RESEARCH REPORT 70

EFFECT OF HABITAT ALTERATION ON BROWN TROUT IN McKENZIE CREEK, WISCONSIN

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ABSTRACT

A study of McKenzie Creek, Polk County, was conducted for 8 years to determine if the brown trout population benefitted from such deliberate habitat changes as installation of current deflectors and cover devices, bank revetment, brush felling and removal of beaver dams. Increases in number of brown trout were observed following habitat alteration. The changes in catchable-sized fish were relatively small and could not be definitely ascribed to the deliberate habitat alteration. The observed changes in number of trout may have been affected by uncontrolled and unmeasured variables in the natural stream environment. Alterations that mainly increase cover on relatively undamaged streams will probably not result in dramatic increases in the number of catchable-sized trout.

ACKNOWLEDGMENTS

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INTRODUCTION

A study of McKenzie Creek, Polk County, was conducted from April, 1957 to October, 1964 to determine if certain deliberate habitat changes benefitted the trout population. Habitat changes consisted mostly of the installation of current deflectors and cover devices, with some bank revetment, brush felling and removal of beaver dams. The trout population consisted mainly of brown trout (Salmo trutta) and a few brook trout (Salvelinus fontinalis). Evaluation was mainly based on changes in the trout population and the fishery.

The McKenzie Creek study was part of a broad program to evaluate the effects of habitat development on several trout streams throughout the state.

McKENZIE CREEK and WATERSHED

McKenzie Creek and its 9-square-mile watershed are located about 10 miles east of the city of Frederic in Polk County, northwestern Wisconsin. The stream begins at McKenzie Lake and flows north about 8 miles to join the South Fork of the Clam River at the upper end of Clam Falls Flowage. Another small lake (Margaret Lake) discharges into McKenzie Creek about 2 miles north of the source and a small tributary enters from the east about one mile upstream from the mouth.

McKenzie Creek lies in a general region of loam and sandy loam soils containing numerous peat bogs. The landscape is hilly with irregular valleys. The watershed includes areas of pitted outwash and old glacial lake bed north of a terminal moraine. Scattered outcroppings of lava rock are evident at the northern end of the watershed.

At the present time, the watershed is almost entirely in wild vegetative cover. Second growth deciduous forest covers much of the upland. Relict white pines remain from cutover and burned-over stands. Marsh areas contain mainly sedge, willow and alder.

Some agriculture was carried on at one time in the watershed but was probably all abandoned at least 25 years ago. Much of the land near the stream has been purchased for public hunting and fishing. The only human habitations on the immediate banks of the watercourse were three summer cottages on McKenzie Lake and one infrequently used hunting and fishing cabin in the study zone.

THE STUDY AREA

Description

The study area was centered near the mid to lower part of McKenzie Creek, where six sections were designated for observation (Fig. 1).

The study area had an average base flow of 15-20 cfs and an average width of about 20 feet. The study sections varied in average width from

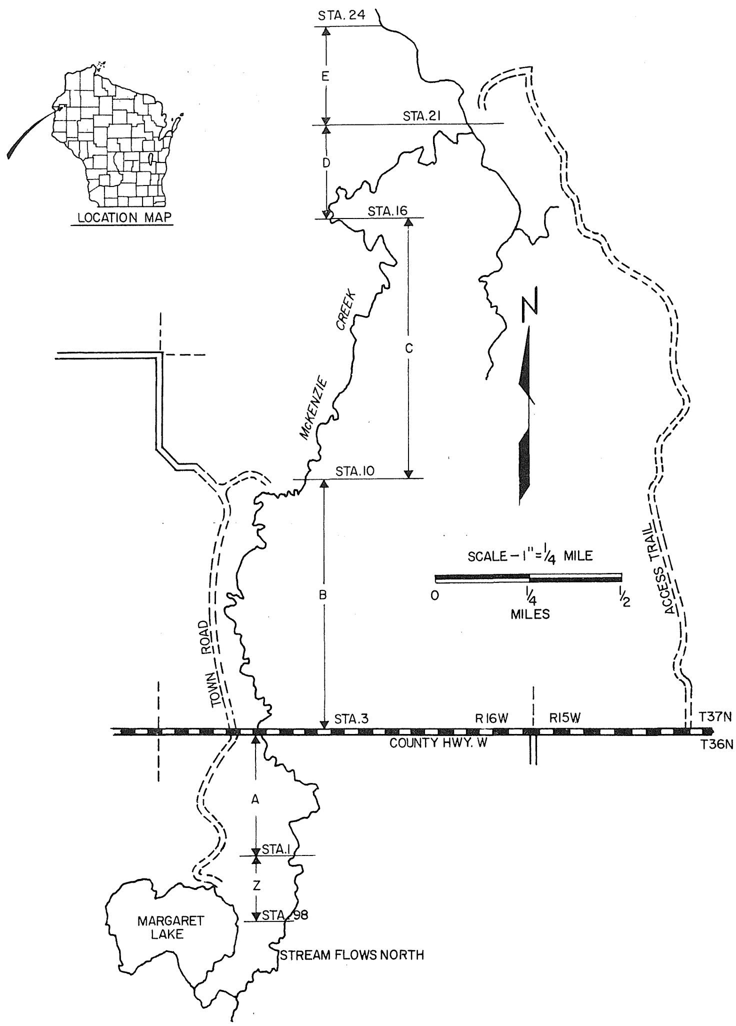

Figure 1. Location of the six sections in the entire study area on McKenzie Creek, Polk County, Wisconsin.

15 to 27 feet and varied in length from approximately 0.25 to 1.2 miles. The entire study area included about 9.5 surface acres of stream (Table 1).

Sections A, B, C and D were studied during 1957-1964 and were collectively referred to as the "regular study area". From 1960 to 1964, trout population studies were extended to include sections Z and E at the upper and lower extremities, respectively, of the regular study area. All six sections were collectively referred to as the "entire study area".*

Section Z had a moderate gradient and flowed through an upland area of mixed hardwoods and low brush. The stream had a moderately open canopy, contained beaver dams in some years and appeared to receive only a small

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*Throughout this paper, the letters A-D refer to the regular study area and the letters Z-E refer to the entire study area.

amount of ground water seepage. Bottom material was sand, gravel, rubble and silt.

Section A was very similar to section Z except that the canopy was more tightly closed near the stream, the bottom type was mainly gravel and rubble and the reach appeared to have a great amount of ground water seepage. This section was considered to be good spawning habitat. The only public road crossed the stream at the lower end of section A.

TABLE 1

Stream Length and Estimated Acreage of the McKenzie Creek Study Area

Stream Section	Stations	Length (in Miles)	Acreage
Z	98-99	0.25	0.8
A	1-2	0.36	0.7
B	3-9	1.19	2.2
C	10-15	1.09	2.6
D	16-20	0.90	2.0
E	21-23	0.52	1.2
Total (A-D)	1-20	3.5	7.5
Total (Z-E)	98-23	4.3	9.5

Section B, near the middle of the study area, had a low gradient, (water velocity less than 0.5 feet per second), was surrounded by a marsh-meadow community and had a bottom composed largely of sand, silt, clay and detritus. The gradient was slightly higher in the lower portion of section B and some gravel areas were exposed. Sedge, grass and low brush dominated the vegetative community. Although the entire section was essentially free of high trees, planted willow and conifers were becoming prominent in the lower part of the section by 1964.

Section C and D, essentially similar to each other, were separated mainly for analytical purposes. Both were in an area of relatively high gradient (water velocity greater than 1 foot per second) in a steep narrow valley heavily shaded in most places. The bottom types were largely boulder, rubble and gravel. Seepage of ground water was evident here. These sections contained excellent trout habitat.

Section E was somewhat similar to C and D in bottom type but was in an area of mainly dense shrub and brush growth rather than primarily hardwood forest. Stream gradient was also lower than in C and D. Ground water seepage was quite low in section E.

Air temperatures average about 41 F in the general area of McKenzie Creek. Winter temperatures are frequently below 0 F and temperatures of -50 F have been reported. Summer air temperatures are frequently above 80 F and maximum temperatures above 100 F have been reported.

Water temperatures in McKenzie Creek vary from 33 to 82 F. Maximum-minimum temperature observations taken periodically during 1957 suggested that summer minimums average 54-69 F daily and that summer maximums average 60-74 F daily.

Measurements of methyl orange alkalinity taken in 1957-58 ranged from 89 to 150 mg/l ($CaCo_3$). Measurements of pH taken at the same time ranged from 7.3 to 8.5 with most near 7.7. Conductivity of 220-280 microhms per cm^3 was measured in various parts of the study area in November, 1958. Samples taken in November, 1958 indicated a dissolved phosphorous level of 0.01-0.015 mg/l; a total organic phosphorous content of 0.14-0.21 mg/l and a free ammonia content of 0.024-0.046 mg/l.

Rooted aquatic vegetation was a minor element of habitat for trout in McKenzie Creek. Sparse growths of potamogetons occurred in unshaded wide shallow areas of the entire study area. The stream lacked watercress and other plants which often influence the conformation of stream channels in other parts of Wisconsin.

Thirteen species of fish other than trout were present in McKenzie Creek. Of these, only the longnose dace, Rhinichthys cataractae, could be considered abundant in zones containing high populations of trout (sections A, C, and D). The distribution of this minnow corresponded to areas of rubble and swift water. The white sucker, Catostomus commersoni; the blacknose dace, Rhinichthys

The McKenzie Creek Study Area, with McKenzie Lake, headwaters of McKenzie Creek, in the foreground; the creek meandering northward in the center and Clam Falls Flowage, where the creek joins the Clam River, in the upper right.

atratulus; and the creek chub, Semotilus atromaculatus were common in sections A and B.

Three beaver dams existed in the entire study area when the study began in 1957. The largest was near the lower end of section B and it was removed in late spring, 1958. A smaller dam was removed from the marsh in section B the same year. After that, beaver were trapped out of the regular study area whenever they were discovered; as a result, the regular study area remained essentially free of dams. The third dam which was abandoned and washed out was a low one located in section Z before this section was included in the study. Another large dam existed just above section Z; its history is unknown.

The road between sections A and B was extended across the creek in 1955. A considerable amount of soil sediment was deposited in the creek as a result. This condition was corrected in 1959, the year habitat alterations were completed.

During the study, McKenzie Creek was open for trout fishing according to statewide angling regulations which provided for a trout season extending from May 1 to September 7, a daily bag limit of 10 trout and a minimum length of 6 inches.

Research operations caused some alteration of habitat. The stream was "cleared" of obstructions to electrofishing gear at the inception of the study. Some maintenance clearing occurred each year thereafter.

Stocking History

McKenzie Creek has an interesting and varied stocking history. The stream has been stocked annually since at least 1937. From 1937 through 1941, slightly more than 120,000 trout were stocked in the stream. Most of these were fingerling rainbow (Salmo gairdneri) and brook trout. From 1942 through 1946, brown and rainbow trout were stocked, but in lesser numbers. From 1947 through 1953, only brown trout were stocked, mostly legal-sized. Except for two years, only legal-sized brown trout have been stocked in McKenzie Creek since 1953 and the number stocked has varied from 1,000 to 5,500 (Table 2).

Habitat Alteration

Habitat alteration was begun in the summer of 1958 and completed during the summer of 1959. The work was performed by employees of the Wisconsin Department of Natural Resources.

Almost all of the work consisted of the installation of six types of devices:

1. Wing deflectors which consisted of constrictions of the channel to direct the flow of water into the opposite bank.

TABLE 2

Stocking History, 1954-1965

Year	Numbers Stocked		Date of Release
	Brown Trout	Brook Trout	
1954	2,450	1,100	Unknown
1955	3,000	1,000	Unknown
1956	4,500		April 24 & June 19
1957	5,500		May 28 & Oct. 14
1958	2,500		March 20
1959	3,500		April 20
1960	5,500		April 9
1961	1,500		Spring
1962	3,500		Spring
1963	1,000		April 19
1964	1,000		Unknown
1965	1,000		April 20

2. Bank covers which created underwater hiding cover by roofing over portions of stream channel.

3. Bank revetments which used riprapping and other treatments to retard bank erosion.

4. Low dams or ramp barriers which were placed across the stream in steep sections to create a pool above and below the device.

5. Submerged brush shelters which consisted of bundles of cut brush averaging 10-15 feet long and 12-24 inches in diameter laid in the edge of the stream and staked to the bottom.

6. Miscellaneous structures such as boulders placed in the stream, unusual types of deflectors and other devices occasionally improvised as the need dictated.

For a more thorough description and a detailed discussion of the devices used in altering trout stream habitat, see White and Brynildson (1967). The definitions and terminology of that paper also apply to this study.

The type and number of devices installed are shown in table 3.

TABLE 3

Type and Number of Devices Installed

Type of Device	No. in Stream Sections B	C	D	E
Wing deflectors	57	27	16	8
Bank covers	62	31	41	19
Bank revetments	28	3	5	6
Low dams	1	2	2	3
Submerged brush covers	3	19	33	22
Miscellaneous structures	13	18	1	0
Percent of Stream Bank and Bottom Affected	40	25	30	15

METHODS

Population Estimates

Population estimates of trout were made each fall, usually during the first week in October. Spring population estimates were made only during 1957, 1958 and 1963, in late March or early April. A 230-volt, 10.6-ampere, D.C. electrofishing unit with two or three electrodes was used. This unit did not permit capture of young-of-the-year trout during the spring population estimate.

During each population estimate, trout were marked on a "first run" through the entire study area. A "second run" was then made to obtain a ratio of marked to unmarked trout (Ricker, 1958). On both runs, trout were measured to the nearest tenth-inch (total length) and all identifying fin clips were recorded. Weights of individual trout were recorded to the nearest gram for samples of trout in each inch-group.

Section B of the McKenzie Creek study area showing the meanders and the flat meadow area along the stream in this section.

An area in section C showing the riffles and wide shallows typical of McKenzie Creek prior to stream improvement.

Data were recorded separately for each stream section. For wild brown trout, population estimates were made for each stream section. In each year, the total population estimates for all of the wild brown trout in the regular study area were obtained from the sum of the individual estimates for each section. However, for wild brook and stocked brown trout, too few fish were marked and recaptured for population estimates to be made for each section. For these fish, combined estimates were made for the regular study area as a whole.

To estimate growth and separate age groups, known-age populations of trout in each age group were established by marking all age 0 trout captured in October. The complete removal of a fin (or combination of fins) enabled recognition of the marked portion of each year class in later samples. Several years (about 5) had to pass after the inception of the study before all age groups in the population were represented by marked fish. The magnitude of sampling errors encountered in making such estimates is discussed by McFadden (1961).

Estimates of the size of trout populations were calculated by use of the formula discussed by Ricker (1958): $N = \frac{M(C+-1)}{R+1}$ where:

N = estimate of population size
M = number of fish marked on first run
C = number of fish examined for marks on second run
R = number of fish recaptured on second run

Calculation of population estimates was done by computer. Although estimates were originally made for each half-inch group, I concluded that estimates made for the youngest age group (age 0) and the combined older age groups (age I+) were more satisfactory because of the avoidance of small sample size.

Growth Estimates

Estimates of growth were obtained by calculating the mean lengths of samples of the known-age marked populations for each age group at every sampling period. Trout marked on the first run and unmarked trout examined on the second run were combined for all estimates of mean length. Selectivity of the collecting gear probably biased the estimates slightly upward (McFadden, 1961). However, the annual and semi-annual differences in growth are considered valid.

Initial marking of fish was done when trout were considered about 9 months of age (fall fingerlings). At that time, more larger fish were marked than were smaller fish in the year class. If the larger fish in a year class exploited their size advantage and continued to grow faster (Brown, 1957), the mean sizes and resulting growth rates in this study could have been further biased upward. Finally, at later sampling dates the bias was augmented by another size selective sample of the known-age marked population.

Weight was related to length by plotting the mean weight for each half-inch group against the mean length (assumed to be the mid-point of the length interval) on a log-log scale. A straight line was then fitted by eye to this regression and lengths were converted to weights by reference to it. This procedure would transfer any biases related to the estimates of mean lengths of age groups to the estimates of mean weight of age groups.

Estimates of Survival Rates

Survival rates were calculated by estimating the numerical size of the marked fish populations of each age group at every sampling date during the study. The rates reflect both mortality and emigration and are actually the survival rate minus the emigration rate. Since trout recruited to the study area bore no marks, they could not influence the estimated survival values.

This method of making survival estimates also has the advantage of starting with a known number (the number of fingerlings marked) rather than an initial estimated value. Survival rates were calculated for sections A, B, C and D combined. The overwinter survivals were the only rates that reflected natural mortality only, since angling mortality occurred during each summer of the study.

Redd Counts

Counts were made of the number of clearly recognizable trout redds in each stream section in November. A clearly recognizable redd was defined as an obvious depression and adjacent mound of excavated material. A recent redd could be identified by the color of the newly turned bottom material which contrasted with the color of the undisturbed stream bottom. Counts of such redds were made by several different persons during the study and probably bear little quantitative relation to one another. Their inclusion is intended only to indicate presence or absence of spawning in the different stream sections.

Evaluation of Angling Effort and Success

A partial creel census was conducted during the 1957 and 1963 trout fishing seasons, in order to evaluate the intensity and success of fishing efforts on McKenzie Creek. As many anglers as possible were contacted during daily and weekly peak periods of fishing pressure. The anglers interviewed were asked to present their catch for examination. Trout were measured to the nearest half-inch and fin-clip markings were recorded. No special publicity was given to the study area.

A pool-riffle part of section A.

RESULTS

Population Density

During the 8-year period of observation, fall population estimates indicated that the regular study area contained an average of about 4,600 wild brown trout, of which 2,800 were fingerlings (age 0). Approximately 90 percent of both groups (Age 0 and Age I and older) were contained in sections C and D. The density of wild brown trout averaged about 1,350 trout/mile or 46 lb./acre for the regular study area. In addition, about 0.2 lb./acre of wild brook trout and 8.4 lb./ acre of stocked brown trout were present (Table 4).

TABLE 4

Fall Population Estimates of Trout by Study Area Section, 1957-1964

									Averages For All Years (1957-1964)			
									Number of Fish		Pounds of Fish	
Study Section	1957	1958	1959	1960	1961	1962	1963	1964	Per Study Section	Per Mile	Per Study Section	Per Acre
Brown Trout												
Wild (Age 0)												
Z	*	*	*	34	0	41	78	0	31	124	0.7	0.9
A	151	478	280	67	111	98	181	22	174	497	5.3	7.6
B	19	101	96	40	195	130	370	36	123	103	3.4	1.5
C	856	804	804	831	1,000	572	1,301	545	839	823	19.7	7.6
D	1,078	1,407	1,886	1,581	2,122	1,789	1,855	1,433	1,644	1,934	33.7	16.9
E	*	*	*	432	695	808	793	380	622	1,195	14.8	12.3
Total (A-D)	2,104	2,790	3,070	2,519	3,428	2,589	3,707	2,036	2,780	815	62.1	8.3
Total (Z-E)	*	*	*	2,985	4,123	3,438	4,578	2,416	3,433	797	77.6	8.2
Wild (Age I & Older)												
Z	*	*	*	61	15	40	38	36	38	152	7.9	9.9
A	24	46	40	101	57	71	91	55	61	175	15.6	22.3
B	62	168	145	185	124	150	177	189	150	126	30.7	14.0
C	588	731	569	675	553	816	706	838	684	671	108.9	41.9
D	720	737	762	883	859	952	1,244	1,068	903	1,062	130.5	65.3
E	*	*	*	346	262	363	599	530	420	809	70.4	58.6
Total (A-D)	1,394	1,682	1,516	1,844	1,593	1,989	2,218	2,150	1,798	527	285.7	38.1
Total (Z-E)	*	*	*	2,251	1,870	2,392	2,855	2,716	2,256	523	364.0	38.4
Stocked (All Ages)												
Comb. (A-D)	175	160	148	312	593	153	115	54	214	61	62.8	8.4
Brook Trout												
Wild (All Ages)												
Comb. (A-D)	15	42	48	14	31	23	15	72	32	9	1.4	0.2

* No estimates are available for sections Z and E in 1957-59 inasmuch as these sections were not designated nor included in the study area until 1960. For these 3 years, total estimates for the entire study area were not calculated.

During the three years that spring population estimates were made for the regular study area, there was an average of about 3,700 wild brown trout, of which 2,250 were estimated to be yearlings (Age I). Again, as in the fall, sections C and D held about 90 percent of both groups. Approximately 1.2 lb./acre of wild brook trout and 48 lb./ acre of stocked brown trout were also present (Table 5).

TABLE 5

Spring Population Estimates of Trout by Study Area Sections, 1957-58 and 1963

				Averages For All Years (1957, 1958 & 1963)			
				Number of Fish		Pounds of Fish	
Study Section	1957	1958	1963	Per Study Section	Per Mile	Per Study Section	Per Acre
Brown Trout							
Wild (Age I)							
Z	*	*	22	-	-	-	-
A	6	176	49	77	220	4.0	5.7
B	89	124	158	124	104	6.0	2.7
C	904	927	569	800	784	30.2	11.6
D	1,273	1,113	1,369	1,252	1,473	41.2	20.6
E	*	*	678	-	-	-	-
Total (A-D)	2,272	2,340	2,145	2.253	661	81.5	10.9
Total (Z-E)	*	*	2,845	-	-	-	-
Wild (Age II & Older)							
Z	*	*	23	-	-	-	-
A	7	29	118	51	146	12.8	18.3
B	37	181	196	138	116	36.7	16.7
C	584	574	680	613	601	131.0	50.4
D	633	556	647	612	720	121.0	60.5
E	*	*	330	-	-	-	-
Total (A-D)	1,261	1,340	1,641	1,414	415	301.5	40.2
Total (Z-E)	*	*	1,994	-	-	-	-
Stocked (All Ages)							
Comb. (A-D)	894	3,768	259	1,640	470	358.7	47.8
Brook Trout							
Wild (All Ages)							
Comb. (A-D)	142	70	22	78	22	8.7	1.2

* No estimates are available for sections Z and E in 1957 and 1958 inasmuch as these sections were not designated nor included in the study area until 1960. For these 2 years, total estimates for the entire study area were not calculated

During the 8-year study period, the number of both fingerlings and older brown trout increased and a strong and near perfect alternation of year class strength occurred (Table 4). On the average, there were more wild brown trout of most age groups in the stream after habitat alteration was completed than there were before. However, during the last year of the study, numbers of Age 0 wild brown trout were again comparatively low. Numerical changes were especially obvious in section D.

The number of wild brown trout longer than 12 inches remaining in the regular study section in October varied from a low 20 to a high of 65 over the 8 years (Fig. 2).

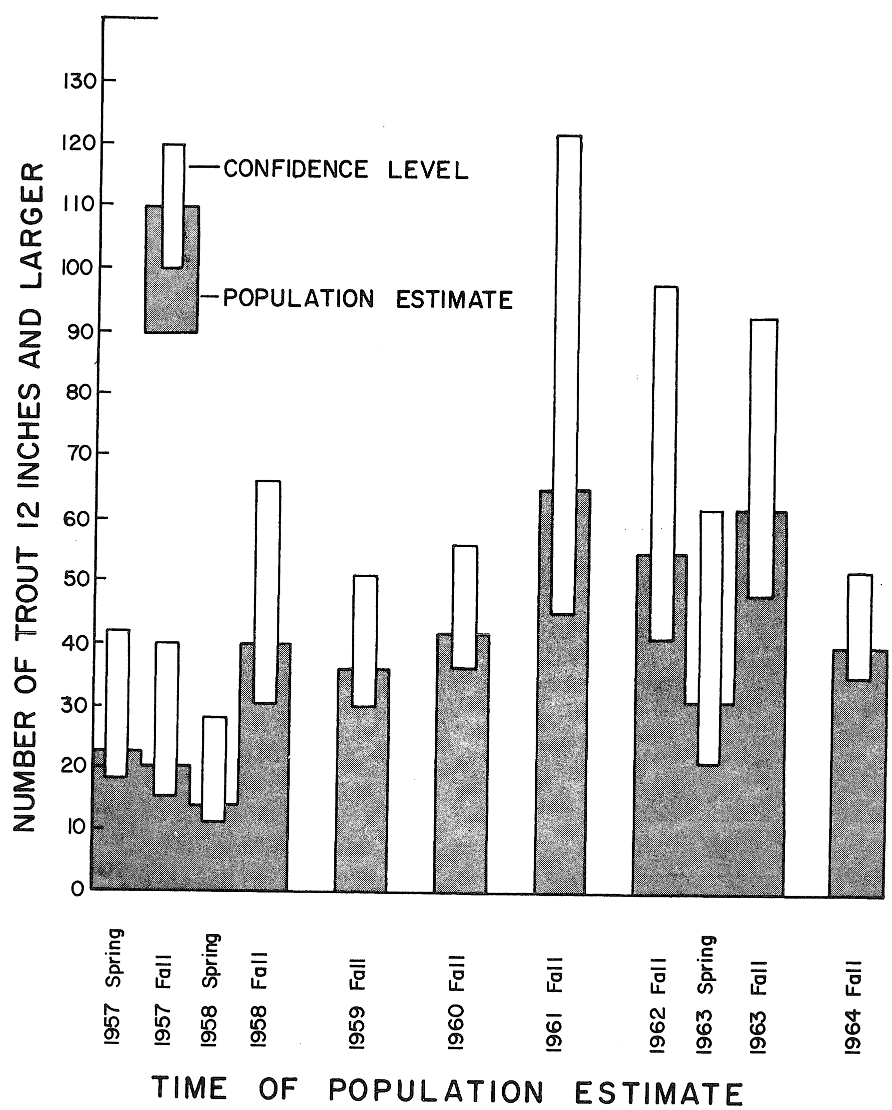

Figure 2. Change in number of 12-inch and larger wild brown trout in the regular study area, 1957-1964.

Numerically the average fall population of wild brown trout in the regular study area (1959-1964) consisted of 61, 29, 7 and 2 percent of age groups 0, I, II and III, respectively. Age groups IV-VII combined made up less than 1 percent of the population. For the one spring estimate, a somewhat similar age structure was found (Table 6).

TABLE 6

Fall Population Estimates of Wild Brown Trout by Age Groups, 1959-1964*

Year	Age Group								Unknown**
	0	I	II	III	IV	V	VI	VII	
Fall									
1959	3,070	1,082	242	45	0	0	0	0	5
1960	2,519	1,484	263	59	24	0	0	0	3
1961	3,428	1,100	356	100	26	4	0	0	3
1962	2,589	1,523	288	129	31	9	8	0	11
1963	3,707	1,494	548	108	50	16	2	1	0
1964	2,036	1,684	338	112	23	6	0	0	3
Average	2,892	1,394	339	92	26	6	2	0	4
Spring									
1963	-	2,145	1,274	189	97	33	0	5	0

* Estimates are recorded only for years when at least four generations of marked fish were present and include data for the regular study area only.

** Unknown fish were those larger than the largest marked fish.

Growth

In the regular study area, fingerling wild brown trout averaged 4.1 inches long in early October. Average maximum size differences between fingerling stocks were 0.5 inches between different years and 0.7 inches between different sections during the same year. The year with the greatest number of fingerlings

(1963) was the year with the least sectional differences in average length and the two years with the lowest numbers of fingerlings (1957 and 1964) were the two years of greatest sectional differences. The average overwinter (age O-I) increment of growth was 0.6 inches (Table 7). The average length of fingerlings was highest in Section B, which had the lowest number of fingerlings. Average length of fingerlings was lowest in Section D, which had the highest number of fingerlings.

TABLE 7

Average Total Length (in Inches) of Fall Fingerling (Age 0) and Spring Yearling (Age I) Wild Brown Trout, 1957-1964

Year	Section						
	Z	A	B	C	D	E	(A-D)*
Fall Fingerlings							
1957	**	4.9	5.0	4.4	4.2	**	4.3
1958	**	4.8	4.7	4.3	4.2	**	4.3
1959	**	4.1	4.5	4.0	4.0	**	4.0
1960	4.1	4.2	4.4	4.1	3.8	4.2	3.9
1961	***	4.1	4.4	4.1	3.9	4.4	4.0
1962	4.0	4.2	4.3	3.9	3.7	3.8	3.8
1963	4.0	4.0	4.1	4.0	3.8	4.0	3.9
1964	***	4.8	4.5	4.1	4.3	4.4	4.2
Average	4.0	4.4	4.5	4.1	4.0	4.2	4.1
Spring Yearlings							
1957	**	5.5	5.2	4.9	4.6	**	4.8
1958	**	5.3	5.2	4.8	4.6	**	4.8
1963	5.0	5.2	5.2	4.8	4.5	4.7	4.6
Average	-	5.3	5.2	4.8	4.6	-	4.7

* Average total lengths of all fish in the sample regardless of section.

** No data are available for sections Z and E in 1957-59 inasmuch as these sections were not designated nor included in the study area until 1960.

*** No length data are available for fish from section Z in 1961 and 1964 because no fish were captured in this section during these years (See Table 4).

The age I and older group of trout averaged 8.0 inches in length in October and grew an average of 0.5 inches by the following April. Sections D and A-B contained the smallest and largest age I and older trout, respectively (Table 8).

TABLE 8

Average Total Length (in Inches) of All Wild Brown Trout (Age I and Older), 1957-1964

Year	Section Z	A	B	C	D	E	(A-D)*
Fall							
1957	**	9.3	8.6	7.9	8.0	**	8.0
1958	**	9.4	9.1	8.0	7.8	**	8.0
1959	**	8.8	8.8	7.7	7.9	**	8.0
1960	8.2	8.1	8.8	8.2	7.9	8.6	8.1
1961	7.8	9.6	9.5	8.2	7.9	8.7	8.2
1962	8.4	8.5	8.7	7.5	7.5	8.2	7.6
1963	8.2	8.6	8.9	8.0	7.4	7.7	7.7
1964	8.9	8.9	7.8	8.1	7.8	8.4	8.2
Average	8.3	8.9	8.8	8.0	7.8	8.3	8.0
Spring							
1957	**	8.4	8.9	8.6	8.3	**	8.5
1958	**	8.9	8.9	8.6	8.4	**	8.6
1963	9.6	8.9	9.3	8.4	8.3	9.2	8.5
Average	-	8.7	9.0	8.5	8.3	-	8.5

* Average total lengths of all fish in the sample regardless of section.

** No data are available for sections Z and E in 1957-59 inasmuch as these sections were not designated nor included in the study area until 1960.

TABLE 9

Average Lengths (in Inches) of the Marked Wild Brown Trout, 1956-1964*

Year Class	1957 Spg.	1957 Fall	1958 Spg.	1958 Fall	1959 (Fall)	1960 (Fall)	1961 (Fall)	1962 (Fall)	1963 Spg.	1963 Fall	1964 (Fall)
1956	4.8	7.3	8.0	9.5	10.8	12.0	14.3	15.2	14.6	17.8	**
1957		4.3	4.8	7.4	9.3	10.8	11.9	12.4	**	15.2	**
1958				4.3	7.2	9.7	10.9	11.4	11.2	12.8	**
1959					4.0	7.5	9.6	10.5	10.7	11.2	12.6
1960						3.9	7.2	9.0	9.5	10.4	12.3
1961							4.0	6.8	7.9	8.9	10.6
1962								3.8	4.6	6.9	9.4
1963										3.9	7.7
1964											4.2

* Includes data for the regular study area only.

** Where no length data are given, no fish of that year class were captured. Although this may have been the result of chance, it was more likely due to the absence of that year class in the total population.

The average annual (fall to fall) increment of growth decreased from about 3 inches for the age 0 group to about 1 inch for fish of age group IV (Table 10). The average size of most of the marked trout decreased towards the middle of the study period and then increased near the end (Table 9).

Survival

About 40 percent of the trout marked as fall fingerlings (Age I) were present in the study area the next fall as yearlings (Age II) (Table 11). A few probably emigrated but most of the decline was probably due to natural and angling mortality. Fall to fall survival of older trout was generally lower than that of fingerlings. During 1962-63, fall to spring survival of all age groups was unusually high, and during 1963-64, fall to fall survival for older age groups was unusually low.

TABLE 10

Average Annual Fall to Fall Growth Increments (in Inches) of Marked Wild Brown Trout, 1957-1964

Section	Age Group 0-I	I-II	II-III	III-IV
A	3.2	2.9	1.3	
B	3.5	2.3	1.9	
C	3.2	2.1	1.2	0.7
D	3.0	2.1	1.3	1.2
(A-D)*	3.2	2.1	1.3	1.1

* Average annual growth increment of all fish in the sample regardless of section.

TABLE 11

Apparent Survival Rate (in Percent) of Marked Wild Brown Trout, 1957-1964*

Year	Age Group 0	I	II	III	IV	V	VI	VII
Fall to Fall								
1957-1958	45	27						
1958-1959	38	25	21					
1959-1960	42	22	22	40				
1960-1961	36	23	36	41	13			
1961-1962	34	24	33	28	33	100		
1962-1963	47	39	40	42	57	33	25	
1963-1964	35	22	20	20	11	0	0	0
Average	40	26	29	34	29	44	13	-
Fall to Spring								
1957-1958	78	81						
1962-1963	80	84	66	75				
Average	79	82	-	-				
Spring to Fall								
1957-1958	**	41						
1958-1959	**	57	33					
1963-1964	**	58	46	61				
Average	-	52	40	-				

* Includes data for the regular study area only.

** No spring-to-fall survival rates are given for age 0 trout inasmuch as these fish were too small to be captured with electrofishing gear.

Spawning

Counts of trout redds early in November were regarded merely as a rough index to the extent of spawning which actually occurred (Table 12). The counts, nevertheless, did indicate that spawning occurred in every section of the stream at one time or another. Generally, those sections (C and D) with the most redds had the greatest numbers of fingerling trout. Although spawning was well under way by early November, a count in December, 1961 suggested that spawning probably occurred in December also.

TABLE 12

Number of Trout Redds Observed in Early November, 1957-1964*

Section	1957	1958	1959	1960	1961**	1962	1964
Z	-	-	3	3	6	0	0
A	11	2	9	4	30	14	3
B	0	1	4	5	36	3	1
C	8	4	10	6	40	4	11
D	3	8	20	6	34	7	17
E	-	2	2	5	48	3	7
Total (A-D)	22	15	43	21	140	28	32

* No redd counts were made in any section in 1963.

** Counts were also made in December of this year and were added to November data.

Angling Effort and Success

During the 130-day trout fishing season in 1957, a partial creel census recorded 565 angler trips, 1,618 hours of effort and a catch of 672 wild brown trout in the regular study area (Table 13). For the 113-day season in 1963, a similar creel census recorded 561 trips, 1,418 hours of effort and a catch of 699 wild brown trout. The catch/hour of wild brown trout increased from 0.42 in 1957 to 0.49 in 1963 but the catch/hour of stocked brown trout

TABLE 13

Creel Census Statistics, 1957 and 1963

Season and Data Obtained	Section A	Section B	Section C	Section D	Total (A-D)	Average (A-D)
1957 Season						
No. of Fishing Trips	64	301	133	67	565	
No. of Fish Caught						
Wild Brown Trout	39	97	279	257	672	
Stocked Brown Trout	145	590	229	22	986	
Wild Brook Trout	6	8	4	7	25	
Size of Fish Caught						
Length of Wild Brown Trout (in Inches)	8.1	8.7	8.4	8.7		8.5
No. Wild Brown Trout Over 12" Caught	1	5	8	7	21	
No. Hours Fished & Fishing Success						
No. Hours Fished	260	769	380	209	1,618	
No. Wild Brown Trout Caught/Hour	0.2	0.1	0.7	1.2		0.4
No. Stocked Brown Trout Caught/Hour	0.6	0.8	0.6	0.1		0.6
1963 Season						
No. of Fishing Trips	96	239	118	108	561	
No. of Fish Caught						
Wild Brown Trout	105	122	273	199	699	
Stocked Brown Trout	107	162	56	17	342	
Wild Brook Trout	65	6	6	9	86	
Size of Fish Caught						
Length of Wild Brown Trout (in Inches)	8.9	8.6	8.8	9.0		8.8
No. Wild Brown Trout Over 12" Caught	5	4	10	6	25	
No. Hours Fished & Fishing Success						
No. Hours Fished	292	477	331	318	1,418	
No. Wild Brown Trout Caught/Hour	0.4	0.3	0.8	0.6		0.5
No. Stocked Brown Trout Caught/Hour	0.4	0.3	0.2	0.1		0.2

decreased from 0.61 in 1957 to 0.24 in 1963. The decline in the catch rate of stocked brown trout probably resulted primarily from the decrease in the number of fish stocked in 1957 (5,500) to the number stocked in 1963 (1,000) (Table 2). The number of brown trout over 12 inches long recorded in the catch was about the same for both years. Size distributions of the catches in 1957 and 1963 were essentially the same (Fig. 3).

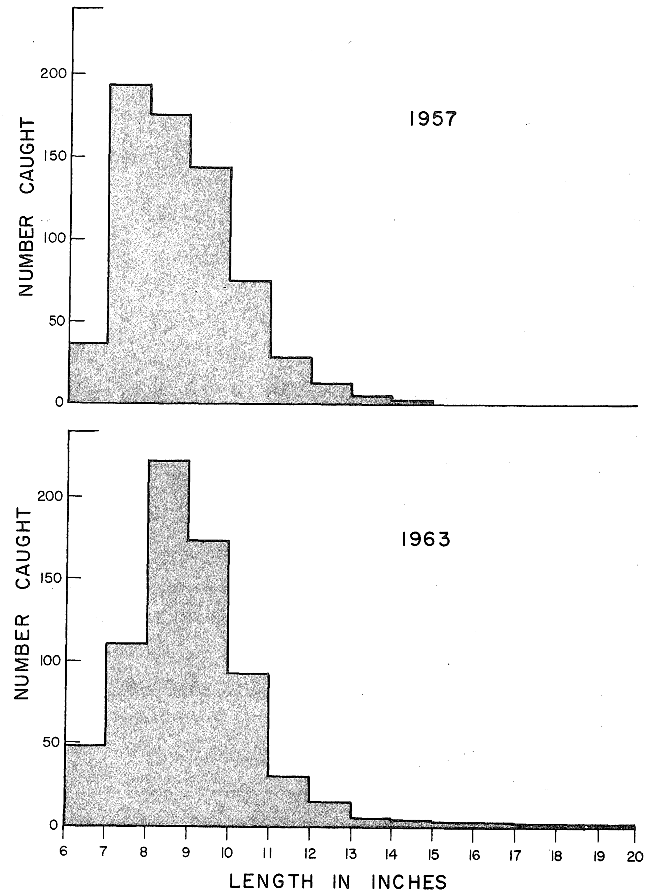

Figure 3. Angler catch of wild brown trout for two years during the study.

DISCUSSIONS

There was an upward trend in the number of adult wild brown trout in the regular study area. This trend was most clearly evident in Section D (Table 4). The number of fingerling wild brown trout present in October almost doubled from 1957 to 1963. In 1964, however, a record low number of fall fingerling trout were present. Annual survival rates after the fingerling stage remained reasonably constant throughout the study. Consequently, I concluded that numerical changes at the population level largely represented changes in the relative survival of year classes during their first 9 months of life. Such differential survival may have been due in part to increased availability of protective cover provided by the brush shelters. It could also be inferred that the brush shelters temporarily increased fingerling survival from 1957 through 1963 and then rotted away to reverse the trend in 1964.

These changes in the trout population might also have been the result of annual differences in groundwater inflow such as Latta (1965) found in

Michigan. Limitations of funds prevented such measurements from being done on McKenzie Creek. However, assuming that annual precipitation totals might be crudely indicative of ground water levels, I analyzed rainfall data for Cumberland, Wisconsin which lies about 20 miles east-southeast of the study area (Table 14). Although admittedly a poor substitute for groundwater data in the McKenzie watershed, the precipitation data yielded some

TABLE 14

Precipitation Totals for Cumberland, Wisconsin, 1955-1964*

Year	Total Precipitation (in Inches)
1955	25.4
1956	23.5
1957	29.1
1958	26.6
1959	38.5
1960	35.1
1961	31.4
1962	41.4
1963	28.1
1964	29.5

* From Wisconsin Climatological Data, Wisconsin Dept. of Agriculture, Madison, Wisconsin.

interesting observations. The two years just prior to the study were unusually dry. The year with the highest fingerling wild brown trout in the fall was preceded by the year with the most rainfall. Three of the four years following habitat alteration were preceded by precipitation totals that were above normal. This suggests that important changes in stream flow probably did occur during the study period. The suspected changes in stream flow may have caused a substantial part of the numerical changes in the population of wild brown trout.

Growth of wild brown trout appeared to be related to density (Tables 8 and 9). The smaller fingerling and adult trout were generally found in those sections with the most dense populations. This relationship suggests that growth of wild brown trout in McKenzie Creek was primarily limited by energy availability and that the production of trout flesh (as defined by Ricker, 1958) probably did not increase in proportion to the increase in the number of trout. This conclusion is supported by the findings of Davis and Warren (1965) who found that sculpin production in laboratory streams actually decreased in some cases as sculpin biomass was experimentally increased.

With the exception of the first year of the study, the population estimates indicated a perfect alternation of year class strength of the wild brown trout at the fall fingerling stage (Table 4). This interesting phenomenon has been observed in other Wisconsin streams (White and Hunt, 1969). Without proffering an explanation, this alternation of year class strength suggests that strong intraspecific factors might be at work. If true, the effects of habitat alteration and other uncontrolled natural variables such as average volume of flow may have been additionally masked.

The data on total catch of trout and hours of fishing effort were incomplete. However, because we concentrated our census effort at times of known peak angling intensity, we believe that at least 90 percent of the catch was examined. In 1963, total catch and catch/hour of wild brown trout were 4 and 14 percent higher, respectively, than in 1957. This probably reflected the increased numbers of adult wild brown trout present in 1963.

Total catch and catch/hour of stocked brown trout were lower in 1963 than in 1957. In 1957 and 1963, 5,500 and 1,000 brown trout were stocked, respectively, before the opening of the angling season. The change in catch of stocked brown trout was probably a reflection of this change in the stocking quota. The reduction in number of stocked brown trout could also have been a factor affecting the increased catch of wild brown trout.

CONCLUSIONS

Definite increases in number of wild brown trout occurred during the period of this study of McKenzie Creek. The average number of catchable-sized wild brown trout (age I and older) was only about 25 percent greater after habitat alteration then it was before. Because of the many uncontrolled variables in this study, even these increases in number of trout cannot be definitely attributed to habitat alteration. Thus, at best, the habitat alteration on McKenzie Creek produced relatively small increases in the number of catchable-sized trout present in the creek.

Habitat alteration that mainly increases cover and is done on relatively undamaged streams such as McKenzie Creek will probably not be rewarded by dramatic increases in the number of catchable-sized trout. However, other investigators have found that under different stream conditions in Wisconsin, habitat alteration can be a more effective tool for increasing trout numbers and angler harvest (White and Brynildson, 1967; Hunt, 1969).

In the past, habitat alteration has generally been referred to as "stream improvement". We should probably classify and design such work as mainly either preservation, restoration, or stimulation of the productive capacity, depending on the condition of the stream under consideration. Criteria should be developed to assist the fish manager in deciding which of these three classes of habitat alteration is most appropriate to apply to the many different trout management situations that may be encountered in Wisconsin.

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