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Results from plantings of marked fingerling brook trout (Salvelinus f. fontinalis Mitchill) in Hunt Creek, Montmorency County, Michigan[1]

[1] Contribution from the Michigan Institute for Fisheries Research

by

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Abstract

Fin-clipped fingerling brook trout (Salvelinus f. fontinalis Mitchill), both hatchery-reared and wild, were released in Hunt Creek in late summer or fall of 1939 and 1940. Their contribution to the catch in subsequent years was followed by means of creel census and anglers' reports. The extensive experiments involved release of 35,109 and 17,635 marked fingerlings respectively throughout the length of Hunt Creek. Marked fish entered the anglers' catches in 1941 and 1942, and made up from 0.27 to 2.56 percent of the observed catch of legal brook trout in various years. The total known percentages of recovery were 0.07 percent (26 fish) of the 1939 release, and 0.28 percent (49 fish) of the 1940 planting.

Intensive experiments with both wild and hatchery-reared brook trout fingerlings marked by different fin combinations were carried on simultaneously in Section C of the experimental waters of Hunt Creek. Marked hatchery-reared fingerlings released in 1939 contributed from 0.0 to 0.26 percent of the total observed catches of legal brook trout in later

years; 1940-marked hatchery fingerlings made up from 0.00 to 0.45 percent of total observed catches in later years. Wild fingerlings marked at the same time made up from 0.00 to 1.80 percent of catches recorded in subsequent seasons. Larger percentages of recovery were noted for the smaller of the two releases (1940).

Through the use of the formula $M = \frac{1000\ A}{BC}$ where M = migration or abundance index from a release locality to a recovery locality, A = number of marked fish recovered in a given locality, B = number of fishing units of effort in a given locality, and C = total number of marked fish released in a given locality, it was demonstrated that the majority of wild and hatchery-reared marked fingerlings in the intensive experiment stayed within the limits of the experimental sections, although they did move out of Section C, except for the hatchery-reared fingerlings recovered in 1942, which were farther downstream than usual.

General growth data on marked fingerlings of both types indicated that probably those fish which were largest at the time of marking and release came into the legal catch first.

It was concluded that brook trout fingerling planting is a wasteful procedure because of the low percentage to reach the anglers' creels. Creel census data available demonstrate that despite the elimination of fingerling stocking in Hunt Creek following 1940, angling quality has not deteriorated.

Results of previous experimental plantings of marked fingerling trout reported by the author (Shetter, 1939) and others (Surber, 1937, 1940; Needham and Cliff, 1938; Chamberlain, 1942; Holloway and Chamberlain, 1942; and Needham and Slater, 1944) indicate that a very small percentage of

trout which are released in streams as fingerlings (2 - 5 inches total length) ever reach anglers' creels as legal fish. The data presented hereafter give additional support to this general conclusion.

With the establishment of the Hunt Creek Fisheries Experiment Station in 1939, plantings of fin-clipped brook trout fingerlings of both wild and hatchery origin were made in a section of the experimental stream, and releases of fin-clipped hatchery-reared brook trout fingerlings only were also made throughout the Hunt Creek system. These marked plantings were followed by creel census in order to record the numbers and kinds of marked and unmarked fish which entered the catch in subsequent years.

Description of the stream

Hunt Creek, one of the shorter tributaries of the Thunder Bay River, is located in the northeastern portion of the Lower Peninsula of Michigan in south-central Montmorency County. Approximately 12 miles long, it flows in a northeasterly direction between rolling, wooded hills of moderate height. Cedar-spruce-tamarack swamps border much of its length in the upper reaches; elsewhere there are scattered meadow stretches which were formed by beaver activity or by old logging dams. As one progresses downstream the channel winds through groves of aspen mixed with conifers and a few hardwoods and allied shrubs. Along the stream border proper there is an abundance of tag alder.

The stream bottom consists chiefly of small rubble and gravel of several degrees of fineness mixed with varying proportions of sand and silt. Some clay can be observed in the lower stretches. The stream varies in width from about 5 feet in the headwaters to about 40 feet in the widest portions toward the mouth, with the average somewhere

between 20 and 30 feet. Maximum depth ranges from 3-4 inches on some of the shallow riffles to 5 or 6 feet in a few of the deeper pools. However, most of the pools are between 2 and 4 feet deep. The current velocity varies from 0.5 to 2.5 feet per second. In the lumbering days, Hunt Creek was reported to be one of the faster streams of the Thunder Bay River drainage on which timber was driven, and the remains of four old logging dams are still evident.

Along almost its entire length, the stream is fed by springs which serve to keep the water temperature below 70° F., except during the hottest part of the summer when the lower reaches may become somewhat warmer.

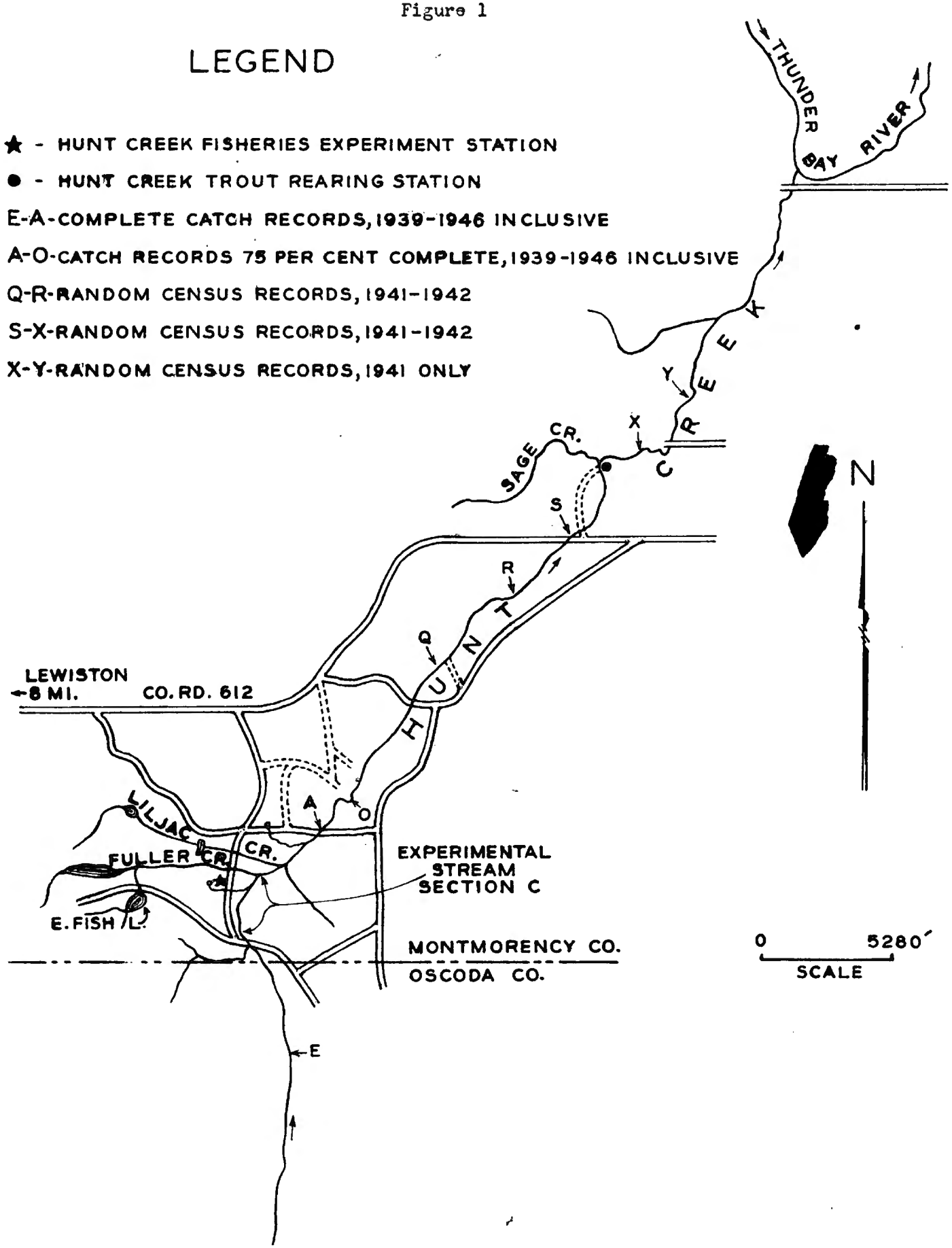
The brook trout is the only species of trout permanently established in Hunt Creek. A few rainbow trout (Salmo gairdnerii) are captured by anglers in the lower stretches each year, but apparently do not reproduce in the stream. Observations during the 1943 and 1944 spawning seasons indicated that brook trout reproduction took place throughout the entire system, but that the upper half of the stream was most used for this purpose.

A sketch map (Fig. 1) shows the location of the major tributaries, and the nature of the creel census operated on different portions of Hunt Creek in the various years.

Methods

Hatchery-reared fingerling brook trout were supplied from a state-owned rearing station located about five miles downstream from the experimental area (Fig. 1) and marking operations on the artificially-reared fish were conducted there (rearing operations were discontinued at the

Figure 1


LEGEND
★ - HUNT CREEK FISHERIES EXPERIMENT STATION
● - HUNT CREEK TROUT REARING STATION
E-A-COMPLETE CATCH RECORDS, 1939-1946 INCLUSIVE
A-O-CATCH RECORDS 75 PER CENT COMPLETE, 1939-1946 INCLUSIVE
Q-R-RANDOM CENSUS RECORDS, 1941-1942
S-X-RANDOM CENSUS RECORDS, 1941-1942
X-Y-RANDOM CENSUS RECORDS, 1941 ONLY
THUNDER BAY RIVER
HUNT CREEK
SAGE CR.
LEWISTON
← 8 MI.
CO. RD. 612
LILJAC CR.
FULLER CR.
E. FISH L.
EXPERIMENTAL STREAM SECTION C
MONTMORENCY CO.
OSCODA CO.
N
0
5280'
SCALE

rearing station at the end of the 1942 season). Wild brook trout fingerlings were obtained for marking by seining in Section C, and were measured, marked and counted as the predetermined numbers were collected within that section. Brook trout fingerlings were fin-clipped for future identification by using a different fin or fin-combination for each year and for each type of fish (wild or hatchery-reared). Curved-blade manicure shears were employed; the fins were removed flush with the body surface. Regeneration of clipped fins has been negligible, probably never so much that marked fish could not be recognized as such by creel census clerks or observant anglers. Shetter (1939) found a difference in mortality of dorsal and adipose fin-clipped brook trout fingerlings over unmarked controls (both lots held in hatchery ponds) of 8.6 percent at the end of two years after marking. There was no significant difference in growth and although some regenerations of the rayed dorsal fin occurred in a few individuals there was no regeneration of the adipose fin, and all the marked fish could be identified readily after two years.

Creel census operations varied on different portions of the Hunt Creek drainage. In all years, catch records from the section E-A (Fig. 1) have been from 97 to 100 percent complete; catch records from the section A-O are estimated to be 75 percent complete for all years. In the years 1941 and 1942, random records were available from the stream sections Q-R and S-X; random census records are available for the section X-Y for 1941 only. In certain years a few additional records were obtained from stream areas elsewhere than indicated, and have been used also in arriving at season totals. The records for Fuller Creek and East Fish Lake outlet are believed to be complete.

When intensive creel census operations were inaugurated in 1939 on the experimental waters of Hunt Creek, four sections of stream, all quite different in character, were designated Sections A, B, C, and D for the purpose of recording the angling results in the different types of brook trout water. Section E was added and checked during 1940 and thereafter. The downstream terminus of Section A is at A (see Fig. 1) and Section E has its upstream boundary at E. The other sections lie in alphabetical order between them, and vary in length from 1,250 feet (Section E) to 3,970 feet (Section C).

In making up season totals for the Hunt Creek angling, use has been made of all available records which represented fishing effort on any portion of the drainage to which the marked fish might have moved.

The total numbers of marked fish recovered have been listed also. By comparing the number of marked fish of legal size with the total legal catch, one can determine the percentage of the total observed catch which consists of either marked wild or hatchery-reared fish.

Marked hatchery fish from the extensive experiments were not included in the total catch when considering results obtained from the intensive experiments, and vice versa. Tagged hatchery fish entering the catch of 1941 from the spring planting of legal-sized fish in that year likewise were not included in the totals for 1941.

In reality, two experiments were operating simultaneously. One, termed "extensive," involved hatchery-reared fingerlings only, planted in large numbers over the entire stream system mostly outside of the experimental area. The smaller, "intensive" experiment involved the use of similar numbers of both wild and hatchery-reared fingerlings of approximately the same size and age, in the same stream area. It was

hoped that the complete creel census data available for the stream section E-A could be utilized to determine the results of the intensive experiment. However, recoveries of marked fingerlings from the intensive experiment outside the area covered by complete census invalidated the use of only the catch figures for the stream section A-E. Instead, it seems more correct to use all available catch data for the entire stream in interpreting the results of both experiments.

Extensive experiments

When research operations were begun on Hunt Creek in 1939, it became desirable to know whether or not the fish which came into the catch in later years were of natural or artificial origin. The stream had been stocked heavily for a number of years preceding 1939, although Hunt Creek was known to produce a plentiful supply of fingerlings each year from natural spawning. To permit accurate determination of which fish in the legal catch of the experimental waters and elsewhere were originating from hatchery-reared fingerlings, the entire plantings of brook trout of this size in 1939 and 1940 were fin-clipped before release. No hatchery-reared fingerlings have been released in the area since 1940. Two thousand legal brook trout, all jaw-tagged, were planted in March, 1941, in the stream below the experimental area. All plantings of legal trout in East Fish Lake in 1940, 1941, and 1942 were marked by either jaw-tag or distinctive fin clip combination. After September, 1941, trout in East Fish Lake were confined to the lake by a fish-tight weir.

The 1939 planting consisted of 35,109 brook trout ranging in size from 2.2 to 4.8 inches (average 3.3 inches, based on a random sample

of 114 specimens). This number was approximately the same as the usual annual planting of fingerlings made in the stream system each year prior to 1939. These fish, marked by clipping the dorsal and adipose fins, were scattered over the length of Hunt Creek at various locations outside the experimental area, except for about 1,200 fish which were planted by error within the confines of the experimental sections. The marking and planting were conducted during the period September 27 - October 4, 1939.

In 1940, a similar procedure was followed, except that only 17,635 brook trout fingerlings were used (approximately one-half of the 1939 release), and the fish were marked by clipping the adipose and right pelvic fins. These were marked and released in Hunt Creek outside of the experimental sections between September 19 and 23, 1940. The size range of the 1940 release was 2.5 to 4.5 inches (average 3.2 inches based on a random sample of 200 specimens).

The length of the stream, the road pattern (which provides numerous points of access), and the number of private cabins combine to make an intensive type of creel census over the entire stream impracticable. Data on the fishing in the years following these plantings were obtained on the lower portions of Hunt Creek outside the experimental area through random census of short portions of the stream, and by reports from interested anglers. Explanatory signs were placed at cabins, bridges, and parking sites requesting reports of fishing success, number of marked and unmarked fish in the catches, etc. From the data secured, it is impossible to estimate the total catch for the stream for any year, or the total percentage of recovery of marked fish, but the percentage of the observed catch contributed by plantings of hatchery-reared fish in 1939

and 1940 can be determined. Data on angling, including the number of marked hatchery-bred fish captured, are listed in Table 1.

No marked fish from the extensive planting of 1939 were observed in the legal catch by Institute personnel in the 1940 trout season, despite the previously-mentioned release of approximately 1,200 marked fish within the experimental waters. The caretaker of the Hunt Creek Rearing Station during the summer of 1940 asserted that "quite a few" legal fish with the dorsal-adipose mark were taken in that year in the vicinity of the rearing station, but could give no estimate of the catch of either marked or unmarked fish.

In 1941, out of 1,251 brook trout examined in fishermens' catches 23 dorsal-adipose marks (1939 planting), and 32 right pelvic-adipose marks (1940 release) were observed. These hatchery fish constituted 1.84 and 2.56 percent respectively of the total observed legal catch of 1941.

In 1942, from a total of 1,126 legal brook trout examined, there were noted 3 dorsal-adipose marks and 17 right pelvic-adipose marks, or 0.27 and 1.51 percent respectively of the observed catch of 1942. No marked fish from either planting were reported in the 1943, 1944, 1945, or 1946 seasons, nor were they observed in any of the catches examined in those years (1943 -- 630 legal fish; 1944 -- 756 legal fish; 1945 -- 585 legal fish; 1946 -- 811 legal fish).

The total known percentage of recovery on the extensive plantings of large numbers of fingerling brook trout is as follows: 1939 planting, 26 out of 35,109 fingerlings recovered by anglers as legal fish, or 0.07 percent; 1940 planting, 49 out of 17,635 fingerlings recovered as legal fish by anglers, or 0.28 percent. Even though one assumes that

Table 1.--Summary of all available angling data for Hunt Creek and tributaries for the seasons 1939-1946 inclusive, showing the numbers of marked fall-planted, hatchery-reared brook trout fingerlings of the "extensive" experiment entering the observed legal catch.

Season	Total anglers interviewed	Total hours of angling	Total legal brook trout taken	Sub-legal brook trout returned	Catch per hour		Number of marked hatchery fish caught		Percentage of marked hatchery fish in catch	
					Legal	Sub-legal	1939 plant	1940 plant	1939 plant	1940 plant
1939	642	1,242.50	730	5,488	0.59	4.42	...	...	...	...
1940	693	1,367.50	623	5,322	0.46	3.89	...	...	0.00	...
1941	1,681	2,974.25	1,251	10,499	0.42	3.53	23	32	1.84	2.56
1942	1,233	2,289.00	1,126	6,666	0.49	2.91	3	17	0.27	1.51
1943	443	990.25	630	4,282	0.64	4.37	...	...	0.00	0.00
1944	633	1,279.50	756	5,510	0.60	4.31	...	...	0.00	0.00
1945	658	1,237.75	585	5,796	0.47	4.68	...	...	0.00	0.00
1946	1,284	2,152.50	811	7,208	0.38	3.35	...	...	0.00	0.00
Totals, averages	7,267	13,533.25	6,512	50,771	0.48	3.75	26	49	0.45	0.95

only one-tenth of the legal catch were observed, it will be noted that the percentages of recovery would still be very low -- 0.70 for the 1939 planting, and 2.80 for the 1940 release.

It should be pointed out that the angling data available from all sources, both intensive and random, indicate that the quality of the fishing (as measured by the number of legal trout caught per hour of fishing) has not suffered since the cessation of stocking fingerling trout in the fall of 1940. If the creel census data for the four years during which it is known that hatchery fingerlings were present in the stream (1939, 1940, 1941, and 1942) is averaged, an average catch per hour of 0.47 legal trout for those years can be demonstrated. For the years when no marked hatchery-reared fingerlings were observed in the creel census, and also when they were not planted (1943, 1944, 1945, and 1946), the average catch per hour of legal trout was found to be 0.49 fish, or slightly better for the latter period.

Undersize brook trout increased noticeably during the four-year period when no hatchery-reared fingerlings were present or planted, according to a comparison of the catch per hour of undersized fish for 1939-1942 (3.55) and 1943-1946 (4.03).

In view of the discontinuance of stocking, it must be concluded that the legal and sublegal fish reported in the last four years are the result of natural spawning and that the quality of fishing has not suffered from a policy of no stocking.

Intensive experiments

Since the start of the 1939 trout season, approximately two miles of the headwaters of Hunt Creek have been under intensive creel census,

a practice which has permitted examination of almost 100 percent of the total catch of the stream section A-B (Fig. 1) since that time.

In August, 1939, Section C was seined throughout its length, and 1,000 fingerling brook trout, all presumably young-of-the-year resulting from the 1938 fall spawning, were marked by clipping the left pectoral fin. The fish were seined up, measured, marked, and immediately returned to the water. These wild brook trout fingerlings ranged in total length from 1.9 to 3.8 inches (average 2.6). One thousand hatchery-reared brook trout fingerlings obtained from the Hunt Creek Rearing Station were measured, and marked by clipping the right pectoral fin. Their size range was from 1.7 to 4.8 inches (average 2.7). They were scattered at random throughout the length of Section C at the rate of 1,320 fish per mile of stream or 934 fish per acre of water (Table 2).

A similar procedure was followed in August of 1940, except that 500 wild brook trout fingerlings were seined, marked, measured and returned to Section C, and 464 hatchery fingerlings were fin-clipped and planted, the latter at the rate of 642 per mile of stream or 433 per acre. The wild fish of 1940 were marked by removing the left pelvic fin, and the hatchery-reared fish by the excision of the right pelvic fin. Their sizes were as follows: hatchery fingerlings, range 1.6 to 3.3 inches, average 2.5; wild fingerlings, range 1.9 to 3.3 inches, average 2.6 (Table 2).

Table 3 lists the number of fin-clipped fish recovered as legal brook trout by angling together with the year, locality of recovery, percentage of recovery, and percentage of the total catch of the experimental sections for the various types of marked fish.

Table 2.--Summary of marking information concerning wild and hatchery-reared brook trout fingerlings in Section C, Hunt Creek, 1939 and 1940. Total lengths are given in inches; weights are given in ounces.

Date released	Origin of fish	Mark used	Number marked	Average size		Range in total length
				Total length	Total weight	
August 21-24, 1939	wild	left pectoral	1,000	2.60	0.09	1.93-3.78
August 25, 1939	hatchery	right pectoral	1,000	2.72	0.12	1.69-4.76
August 10, 1940	wild	left pelvic	500	2.64	0.11	1.97-3.35
August 12, 1940	hatchery	right pelvic	464	2.52	0.09	1.57-3.35

Table 3.-- Number of marked hatchery-reared and wild brook trout fingerlings recovered from the markings and plantings in Section C, Hunt Creek, in 1939 and 1940, together with locality of recovery, and percentages of the total catch made up by the various plantings, and percentages of recovery for the period 1940-1946 inclusive. (W = wild, H = hatchery.)

Item	1941 season				1942 season				1943 season				1944 season				Totals, all seasons [1]			
	1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting	
Recovery area	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H
Section E	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Section D	7	3	1	1	6	0	13	1	0	0	0	0	0	0	0	0	13	3	14	2
Section C	3	0	0	0	4	0	4	0	1	0	2	0	0	0	1	0	8	0	7	0
Section B	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	1	0
Section A	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	2	1	0
Below A	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1
Other	1	0	0	0	1	0	1	3	0	0	0	0	0	0	0	0	2	0	1	3
Total recoveries each year	12	3	1	1	11	0	21	5	2	0	2	0	0	2	1	0	26	5	25	6
Number available in year	999	1,000	500	464	987	997	499	463	976	997	478	458	974	997	476	458	1,000	1,000	500	464
Total observed catch of legal trout in year	1,200				1,111				630				758				5,718		5,095	
Percentage of total observed catch made up by various markings	1.00	0.25	0.08	0.08	0.99	0.00	1.80	0.45	0.32	0.00	0.32	0.00	0.00	0.26	0.13	0.00	0.45	0.09	0.49	0.12
Cumulative percentage of recovery at end of each year	1.30	0.30	0.20	0.21	2.40	0.30	4.40	1.29	2.60	0.30	4.80	1.29	2.60	0.50	5.00	1.29	2.60	0.50	5.00	1.29

[1] In 1940, one wild marked fish, taken in Section B, was observed among the total of 623 legal trout checked. In 1945, no marked trout were seen in the total of 585 legal trout observed; in 1946 no marked trout were among the total of 811 examined.

One recovery of a wild fingerling marked in 1939 appeared in the 1940 catch of the experimental waters. During the 1941 season, the 1939 mark was most common. In the 1942 season the fingerlings marked in 1940 contributed more fish than the 1939 releases, while in 1943 and 1944, the few recoveries were about equally distributed between the two releases. From the creel census data available, it may be computed that the hatchery-reared brook trout planted as fingerlings have either failed to increase the total catch or have increased it by only an insignificant amount. The 1939 planting of 1,000 hand-reared fingerlings which later grew to legal size constituted 0.00 percent of the 1940 catch (no hatchery fish taken), 0.25 percent of the 1941 catch (3 fish), 0.00 percent of the 1942 and 1943 catches (no fish), and 0.26 percent of the 1944 catch (2 fish).

The 1940 planting of 464 hatchery-bred brook trout fingerlings made up the following percentages of the total catch in succeeding years: 1941 - 0.08 percent (1 fish); 1942 - 0.45 percent (5 fish); 1943 and 1944 - 0.00 percent (no fish from this planting in either year).

The total percentage of recovery on each category of marked fish up to the end of the 1944 season was as follows: From the 1,000 wild brook trout fingerlings clipped and released in August, 1939 - 2.60 percent; from the 1,000 marked hatchery fingerlings released at the same time - 0.50 percent; from the August, 1940, marking of 500 wild brook trout fingerlings - 5.00 percent; from the 464 hatchery fingerlings marked and planted in August, 1940 - 1.29 percent. Note that the smaller plantings yielded percentages of recovery that were over twice or nearly twice as large as the larger plantings both for native and planted stock. Apparently, the reduction in the rate of stocking by

one-half increased the survival rate proportionately. The reason for the increased survival rate, and in turn the increased percentage of recovery by anglers, probably lies in the fact that the smaller planting of hatchery-reared fingerlings resulted in considerably less competition for food and space between wild and hatchery-reared fingerlings and between the introduced fingerlings themselves. Similar results were noted in the extensive experiment, where 26 of 35,109 hatchery fingerlings were reported as legal fish (0.07 percent recovery), while 49 of 17,635 fingerlings planted the following year were reported later as legal brook trout (0.28 percent recovery). Surber (1938) also found higher survival from smaller plantings when stocking rainbow trout fingerlings. In experiments involving the planting of various numbers of marked legal-size trout, higher rates of survival to the angler have been noted by Shetter and Hazzard (1941) and Gee (1942) for smaller plantings than for larger plantings. Considered as a whole, these facts suggest that when more trout are released in a stream than can be supported by that body of water, survival rates for both the planted trout and the native trout are lowered.

No marked fish from these experiments entered the catches in 1945 and 1946. One left pectoral-marked brook trout was observed in the catch of Below Section A in 1944, and a right pectoral-marked fish of less than legal size (6.9 inches, total length) was removed from the same section in 1945. However, examination of the scales of these fish by Mr. E. L. Cooper demonstrated that they were not from the 1939 markings, as no more than 3 annuli were to be observed on the scales of either fish. It is believed that they had suffered natural injuries to these fins, or were fish from experimental markings in Sections A and C in

which the dorsal plus either the right or left pectoral fins were removed, and on which the dorsal fin had regenerated.

Migration of the fingerlings released or marked in Section C

Since the fishing effort (hours of angling) was known for the various localities in which the marked fish were recovered, it is possible to calculate an "abundance index" for the various localities; or the index figure so obtained may be regarded as indicating the amount of migration from Section C, where all of the marked fingerlings of the intensive experiment were liberated. Such treatment of the recovery data from the extensive experiments was not possible because marked fish were scattered at various localities along the length of Hunt Creek and the fishing effort was not known outside of the experimental area.

Other fisheries workers have realized that there is a relationship between fishing intensity and the number of marked fish recovered. Schroeder (1930) stated that the intensity of the cod fishery in the Nantucket shoals had a direct bearing on the proportion of marked cod in the catch, but his data were insufficient for the calculation of any abundance or migration indices. Thompson and Herrington (1930) demonstrated a definite relationship between the actual number of tagged halibut recovered and the possible number that probably would be recovered by the intensity of the fishery on the halibut grounds off the southern coast of the Alaskan Peninsula. Although the results of calculations relating to brook trout migrations are expressed here in a manner differing from that employed by Thompson and Herrington, the basic factors considered have been the same, namely, the number of marked fish

recovered, the number of marked fish available, and the number of units of fishing effort expended to effect recoveries in the various areas.

If the number of units of fishing effort in all areas was constant, the number of marked fish recovered in the various localities would furnish an accurate picture of the migrational tendencies of a planting of marked fish. However, angling pressure over different stream areas is seldom uniform, and the number of units of fishing effort must enter into the calculations. The proper interpretation of the factors listed above is of considerable importance, as may be illustrated by a hypothetical example. Suppose 100 marked fish are introduced into area T on a stream, and in their dispersion 70 move upstream into area U and 30 move downstream into area D. If there are 10 hours of fishing in area D, and only 1 hour of fishing in area U, the possibilities are much greater of recovering fish which have migrated downstream. Assume further that the aforementioned fishing in the two localities produced 20 recoveries in area D and 5 recoveries from area U. Judged only on the basis of comparative numbers of fish recovered, it would appear that there was a stronger tendency for the fish to move downstream than upstream whereas exactly the opposite was the case.

If the results just given were weighted by the available number of marked fish and the number of units of fishing effort used in each area, the true migration indices from area T to areas U and D would be obtained. In determining this index the number of marked fish captured per unit of fishing effort in a given area is divided by the number of marked fish available from a given area of release, and the resulting figure multiplied by 1,000 for the sake of convenience. This procedure

may be expressed by the formula: $M = 1000 \frac{A/B}{C} = \frac{1000\ A}{BC}$, in which M = migration (or abundance) index from any given area of release to any given area of recovery.

A = number of marked fish recovered in any given area

B = number of units of fishing effort in any given area

C = total number of marked fish released in any given area.

Substituting the hypothetical values in the formula we find the following results:

Migration index from area T to area U upstream

$$M = \frac{1000 \times 5}{1 \times 100} = \frac{5000}{100} = 50;$$

Migration index from area T to area D downstream

$$M = \frac{1000 \times 20}{10 \times 100} = \frac{20000}{1000} = 20.$$

In other words, instead of a greater tendency toward downstream movement, as conjectured from the recoveries alone, there is actually indicated an upstream migration 2.5 times as great as the downstream movement.

The recovery data from the fingerlings planted in or marked in Section C were analyzed by the method just described. Fishing effort (hours of angling) was known for the various stream sections in which recoveries were made. The results of this analysis are presented in Table 4. The larger the index figure, the greater the amount of migration which took place from Section C, or expressed in another manner, larger index figures indicate a greater abundance of marked fish in that particular section. Where the symbol....is listed this means the index was 0.0 (no recoveries made, although the various areas were all fished over each year). It will be observed from this table that there was some shift in the centers of abundance of the marked fish after marking

Table 4.--Migration indices for marked wild and hatchery-reared brook trout fingerlings released in Section C in the falls of 1939 and 1940. (The symbol ... indicates that the index is zero. W = wild; H = hatchery.)

Stream section	1940		1941				1942				1943		1944			
	1939 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting	
	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H
E	...	...	...	...	...	...	...	...	0.043	...	...	...	...	...	...	...	...	...
D	...	...	0.011	0.005	0.004	0.004	0.012	...	0.047	0.004	...	...	...	...	...	...	...	...
C	...	...	0.007	...	...	...	0.010	...	0.020	...	0.008	...	0.031	...	...	...	0.013	...
B	0.116	...	...	...	...	...	...	...	0.016	...	0.014	...	...	...	...	...	...	...
A	...	...	...	...	...	...	...	...	0.010	...	...	...	...	...	...	0.013	...	...
Below A	...	...	0.001	...	...	...	...	...	...	0.003	...	...	...	...	...	...	...	...
Other	...	...	0.001	...	...	...	0.003	...	0.005	0.016	...	...	...	...	...	...	...	...

or after release in Section C, among both the wild and the hatchery-reared fish.

Considering the indices by trout seasons, the legal fish originating from the two plantings were dispersed as follows (with the center of greatest abundance given first, and those of lesser abundance following in order):

1940 season - 1939 wild fish - Section B
1939 hatchery fish - not known

1941 season - 1939 wild fish - Section D, Section C, Below A,
Other hatchery fish - Section D
1940 wild fish - Section D
hatchery fish - Section D

1942 season - 1939 wild fish - Section D, Section C, Other
hatchery fish - not known
1940 wild fish - Section D, Section E, Section C,
Section B, Section C, Other
hatchery fish - Other, Section D, Below A

1943 season - 1939 wild fish - Section B, Section C
hatchery fish - not known
1940 wild fish - Section C
hatchery fish - not known

1944 season - 1939 wild fish - not known
hatchery fish - Section A
1940 wild fish - Section C
hatchery fish - not known

The majority of the 1939 (23 of 26) and 1940 (24 of 25) wild marked fingerlings appear to have stayed within the limits of the experimental

sections, although most of them moved out of Section C before capture.

Of the five 1939 hatchery fingerlings taken as legal-size fish, three were recovered in Section D in 1941, and two were recaptured in Section A in 1944. Hatchery fingerlings released in 1940 exhibited a greater tendency to move downstream after 1941. In 1942, four of the five recoveries from this planting were retaken at points downstream from the experimental sections. The apparent wandering noted for the smaller of these two releases has been puzzling. However, the data in Table 4 would indicate that the majority of hatchery fingerlings were recovered as fish 7 inches or larger less than a mile from the locality of release. The same was true for the wild fingerlings marked in Section C.

The argument might be advanced that the recoveries observed do not give the entire picture of the movements of the marked fish. The angling in the experimental sections has been completely checked each year since 1939, while the catches from varying portions of Hunt Creek were inspected outside the experimental sections in all years. The only way in which to determine the amount of emigration from the sections A-E (Map, Fig. 1) would be to install two-way fish traps in the vicinity of those localities.

The growth of the marked fish

Information of a general nature is available on the growth of the marked fish, since the size of all marked fish at recovery in the legal catch is known, as is the average size of the wild and hatchery-reared fingerlings at the time of marking and release, (Table 2). The average

size, range in total lengths, and the increases in average length for the various plantings recovered in the different seasons by anglers are presented in Table 5.

As might be expected, the minimum size was very close to 7 inches, since that was the legal size limit set on the experimental stream at that point. The largest wild marked fish recovered from the 1939 planting was 9.7 inches; from the 1940 marking of wild fish, 10.6 inches. The largest marked hatchery fish recovered were as follows: From the 1939 planting, 7.6 inches; from the 1940 planting, 8.3 inches.

It would appear that the faster-growing individuals or those which were larger at the time of marking came into the legal-size class and into the catch in earlier years. The individuals which became 7 inches long three or more years after release unquestionably were the more slow-growing individuals. There seemed to be little regularity in the increase in the average lengths probably because of the small number of recoveries. For almost any planting, the average increment based on the size at recovery might be less for one year than for the year preceding.

Conclusions

Experimental work in California's "test stream," Convict Creek, by Needham and Slater (1944), where 63 planting experiments with brown trout and rainbow trout fingerlings using different numbers of hatchery fish and introducing them into areas where the populations of wild trout were known, led to the following conclusions:

1. Heavy stocking where there is a large resident population increases the food demand beyond the supply, and both the wild and the introduced stock have lower survival percentages as a result.

Table 5.--Average size of marked fingerling brook trout planted or marked in Section C, Hunt Creek in August, 1939 and August, 1940, on recovery by angling in later years. Total length measurements are given in inches; weights are given in ounces. (Numbers in parentheses show number of specimens which were actually weighed).

Year of recovery and item	Year of planting and type of fish			
	1939 wild	1939 hatchery	1940 wild	1940 hatchery
1940 - Number recovered	1	...	---	---
Size range	8.6	...	---	---
Average total length	8.6	...	---	---
Average weight	3.2	...	---	---
Increase in average total length	6.0	...	---	---
1941 - Number recovered	12	3	1	1
Size range	7.0-9.7	7.0-7.4	8.0	7.0
Average total length	7.5	7.2	9.0	7.0
Average weight	2.3	2.2	3.3	1.9
Increase in average total length	4.9	4.5	5.4	4.5
1942 - Number recovered	11	...	21	5
Size range	7.0-8.1	...	6.9-8.6	7.0-7.6
Average total length	7.3	...	7.5	7.5
Average weight	2.2 (10)	...	2.3	2.2 (2)
Increase in average total length	4.7	...	4.9	5.0
1943 - Number recovered	2	...	2	...
Size range	8.0-9.9	...	7.6-8.8	...
Average total length	8.9	...	8.3	...
Average weight	4.6	...	3.0	...
Increase in average total length	6.3	...	5.7	...
1944 - Number recovered	...	2	1	...
Size range	...	7.1-7.6	7.2	...
Average total length	...	7.3	7.2	...
Average weight	...	2.0	2.2	...
Increase in average total length	...	4.6	4.6	...

2. Although they could not measure the relationship between the rate of planting and the "food ratio," they were able to demonstrate that a light planting was more successful than a heavy planting under the same food conditions (a finding also borne out in the Hunt Creek data, where a better percentage of survival to the creel was obtained from the 1940 plantings which were only approximately one-half as large as the 1939 plantings in both the intensive and extensive experiments).

3. Fingerling plantings are of little use in streams containing numerous wild trout, because competition and predation prevent any significant survival.

Both from the intensive and extensive experiment on Hunt Creek, and from research described for other parts of the continent, it would appear that anglers may expect to recover as legal fish a comparatively small percentage of a planting of fingerling brook trout. Assuming again that the creel census from the extensive experiment on Hunt Creek was only 10 percent efficient, one could expect a maximum recovery of only about 3 percent of fall-planted fingerling brook trout. Under conditions or seasons unfavorable to hatchery-reared fish this would probably approach zero. The great majority of recoveries that survive to reach the angler's creel will be made in the first two years after release. On Hunt Creek, hatchery fingerlings from any one planting have never constituted more than 2.56 percent of the observed total catch in any one year, and the percentage declines rapidly to zero in following years. Since the elimination of hatchery planting of fingerling brook trout in Hunt Creek, creel census records furnish evidence that angling quality has been as good or slightly better than in those years hatchery fingerlings were present.

In view of the experimental evidence recorded elsewhere in the literature plus the facts discussed above, the conclusion is inescapable that the planting of fingerling brook trout in streams which produce numerous brook trout fry by natural methods is an inefficient management procedure. Neither the stream bionomics nor the anglers' creels are benefited. In all probability any such hatchery fingerlings which arrive at the legal size of 7 inches do so at the expense of an equal number of naturally-reared brook trout. It would appear that emphasis in trout management should be placed upon increasing the natural carrying capacity of the habitat, rather than upon trying to force the habitat to support two legal brook trout where there is space and food for only one. Since the productive capacities of trout waters are definitely limited, lower creel limits will also aid in spreading the available supply among more anglers.

The only instances where fingerling plantings of brook trout in streams might appear to be justified would be: (1) where angling pressure has been so extremely heavy as to leave insufficient brood stock; (2) where the breeders of a stream system have been removed by some natural catastrophe; (3) where suitable spawning conditions do not exist and cannot be created at a reasonable cost.

The stocking of brook trout fingerlings in a stream where there is adequate natural reproduction may be likened to pumping water into a bucket which is already full. The excess runs over the side and is wasted.

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