presentation
ch American Wildlife
erence March 8-10, 1954

Original: North American Wildlife Conference
cc: Fish Division
Education-Game
Inst. for Fish. Res.
C. T. Yoder
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March 5, 1954

Report No. 1399

THE EFFECT OF CHANGED ANGLING REGULATIONS ON THE TROUT POPULATION

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Abstract

The early history of brook trout fishing in the North Branch of the Au Sable River indicates that there has been a decline in angling quality since 1900. The various corrective measures attempted are listed.

In 1949 the Michigan Conservation Commission increased the minimum legal length for brook trout from 7 to 10 inches for a 4.6-mile stream section to test the effect of such legislation on the brook trout population and brook trout fishing. In 1950 an additional 2.3 miles of stream were added to the restricted water; brown trout also were brought under the minimum size rule; the daily creel limit was reduced to ten fish, not more than five of which could be brook trout; and all lures except artificial flies were excluded. Plantings of legal-sized brook trout were continued only in the unrestricted water.

A partial creel census, conducted by the same Department employee each season and at the same sites and on the same schedule for the years 1950-1953 inclusive, indicates that the restricted

portion of the stream is as popular as those sections operating under the normal, less stringent, state-wide regulations. Angling quality, as measured by catch per hour indices, has been better on the normal waters due at least in part to plantings of legal-sized trout. However, creel census indicates a significant increase in the catch of brook and brown trout larger than 10 inches from the restricted water during the past four seasons.

Index figures of population changes were obtained from timed collections with an AC electric shocker. These indices suggest that the total brook trout population of the restricted water in 1953 was about two and one-half times larger than it was in 1948 before the restrictions were applied.

Age and growth determinations on scales taken from angler-caught and shocker-collected brook trout show no change in growth rate after application of the restrictions despite the increase in trout population in the restricted water. Brook trout from the restricted water are mainly Age-Group II fish with a few Age-Group III included. From the normal water about three-fourths of the catch consists of Age-Group I fish (many of which have not yet spawned) with the remainder made up of Age-Group II along with a few fish from Age-Group III.

The factors thought to be responsible for the population increase are protection of a majority of Age-Group I brook trout to a size permitting them to spawn at least once, and elimination of

much of the hooking mortality among angler-caught fish smaller than the 10-inch minimum legal length by mandatory exclusion of all lures except artificial flies.

Prepared for presentation
at North American Wildlife
Conference March 8-10, 1954

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Introduction

The North Branch of the Au Sable River, lying about 200 miles north of Ann Arbor in Michigan's Lower Peninsula, has long been regarded as one of the State's better brook trout streams. Originally the Au Sable drainage was noted for its grayling fishing (from which the town of Grayling on the Main Stream derived its name). The grayling decline began in about 1880. In an effort to replace the grayling, the Michigan Fish Commission planted 20,000 brook trout (Salvelinus fontinalis) fry in the Main Au Sable in March, 1885. Introduction of brown (Salmo trutta) and rainbow (Salmo gairdneri) trout fry followed by 1891.

The early brook trout plantings soon provided excellent fishing in the North Branch. In 1900, according to Mershon (1923, p. 165), of 1,038 trout taken by him and his guests during the period May 12-14, all were brook trout except four rainbow trout. By 1926, the ratio of brook trout to rainbow trout had changed to 4:1 (personal communication from Milton P. Trautman). In 1937-1940 the species ratio in anglers' catches was about five brook trout to one brown trout; few rainbow trout were observed. In the 1950-1953

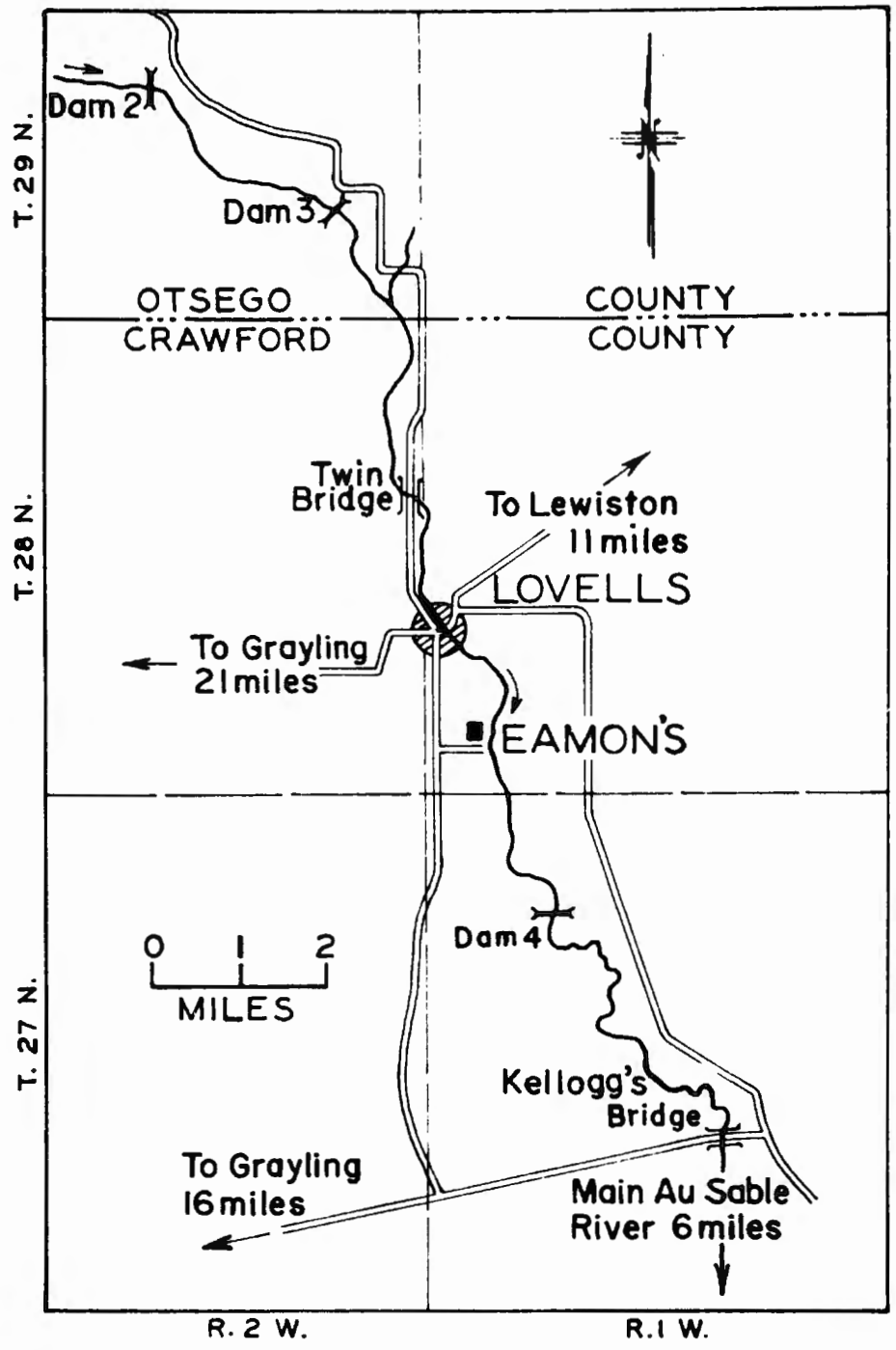
period, partial creel census records for the stream sections with unchanged regulations (discussed later) suggest a species ratio of 2.7 brook trout to 1 brown trout.

The brook trout, however, is the favorite species of the North Branch fishermen, and the gradual decline in numbers of large specimens and catchable fish per angler since 1900 has prompted various regulations to renew the fishing of the early days. Between 1903 and 1927 the daily bag limit was reduced from 50 to 15 trout. An 8-inch minimum size limit was prescribed during two different periods, and lures were restricted to artificial flies during six different years. Stream improvement devices were installed in parts of the stream in 1934-1935, and again in 1949-1950, in an effort to rehabilitate the angling.

From 1928 to 1948 the regulations governing trout fishing on the North Branch were the same as those in force on other Michigan trout streams, namely: daily creel limit, 15 trout; minimum size limit, 7 inches; natural and artificial lures were permitted; the trout season length was the same as for other Michigan brook trout waters.

There are no data available for the early days of the century from which reliable indices of angling quality can be computed. The earliest creel census records covering a large enough series of angling trips were obtained during 1937-1940 by Civilian Conservation Corps enrollees directed by Conservation Department personnel. A 4.6-mile stretch of the North Branch, extending from the Crawford-

Figure 1. North Branch of the Au Sable River (Crawford and Otsego counties, Michigan), traced from Michigan Department of Conservation County Maps


Dam 2
Dam 3
T. 29 N.
OTSEGO COUNTY
CRAWFORD COUNTY
Twin Bridge
To Lewiston 11 miles
LOVELLS
T. 28 N.
To Grayling 21 miles
EAMON'S
Dam 4
0 1 2
MILES
T. 27 N.
Kellogg's Bridge
To Grayling 16 miles
Main Au Sable River 6 miles
R. 2 W.
R. 1 W.

Otsego county line to the Lovells Bridge (Figure 1), was observed daily during the trout season between 6 a.m. - 9 p.m. Records of all fishing trips were tallied, and as many fishermen as possible were contacted personally to secure pertinent fishing records. During 1937-1940, total angling trips varied between 1,622 and 2,556 trips. The observed catch ranged between 2,095 and 3,143 trout; about five-sixths were brook trout. Catch per hour indices fluctuated from 0.33 fish in 1940 to 0.48 fish in 1938. The percentage of successful trips, chronologically, was 47, 48, 37 and 37. In this period anglers expended between two and three hours of effort for each legal trout removed. The yearly average size of brook trout taken was between 7 and 8 inches, while brown trout yearly average sizes ran from 9.5 to 10.5 inches.

The doctoral researches of Edwin L. Cooper, conducted in the period 1946-1948, included sampling in the same area where creel census operations were conducted. He (1949, p. 100) found that the intensive sport fishery cropped off the fast-growing members of the brook trout population almost as soon as they reached the legal size of 7 inches during their second summer. As a result, a high percentage of each years' catch consisted of fish which had not yet spawned. He also offered evidence which demonstrated that very few three-summer-old brook trout lived to spawn a second time.

The Experimental Regulations

Early in 1949 Cooper's research, combined with the available creel census data, resulted in a recommendation to the Conservation Commission that the minimum size limit be increased to 10 inches on that portion of the North Branch between Lovells Bridge and the county line; the objective was to increase the numbers of brook trout in the experimental section by allowing a larger number of mature fish to spawn at least once. Only the minimum size limit was changed under terms of a Commission order which took effect for the 1949 trout season. Field checks with an AC shocker were made during the late summer and fall to collect scale samples and obtain density indices.

Before the 1950 trout season opened, an additional 2.3 miles of water immediately downstream were placed under the experimental restrictions. At the insistence of the Lovells Hook and Trigger Club, artificial flies were specified as the only legal lure. The Conservation Commission clarified and reworded the restrictions. The regulations applying to this experimental water for the period 1950-1953 have been: 10-inch minimum size; 10 trout daily, not more than five of which may be brook trout (or 10 pounds and one trout); only artificial flies permitted.

How Changes were Measured

Partial creel census results.--The effect of these more stringent regulations on the fishing has been measured by continued use of the shocker and by a partial creel census operated during

the past four seasons. The same schedule of sampling days was followed each year by the same individual, who collected fishing statistics at the same sites. Equal numbers of four 10-hour days each season were spent in the recording of anglers' catches from the restricted water and from the stream sections above and below still under the normal state-wide trout regulations (hereinafter referred to as "normal" water). The sampling schedule included each Saturday, Sunday, and holiday. Midweek days were rotated throughout the season. Only records of completed fishing trips were listed. While these records do not provide knowledge either of total pressure or of total catch, they do furnish valid information on the trends in the fishing, and the relative returns from both types of water since they are generous and equal samples collected in the same manner each year. The pertinent statistics are given in Table 1.

The following general conclusions may be drawn from the creel census summary:

1. Except for 1950, more angling trips were recorded on the restricted water than on the normal water. This observation is interpreted to mean that the North Branch fishermen are using the restricted water, despite the added restrictions, in numbers as large or slightly larger than those who fish the normal stream sections. The latter area downstream, in addition to the less stringent regulations in force, was planted yearly with 6,000 to 7,800 (all fin-clipped), hatchery-reared brook trout of "keeper size."

Table 1.--Partial creel census statistics, North Branch Au Sable River, Crawford County, Michigan, 1950-1953 inclusive. (Average total lengths, given in inches, are in parentheses)

Type of water	Year	Total angler-trips contacted	Total unsuccessful trips	Total hours of fishing	Trout caught			Total catch observed	Catch per hour, all trout	Catch per hour, all native trout
					Wild brook	Hatchery brook	Wild brown			
Restricted water	1950	404	362	1,055.5	23 (10.2)	...	50 (12.5)	73	0.07	0.07
	1951	530	451	1,605.5	36 (10.3)	...	76 (11.9)	112	0.07	0.07
	1952	574	471	1,747.5	52 (10.4)	...	105 (12.5)	157	0.09	0.09
	1953	537	412	1,658.5	104 (10.3)	...	108 (13.0)	212	0.13	0.13
Normal water	1950	487	276	1,683.5	331	[1]318 (7.7)	97 (9.0)	746	0.44	0.25
	1951	430	232	1,541.0	436	[1]65 (7.5)	184 (8.4)	685	0.44	0.40
	1952	480	233	1,743.0	469	[1]208 (7.7)	166 (8.7)	850	[2]0.49	0.36
	1953	407	205	1,443.0	407 (7.7)	175 (8.3)	163 (9.1)	745	0.52	0.40

[1]Average total length data in these years are for both wild and hatchery trout combined, as measurements were not differentiated on the creel cards.

[2]Includes 7 rainbow trout (average total length 9.4 inches)

2. The percentage of successful fishing trips on the restricted water increased regularly each year from 10.4 in 1950 to 23.3 per cent in 1953. The proportion of successful trips on the normal water increased during the 1950-1952 seasons from 43.3 to 51.5 per cent, then dropped back to 49.6 per cent in 1953.

3. The observed catch of brook trout larger than 10 inches from the restricted water also has increased each year since 1950 (from 23 fish in 1950 to 104 fish in 1953). Brown trout also were observed to increase in the catch from the restricted water, following a similar pattern through 1952 (50 fish in 1950, 105 fish in 1952). The recorded 1953 brown trout catch was only slightly above that for 1952 (108 fish).

Catches of wild brook trout from the normal water ranged from 331 fish in 1950 to 469 fish in 1952, while brown trout creeled varied between 97 in 1950 and 184 in 1951. Anglers' creels were further augmented by hatchery brook trout--from a low of 65 hatchery fish in 1951 to a high of 318 hatchery fish in 1950.

4. Angling quality, as measured either by simple catch per hour or catch per hour per trip, has been best in the normal stream sections each year. This was not unexpected in view of differences in regulations and planting procedure on the two areas. However, angling quality in the restricted water was significantly better in 1953 than in any of the three previous years. Differences between the mean catch per hour per angler indices for 1952 and 1953 were examined by the standard "t" test. A value of $t = 3.5$

indicates that there are about 999 chances in a 1,000 that the indices are significantly different.

5. Because of the difference in minimum size regulations in effect, the average size of the angler-caught brook trout in the restricted water has been consistently about two inches larger than for those caught in the normal water. Brown trout average sizes from the restricted water have exceeded those from the normal stream sections by about three and one-half inches.

The weighted average percentages of the total catches found in the various inch-groups are listed in Table 2. The size range of the brook trout catch in normal water is 7.0-10.9 inches. About 73 per cent of the catch is drawn from the 7.0- to 7.9-inch group; about 95 per cent comes from fish between 7.0 and 8.9 inches long. In the restricted water, the size range of the anglers' take has been from 10.0 to 14.9 inches. Here again a high proportion (59.2 per cent) of the brook trout removed are in the first inch-group above the minimum legal length, while most of the remainder are between 11.0 and 11.9 inches long. This suggests that the fishery for the species on both waters is very intensive and is removing a high proportion of the brook trout in both areas very soon after they reach either the 7- or 10-inch minimum length.

Proportions of the total brown trout catches observed in the various inch-groups differed noticeably. There was no great concentration of fish in the inch-group just above the legal length, and a more even distribution of the catch among the inch-groups was evident.

Table 2.--Weighted average percentage of total catch in various inch-groups, normal and restricted water, North Branch Au Sable River, 1950-1953

Species	Type of water	Average percentage of yearly catch in inch-group								
		7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-12.9	13.0-13.9	14.0-14.9	15.0-23.9
Brook trout	Normal[1]	73.4	21.8	4.4	0.4	...	...	...	...	...
	Restricted	...	...	...	89.2	9.8	0.5	...	0.5	...
Brown trout	Normal	40.9	24.2	13.6	9.8	4.7	3.6	1.3	1.1	0.8
	Restricted	...	...	...	33.1	24.6	14.1	8.4	6.0	13.8

[1] Hatchery brook trout were included in these tabulations for 1950-1952, as they were not identifiable in the creel census records in those years.

6. The estimated total weight[1] of the observed catch of wild

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[1] Weights were assigned to each fish recorded on the basis of measured length. For brook trout, the length-weight curve for Michigan brook trout, prepared by Edwin L. Cooper (1949, p. 90), was utilized. A length-weight curve for North Branch brown trout (Tody, 1949, p. 17), was available from earlier investigations.

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brown trout from the restricted water consistently exceeded the poundage of brown trout observed in creels from the normal water (Table 3). The poundage of 10-inch and larger wild brook trout from the restricted water has been less than the poundage of 7-inch and larger brook trout from the normal water because of the great disparity in the numerical catch. The difference becomes progressively less each year, and if the 10-inch brook trout continue to increase in numbers, the restricted water may eventually yield as many pounds of brook trout, although not as many fish, as are taken from the normal waters. The 1953 calculations (Table 3) show that the total poundage of all wild trout observed from the restricted water slightly exceeded the total poundage of wild trout in the catches of fishermen contacted on the normal water (139 pounds as compared with 135 pounds), although numerically the total catches of wild fish were 212 as compared with 570.

It has not been possible to measure the increase in sport furnished by the restricted water. Although success in terms of

Table 3.--The estimated poundage of trout taken by anglers contacted in the partial creel census, restricted and normal water, North Branch Au Sable, 1950-1953.

Year	Pounds of trout taken by angling, restricted water			Pounds of trout taken by angling, normal water			
	Wild brook	Wild brown	Total	Wild brook	Hatchery brook	Wild brown	Total
1950	8.85	35.54	44.39	...	¥123.14	27.36	150.50
1951	14.76	53.06	67.82	...	¥ 92.92	49.69	142.61
1952	22.10	80.08	102.18	...	¥133.06	51.56	184.62
1953	44.27	94.78	139.05	80.69	42.54	54.03	177.26

¥Weights given in these years are for wild and hatchery brook trout combined. They were not differentiated on creel cards.

creelable fish is lower than on normal water, under average fishing conditions more 7.0- to 9.0-inch trout will be played and released in the restricted water than will be hooked in the normal stream. As elsewhere, the skillful and the lucky anglers creel the majority of the fish.

Electrofishing indices of population density.--Information on the population left each fall after the fishing season was obtained by electrofishing with an AC shocker (Universal, 60 cycle, 500 watts, 110 volt capacity). Timed collections were made each fall starting with 1948 in the vicinity of the Twin Bridge (located about midway in the restricted water). The numbers of trout caught per hour were used as indices of changes in population density. Although the efficiency of the collecting gear used will vary with weather, water stage and personnel, any marked change in actual population density should be detectable even though the magnitude cannot be determined exactly. The Twin Bridge collections were taken between late September and early November; always with an AC shocker of the capacity described, and always with at least one party member who had made the collections in previous years. The results of the electrofishing operations at Twin Bridge 1948-1953 inclusive are given in Table 4.

The data for September, 1948 show the size composition of the brook trout population remaining at the end of the last season of fishing under a 7-inch minimum size. Only 60 brook trout of 230 collected (27 per cent) in two hours of electrofishing were between

Table 4.--Size composition of brook trout taken with AC shocker, Twin Bridge, North Branch of the Au Sable, restricted water, with catch per hour indices, 1948-1953. (Percentage of total sample in each inch-class is given in parentheses)

Size range in inches	Numbers in inch-group in year					
	September, 1948	November, 1949	October, 1950	October, 1951	September, 1952	September, 1953
2.0 - 2.9	44 (19)	5 (3)	1 (1)	½...	½...	15 (6)
3.0 - 3.9	83 (36)	28 (19)	20 (13)	½...	½...	88 (36)
4.0 - 4.9	8 (3)	21 (13)	44 (27)	½...	½...	26 (11)
5.0 - 5.9	9 (4)	5 (3)	26 (16)	1	10	22 (8)
6.0 - 6.9	26 (11)	14 (9)	10 (6)	12	15	24 (10)
7.0 - 7.9	52 (23)	36 (23)	21 (13)	29	69	21 (9)
8.0 - 8.9	6 (3)	35 (22)	23 (14)	60	46	29 (12)
9.0 - 9.9	2 (1)	11 (7)	8 (5)	21	18	15 (6)
10.0 - 10.9	...	2 (1)	6 (4)	5	8	2 (1)
11.0 - 11.9	...	...	1 (1)	...	1	3 (1)
12.0 - 12.9	...	...	...	...	...	...
13.0 - 13.9	...	...	...	1	...	...
Total collected	230	157	160	129	167	245
Minutes shocked	120	40	44	23	38	35
Fish shocked/hour						
2.0 - 4.9 inches	68	84	89	...	...	221
5.0 inches up	47	155	130	337	264	199
All sizes	115	236	218	...	...	420

½/Fish in these inch-groups were present but not recorded in these years.

7.0 and 9.9 inches long. Brook trout smaller than 5.0 inches were taken at the rate of 68 fish per hour; those from 5.0 inches to 9.9 inches were found at the rate of 47 fish per hour; all sizes together were captured at a rate of 115 fish per hour.

Evidence that the 10-inch minimum size limit accomplished its purpose almost immediately was obtained in August, 1949. One hour of electrofishing at Twin Bridge yielded 219 brook trout from 4.0 to 9.9 inches, of which 170 were above 7.0 inches in length. Another hour of shocking just below the county line (also in the restricted water but not as good brook trout habitat as at Twin Bridge), produced 29 brook trout of which 20 were in the 7.0- to 9.9-inch size classes. Shocking one hour at Eamon's (a locality not under restrictions in 1949) yielded 33 brook trout, only 10 of which were between 7.0-9.9 inches in length.

The fall sampling for the years 1949 through 1953 demonstrates increases in all sizes of brook trout present, although the population enlargement has not been at a regular rate. Prior to inception of the 10-inch minimum size regulation, the 1948 sample yielded 68 brook trout per hour smaller than 5.0 inches. In September, 1953, an index figure of 221 brook trout per hour was obtained for this category, which is made up almost entirely of young-of-the-year fish.

The catch per hour index for brook trout larger than 5.0 inches in 1946 was 47 fish. In succeeding years these indices increased variably to 155, 130, 337, 264, and 199. The irregularities may or may not represent actual population fluctuations. The

differences noted are evidence of an increase of brook trout larger than 5.0 inches of about four times for the Twin Bridge area, following operation of the restrictions. Based on the 1948 and 1953 indices for brook trout smaller than 5.0 inches, fish in this size range increased to slightly more than three times their former numbers.

The electrofishing data were examined to determine changes in the size composition of the fall brook trout populations after application of the restrictions. For convenience, the numbers of fish larger than 5.0 inches were compared with the numbers of fish smaller than 5.0 inches in each year's sample. A significantly greater fraction of 1949 and 1950 samples were larger than 5.0 inches on comparison with the 1948 sample. Adjusted Chi-square values, following the methods outlined by Snedecor (1948, p. 197), yield values of 21.00 and 11.62 with corresponding percentages of confidence of 99.9 and 99.7 respectively. Unfortunately, measurements on brook trout less than 5.0 inches were not recorded in 1951 and 1952. However, by 1953, the proportion of large fish to small fish was approximately the same as in 1948 (Chi-square = 1.52, P = 78 per cent). Apparently the 1949 and 1950 populations differed from 1948 because of the protection afforded the 7.0- to 9.9-inch fish because the potential fingerlings available from the spawning of these fish were not yet present in the stream. By 1953, enough additional spawning had taken place to increase the numbers of fish less than 5.0 inches, and bring the proportion of large fish to small fish back closer to 1948 levels.

The main differences between the Twin Bridge samples of 1948 and 1953 are that the range in total length of the 1953 sample was greater, and both large and small fish were present in greater numbers.

The Twin Bridge sampling was augmented during the 1953 fall season by collections at four additional sites in the restricted water and at five sites in the normal water. A total of 517 brook trout were captured in the restricted water in 142 minutes of shocking, while only 231 brook trout were found in 153 minutes of electrofishing from normal stream sections (Table 5).

Ideally, we should have similar series of collections for 1948 from both restricted and normal waters to measure the changes that took place. The 1953 data support the conclusion that there has been a population increase in the restricted water. About 2.4 times as many brook trout (218 per hour) were found in the restricted section as in the normal section (91 per hour). We do not know with certainty if the population level of the normal section has increased or decreased since application of restrictions, as the only measure available for the pre-restricted period is the 1948 fall sample taken when the Twin Bridge area was under normal fishing regulations. Comparison of the 1948 Twin Bridge sample with the 1953 sample (composed of collections from five widely dispersed areas in the normal water) suggests that brook trout smaller than 5.0 inches were present in about equal numbers in 1948 at Twin Bridge and in 1953 in the normal waters as a whole (1948

Table 5.--Size composition of post-season brook trout populations, restricted water and normal water, 1953, as determined from AC shocker collections at five sites in each area

Size range in inches	Brook trout from	
	Restricted water	Normal water
2.0 - 2.9	41	38
3.0 - 3.9	200	97
4.0 - 4.9	50	30
5.0 - 5.9	47	15
6.0 - 6.9	52	27
7.0 - 7.9	43	20
8.0 - 8.9	43	2
9.0 - 9.9	31	1
10.0 - 10.9	7	1
11.0 - 11.9	3	...
Total collected	517	231
Minutes shocked	142	153
Fish shocked per hour		
2.0 - 4.9 inches	123	65
5.0 inches up	95	26
All sizes	218	91

sample catch per hour of 2.0- to 4.9-inch fish was 68; 1953 normal water sample catch per hour 2.0- to 4.9-inch fish was 65). The greatest difference between these two samples is in the catch per hour indices for fish larger than 5.0 inches. In 1946, the catch per hour index was 47 fish; in 1953 it was 26 fish. The difference noted is ascribed to a combination of factors including size of sample, differences in habitat, and possible differences in angling pressure on fish larger than 7 inches during 1946 and 1953. The fact that the indices for total brook trout taken differed only by 24 fish per hour, or about 20 per cent, lends some weight to the belief that the 1946 Twin Bridge sample and the 1953 normal water sample were from brook trout populations of the same approximate magnitude.

If this latter assumption is granted, then it is reasonable to compare the 1953 samples from the restricted water with the 1953 samples from the normal water to determine the effects of the restrictions on the residual fall populations. As with the Twin Bridge series of samples, the conclusion is reached that all sizes of brook trout have increased in numbers. As to just how much, the 1953 data probably furnish the best estimate, since the figures tabulated are a composite of good, poor and average sites within both restricted and normal stream sections. The Twin Bridge data represent what happened in the better brook trout habitat following changes in the regulations.

For the restricted water as a whole, large fish (over 5.0 inches) have increased about 3.6 times in numbers, while small fish (less than 5.0 inches) have increased about 1.8 times in numbers. In the vicinity of the Twin Bridge, the increase of large fish was approximately 4.2 times; the increase of small fish was on the order of 3.2 times.

Age composition of anglers' catch

In addition to scale collections made during each fall shocking, as many scales as possible were obtained from angler-caught fish in both restricted and normal water areas. Cooper (1951, describes evidence which indicates that brook trout scales provide a true index of the age, and in a later paper (1952) gives the scale-sampling procedure and mounting method).

The age composition of angler-caught fish in both restricted and normal waters is given in Table 6. Age-Group II brook trout dominated the catches in the restricted water (70-97 per cent), while Age-Group I fish were found most often (73-82 per cent) in creels from the normal stream sections when the 1950 data are excluded (the 1950 sample was too small numerically and did not include enough fish caught in July and August when many two-summer-old fish ordinarily enter the catch under a 7-inch minimum size limit).

Age-Group III brook trout were few in numbers (3 per cent in the 1950 catch on the restricted water, but have varied since

Table 6.--Age composition of angler-caught brook trout, restricted and normal stream sections, North Branch of Au Sable, 1950-1953. (Size ranges are given in inches in parentheses)

Year	Age group	Restricted water[1]		Normal water	
		Number	Percentage of sample in age-group	Number	Percentage of sample in age-group
1950	I	...	...	33 (7.0-8.7)	45
	II	36 (9.6-10.5	97	39 (7.0-9.6)	53
	III	1 (11.5)	3	2 (9.3-9.6)	2
1951	I	...	...	268 (6.7-8.9)	82
	II	35 (9.7-11.0)	74	60 (7.0-10.1)	18
	III	12 (10.0-11.5)	26	...	...
1952	I	1 (10.0)	1	264 (6.5-8.8)	76
	II	65 (9.7-11.6)	88	80 (7.1-10.2)	23
	III	8 (10.3-14.0)	11	5 (7.6-11.4)	1
1953	I	...	...	165 (6.8-8.8)	73
	II	102 (9.0-11.5)	70	54 (7.4-11.9)	24
	III	42 (8.8-12.2)	29	8 (8.6-11.4)	3
	IV	1 (11.6)	1	...	...

[1] The few fish smaller than 10.0 inches and 7.0 inches which appear in this table were not included in catch totals in other tables. They have been utilized to show age and size distribution here.

between 11 and 29 per cent. One brook trout with four annuli was found among the 1953 anglers' catch, and one Age-Group I fish was observed in the 1952 catch from the restricted water.

In the normal stream sections Age-Group II brook trout constituted the minor fraction of the catch (18 to 24 per cent) when the 1950 sample is excluded for reasons already given. Age-Group III fish have never exceeded 3 per cent of creeled fish from the normal waters in any year.

Growth of the brook trout

The growth of the North Branch brook trout was studied following methods listed by Cooper (1953, p. 152), utilizing his previously-constructed nomograph for calculations of total lengths at the end of various years of life. These calculations are given in Table 7, where average calculated total lengths at various ages from angler- and shocker-caught brook trout are compared for pre- and post-restriction years for the restricted waters. Comparisons also may be made for angler-caught fish between the pre- and post-restriction periods for normal and restricted waters, although the numbers involved in all but Age-Group II are few in numbers.

Some scales from fish, taken both by angling and by electric shocker, were available from 1947, as well as for the years 1948 through 1953. For Age-Group I fish, the calculated total length at the annulus represents growth made in the previous calendar year. To obtain the proper grouping so that average growth for I's before

Table 7.--Comparison of calculated total lengths (in inches, with standard errors) for angler- and shocker-caught brook trout from restricted and normal stream areas before and after restrictions were applied, North Branch of Au Sable River

Type of water	Age-group[1]	Period	Taken by angling: Number in sample	Taken by angling: Calculated lengths at end of successive years of life: 1 year	2 years	3 years	Taken by AC shocker: Number in angle	Taken by AC shocker: Calculated lengths at end of successive years of life: 1 year	2 years	3 years
Restricted water	I	Pre-	...	...	...	...	308	3.68±0.04	...	...
		Post-	1	6.90±0.00	...	...	432	3.98±0.04	...	...
	II	Pre-	30	4.18±0.013	7.73±0.10	...	50	3.44±0.95	6.78±1.37	...
		Post-	202	4.39±0.054	8.27±0.68	...	131	3.55±0.06	6.82±0.07	...
	III	Pre-	1	3.60±0.00	5.80±0.00	9.40±0.00	3	3.33±4.92	5.90±7.37	8.37±4.85
		Post-	62	3.39±0.82	6.74±1.18	9.54±1.41	17	3.31±2.51	6.34±2.54	8.62±2.11
Normal water	I	Pre-	11	4.08±0.13						
		Post-	729	4.06±0.25						
	II	Pre-	43	3.40±1.11	6.63±1.48					
		Post-	194	3.40±0.49	6.92±0.74					
	III	Pre-	3	3.73±2.42	6.63±4.71	9.27±4.38				
		Post-	13	3.24±2.08	6.30±2.96	9.00±3.32				

[1] Two Age-Group IV fish were collected in 1953 from the restricted water, one by angling (calculated lengths were: 2.8, 5.8, 8.3, 11.0) and one by shocking (calculated lengths were: 3.0, 5.4, 7.4, 9.6).

and after inception of the restrictions can be assessed, the available data has been grouped 1947-1948-1949 (pre-period in Table 7) and 1950-1951-1952-1953 (post-period in Table 7).

For Age-Groups II and III, the pre-period grouping was 1947-1950 inclusive, while the post-period was 1951-1953 inclusive. Some slight error is introduced here, as calculated growth made during the last year in the 1950 samples is included in the pre-period calculations, rather than in the post-period, where it properly belongs. Under the method of analysis there seems to be no alternative. All groupings of three- and four-summer-old fish were treated in the same manner, however.

Samples obtained by angling from restricted and normal waters indicated only slight differences in calculated total lengths between the two stream areas. Statistical tests (t test) between similar groupings (Age-Group II, restricted water, pre-period vs Age-Group II, normal water, pre-period, etc.) all were non-significant.

Comparison of differences between average calculated lengths of angler-caught fish from normal waters for the pre- and post-periods for all age groups also yielded non-significant t values. The same was true for fly-caught brook trout taken in the restricted water, and also for Age-Groups II and III among shocker-collected brook trout in restricted water.

Age-Group I fish collected by shocker in 1950-1953 exceeded in size by 0.30 inches those of a similar age taken by electrofishing in 1947-1949. This significant difference ($t = 5.30$, $P = 99.9$

per cent) can be explained by the fact that in 1946-1948 (when the calculated growth of the 1947-1949 sample took place) anglers were removing a high percentage of the faster-growing two-summer-old brook trout under the 7-inch minimum legal length then in effect. In 1950-1953, the Age-Group I fish were not available to the anglers because of the 10-inch minimum legal size limit.

Comparison of the average calculated total lengths obtained from fly-caught fish with those taken by shocker suggests that angler-captured brook trout grew slightly faster. This selectivity of fishing in taking the faster-growing fish in each age group has been described by Cooper (1953, p. 156) for Pigeon River brook trout. However, only one comparison among the North Branch samples (Age-Group II, post-period) yielded a statistically significant value when the t test was applied ($t = 2.12$, $P = 96.5$ per cent). It is believed that this significant difference resulted from the removal by angling of a high percentage of the available Age-Group II brook trout in the restricted water.

No pronounced differences were found between pre- and post-restriction average calculated lengths which cannot be explained, either among fly-caught or shocker-collected samples. It is concluded that the rate of growth has not changed since inception of the restrictions in 1949, even though the brook trout population is now about two and one-half times larger than in 1948.

Possible effects of stream improvement

It is likely that the stream improvement, performed in 1949 and 1950, had a beneficial effect on the brook trout environment. This might have affected the results of the experiment. The improvements consisted of deepening and narrowing about one and one-half miles at the upper end of the restricted water, and about one-half mile of stream in the normal water. Wide, shallow, weed-filled inactive portions of the stream were filled in by drag-line and bulldozer using bottom materials removed in deepening the main channel. Maximum depths were increased from 2 to 3 feet to 5 to 7 feet, and in places the channel width was decreased from 100 feet to 40 feet or less. Cover in the form of logs and stumps was anchored in these channels.

The speeding of the current and the narrowing of the stream bed may have lowered water temperatures. Greater average depth, faster current and bottom type alteration doubtless changed the nature of the food supply. However, these two factors are not believed to have been limiting on the size of brook trout populations in the sections of the North Branch included in this study. Although water temperatures in the mid-seventies are common in much of this part of the stream following peak summer air temperatures, there are many spring-fed areas to which brook trout retreat during such critical periods. As concerns effects on the food supply, the North Branch has always rated at the top of the list of Michigan streams which have been studied. There is no reason to

believe that narrowing and deepening the channel would have caused any marked increase in bottom food organisms.

The channel deepening may have increased the survival of brook trout by creating better and more escape cover in the form of deeper holes and runs, and may have aided in the population increases described. Earlier Michigan studies noted (D. S. Shetter and A. S. Hazzard, 1939, p. 295; D. S. Shetter and J. W. Leonard, 1943, p. 41) that deeper water usually contained more and/or larger trout. However, it should be noted that none of this type of improvement work was done immediately upstream from the Twin Bridge in the restricted water where the population studies have been made each year (Table 4).

If channel improvement was a factor in the population increase among brook trout of the restricted water, why did it not operate similarly in the normal water? Numerous successful fishing trips were recorded in the channel-improved portions of the restricted water, but very few successful anglers were seen by the census clerk along the improved channel in the normal water. Although the arguments concerning the effect of the stream improvement are weak, and are not supported by any data, the possibility is not excluded that a portion of the increases noted in the anglers' catches stems from increased survival brought about by stream improvement done coincident with regulation changes.

Summing up all arguments, two factors are mainly responsible for the brook trout population increase in the restricted water and the progressive enlargement in the total catch of the species there.

They are:

1. Protection of a high proportion of fish to a size which permits them spawn at least once. The increased spawning has led to an increase of fingerlings present in the restricted stream areas; and,
2. Elimination of considerable hooking mortality among fish less than the minimum legal length by utilizing a "flies only" regulation.

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