total stream area or in average depth in the entire stream section was apparent. Bottom scouring and deposition are therefore considered to be local and compensatory.

(5) Preliminary studies of the bottom food supply indicated a decrease in the total number and volume of all organisms but an increase in the forms found most frequently in stomachs of trout from the stream.

(6) Fish population studies made by the block-and-seine method and by the use of the electric shocker in five sample areas demonstrated a slight increase in the number of brook trout of all size groups, a small decrease in the average size of fingerling and sublegal brook trout, an increase of muddlers and minnows, and a decline in the number of crayfish.

(7) Averaging the creel census figures for the 3-year period before and the 5-year period after improvement showed increases in the anglers' catch after improvement of 120 percent in total number and 141 percent in total pounds of legal trout, and 35 percent in number and 46 percent in pounds per fisherman-hour, in spite of a 64 percent increase in fishing pressure. Average size of the trout caught decreased 1.2 percent in length and 3.4 percent in weight. The percentage of unsuccessful anglers decreased 20.3 percent.

(8) The increase in trout population and yield (as shown by census of the anglers' catch) was due mainly to a greater survival of young trout produced in Section B, and not to migration to this section from tributary streams or from the stream above or below the experimental area, was demonstrated by the recovery in Section B, by seining or by creel census, of few fish which had been marked descending through weirs on the tributaries or in the sections on either side.

(9) Comparison of creel census figures for the sections of stream immediately above and below the experimental area failed to show improvement in quality of fishing and size of yield similar to that of Section B during the period after installation of the deflectors.

(10) The improvement in trout fishing in Section B of Hunt Creek is due to beneficial changes in the physical and biological environment wrought by current deflectors.

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