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THE EFFECTS OF STREAM IMPROVEMENT UPON THE ANGLERS' CATCH AND STANDING CROP OF TROUT IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN [1]

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Abstract

In the fall of 1953, at the end of the trout fishing season, experimental Section A (1.3 miles long) of the Pigeon River was improved as habitat for brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta) by the addition of sheet-piling deflectors, stumps, and sodded logs. The anglers' catch and standing crop of trout were estimated in order to evaluate the effects of the improvement structures. Variations in the catch and standing crop were such that control for environmental variability was essential. Therefore Section B (1.2 miles long), the experimental water immediately upstream, was designated as the control. The yearly parameters of catch and standing crop in Section A were related to those in Section B through a ratio of A to B. The experimental design called for a comparison of the parameters for the 5 years before stream improvement, 1949-53, with the 5 years during stream improvement, 1954-58, i.e., while the

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improvement structures were in place. From the first 5-year period through the second, there was a statistically significant increase in the catch (A to B ratio) but not in any aspect of the standing crop. However, because of high fishing pressure in Section B during the "before" years, the increased catch could not be regarded as valid. Therefore, the experiment was extended for another 5 years, 1960-64. For this experimental extension, in 1959, the improvement structures and cover were removed from Section A and sand was added to fill the holes created by the deflectors. The changes in physical environment were recorded by detailed mapping of 13 randomly selected 100-foot segments of Section A and 10 like segments of Section B. Mapping was first done in 1958, before the improvement structures were removed; then in 1960, after they were removed; and finally, in 1964 at the end of the experiment. Square footage for three parameters was recorded: bottom soil types, water depth, and cover.

In the fall of 1959 and 1961, during the estimates of standing crop in experimental waters, large numbers of trout were marked by clipping a fin, distinctive for each section. Movement between sections was noted, by returns in the catch and in succeeding fall population estimates.

From the maps it was determined that there was a decline in the area of water over 3 feet deep and a decline in amount of cover, but little or no change in bottom soil types, after removal of the stream structures.

An assessment of the movement data indicated little interchange of trout with the water outside of the experimental area, but substantial interchange between sections.

A comparison of the means of A:B ratios for the "before" years (1949-53), with the "during" years (1954-58), and the "after" years (1960-64), for catch and standing crop, showed a consistent increase of brook trout for the years (1954-58) when the structures were in the stream. However, for the brown trout there appeared to be a steady increase throughout the three time periods, independent of the addition or removal of structures. For brook trout, a statistically significant increase occurred in numerical catch, in fall standing crop (pounds), in fall standing crop plus catch (pounds), and in numbers of age-I and older fish. Fishing pressure remained constant for the during (1954-58) and after (1960-64) years. The increase in brook trout as recorded in catch and standing crop must be attributed either to better survival or to migration of trout in response to the addition of cover.

Introduction

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 trout (Salvelinus fontinalis) and brown trout (Salmo trutta) in the Pigeon River, Otsego County, Michigan. From 1949 through 1965, six miles of the Pigeon River, divided into five almost equal experimental sections, were under the control of the

Pigeon River Trout Research Station of the Michigan Department of Conservation (now Natural Resources). Cooper (1952) and Benson (1953) gave descriptions of the area and the watershed. The experimental sections were identified as A through E, with Section A at the downstream end.

Section A was improved at the end of the trout fishing season during the fall of 1953. Stumps, sodded logs, a barrier dam and sheet-piling deflectors were installed, and a channel was cleared at one place (see Fig. 1 and Table 1). Section A was chosen for the study because the records for 1949-53 had shown that, relative to the other sections, Section A had been consistently low in contributing trout to the anglers' catch and also low in the fall standing crop. Section A was 1.31 miles long and had an area of 7.16 acres. Most of Section A consisted of wide, shallow areas of shifting sand. The gradient was low and there was little groundwater (Benson, 1953).

During the years 1954-58, 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.

Although the study was planned originally to be a before-and-after analysis of the effects of improvement in Section A alone, it became apparent in the early years that this approach would not be sufficient (Waters, 1958). The variations in the catch and in standing crop were such that a control for environmental variability was essential. For example, a consideration of the fall standing crop in Section A indicates that there was a steady increase in pounds of trout from 1949 through 1954; the structures were installed in late 1953; and then the population "crashed" in 1955-57 (Fig. 2). Without a control, it would appear that the structures were responsible for the decrease in trout population. However, the population in the experimental (not improved) Section B immediately upstream from Section A also changed through the years in a way similar to the change in Section A. Section B was 1.19 miles long and had an area of 5.90 acres. Catches and standing crops were almost always greater in Section B than in Section A (Figs. 2 and 3). In addition, Section B had more groundwater, more spawning, a greater gradient, and much less sand.

There was a complication in the use of Section B as a control, due to the fact that fishing pressure in B was unusually high during the years 1949-51 (Fig. 4), when this section was planted with legal-size hatchery trout. (The planting of trout was part of another study.) Even though no hatchery trout were included in the present evaluation, the planting produced a serious complication in the study, because the impact of the unusually high fishing pressure on the catch and standing crop of native trout cannot be determined.

In 1958, after improvement structures had been in Section A for 5 years, I attempted to evaluate the effect on catch and standing crop (Latta, 1960). Because of the high fishing pressure in Section B (as I will illustrate below), I was not able to draw any definite conclusions regarding changes in the trout catch or standing crop. It was decided, therefore, that the study should be extended another 5 years without improvement structures, and hopefully with a constant fishing pressure in both A and B. During the summer of 1959, all man-made structures plus all logs uncovered by the action of the deflectors were removed from Section A. In addition, sand was dumped into Section A to fill the holes which had been created by the deflectors. A log-jam similar to the original one was created at the downstream end of the section, to trap the moving sand and to form the shallow shifting areas that existed before stream improvement. I calculated that the amount of sand dumped in Section A was enough to cover the entire stream bed to a depth of 4 inches.

Methods

Fishing in the experimental sections of the river was allowed only by a daily permit. All anglers were required to report their catch, at the end of each trip to each section, which guaranteed a nearly complete record of the catch. The fishing regulations in sections A and B remained the same from 1949 through 1964: five trout per day and a minimum length of 7 inches. Each fishing season extended from the last Saturday in April through the second Sunday in September.

The mark-and-recapture method (Ricker, 1958) was used to calculate the number of trout present each fall, immediately after the close of the fishing season, in each experimental section. Two trips were made through each section using an electric shocker to take samples of trout (one trip to mark trout and the second to recapture, with an interval of a week between trips). I calculated the number of fish in each 1-inch size group of each species for each section. In 1953, and 1956 through 1964, about 15 scale samples were taken from each 1-inch size group of each species in each section, in order to delimit age groups. Age-group 0 (young-of-the-year) and age-group I (yearlings) were found to overlap in the 4- and 5-inch size groups. Average percentage of overlap of 0 and I age groups from the years 1953 and 1956-60 was used to delimit age groups in the years in which no scale samples were taken (Latta, 1965). Actually the age groups could be separated mostly on the basis of size alone; all trout 4 inches and less in length could be considered young-of-the-year. Examples of 95% confidence limits for the trout populations are given in Latta (1965).

In order to compute pounds of trout in the estimated populations, the average weight of each 1-inch group of each species was determined from the calculated weight at each 0.1 inch. The calculations were based on the length-weight relationships of Pigeon River trout as described by Cooper and Benson (1951).

Streams were mapped in 1958 while structures were still present in Section A, in 1960 after structures were removed, and in 1964 at the completion of the study; on 13 randomly selected 100-foot segments of Section A and 10 like segments of Section B, I measured square footage of bottom soil types, water depths and cover. Mapping included approximately 19% of the area of Section A and 16% of Section B. Each map was prepared on a plane table. Depth profiles were made across the stream every 10 feet. Depth was measured and bottom soil types were recorded every 2 feet along the traverse. Bottom soil types were recorded as silt, sand, sand and gravel, gravel, gravel and cobble, cobble, clay. Mixed categories were used when the lesser component made up more than one-third of the soil type. Cobble was defined as larger than 2 1/2 inches in diameter, gravel as less than 2 1/2 inches. Boulders were recorded as cover items. Cover was interpreted as the area under any stick, log, stump, boulder or undercut bank. Sticks as small as 2 inches in diameter were recorded. More subjective measurements were made of the square footage of shade, and of water turbulence. Shade was the vertical overhang of vegetation on the stream, and included that immediately above the water as well as large shrubs and trees high above the surface. Surface turbulence was categorized as water surface broken enough to hinder seeing a fish at a depth of 1 foot.

All field maps were adjusted to a standardized stream level. Contours were drawn for each foot of depth, and areas of bottom types were delimited on each map. The mean square feet of water depths, bottom soil types and cover in the 100-foot sample segments of sections A and B in 1958, 1960 and 1964, were calculated.

The yearly parameters of catch and standing crop in Section A were related to those in Section B, to give an A:B ratio. The single-factor analysis of variance was used to test for a significant difference between years. In those cases in which there was a significant difference, the test was extended to compare the before stream improvement years 1949-53, with the during years 1954-58, the during years with the after years 1960-64, and finally, the before years with the after years. In these comparisons, data for 1959 were not included because this was the summer in which the structures were removed from Section A and the resultant change occurred over a considerable portion of the year.

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 also was a period of transition, in which the stream was changing both physically and biologically after installation of the improvement structures. (The structures were installed in late 1953 after close of the fishing season.) It would follow that records for 1954 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. In our first analysis of the data for the Pigeon River, the records for 1954 were both included and excluded. There was no difference; therefore the data for 1954 are included in the present analysis.

Analysis of catch and standing crops

The analysis of catch included both numbers (Table 2) and pounds (Table 3) of brook trout and brown trout taken by anglers in sections A and B, 1949 through 1964. The means for the A:B ratios and the appropriate F values are presented in each table for comparison of the before-, during- and after-years of stream improvement. In the consideration of trout population abundance, the problem was what aspects should be considered. Historically, standing crop in pounds has always been a basic population measurement (Table 4). Another pertinent measurement, when no estimates of production are possible, is the summation of the fall standing crop with the catch in pounds for the year (Table 5). This measurement lacks only the estimate of pounds of trout lost to natural causes, to equal annual production. Numbers of trout are important in order to make judgments on population changes, and on the catch which is regulated in numbers. Age-I and older trout, plus the number caught, should be a sensitive measurement of any influence of stream improvement on numbers of trout (Table 6). Young-of-the-year trout are the key to recruitment to the population (Table 7), but in the Pigeon River they are largely controlled by environmental factors (Latta, 1965). Presumably, their deletion from the total population numbers would leave the remaining part of the population as a more sensitive reflector of the habitat manipulation. Increased survival of age-I and older trout in Lawrence Creek, Wisconsin, was accredited to stream improvement according to Hunt (1969). In the present analysis, the number of age-I and older trout in the fall populations is considered (Table 8), as well as the number which are 7 inches and larger (Table 9). With a minimum size limit of 7 inches, there is concern about the number of legal-size fish present in the stream at the close of the season.

In order to complete the analysis, consideration must be given to fishing pressure on sections A and B (Table 10, Fig. 4) and to the number of trout caught per hour per trip (Table 11, Fig. 5).

The catch and the various aspects of the population abundance as presented above are summarized in Table 12. For the brook trout the means of A:B ratios follow the same pattern for the catch and standing crop, of low for the before years (1949-53) high for the during years (1954-58), and low for the after years (1960-64). The two lows, for the before and after years, are of the same magnitude. The only exception to this pattern was for the number of trout 7 inches and larger in the fall population, in which the ratio for the before years appears to be particularly high (perhaps as a result of the high fishing pressure in Section B depleting the standing crop). Within the fairly consistent pattern, differences which were statistically significant involved the catch in numbers, the fall standing crop in pounds, the standing crop plus catch (pounds), and the number of age-I and older fish plus catch. In the detailed statistical comparisons none of the F values for the before-versus-after years were significant. Also the F value for the before-versus-during years for the fall standing crop (pounds) was not significant.

For the brown trout the means of A:B ratios also follow a pattern, but one entirely different than for the brook trout. In this case the means of the ratios increase steadily from the before years through the after years. Only the catch in numbers, and the age-I and older plus catch (numbers), were significant. In the detailed comparisons of these two measurements, only the F values for the before-versus-after years were statistically significant. For total fishing pressure, and catch per hour per trip, there were significant differences between periods. For fishing pressure, there were statistically significant differences in the before-versus-during, and before-versus-after, but not in during-versus-after comparisons. For the catch per hour per trip there was only a significant difference in the before-versus-after comparison.

It is obvious after consideration of the yearly changes in pounds of standing crop (Fig. 2), or in numbers of age-I and older plus catch (Fig. 6), that you must relate Section A to a control such as Section B. Verification of Section B as being typical of the Pigeon River is provided by considering trout populations in sections C and D, the two-plus miles of experimental water immediately upstream from Section B. In these sections the populations show the same trends in growth and decline as they did in Section B. In sections C and D as in Section B, through the years 1949-64, there was a tendency for the brook trout population to gradually increase in both numbers and weights, whereas the brown trout population decreased.

The brook trout and brown trout in Section A did not follow these trends, presumably as a result of the stream habitat manipulation. The brown trout in Section A, relative to those in Section B, maintained the same population size, or increased slightly, at the same time that the population in Section B was decreasing. This resulted in the observed increase in means for the A:B ratios through the time periods (Table 12). I conclude that the brown trout population did not respond to either the addition of stream improvement structures or to the removal of those structures.

It would appear that the brook trout in Section A, relative to Section B, increased somewhat while the structures were in the section, and then decreased considerably after the structures were removed. Although this was the trend, it could not be established statistically in all aspects of catch and standing crop, as indicated above. The inference is that certain parameters are more sensitive to change than are others.

From the first 5-year period, the before years, through the second, the during years, there was a statistically significant increase in the A:B ratios of the catch for both brook and brown. However there was no significant increase during these years for any of the standing crop ratios. As mentioned earlier the extremely heavy fishing pressure in Section B (Fig. 4) during the years 1949-51 makes the comparisons of the data for the before-years with the other periods of dubious value. The fishing pressure was generated for hatchery fish, but it would seem reasonable to assume that there was also an increased harvest of the native trout, particularly brook trout which are so much easier to catch than brown trout. This presumed increase in numbers and pounds in the catch would lead to a decrease in the A:B ratio, and to the appearance of a real difference in the comparison of the before-versus-during years, when actually no difference existed. Likewise, a presumed decrease in Section B in the standing crop, which would be expected because of the heavy fishing pressure, would result in an increase in the A:B ratio, which in turn might mask a significant difference in the comparison of the before-versus-during years.

The low ratio for total fishing pressure and the high ratio for catch per hour per trip for the 1949-53 before period (Table 12) show the effect of the very high fishing pressure in Section B during three of the before years.

Because of the confounding fishing pressure, I hesitate to say that there was a real increase in the catch and standing crop of brook trout with the addition of structures to Section A in considering the before-versus-during years in the present analysis (Table 12). But for the comparison of the during years (1954-58), with the after years (1960-64), the fishing pressure was essentially the same in Section A relative to Section B (Table 12). The ratio of 0.80 for the during years was not significantly different from the 0.88 of the after years. Therefore with the fishing pressure remaining constant, it would appear that the significant decreases observed in the means of the ratios for the brook trout after removal of the structures are real and the result of the habitat destruction.

Mean values for the catch and fall population of brook and brown trout for the three time periods for sections A and B are presented in Table 13, and likewise, the mean values for fishing pressure and catch per hour per trip in sections A and B are given in Table 14. Considering Section A alone, the catch in numbers and pounds for both species increased during the years of stream improvement, while the standing crop of brook trout decreased and that of brown trout increased (Table 13). With the removal of the structures, these mean values show an increase in the standing crop for both species of trout. Obviously, as stated before, Section A has to be related to a control. The fishing pressure in Section A did not increase greatly during the years of stream improvement. For the period 1949-53, it was 866.9 hours, and it increased to a mean value of 963.6 hours for the period 1954-58 (Table 14). For the after years of 1960-64, it remained essentially the same--963.8 hours--as the during years of 1954-58.

Physical changes in the stream

In the years 1960-64 after the removal of the stream improvement structures and the addition of sand in Section A, the brook trout population appeared to decline while the brown trout population at least retained its abundance. The maps of the sample segments of sections A and B provide a somewhat quantitative insight into what physical changes actually took place during those years. Mean areas of water depths, of bottom soil types, and of cover for fish were calculated for the 100-foot sample segments of sections A and B (13 segments in Section A and 10 segments in Section B). Ratios of the means, Section A to Section B, were used for comparisons among years. For the depth of water, it appears that after removal of the structures from Section A, there was a decline in the area of water over 3 feet deep (Table 15). The ratios of the means go from 1.75 in 1958, to 0.21 and 0.22 in 1960 and 1964, respectively. The mean square feet in Section A was reduced to 9 and 18 in 1960 and 1964, from 49 in 1958. In percentage of the total, this changed from 1.1% of the total in 1958, when the structures were in place, to 0.2% in 1960, after structures were removed and sand was dumped into the river to fill the holes, to 0.4% in 1964. Although there appears to be a reduction in area of water 2 to 3 feet in depth, it is not so pronounced as for the water deeper than 3 feet.

The changes in bottom soil types are documented in Table 16. Although there was an increase in the amount of sand present in Section A in 1960, after habitat destruction, a similar change took place in Section B, the control section. In all probability this reflects the flood of 1957, in which the dam washed out at the upper end of the experimental water--the upstream end of Section E. This dam, which created a 65-acre impoundment, washed out on May 15, 1957, after a heavy rainfall the preceding day, and released a large amount of sand from the impoundment into the river. The sand moved slowly through the experimental sections. By the fall of 1958 it had not yet reached Section B, which was 3.5 miles below the dam. It appears that the sand was in Section B in 1960, but it had passed on through by 1964. Likewise, in Section A by 1964, the sand from the flood, as well as the sand placed in the stream, had either moved downstream or been left along the banks after high water. As indicated above, a large constructed log jam at the lower end of Section A prevented the sand from moving beyond the section. Above the log jam flat shallow areas of predominantly sand substrate were created. However, between 1960 and 1964 in Section A the flowing waters cleaned many of the riffles of sand, dug some new holes, undercut the bank in places, and in general repaired much of the damage done by the removal of structures and the placement of sand.

The fall population estimates in 1957 and 1958, after the flood, did not indicate any pronounced changes in the trout populations throughout the Pigeon River, except a decrease in young-of-the-year fish in Section E in 1957. There was no evidence that the flood caused any large mortality or movement of 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 sections A and B.

In 1964, it appears that there was a decided increase in the area of cobble in Section A (Table 16). I have no explanation for this increase, except to suggest that by 1964 some riffles were cleaned of sand and the cobbles may have been included in the addition of the sand in 1959. The ratios of the means for the other bottom soil types do not indicate any strong trends or meaningful changes in bottom soils with the removal of the stream structures.

The most obvious change in Section A took place in the amount of cover available for trout (Table 17). Shade--measuring vegetation growth--increased regularly from 1958 to 1964 in both Section A and Section B. Turbulent water in Section A, although a very subjective measurement, appears to have decreased from 1958 to 1960 to 1964. In Section B it increased from 1958 to 1960, and then decreased. The ratios suggest a decrease from 1958 to a lower level in 1960 and 1964. Undercut bank in Section A was halved from 1958 to 1960, but increased to the 1958 level in 1964. In 1959, while structures were being removed from the river, the undercut bank was cut in areas of deflectors, but in the following years natural stream action reestablished some of the undercut. In Section B the trend in area of undercut follows the same pattern as in Section A. The ratios suggest a constant decline in amount of undercut bank available in Section A. A very obvious change took place in the square feet of log and stump cover available for trout in Section A. From 1958 to 1960 the mean area of cover decreased from 280 to 136 square feet and did not recover, while in Section B cover went from 242 to 256 to 194 square feet. The ratios indicate a decrease from 1958 to a much lower level in 1960 and 1964.

The mapping demonstrates that Section A, in comparison with Section B, had a decrease in amount of deep water, and had decreases in turbulent water, undercut bank and particularly log and stump cover, after structures were removed from Section A. There was relatively little change in bottom soil types with the removal of the structures.

Movement of trout

Shetter (1968) has established that brook trout and brown trout move generally less than a mile in Michigan streams. In order to check upon the movement of fish into the experimental area, a run was made in the fall of 1960 with the direct-current shocker through 1.5 miles of the Pigeon River immediately below Section A, and through 0.5 mile of stream above the dam and impoundment at the upstream end (Section E) of the experimental area. Below Section A, 339 brook trout and 338 brown trout were given fin clips; above the area, 1,168 brook trout and 1 brown trout were marked by clipping different fins. In addition to the 339 brook trout captured and marked in the waters below Section A, 4 marked brook trout were captured that had moved out of the experimental sections, one each from sections A, B, C and D. These fish had been fin clipped in the fall of 1959 (see below). Another 4 trout had a caudal nick indicating they had been handled in the previous 2 weeks, during the annual fall population estimate in the experimental sections. Of the brown trout captured, 4 were fish marked in 1959, 1 from Section B, 2 from Section C and 1 from Section E, and one had been marked in the 1960 population estimate.

Four brook trout marked in the water below, and 2 brook trout from above the area, were recorded in the catch from the experimental sections during the 1961 fishing season. In the population study in the fall of 1961, 1 brook trout and 5 brown trout from below, and 1 brook trout from above, were recorded. The totals therefore for the fish marked in the fall of 1960 above and below the experimental water were: upstream, 5 brook trout and 5 brown trout; downstream, 3 brook trout. Obviously the dam at the upper end of the experimental water does not prevent downstream migration but appears to prevent upstream migration.

In general, there does not appear to be much recruitment to the trout populations either from downstream or upstream. However, it has not been established how much movement there is between sections in the 6 miles of experimental water of the Pigeon River. In the fall of 1959, all of the trout taken during the first run with the direct-current shocker through the experimental sections of the river were given a fin clip distinctive for each section (Tables 18 and 19). No trout were marked in 1960. It was decided that marking another large group of fish in the fall of 1960 might cause some confusion in the identification of fin clips from both years, and that it would be better to wait until most of the fish marked in 1959 were gone from the population. In the fall of 1961, however, all trout less than 4 inches long (young-of-the-year) taken during the first run with the shocker were given a fin clip distinctive for each section (Tables 20 and 21). No fish were marked in the uppermost of lowermost 200 yards of each section, in order to reduce minor movement at the section dividing lines.

The numbers of marked trout recovered in 1960 following marking in the fall of 1959 within the sections are given for brook and brown trout in Tables 18 and 19, respectively. The numbers caught by anglers are listed separately from those found in the 1960 fall population studies. It is obvious from the returns of marked fish that there was considerable movement of trout among sections. A comparison of the total trout marked with the same clip and the total marked trout found within a section, allows a judgment as to the gain or loss of marked fish within a section. An example of this procedure would be the total of 33 (17 + 16) brook trout from Section A marked right pelvic compared with the 53 trout of all clips found within Section A (Table 18). The difference between 53 and 33 indicates the number of trout (20) gained by Section A in the movement exchanges. Likewise Section B gained 17 trout, Section C lost 44, Section D lost 3, and Section E gained 10. The per cent movement into, or out of each section is also given in Table 18. Obviously sections A and B gained trout primarily at the expense of Section C.

A similar comparison for brown trout indicates more of a balance between gain and loss (Table 19), but the slight gains made were again at the expense of Section C.

Perhaps of more interest is the question: How many fish from the total catch in Section A were from some other section? The mean ratio, of marked brook trout to estimated population size in the experimental sections in the fall of 1959, was 0.39. The number of marked fish in Section A from outside the section, and caught in 1960, divided by the ratio gives an estimate of 44 brook trout. The total catch of brook trout for 1960 in Section A was 94 and of that total, 44 immigrated from some other section. Similarly in Section B the estimate was that 56 of the total catch of 145 were fish which immigrated from outside the section.

The movement data for 1962 show essentially the same pattern, even though the fish were all young-of-the-year when marked in the fall of 1961 and there was left a buffer zone of 400 yards between sections during the marking (Tables 20 and 21). Again there was more of a balance between movements for the brown trout than for the brook trout (Table 21). For the brook trout, apparently Section A gained marked fish, sections B and C lost fish, and sections D and E gained fish. The data suggest, particularly for the brook trout, that Section C with the highest density of trout contributes to those sections with a low density. During the years 1951-64 the minimum legal length in sections C and D was 9 inches. The creel limit in 1951-54 was 2 trout, and in 1955-64 it was 5 trout. Lures were restricted to artificial flies only, in 1958-64. Catches were low from these sections during the years 1951-64 because of the restrictive regulations. This would tend to encourage a greater density of larger trout, at least during the summer months. Hunt (1965) reported on movement of young-of-the-year brook trout in Lawrence Creek for a 5-year period. Under experimental conditions almost identical to the Pigeon River, Hunt obtained similar magnitudes of movement between sections and also noted an increase in movement with an increase in density of the fingerlings.

I must conclude that movement, particularly of brook trout, was disproportionate enough and of sufficient magnitude to have some influence upon the stream improvement evaluation. I would hypothesize that as long as fishing pressure, fish harvest and environmental conditions stayed rather constant, movement would stay rather constant, but that any major change in conditions might encourage or restrict movement. Fortunately during the present study the fishing pressure remained fairly constant in Section A, but as noted earlier, was disproportionately high in Section B in 1949-1951 (Fig. 4). The environment in Section A, of course, was changed drastically in 1953 and again in 1959 as part of the experimental procedure. I have no satisfactory way of adjusting for disproportionate movement and can only guess that any increase or decrease noted as the result of stream improvement may very well have been the result of movement rather than increased or decreased survival of fish.

Discussion

To date, publications on the methods of stream improvement (Hubbs, Greeley and Tarzwell, 1932; Gee, 1952; White and Brynildson, 1967) have been more impressive than reports on the effects of stream improvement. The early attempts to evaluate stream habitat improvement concentrated on the physical and bottom fauna changes and barely considered the trout populations (Tarzwell, 1937; Madsen, 1938; Hunter, Thorpe and Grosvenor, 1941). The studies of the effects of habitat improvement which emphasized trout and the anglers' catch started with Tarzwell (1938) and continued with Shetter, Clark and Hazzard (1949); Gowing (1968); Hale (1969), and Hunt (1969). The four latest studies are characterized by rather substantial increases in fishing pressure and catch in the streams after habitat improvement. The increases noted in the standing crops of trout were generally much less than for the catch (with the exception of Hale's study). The question of the influence of the increased fishing pressure upon the catch immediately arises. It appears that there are three possibilities for the origin of the increased catch. The first, which is claimed by most of the above authors, is that habitat improvement has led to increased recruitment and/or survival which has led to increased catch with a resulting increased fishing pressure; the second possibility that exists is that increased fishing pressure leads to increased catch because of underexploitation and/or increased survival and growth of the stock with increased exploitation; and the third possibility is that with increased exploitation and/or habitat improvement there is movement of trout from other parts of the stream to the section of lower density. Perhaps all three things are happening, but to date, I do not believe that any author has demonstrated conclusively the reasons for the additional numbers of trout.

Hunt (1969) stated that, "Improvement in the trout population appeared to be largely the result of increased rates of overwinter survival rather than greater recruitment of young trout or increased growth rate." In 1971, Hunt restated the case for increased overwinter survival. However in discussing angling regulations on Lawrence Creek, Hunt (1970) observed in a footnote to Table 12 on page 34, that, "Since there are no barriers between zones, overwinter changes in the trout populations in the two zones reflect movement as well as survival. Only the values for the entire stream reflect true survival."

Undoubtedly, trout are attracted to cover (Boussu, 1954; Gibson, 1966; Gibson and Keenleyside, 1966; Elser, 1968; Gunderson, 1968; Lewis, 1969; Hunt, 1971). Saunders and Smith (1962) reported that an increase in cover led to increased survival of age-I and older brook trout in a small stream on Prince Edward Island, Canada.

In the present study the mapping surveys indicated that the most drastic change took place in the amount of cover in Section A. Fishing pressure remained constant over the years of most meaningful comparison--the "during" years (1954-58) with the "after" years (1960-64). The changes in catch and standing crop of brook trout can undoubtedly be attributed to the manipulations of the stream environment. With the fishing pressure remaining constant, it would appear that the decrease in brook trout has to be the result of decreased survival, or to movement in response to less cover. The brown trout apparently did not respond to cover, nor did they move as much as the brook trout. The brown trout in Section A maintained the same population size or perhaps slightly increased during the years of habitat manipulation.

Hunt (1971) discussed some of the problems associated with calculating the cost-benefit ratio for stream improvement. The discussion was primarily based on the assumption of increased survival of trout after stream improvement. If, in many cases, stream structures result only in a greater concentration of trout in the improved section of stream, the benefits would appear to be negligible.

Still to be conclusively demonstrated is the source of brook trout associated with the addition of cover to a trout stream. Also needed is further evaluation of the relationship of brown trout to manipulation of the stream environment. As Mullan (1962) stated, " . . . at present most stream improvement can only be regarded as experimental and that this labeling carries with it the obligation of evaluation . . ."

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

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

Table 2.--Numbers of brook trout and brown trout taken by anglers in sections A and B, Pigeon River, 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	97	150		23	70	
1950	93	151		27	92	
1951	177	227		28	162	
1952	168	234		28	72	
1953	118	166	0.70	22	61	0.31
During years						
1954	243	283		45	122	
1955	165	169		24	48	
1956	107	103		40	79	
1957	228	147		30	46	
1958	152	196	1.04	28	48	0.52
After years						
1959	40	89		4	18	
1960	94	145		26	39	
1961	126	208		30	55	
1962	160	211		30	30	
1963	151	170		21	24	
1964	140	165	0.75[a]	14	35	0.70[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	4.71*	7.33**
Before versus during	8.18*	4.40
During versus after	5.47*	2.98
Before versus after	0.21	14.62**

[a] Mean ratio does not include year 1959.

Table 3.--Pounds of brook and brown trout taken by anglers in sections A and B, Pigeon River, 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	16.0	25.3		5.7	16.9	
1950	15.3	25.9		6.8	21.4	
1951	32.0	37.6		7.7	35.7	
1952	28.5	37.7		7.5	18.0	
1953	23.9	31.5	0.72	6.8	17.1	0.34
During years						
1954	48.1	46.6		14.2	41.7	
1955	31.3	31.1		7.4	19.8	
1956	17.9	17.6		19.4	26.9	
1957	40.5	28.3		14.0	19.2	
1958	26.9	35.7	1.05	15.0	18.6	0.59
After years						
1959	7.2	16.8		1.0	6.0	
1960	21.3	27.1		8.7	16.6	
1961	23.4	36.3		12.1	23.9	
1962	36.1	44.2		19.0	19.4	
1963	36.9	32.8		10.1	7.2	
1964	37.3	31.5	0.91[a]	5.6	24.4	0.73[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	3.33	2.17

[a] Mean ratio does not include year 1959.

Table 4.--Standing crop in pounds of brook and brown trout of all sizes in sections A and B, Pigeon River, after the fishing season in 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	23.9	44.7		40.9	73.7	
1950	35.3	49.9		38.8	59.3	
1951	51.0	53.6		29.7	67.8	
1952	47.2	58.3		39.2	93.8	
1953	70.7	76.2	0.79	60.1	102.6	0.53
During years						
1954	79.1	96.3		46.5	108.4	
1955	47.1	39.0		60.9	90.4	
1956	20.6	29.6		31.5	56.9	
1957	21.1	26.2		60.7	47.9	
1958	33.6	35.3	0.90	60.6	63.5	0.77
After years						
1959	22.0	53.0		40.2	66.7	
1960	28.6	53.8		37.3	60.9	
1961	40.1	69.5		37.6	55.3	
1962	60.2	90.7		68.2	65.6	
1963	54.5	90.1		57.5	42.8	
1964	58.3	95.7	0.60[a]	73.0	80.6	0.92[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	4.97*	2.69
Before versus during	1.26	-
During versus after	9.70**	-
Before versus after	3.97	-

[a] Mean ratio does not include year 1959.

Table 5.--Fall standing crop and anglers' catch in pounds of brook and brown trout in sections A and B, Pigeon River, 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	39.9	70.0		46.6	90.6	
1950	50.6	75.8		45.6	80.7	
1951	83.0	91.2		37.4	103.5	
1952	75.7	96.0		46.7	111.8	
1953	94.6	107.7	0.76	66.9	119.7	0.48
During years						
1954	127.2	142.9		60.7	150.1	
1955	78.4	70.1		68.3	110.2	
1956	38.5	47.2		50.9	83.8	
1957	61.6	54.5		74.7	67.1	
1958	60.5	71.0	0.96	75.6	82.1	0.73
After years						
1959	29.2	69.8		41.2	72.7	
1960	49.9	80.9		46.0	77.5	
1961	63.5	105.8		49.7	79.2	
1962	96.3	134.9		87.2	85.0	
1963	91.4	122.9		67.6	50.0	
1964	95.6	127.2	0.68[a]	78.6	105.0	0.87[a]

F values for analysis of variance of ratios
(* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	6.40*	3.08
Before versus during	6.12*	-
During versus after	12.08**	-
Before versus after	1.00	-

[a] Mean ratio does not include year 1959.

Table 6.--Numbers of brook and brown trout, age I and older (after the fishing season) plus the anglers' catch, in sections A and B, Pigeon River, 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	320	560		137	336	
1950	314	471		151	314	
1951	418	508		127	424	
1952	385	467		144	291	
1953	693	753	0.76	210	453	0.43
During years						
1954	808	979		222	409	
1955	587	512		199	417	
1956	252	313		107	191	
1957	316	254		149	140	
1958	385	406	0.99	194	219	0.70
After years						
1959	261	609		221	377	
1960	274	507		139	229	
1961	400	566		104	199	
1962	587	851		238	219	
1963	648	1,072		181	172	
1964	557	736	0.66[a]	178	204	0.83[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	6.81*	4.58*
Before versus during	6.34*	4.16
During versus after	12.91**	0.84
Before versus after	1.16	8.73*

[a] Mean ratio does not include year 1959.

Table 7. --Numbers of young-of-year brook and brown trout in sections A and B Pigeon River, after the fishing season in 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	155	496		139	834	
1950	612	889		56	758	
1951	757	1,653		365	410	
1952	1,144	2,559		249	965	
1953	1,068	2,202	0.48	283	343	0.44
During years						
1954	1,720	2,651		291	438	
1955	581	796		490	635	
1956	372	694		257	381	
1957	634	860		513	915	
1958	341	1,242	0.59	997	1,308	0.68
After years						
1959	363	1,318		199	767	
1960	386	1,469		97	350	
1961	862	3,091		793	815	
1962	1,214	3,003		477	472	
1963	910	1,954		514	412	
1964	1,777	4,401	0.36[a]	687	860	0.86[a]

F values for analysis of variance of ratios
(* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	2.93	2.29

[a] Mean ratio does not include year 1959.

Table 8.--Numbers of age I and older brook and brown trout in sections A and B, Pigeon River, after the fishing season in 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	223	410		114	266	
1950	221	320		124	222	
1951	241	281		99	262	
1952	217	233		116	219	
1953	575	587	0.80	188	392	0.48
During years						
1954	565	696		177	287	
1955	422	343		175	369	
1956	145	210		67	112	
1957	88	107		119	94	
1958	233	210	0.93	166	171	0.79
After years						
1959	221	520		217	359	
1960	180	362		113	190	
1961	274	358		74	144	
1962	427	640		208	189	
1963	497	902		160	148	
1964	417	571	0.64[a]	164	169	0.85[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	3.18	3.14

[a] Mean ratio does not include year 1959.

Table 9.--Numbers of brook and brown trout, 7 inches and larger, in sections A and B, Pigeon River, after the fishing season in 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Brook trout			Brown trout		
	Section A	Section B	Mean ratio A:B	Section A	Section B	Mean ratio A:B
Before years						
1949	26	22		92	193	
1950	72	94		113	152	
1951	150	57		80	205	
1952	76	33		99	203	
1953	99	61	1.70	142	227	0.55
During years						
1954	83	94		142	238	
1955	55	66		118	207	
1956	22	30		50	96	
1957	50	34		108	79	
1958	82	25	1.44	139	129	0.83
After years						
1959	33	48		127	214	
1960	73	44		102	162	
1961	87	66		54	105	
1962	83	61		109	127	
1963	70	65		118	103	
1964	74	56	1.35[a]	124	137	0.81[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

	Brook trout	Brown trout
Between treatments	0.28	1.67

[a] Mean ratio does not include year 1959.

Table 10. --Total fishing pressure in hours in sections A and B, Pigeon River, 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Section A	Section B	Mean ratio A:B
Before years			
1949	861.0	2,385.0	
1950	898.0	2,130.5	
1951	950.5	3,148.0	
1952	660.0	1,563.0	
1953	965.0	1,535.0	0.43
During years			
1954	1,119.5	1,756.0	
1955	977.0	1,125.0	
1956	882.0	1,046.0	
1957	848.5	931.5	
1958	991.0	1,308.5	0.80
After years			
1959	342.5	894.5	
1960	489.5	891.0	
1961	767.5	1,165.0	
1962	1,083.0	1,110.0	
1963	1,222.0	1,169.5	
1964	1,257.0	1,073.5	0.88[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

Between treatments	9.24**
Before versus during	11.16**
During versus after	0.45
Before versus after	16.10**

[a] Mean ratio does not include year 1959.

Table 11.--Catch per hour per trip (number of trout) in sections A and B Pigeon River, 1949-64, with statistical analyses for three periods: 1949-53 before improvement, 1954-58 during improvement, and 1960-64 after improvement

Years	Section A	Section B	Mean ratio A:B
Before years			
1949	0.16	0.10	
1950	0.13	0.12	
1951	0.26	0.12	
1952	0.31	0.20	
1953	0.16	0.16	1.48
During years			
1954	0.26	0.26	
1955	0.17	0.18	
1956	0.17	0.17	
1957	0.28	0.19	
1958	0.17	0.18	1.07
After years			
1959	0.11	0.10	
1960	0.23	0.18	
1961	0.21	0.22	
1962	0.18	0.21	
1963	0.13	0.15	
1964	0.11	0.17	0.92[a]

F values for analysis of variance of ratios (* for 5%, ** for 1% level)

Between treatments	3.86*
Before versus during	3.88
During versus after	0.51
Before versus after	7.19*

[a] Mean ratio does not include year 1959.

Table 12.--Means of ratios for Section A to Section B of annual trout population statistics from Pigeon River, 1949-1964, and analysis of variance for differences between experimental periods

Species and years	Trout in catch: Number	Trout in catch: Pounds	Fall standing crop (pounds)	Fall standing crop plus catch (pounds)	Age I and older plus catch (numbers)	Number of trout in fall population: Young of year	Number of trout in fall population: Age I and older	Number of trout in fall population: 7 inches and larger
Brook								
1949-53	0.70	0.72	0.79	0.76	0.76	0.48	0.80	1.70
1954-58	1.04	1.05	0.90	0.96	0.99	0.59	0.93	1.44
1960-64	0.75	0.91	0.60	0.68	0.66	0.36	0.64	1.35
Brown								
1949-53	0.31	0.34	0.53	0.48	0.43	0.44	0.48	0.55
1954-58	0.52	0.59	0.77	0.73	0.70	0.68	0.79	0.83
1960-64	0.70	0.73	0.92	0.87	0.83	0.86	0.85	0.81
Levels of significance for analyses of variance (** at 1%; * at 5%; 0 at >5%)								
Brook								
Between treatments 1949-64	*	0	*	*	*	0	0	0
Before vs during	*	0	0	*	*	0	0	0
During vs after	*	0	**	**	**	0	0	0
Before vs after	0	0	0	0	0	0	0	0
Brown								
Between treatments 1949-64	**	0	0	0	*	0	0	0
Before vs during	0	0	0	0	0	0	0	0
During vs after	0	0	0	0	0	0	0	0
Before vs after	**	0	0	0	*	0	0	0

Brook plus brown	Total fishing pressure	Catch per hour per trip
1949-53	0.43	1.48
1954-58	0.80	1.07
1960-64	0.88	0.92
Levels of significance for analyses of variance		
Between treatments 1949-64	**	*
Before vs during	**	0
During vs after	0	0
Before vs after	**	*

Table 13.--Mean values for the catch and fall population of brook and brown trout before (1949-53), during (1954-58) and after (1960-64) stream structures, sections A and B, Pigeon River

Species and years	Trout in catch: Number	Trout in catch: Pounds	Fall standing crop (pounds)	Fall standing crop plus catch (pounds)	Age I and older plus catch (numbers)	Number of trout in fall population: Young of year	Number of trout in fall population: Age I and older	Number of trout in fall population: 7 inches and larger
				Section A				
Brook								
1949-53	131	23.1	45.6	68.8	426	747	295	85
1954-58	179	32.9	40.3	73.2	470	730	291	58
1960-64	134	31.0	48.3	79.3	493	1,030	359	77
Brown								
1949-53	26	6.9	41.7	48.6	154	218	128	105
1954-58	33	14.0	52.0	66.0	174	510	141	111
1960-64	24	11.1	54.7	65.8	168	514	144	101
				Section B				
Brook								
1949-53	186	31.6	56.5	88.1	552	1,560	366	53
1954-58	180	31.9	45.3	77.1	493	1,249	313	50
1960-64	180	34.4	80.0	114.3	746	2,784	567	58
Brown								
1949-53	91	21.8	79.4	101.3	364	662	272	196
1954-58	69	25.2	73.4	98.7	275	735	207	150
1960-64	37	18.3	61.0	79.3	205	582	168	127

Table 14. --Mean values for the fishing pressure and catch per hour per trip of brook and brown trout before (1949-53), during (1954-58), and after (1960-64) stream structures, sections A and B, Pigeon River

Section and years	Total fishing pressure (hours)	Catch per hour per trip (brook plus brown)
Section A		
1949-53	866.9	0.20
1954-58	963.6	0.21
1960-64	963.8	0.17
Section B		
1949-53	2,152.3	0.14
1954-58	1,233.5	0.20
1960-64	1,081.8	0.19

Table 15.--Mean area of water depths in square feet, and ratio of the means, for 100-foot sample segments of sections A and B Pigeon River, 1958, 1960 and 1964

Water depth (feet)	Section A			Section B		
	1958	1960	1964	1958	1960	1964
0 to 1	2,650	2,693	2,583	2,144	2,178	2,049
1 to 2	1,444	1,516	1,547	1,792	1,707	1,799
2 to 3	265	190	260	209	246	242
3 plus	49	9	18	28	42	83
Total	4,408	4,408	4,408	4,173	4,173	4,173

	Ratio Section A to Section B		
	1958	1960	1964
0 to 1	1.24	1.24	1.26
1 to 2	0.81	0.89	0.86
2 to 3	1.27	0.77	1.07
3 plus	1.75	0.21	0.22

Table 16.--Mean area of each bottom soil type in square feet, and ratio of the means, for 100-foot sample segments of sections A and B, Pigeon River, 1958, 1960 and 1964

Bottom type	Section A			Section B		
	1958	1960	1964	1958	1960	1964
Silt or organic	402	291	441	747	417	572
Sand	956	1,666	1,309	695	1,252	851
Sand and gravel	1,144	793	648	1,043	960	1,047
Gravel	1,190	833	1,093	926	601	910
Gravel and cobble	689	754	661	647	897	705
Cobble	11	53	247	53	38	71
Clay	16	18	9	62	8	7
Total	4,408	4,408	4,408	4,173	4,173	4,173

	Ratio Section A to Section B		
	1958	1960	1964
Silt or organic	0.54	0.70	0.77
Sand	1.38	1.33	1.54
Sand and gravel	1.10	0.83	0.62
Gravel	1.28	1.39	1.20
Gravel and cobble	1.06	0.84	0.94
Cobble	0.21	1.39	3.48
Clay	0.26	2.25	0.53

Table 17. --Mean area of cover for fish in square feet, and ratio of the means, for 100-foot sample segments of sections A and B, Pigeon River, 1958, 1960 and 1964

Cover type	Section A			Section B		
	1958	1960	1964	1958	1960	1964
Logs, stumps, etc.	280	136	109	242	256	194
Undercut bank	34	16	31	24	16	36
Shade	332	504	598	554	713	847
Turbulent water	552	454	257	308	465	235
Total	1, 198	1, 110	995	1, 128	1, 450	1, 312

	Ratio Section A to Section B		
	1958	1960	1964
Logs, stumps, etc.	1. 16	0. 53	0. 56
Undercut bank	1. 42	1. 00	0. 86
Shade	0. 60	0. 71	0. 71
Turbulent water	1. 79	0. 98	1. 09

Table 18.--Number of marked brook trout (C) caught during the fishing season and number (E) identified in the fall estimates for each experimental section, Pigeon River, 1960

Fin clip and number marked[1]		Stream section A	B	C	D	E	Total
Right pelvic (272)	C	14	-	-	1	2	17
	E	11	3	-	1	1	16
Left pelvic (730)	C	2	24	-	-	4	30
	E	4	22	5	5	-	36
Left pectoral (1, 349)	C	7	12	4	-	9	32
	E	6	7	110	18	4	145
Dorsal (1, 196)	C	5	7	1	6	12	31
	E	-	3	10	85	3	101
Right pectoral (1, 106)	C	3	3	-	-	85	91
	E	1	2	3	13	71	90
Total		53	83	133	129	191	589
Per cent moved into section		53	45	14	29	18	
Per cent moved out of section		24	30	36	33	14	

1 Trout were marked in fall of 1959 in stream sections and with fin clips according to sequence in this table, namely fish in Section A were marked with a right pelvic clip, Section B with left pelvic, etc.

Table 19.--Number of marked brown trout (C) caught during the fishing season and number (E) identified in the fall estimates for each experimental section, Pigeon River, 1960

Fin clip and number marked[1]		Stream section A	B	C	D	E	Total
Right pelvic (211)	C	6	-	-	-	-	6
	E	11	2	1	-	2	16
Left pelvic (403)	C	-	10	-	1	5	16
	E	-	22	1	3	1	27
Left pectoral (400)	C	1	3	4	1	3	12
	E	4	1	23	2	-	30
Dorsal (290)	C	2	1	-	4	8	15
	E	-	1	-	26	1	28
Right pectoral (234)	C	-	1	-	3	29	33
	E	-	1	2	3	28	34
Total		24	42	31	43	77	217
Per cent moved into section		29	24	13	30	26	
Per cent moved out of section		23	26	36	30	15	

[1] Trout were marked in fall of 1959 in stream sections and with fin clips according to sequence in this table, namely fish in Section A were marked with a right pelvic clip, Section B with left pelvic clip, etc.

Table 20.--Number of marked brook trout (C) caught during the fishing season and number (E) identified in the fall estimates for each experimental section, Pigeon River, 1962

Fin clip and number marked [1]		Stream section A	B	C	D	E	Total
Right pelvic (371)	C	3	-	-	-	-	3
	E	21	2	-	6	5	34
Left pelvic (909)	C	1	7	-	-	1	9
	E	12	47	13	7	11	90
Left pectoral (1, 341)	C	1	5	-	-	2	8
	E	6	9	143	22	14	194
Adipose dorsal (978)	C	2	-	-	-	2	4
	E	-	2	4	105	9	120
Right pectoral (499)	C	-	-	-	-	4	4
	E	1	2	3	2	43	51
Total		47	74	163	142	91	517
Per cent moved into section		49	27	12	26	53	
Per cent moved out of section		35	45	29	15	15	

[1] Trout were marked in fall of 1961 in stream sections and with fin clips according to sequence in this table, namely fish in Section A were marked with a right pelvic clip, Section B with left pelvic, etc.

Table 21.--Number of marked brown trout (C) caught during the fishing season and number (E) identified in the fall estimates for each experimental section, Pigeon River, 1962

Fin clip and number marked [1]		Stream section					Total
		A	B	C	D	E	
Right pelvic							
(117)	C	2	-	-	-	-	2
	E	1	1	-	-	-	2
Left pelvic							
(244)	C	-	2	-	-	-	2
	E	-	9	2	2	1	14
Left pectoral							
(184)	C	-	-	-	-	-	-
	E	1	-	16	-	2	19
Adipose dorsal							
(42)	C	-	-	-	-	1	1
	E	-	-	-	4	1	5
Right pectoral							
(49)	C	-	-	-	-	-	-
	E	1	-	-	-	4	5
Total		5	12	18	6	9	50
Per cent moved into section		40	8	11	33	56	
Per cent moved out of section		25	31	16	33	20	

[1] Trout were marked in fall of 1961 in stream sections and with fin clips according to sequence in this table, namely fish in Section A were marked with a right pelvic clip, Section B with left pelvic, etc.

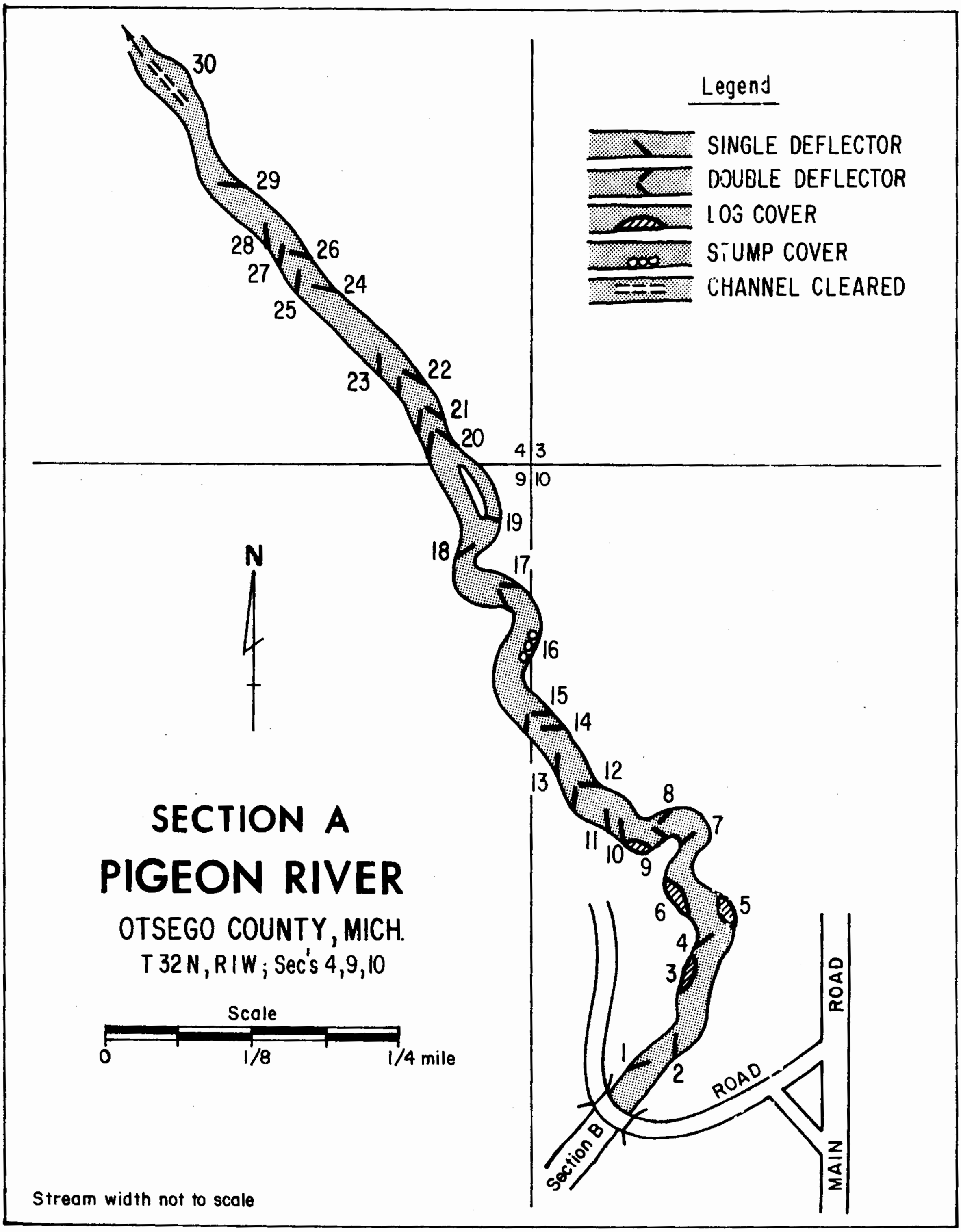

Figure 1.--Section A of the Pigeon River showing locations of 30 stream improvement structures installed in 1953. The individual structures are described in Table 1.

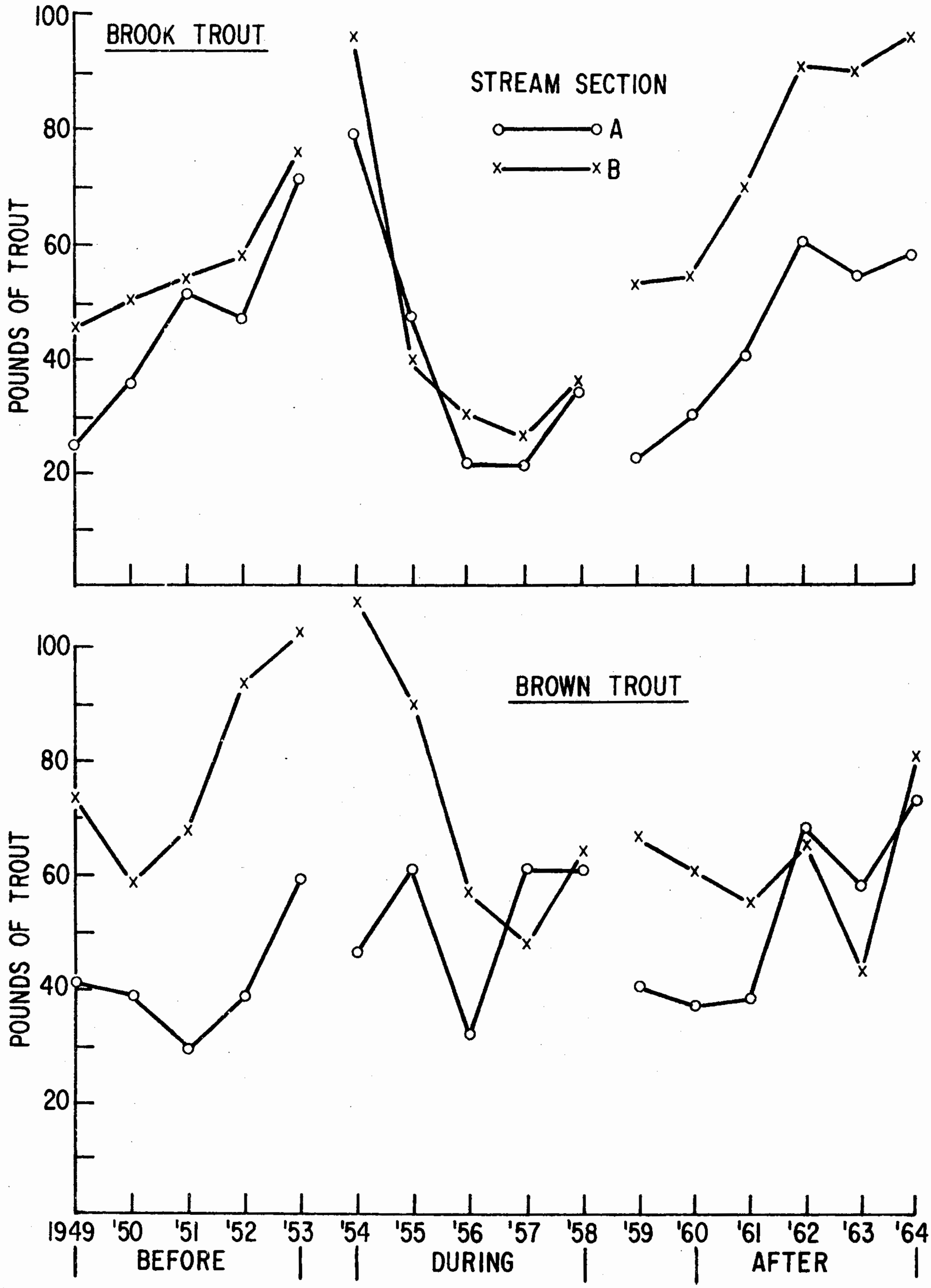

Figure 2.--Fall standing crop in pounds of brook trout (upper) and brown trout (lower) in sections A and B of the Pigeon River before, during, and after structures in Section A.

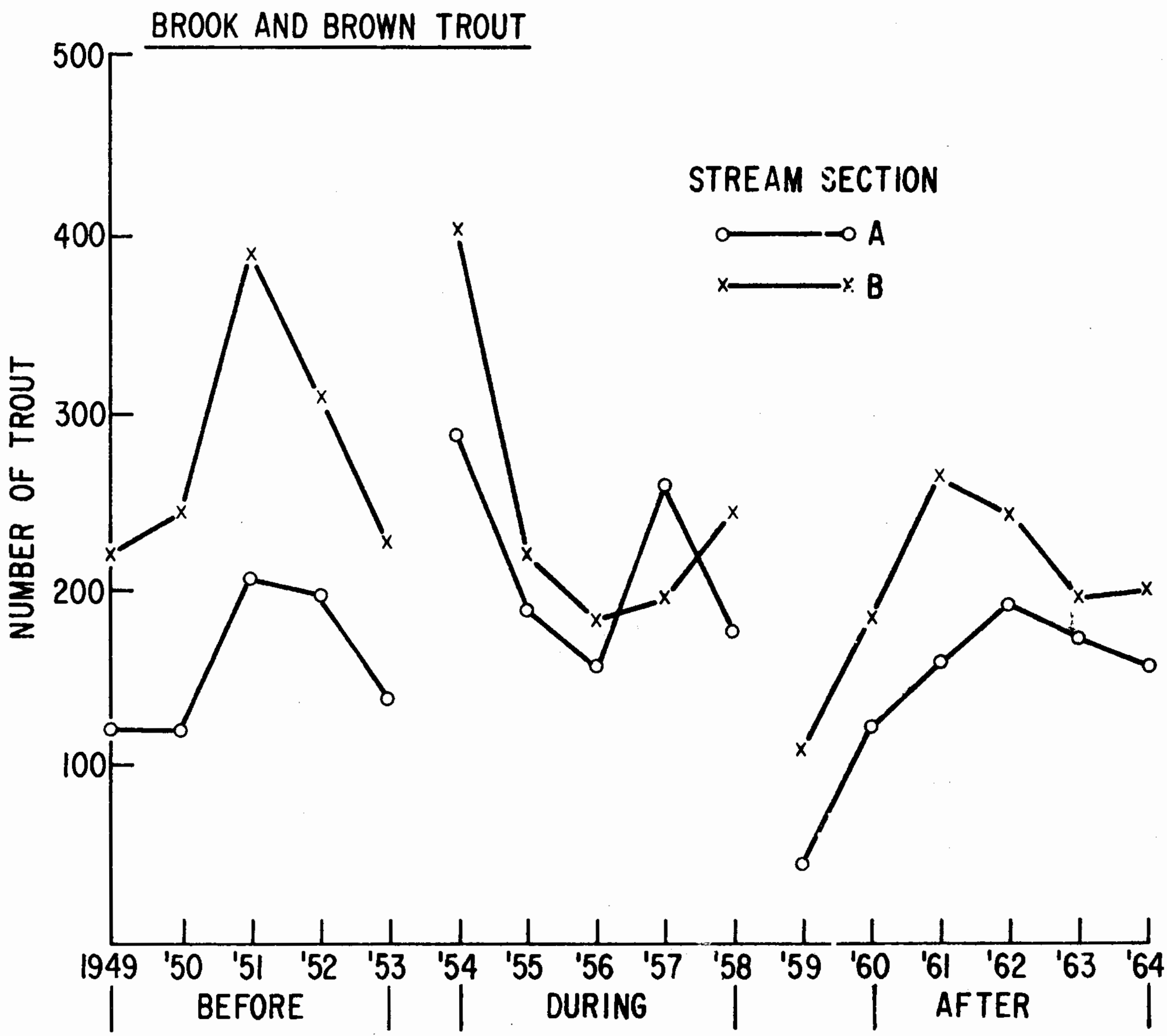

Figure 3.--Number of trout (brook plus brown) caught by anglers in sections A and B of the Pigeon River before, during, and after structures in Section A.

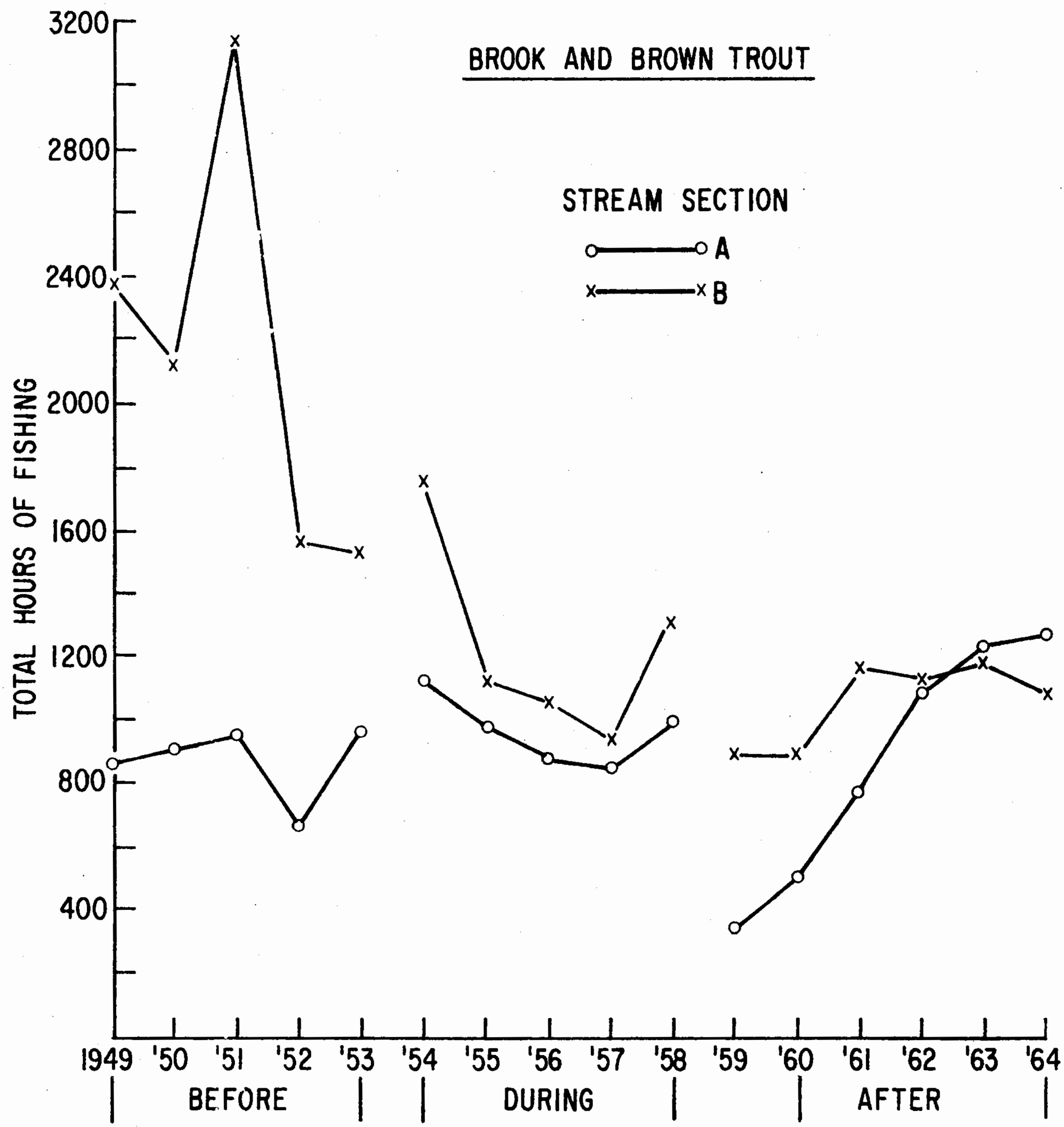

Figure 4. --Total hours of fishing by anglers in sections A and B of the Pigeon River before, during, and after structures in Section A.

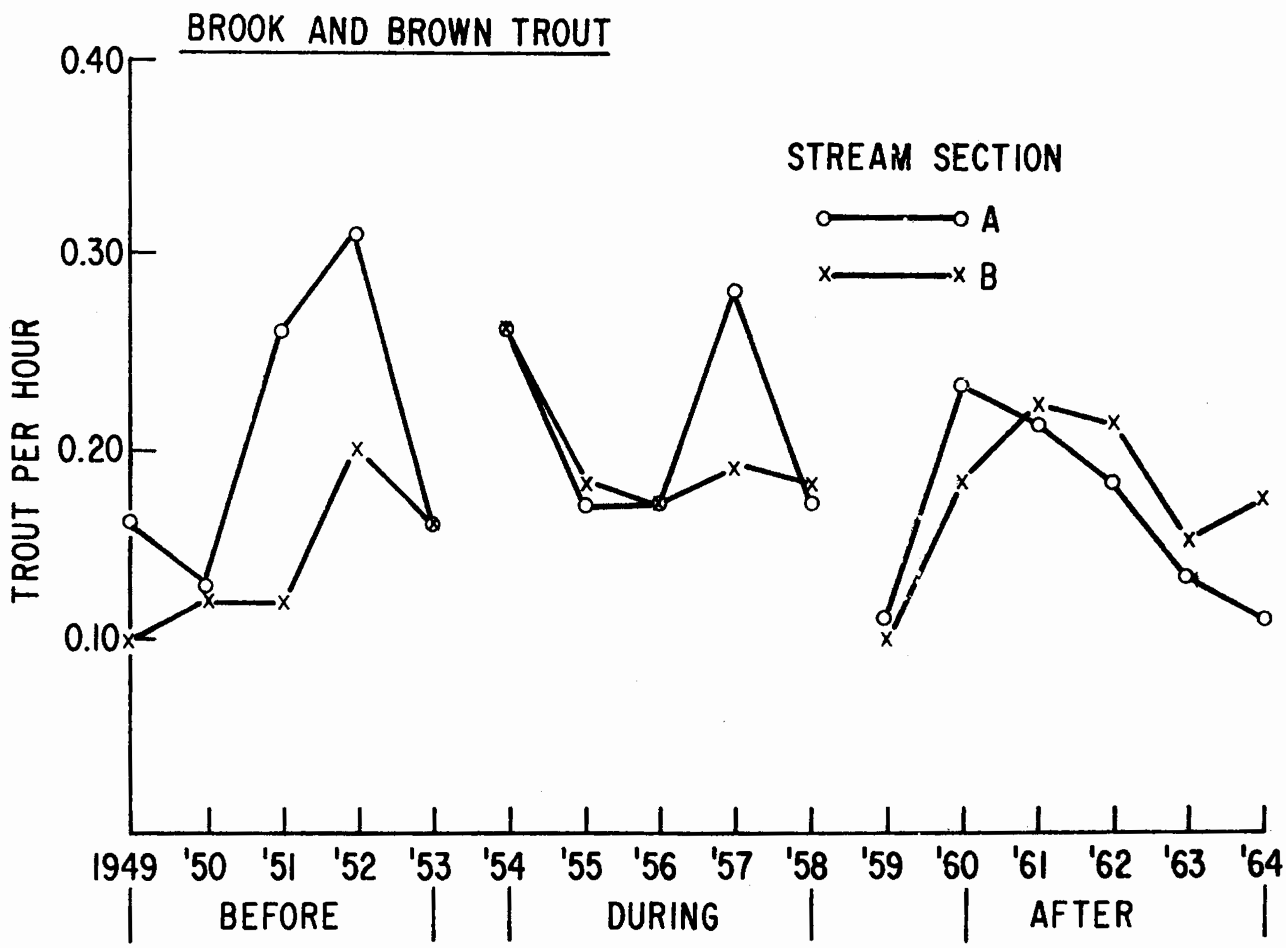

Figure 5. --Catch per hour per trip of trout (brook plus brown) by anglers in sections A and B of the Pigeon River before, during, and after structures in Section A.

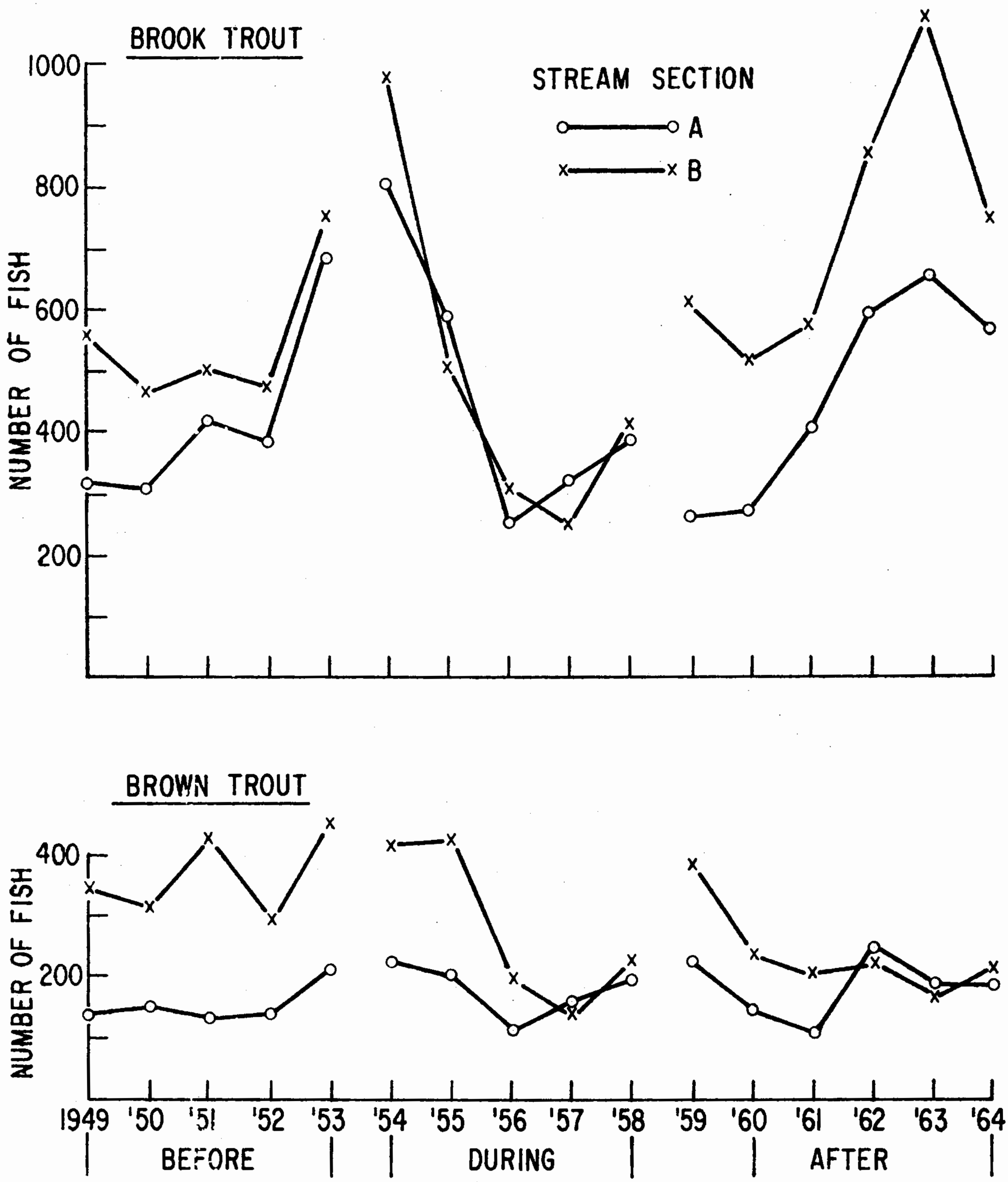

Figure 6.--Number of age-I and older, plus anglers' catch of brook trout (upper) and brown trout (lower) in sections A and B of the Pigeon River before, during, and after structures in Section A.

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