Submitted for possible publication
in The Progressive Fish-Culturist

Original: W. F. Carbine
cc: Fish Division
Education - Game
Institute for
Fisheries Res.
E. L. Cooper
D. S. Shetter

March 27, 1953

Report No. 1367

MORTALITY RATES OF BROOK TROUT AND BROWN TROUT IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN

Edwin L. Cooper *

* Formerly in charge of the Pigeon River Trout Research Area, now Chief Aquatic Biologist with the Wisconsin Conservation Department.

Abstract

Mortality rates for the first year of life of brook and brown trout have been estimated by comparing the number of surviving fingerlings with the potential egg production. These estimates indicate a survival of 3 to 4 percent for the two species.

Mortality rates for the second, third and fourth years of life were estimated by comparing the survivors of individual year classes. Survival varies from year to year, around an average value of about 30 percent. Brown trout survive somewhat better than brook trout under the same stream conditions. The major contribution of a year class to the angling crop occurs during the second and third growing seasons. Total survival to the creel from fingerlings, under a 7-inch size limit, was about 35 percent for brook trout and 18 percent for brown trout. Under a 9-inch size limit the legal catch would be less than 5 percent of the number of brook trout fingerlings produced and less than 7 percent of the brown trout fingerlings.

Wild fingerling trout are better able to survive in a stream than hatchery trout of the same age and size. Fin-clipped wild trout apparently survive as well under stream conditions as do unmarked fish of the same population.

Submitted for possible publication
in The Progressive Fish-Culturist

Original: W. F. Carbine
cc: Fish Division
Education - Game
Institute for
Fisheries Research
E. L. Cooper
D. S. Shetter

March 27, 1953

Report No. 1367

MORTALITY RATES OF BROOK TROUT AND BROWN TROUT IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN[1]

Edwin L. Cooper[2]

---

[1] Contribution from the Michigan Institute for Fisheries Research.
[2] Formerly in charge of the Pigeon River Trout Research Area, now Chief Aquatic Biologist with the Wisconsin Conservation Department.

Introduction

The Pigeon River Trout Research Area has been operated by the Michigan Department of Conservation, Institute for Fisheries Research, since April, 1949. Here, a 4.8-mile portion of the stream has been used to study some phases of the ecology of brook and brown trout. The present report deals with the mortality rates of naturally spawned trout based on annual population estimates plus a complete record of the catch by anglers, and with the mortality of fall fingerling plantings of brook and brown trout of hatchery origin through one year of stream life. Native rainbow trout at present are too few to permit accurate estimates of mortality.

Procedure

Annual mortality rates or survival rates of fish populations have been computed by investigators from the age-composition of a randomly selected sample (Shetter and Leonard, 1943; Schuck, 1945; Ricker, 1949; Allen, 1951).

For the Pigeon River, estimates of the numbers of wild trout (i.e., excluding those of hatchery origin) in 4.8 miles of stream were made each fall with the use of electric shockers (Cooper, 1952). These population estimates have been subdivided by year classes by use of extensive data on age and growth (Cooper, 1953). Also, because of a change in fishing regulations in a portion of the research area, it has been advantageous to compute separate mortality rates for two different parts of the population. The mortality rates were computed from estimated survival of individual year classes; this approach seemed advisable because there were large differences in egg production and in the resultant production of fingerlings from year to year and between different sections of the stream. It has been very difficult to obtain a sample of the trout population, unbiased as to age composition, by either angling or electric shocker.

Movement of trout between adjacent sections of the experimental portion of the Pigeon River, or out of these sections, has been demonstrated by marking experiments to be minor in extent (Cooper, 1952). The pattern of distribution of the fish in different parts of the stream, as shown by repeated population estimates, also supports the view that we are dealing with fish populations that are quite sedentary.

A determination of the age of each trout caught by hook-and-line was made possible by the permit system of angling which was in effect on this portion of the Pigeon River (Cooper, 1952). The data on fall population estimates and on age composition of anglers' catches were used to calculate the mortality of successive year classes of trout due to angling.

A direct estimate of the population of trout less than a year old (i.e., younger than fall fingerlings) was not made. However, the egg

production was based on egg counts and estimates of the fall spawning population, and this gave some indication of the probable mortality rate of the trout during the first year of life.

In August, 1951, a separate estimate was made of the number of wild brook and brown trout of the 1951 year class in Section C, a 1.13-mile portion of the research area. During this operation the fish were fin-clipped for future identification. In October, 1951, approximately the same number of hatchery fingerlings of the same age were fin-clipped and planted in the section, to evaluate possible differences in survival between wild and hatchery fish.

Egg Production and First Year Survival

Direct evidence concerning the proportion of mature female trout in the fall population estimates of the Pigeon River is somewhat meagre. Because extensive information of this sort would have meant the dissection of a large number of adult-sized trout, these data were deliberately not collected. To use the estimates of fall trout populations in the Pigeon River to compute egg production, it is necessary to rely on other sources for data concerning sex ratios, size at maturity, and egg production in relation to size. These data are summarized below.

In a compilation of collections from fifteen different localities in Michigan, female brook trout constituted 55 percent of 1,712 fish over one year of age (Cooper, 1949, thesis). Smaller collections of brown trout from the Manistee River and from the North Branch of the Au Sable River have been examined; the sexes were evenlydivided--of 308 trout over one year of age, 154 were females.

Brook trout commonly mature at a smaller size and at a younger age than do brown trout. Mature female brown trout less than three

years old have seldom been found in Michigan, but female brook trout of this age are commonly mature. Consequently, the bulk of the mature female brook trout are often of smaller size than the smallest spawning brown trout. Data on size and sex ratio of mature trout, from localities cited above, are as follows:

Brook Trout				
Total length in inches	5.0-5.9	6.0-6.9	7.0-8.9	9.0-10.9
Percent of females mature	62.5	88.9	96.6	100.0
Number of females	56	81	59	4

Brown Trout			
Total length in inches	8.0-9.9	10.0-13.9	14.0-20.9
Percent of females mature	4.8	79.6	100.0
Number of females	42	54	29

Information concerning egg production of brook and brown trout has been assembled from many collections, since it is seldom practical to kill a large number of mature females from any one locality. Fish from the Pigeon River have been included in this compilation insofar as data were available. The number of eggs in each female was determined by actual count, and the average values for successive inch-groups were adjusted by a moving average of threes to produce a smooth curve. Brook trout averaged a few more eggs than did brown trout of equal size, although the number of fish of comparable sizes was limited (Table 1).

The data on sex ratios, size at first maturity, and egg production by size have been used in conjunction with the trout population estimates for the Pigeon River to calculate the egg production which resulted in the year classes of 1950, 1951 and 1952. Estimates of the number of fall fingerlings resulting from this egg production indicate a very low survival during the first year of life, averaging three to four percent (Table 2).

The accuracy of mortality rates based on estimates of egg production may rightly be questioned. On the other hand, estimates of

Table 1.--Egg production of brook and brown trout from Michigan.

Average number of eggs computed from moving average of threes

Size group in inches	Brook trout		Brown trout	
	Number of females	Average number of eggs per female	Number of females	Average number of eggs per female
4.0-4.9	38	104	..	..
5.0-5.9	91	169	..	..
6.0-6.9	59	268	..	..
7.0-7.9	24	395	1	437
8.0-8.9	15	525	0	488
9.0-9.9	8	643	2	547
10.0-10.9	4	753	14	644
11.0-11.9	..	..	17	782
12.0-12.9	..	..	12	974
13.0-13.9	..	..	7	1,133
14.0-14.9	..	..	6	1,270
15.0-15.9	..	..	4	1,410
16.0-16.9	..	..	2	1,703
17.0-17.9	..	..	2	2,068
18.0-18.9	..	..	3	2,394
19.0-19.9	..	..	4	2,622
20.0-20.9	..	..	2	2,857
21.0-21.9	..	..	1	3,148
22.0-22.9	..	..	1	3,461

Table 2.--Survival of fingerling trout from potential egg production in the Pigeon River

Year	1950		1951		1952	
Stream sections	A and B	C and D	A and B	C and D	A and B	C and D
Size limit	7-inch	7-inch	7-inch	9-inch	7-inch	9-inch
Brook trout						
Number mature females present preceding fall	98	431	216	637	236	950
Potential egg production	28,548	122,172	62,227	167,889	75,251	295,332
Number of fingerlings surviving	1,463	4,028	2,790	6,807	3,250	7,510
Percent survival	5.1	3.3	4.5	4.1	4.3	2.5
Brown trout						
Number mature females present preceding fall	33	36	40	38	21	44
Potential egg production	29,286	31,844	36,395	31,882	17,543	35,548
Number of fingerlings surviving	884	737	599	431	1,011	1,309
Percent survival	3.0	2.3	1.6	1.4	5.8	3.7

natural reproduction based on a count of redds, or on an estimation of free-swimming fry, are likewise of doubtful accuracy. However, the data suggest both that total mortality is high during the first year of life, and that it varies from year to year. The causes for the survival rates being variable between species and between calendar years are obscure, and explanations would be highly speculative in the absence of further information.

Mortality Rates After First Year

In studies of fish populations and of mortality rates, a precise definition of terms seems necessary because of the lack of standardization that exists among fishery workers at the present time. An excellent review and discussion of the nature of the terms "production," "stock" and "crop," as they pertain to fish populations, is given by Allen, 1951. These definitions appear to be satisfactory and have been followed in the present report. Stock refers to the number of fish present at any one time and crop is the same as yield to the angler.

Some individuals of both brook and brown trout populations in the Pigeon River reach legal size during their second year of life. During 1949 and 1950, a 7-inch size limit was in effect for all sections. During 1951 and 1952, the size limit was 9 inches in sections C and D. This change in size limit had the effect of excluding most of the yearling fish from the legal catch of 1951-52 (Table 3).

The annual mortality rates for brook and brown trout in the Pigeon River are high, resulting in very few old fish in the population. Survival varies from year to year, but is usually about 30 percent. Brown trout are somewhat more hardy than brook trout under the conditions encountered in this stream. The major portion of the second-year

Table 3.--Survival of trout in Pigeon River from number of fingerlings present. Data given are the number taken during the year by anglers (crop) and the number surviving in the fall at the end of the angling season (stock). In parentheses under crop is the percentage of the catch in the decrease from one year to the next. In parentheses under stock is the percentage survival from number of fingerlings

Brook trout:		Calendar year							
		1949		1950		1951		1952	
Stream sections	Year class	Crop	Stock	Crop	Stock	Crop	Stock	Crop	Stock
A and B	1949	0	737	39	458	202	26	7	4
		(0.0)	(100.0)	(14.0)	(62.1)	(46.8)	(3.5)	(31.8)	(0.5)
	1950	..	..	0	1,463	169	468	117	19
				(0.0)	(100.0)	(17.0)	(32.0)	(26.1)	(1.3)
	1951	..	..	..	..	0	2,790	269	383
						(0.0)	(100.0)	(11.2)	(13.7)
C and D	1949	0	3,623	73	1,398	36	120	6	7
		(010)	(100.0)	(3.3)	(38.6)	(2.8)	(3.3)	(5.3)	(0.2)
	1950	..	..	0	4,028	3	1,898	47	105
				(0.0)	(100.0)	(0.1)	(47.1)	(2.6)	(2.6)
	1951	..	..	..	..	0	4,995	7	1,140
						(0.0)	(100.0)	(0.2)	(22.8)
Brown trout:									
A and B	1949	0	646	24	320	73	43	3	10
		(0.0)	(100.0)	(7.4)	(49.5)	(26.4)	(6.7)	(9.1)	(1.5)
	1950	..	..	0	884	99	289	26	45
				(0.0)	(100.0)	(16.6)	(32.7)	(10.7)	(5.1)
	1951	..	..	..	..	0	599	71	132
						(0.0)	(100.0)	(15.2)	(22.0)
C and D	1949	0	817	26	419	29	91	4	16
		(0.0)	(100.0)	(6.5)	(51.3)	(8.8)	(11.1)	(5.3)	(2.0)
	1950	..	..	0	737	0	545	24	89
				(0.0)	(100.0)	(0.0)	(73.9)	(5.3)	(12.1)
	1951	..	..	..	..	0	276	1	141
						(0.0)	(100.0)	(0.7)	(51.1)
Minimum size limits									
A and B	..	7 inches		7 inches		7 inches		7 inches	
C and D	..	7 inches		7 inches		9 inches		9 inches	

mortality cannot be accounted for by the legal catch, for the catch never made up more than 17 percent of the decrease in numbers from the first year to the second. Under a 7-inch size limit the greatest contribution of any year class to the catch is made during its third season (Figure 1). Also, a higher proportion of the mortality during this year, at least for the brook trout, is accounted for by the legal catch. Under a 9-inch size limit in this stream, with no bait restrictions of any kind, a very small fraction of the naturally produced fingerlings carry over to the legal catch. No estimate is possible of the mortality of sub-legal trout which were hooked and released by anglers, although it is possible that this factor might be a major source of mortality in heavily fished waters.

Comparison of Survival of Wild and Hatchery Fingerlings

During August of 1951, an estimate of the 1951 year class of brook and brown trout in Section C was made in conjunction with an attempt to fin-clip a large proportion of this year class in the stream. Starting on August 20, five trips were made through the section with a direct-current electric shocker and four independent estimates of the population were made (Table 4). The rate of recapture of marked fish varied only slightly in the four recovery runs. Brown trout were a little easier to recover than were brook trout, probably because of the slightly larger size of the former.

In October of 1951, 3,000 hatchery brook trout fingerlings and 300 hatchery brown trout fingerlings were fin-clipped and planted in Section C. Survival rates to the following September indicate that the brown trout survive better than brook trout and also that wild fish are better able to survive than their hatchery counterparts under the

Figure 1.--Effect of legal size limits on mortality, stock and crop (angler harvest) of brook and brown trout in the Pigeon River, Otsego County, Michigan. Based on part of the data in Table 3. Data for the 1949 year class are from stream sections A and B; for the 1950 year class, from sections C and D. Percentage survival figures on stock are directly from Table 3; percentage figures on crop and mortality are derived from data in Table 3.

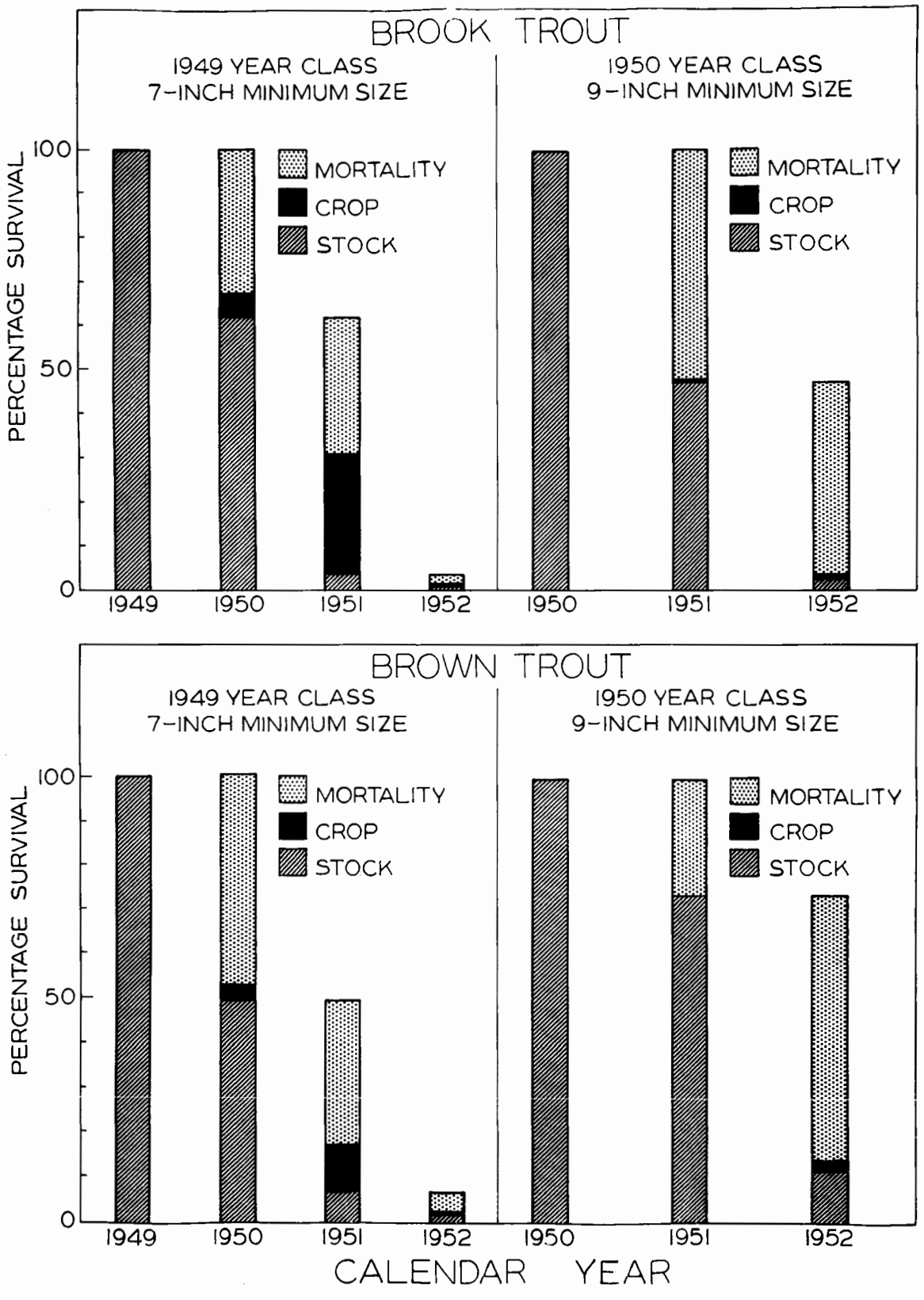
BROOK TROUT
1949 YEAR CLASS
7-INCH MINIMUM SIZE
1950 YEAR CLASS
9-INCH MINIMUM SIZE
MORTALITY
CROP
STOCK
PERCENTAGE SURVIVAL
100
50
0
1949
1950
1951
1952
1950
1951
1952
BROWN TROUT
1949 YEAR CLASS
7-INCH MINIMUM SIZE
1950 YEAR CLASS
9-INCH MINIMUM SIZE
MORTALITY
CROP
STOCK
PERCENTAGE SURVIVAL
100
50
0
1949
1950
1951
1952
1950
1951
1952
CALENDAR YEAR

Table 4.--Population estimates of 1951 year class of brook and brown trout in Section C, Pigeon River

Species and date	Number of fish caught	Number of marked fish present	Number of marked fish recovered	Percent recovery	Population estimate (stock)
Brook trout					
August 20, 1951	749	0	...	...	...
August 22, 1951	667	749	113	15.1	4,420
August 24, 1951	668	1,281	205	16.0	4,175
August 27, 1951	647	1,744	275	15.8	4,103
August 29, 1951	639	2,116	332	15.7	4,073
Total fish marked	...	2,423	...	...	...
Brown trout					
August 20, 1951	66	0	...	...	...
August 22, 1951	79	66	18	27.3	290
August 24, 1951	62	115	24	20.9	297
August 27, 1951	50	153	28	18.3	273
August 29, 1951	61	175	34	19.4	314
Total fish marked	...	202	...	...	...

same stream conditions (Table 5). This better survival of wild trout over hatchery trout was also noted by White (1927), Hobbs (1948), et.al.

The survival of the naturally spawned wild brook and brown trout of the 1951 year class which were fin-clipped was not much different from that of unmarked fish of the same year class. Thus, fin-clipping could not be demonstrated to be a cause of additional mortality (Table 5).

Various investigators (Shetter, 1939, 1950; Surber, 1937, 1940; Schuck and Kingsbury, 1948; Schuck, 1948; et al.) have shown that plantings of fingerling hatchery trout give very low survival rates and yield very few fish to the creel. Needham, Moffett and Slater (1945), Schuck (1945), and Needham (1949) also point out that the mortality of native trout populations is high, averaging better than 50 percent per year.

Acknowledgment

The special contribution of Messrs. Gerald F. Myers, Wayne H. Tody and Norman G. Benson in all phases of the field and laboratory work is gratefully acknowledged. The study was supervised by Drs. A. S. Hazzard and G. P. Cooper who also critically reviewed the manuscript.

Table 5.--Survival of marked brook and brown trout of 1951 year class in the Pigeon River. In parentheses is the percentage of survival of unmarked trout of 1951 year class in the same stream

Date	Number of trout present			
	Brook		Brown	
	Wild	Hatchery	Wild	Hatchery
August 20-29, 1951	2,423	..	202	..
September 20, 1951	1,812	..	155	..
October 5, 1951	..	..	..	300
October 8, 1951	..	3,000	..	...
September 22, 1952	329	92	65	66
Percent survival from fall of 1951 to September 22, 1952	16.4 (19.6)	3.1 ..	41.9 (30.8)	22.0 ..
Percent of mortality appearing in legal catch	0.9	0.2	0.0	0.0

Literature Cited

Allen, K. Radway

1951. The Horokiwi Stream, A study of a trout population. New Zealand Marine Dept., Fish. Bull. No. 10, 231 pp.

Cooper, Edwin L.

1949. The age and growth of the brook trout (Salvelinus fontinalis) in Michigan. Doctorate thesis, Univ. of Michigan, microfilmed.

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

1953. Growth of brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta) in the Pigeon River, Otsego County, Michigan. Mich. Acad. Sci. Arts and Letters.

Hobbs, Derisley F.

1948. Trout fisheries in New Zealand, their development and management. New Zealand Marine Dept. Fish. Bull. No. 9, 175 pp.

Needham, Paul R.

1949. Survival of trout in streams. Trans. Amer. Fish. Soc. 77: 26-31

Needham, Paul R., James W. Moffett, and Daniel W. Slater

1945. Fluctuations in wild brown trout populations in Convict Creek, California. Jour. Wildlife Man. 9 (1): 9-25.

Ricker, W. E.

1949. Mortality rates in some little-exploited populations of fresh-water fishes. Trans. Amer. Fish. Soc. 77: 114-128.

Schuck, Howard A.

1945. Survival, population density, growth, and movement of the wild brown trout in Crystal Creek. Trans. Amer. Fish Soc. 73: 209-230.

Schuck, Howard A.

1948. Survival of hatchery trout in streams and possible methods of improving the quality of hatchery trout. Progressive Fish Culturist, 10 (1): 3-14.

Schuck, Howard A. and Oliver R. Kingsbury

1948. Survival and growth of fingerling brown trout (Salmo fario) reared under different hatchery conditions and planted in fast and slow water. Trans. Amer. Fish. Soc., 75: 147-156.

Shetter, David S.

1939. Success of plantings of fingerling trout in Michigan waters as demonstrated by marking experiments and creel censuses. Trans. Fourth N. Amer. Wildlife Conf., pp. 318-325.

1950. Results from plantings of marked fingerling brook trout (Salvelinus f. fontinalis Mitchell) in Hunt Creek, Montmorency County, Michigan. Trans. Amer. Fish. Soc., 79: 77-93.

Shetter, David S. and Justin W. Leonard

1943. A population study of a limited area in a Michigan trout stream, September, 1940. Trans. Amer. Fish Soc., 72: 35-51.

Surber, Eugene W.

1937. Rainbow trout and bottom fauna production in one mile of stream. Trans. Amer. Fish. Soc., 66: 193-202.

1940. "Lost: 10,839 fingerling trout!" Progressive Fish Culturist, No. 49, pp. 1-13.

White, H. C.

1927. A preliminary report on investigations in Forbes Brook in 1925 and 1926. Contr. Can. Biol. & Fish. N. S., Vol. III, No. 15.

INSTITUTE FOR FISHERIES RESEARCH

Approved by: A. S. Hazzard

Edwin L. Cooper

Typed by: Nancy Greenman