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Fisheries Research Report No. 1899
December 30, 1981

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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TROUT OF NEWTON CREEK, CLARE COUNTY, MICHIGAN: A TRANSITIONAL ZONE TROUT STREAM

By Gaylord R. Alexander and Donald R. Peterson

Abstract

In Newton Creek, a central Michigan cold-water stream, the vital statistics of the trout population were measured in relation to habitat, trout stocking, and changing angling regulations. The trout population was found to consist of 88% wild brown trout, 11% hatchery brown trout, and 1% wild brook trout. The level of the stock of wild brown trout was much lower than the average found in other Michigan streams; it ranked only at the twenty-seventh percentile. Survival and growth rates of wild brown trout were similar to those measured for other streams. Annual production of wild brown trout was 46 kg per hectare compared to an average of 82 kg per hectare for other Michigan wild brown trout populations.

The average annual survival rate of planted brown trout was about 16% compared to 34% for wild fish. Growth also was better for wild brown trout with fish attaining a length of about 430 mm at age VI compared to only 350 mm for planted fish. The planted fish increased the stock of age I and older fish by about 24% without adverse effects on growth or survival of wild fish. The brook trout stock was very small. A creel census of angling indicated brook trout were more vulnerable to fishermen than brown trout and that hatchery brown trout were more vulnerable than wild brown trout. More stringent angling regulations caused trout standing crops to average 70% larger. Annual trout production also increased by 56%. Apparently Newton Creek has a smaller than average trout population and production because of poor recruitment.

Introduction

Newton Creek is representative of trout streams in the central portion of Michigan's Lower Peninsula. This region of the state is the transitional zone between the heavily forested lands of the north and the farm-urban lands of the south. Streams of this area lie near the southern fringe of the range for trout in Michigan. Typically they have the physical characteristics that permit trout habitation only in their upper reaches and tributaries. The environment for trout generally deteriorates rather quickly from the headwaters downstream. The streams emerge from relatively shallow glacial deposits in areas of only moderate relief. Sources of the streams are at elevations of 900 to 1,050 feet above sea level compared to 1,100 to 1,300 feet for the better trout streams further north. The glacial till, composed of much sand and gravel, is favorable for high infiltration rates and high yields of groundwater to the headwater streams, however, the groundwater portion of the stream flow diminishes rather quickly down the drainage because the streams meander through lands of low relief, heavier soils, and decreased groundwater input. In addition, man's activities in this region of the state have degraded lotic environments through physical alterations of stream channels and water discharge patterns; and increases in chemical and sediment loadings and water temperatures.

Even though these streams have shorter trout zones and generally poorer trout habitat than the more northerly streams, they are very important to trout fishermen because of their proximity to the urban centers of Michigan. Information on trout populations in streams of this region is scarce. This study provides a data set upon which to judge habitat and trout population characteristics of such streams. Specifically, the purpose of the study on Newton Creek was three-fold: (1) to measure stock, recruitment, survival, and growth of wild trout; (2) to assess the survival and growth of hatchery planted brown trout and their possible influence on wild trout; and (3) to determine the impact of a change in fishing regulations on trout stocks.

Study area

The area of study is a 7.6-km (7.0-hectare) section of Newton Creek, a major tributary of the Tobacco River. The upstream boundary of the area is located at the site of the former State of Michigan trout rearing facility, approximately 5 km northeast of Farwell, Michigan. The downstream boundary is located just below the bridge on highway U.S. 10, where the stream joins

the South Branch of the Tobacco River, about 3.5 km southeast of Farwell (Fig. 1). The average width and depth of Newton Creek is approximately 9.7 m and 45 cm, respectively. Considerable groundwater enters the stream as shown by changes in stream discharge taken at the upper and lower ends of the study section. Discharge measurements taken by the U.S.G.S. on September 10, 1979, indicated a flow of 0.36 m^3 per second at the upper boundary, and 0.76 m^3 per second at U.S. 10, the downstream boundary of the section. One small tributary stream with a flow of 0.08 m^3 per second enters about half way through the study stretch of stream. Average gradient is 1.68 m/km with the greatest drop in the upper part of the section.

Water temperatures taken by McClain (1976) in summer (June, July, and August) averaged 16 C at the upper and 18 C at the lower end of the study section. Of significant importance is that maximum water temperatures reached only 22 C at the upper end and 23 C at the lower end of the study area, both well within the tolerance range of trout.

Streambed substrate as judged by McClain (1976) at the bed-water interface consisted of 8% cobble, 15% gravel, 19% sand-gravel mix, 30% sand, 7% vegetation, and 21% organic detritus. Gravimetric analysis of standard scoop samples of streambed soils, taken at cross-section transects, showed 45% of the bed material was gravel (larger than 2.0 mm in diameter), 53% sand (2.0-0.05 mm), and 2% silt and clay (smaller than 0.05 mm). Obviously, organic detritus was mostly a veneer at the streambed surface. The streambed gravel appeared adequate for good trout reproduction providing water quality remained suitable within the gravel during egg incubation. In this regard, the amount of organic detritus, silt, and clay may affect water quality within spawning gravels. The food supply for trout was judged by us from inspection of the substrate for invertebrates to be of average abundance compared to other trout streams. Fish species present other than trout were diverse and of normal abundance. Mottled sculpins (Cottus bairdi), blacknose dace (Rhinichthys atratulus), and creek chubs (Semotilus atromaculatus) were the most numerous non-game fish present.

Methods

Three stations, from 305 to 457 m in length, were sampled using direct current electrofishing gear in the spring and fall. General locations of stations are shown in Figure 1. Calculations of trout abundance were made using the Petersen mark-and-recapture method. The population estimates for the three

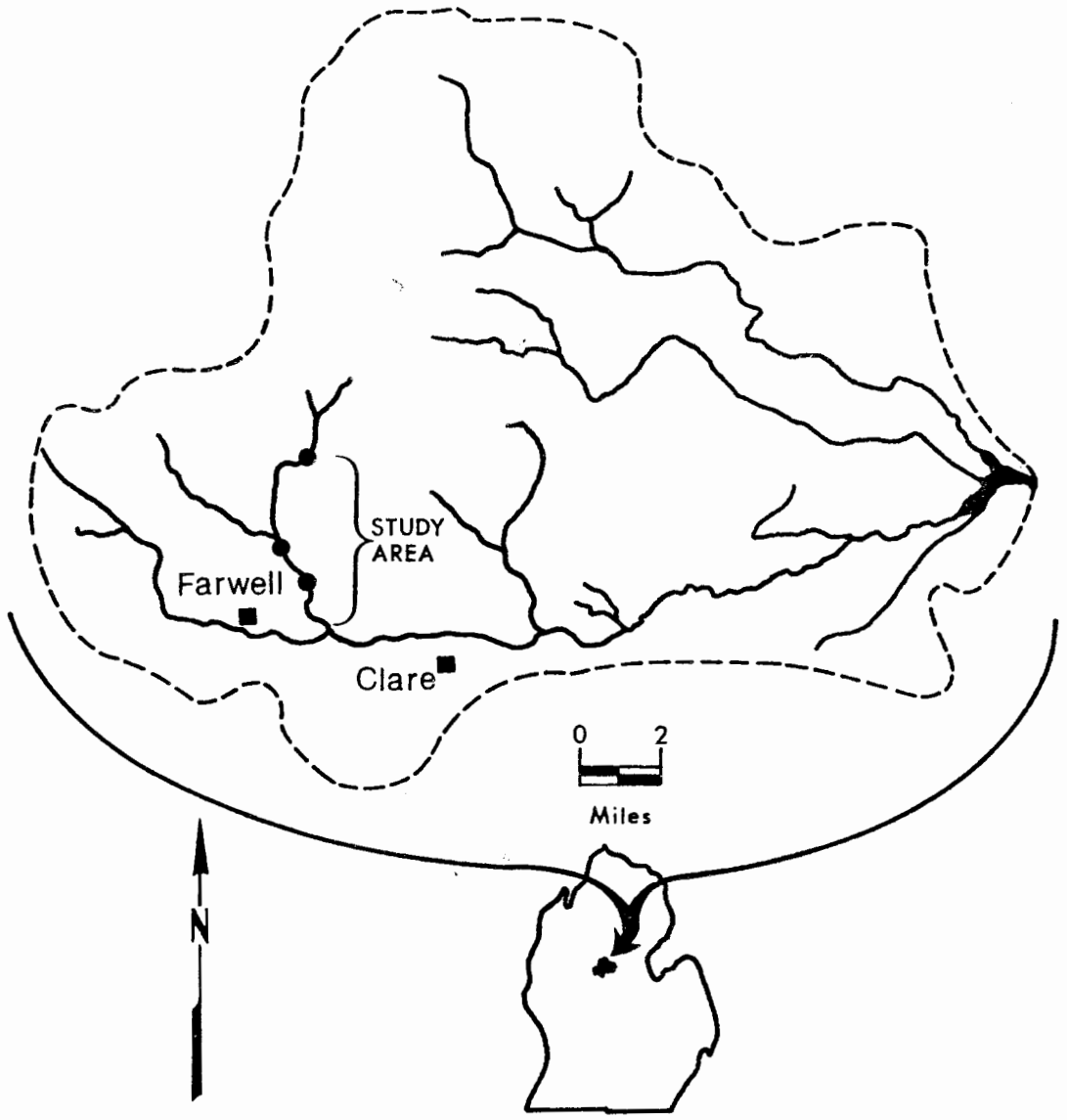

Figure 1.--The Tobacco River watershed of Michigan showing location of the Newton Creek study area and trout sampling sites (●).

sample stations were averaged to arrive at the population density per hectare for the study area.

Scales were taken from each length group of wild brown trout for age determinations. This permitted the estimates of trout abundance within length groups to be apportioned to age groups. Assignment of hatchery trout to age groups was done directly because fish were of known age. All stocked trout were marked with distinctive fin clips when planted. Each May from 1965 through 1975, about 2,000 brown trout (mean T.L. 135 mm) were planted in the study area. Numbers of wild and hatchery brown trout estimated to be present in Newton Creek 1967-1979 are given in Tables 1-6 of the appendix.

Growth rates of wild trout were ascertained from scale readings to derive average sizes at sequential ages. Trout production was calculated by the procedure outlined by Ricker (1975). Statistical comparisons were made of various data sets using regression analysis. A 95% level of confidence was set to judge statistical significance.

Results

Trout populations.--Brown trout (Salmo trutta) dominated the trout population of Newton Creek. The population consisted of 88% wild brown trout, 11% hatchery stocked brown trout, and 1% wild brook trout (Salvelinus fontinalis). The densities of average fall trout populations in Newton Creek during the 10-year period 1969-1978 are given in Table 1 and densities for spring populations for 1970-1979 are in Table 2.

We compared the fall trout population of Newton Creek (all species combined) with trout stocks found in 14 other northern Lower Peninsula of Michigan streams as reported by Gowing and Alexander (1980). The Newton Creek trout population was much smaller than the average of the 14 streams. The average of these streams was 2,422 trout weighing about 88 kg per hectare. Newton Creek's trout population was only 829 trout per hectare weighing 49 kg. Relative number and weight of trout in Newton Creek by length class compared to those of 14 streams is shown in figures 2 and 3. These figures not only demonstrate the lower overall stock of trout in Newton Creek, but also show the relatively lower stock of small size fish.

Wild trout.--The stock level of wild brown trout was much lower than average stocks of brown trout found in other Michigan streams as reported in Gowing and Alexander (1980). The survivorship curve for wild brown trout in Newton Creek was compared with the average curve for wild brown trout

Table 1.--Average number (per hectare) and weight (grams per hectare) of trout in Newton Creek, by species and size class, in the fall 1969-78.

Size class (mm)	Wild brown		Hatchery brown		Brook		Total trout	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
51-75	18.0	45	0.0	0	2.1	5	20.1	50
76-101	287.2	1,826	0.0	0	1.8	12	289.0	1,838
102-126	114.6	1,615	0.2	3	0.3	4	115.1	1,622
127-151	13.6	352	3.8	100	0.3	9	17.7	461
152-177	64.1	2,652	24.6	1,019	1.0	43	89.7	3,714
178-202	72.9	4,805	34.5	2,277	0.3	19	107.7	7,101
203-228	48.7	4,652	13.8	1,314	0.6	61	63.1	6,027
229-253	37.1	4,894	5.2	684	0.0	0	42.3	5,577
254-278	30.1	5,342	3.6	635	0.0	0	33.7	5,977
279-304	17.6	4,084	2.4	562	0.0	0	20.0	4,646
305-329	11.5	3,471	1.0	317	0.0	0	12.5	3,788
330-355	9.7	3,719	0.7	263	0.0	0	10.4	3,982
356-380	3.0	1,395	0.2	95	0.0	0	3.2	1,490
381-405	1.8	1,033	0.0	0	0.0	0	1.8	1,033
406+	2.3	1,589	0.0	0	0.0	0	2.3	1,589
Totals	732.2	41,474	90.0	7,268	6.4	153	828.6	48,895

Table 2.--Average number (per hectare) and weight (grams per hectare) of trout in Newton Creek, by species and size class, in the spring 1970-79.

Size class (mm)	Wild brown		Hatchery brown		Brook		Total trout	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
51-75	0.0	0	0.0	0	0.0	0	0.0	0
76-101	6.2	39	0.0	0	1.0	7	7.2	46
102-126	160.8	2,265	0.0	0	1.7	25	162.5	2,290
127-151	121.4	3,145	0.2	5	0.8	22	122.4	3,172
152-177	22.7	941	4.6	192	0.6	28	27.9	1,161
178-202	36.9	2,430	7.7	506	0.6	40	45.2	2,976
203-228	54.5	5,199	15.5	1,479	0.3	32	70.3	6,710
229-253	42.2	5,567	14.7	1,941	0.4	54	57.3	7,562
254-278	36.9	6,535	7.8	1,381	0.0	0	44.7	7,916
279-304	17.9	4,163	2.9	681	0.0	0	20.8	4,844
305-329	11.0	3,310	1.3	390	0.0	0	12.3	3,700
330-355	6.9	2,635	0.8	286	0.0	0	7.7	2,921
356-380	1.5	714	0.4	190	0.0	0	1.9	904
381-405	1.1	635	0.0	0	0.0	0	1.1	635
406+	0.5	359	0.0	0	0.0	0	0.5	359
Totals	520.5	37,937	55.9	7,051	5.4	208	581.8	45,196

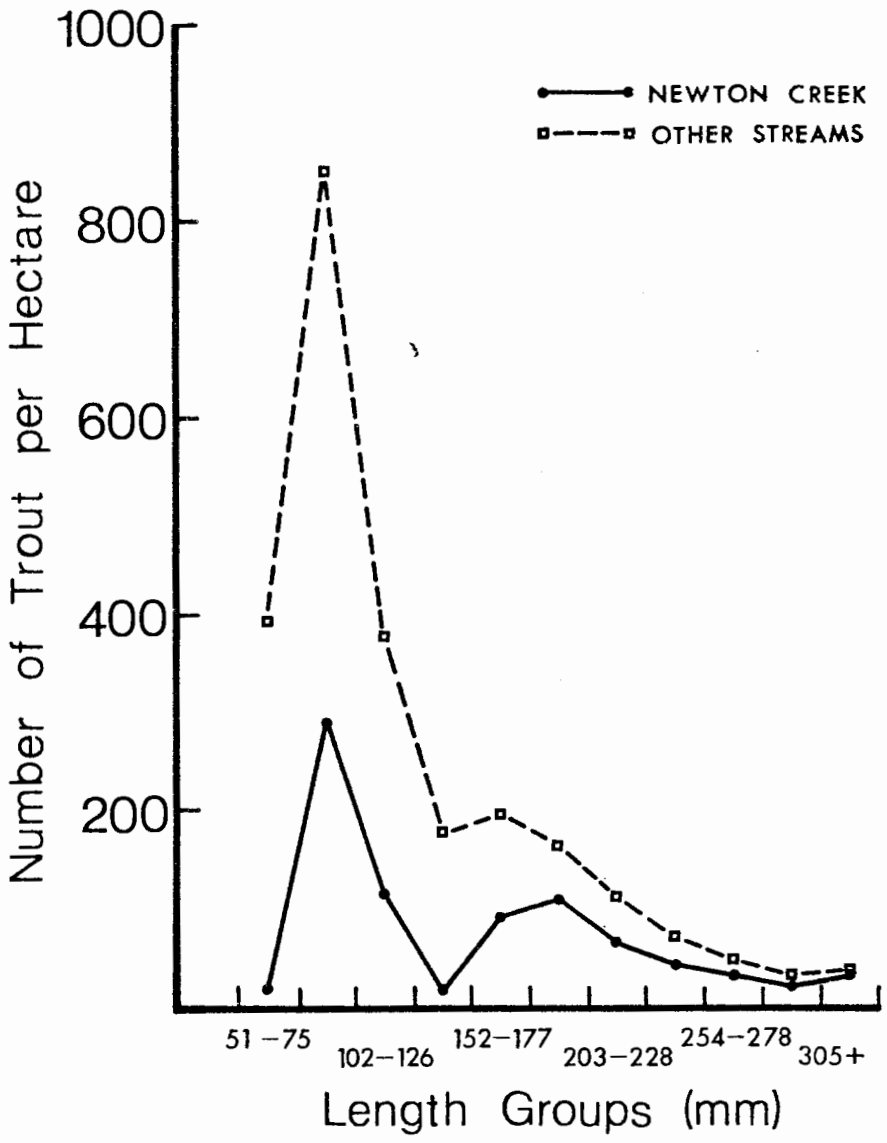

Figure 2.--Average number of trout (all species) by length group in Newton Creek in the fall compared to the average stock of 14 other Michigan streams.

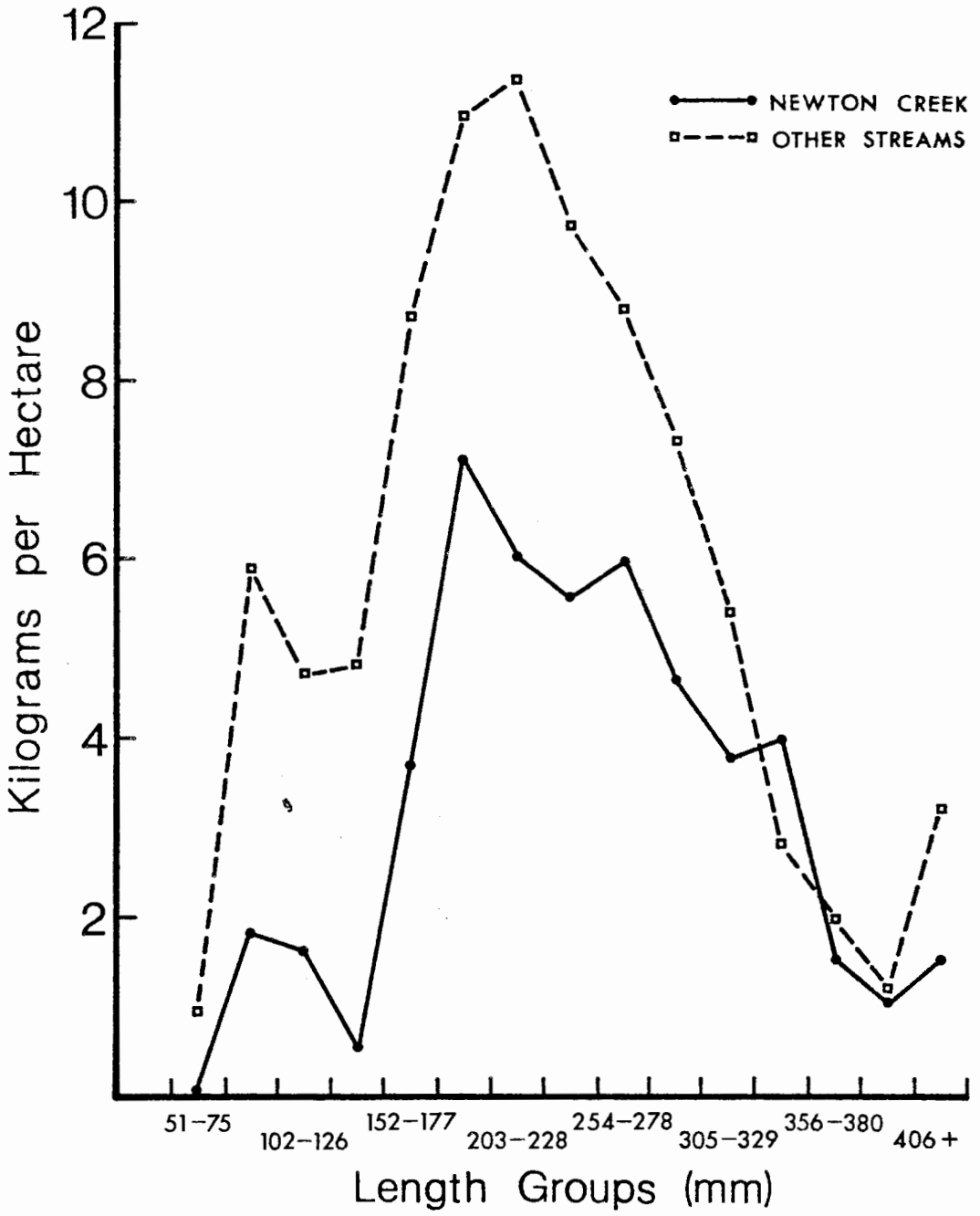

Figure 3.--Average weight of trout (all species) by length group in Newton Creek in the fall compared to the average stock of 14 other Michigan streams.

(± 1 standard deviation) for 14 streams (Fig. 4). Wild brown trout in Newton Creek had the same survival rate as trout in other streams. Note also that the survivorship curve had the typical convex arch caused by a progressive decrease in the survival rate with age. The main difference in Newton Creek is that the survivorship curve is of a lower magnitude. Recruitment of trout to age group 0 was responsible for the smaller population. Comparing the magnitude of the wild brown trout stock in Newton Creek to the average stock and its variance in 14 streams, it would rank at about the twenty-seventh percentile or 73 out of 100 trout populations would be larger.

Growth of wild brown trout is shown in Figure 5. The growth rate of age 0-IV wild brown trout in Newton Creek was slightly above the average growth rate for wild brown trout in 14 streams. Growth of trout older than age IV appeared to drop off in Newton Creek but there were few of these older fish for comparison.

Production of both wild brown trout as well as all trout combined in Newton Creek was compared to the average production values cited by Gowing and Alexander (1980). Production of wild brown trout in Newton Creek was about 46 kg per hectare compared to an average of 82 kg per hectare for average wild brown trout populations. Production of all trout, species combined, in Newton Creek amounted to about 55 kg per hectare compared to an average of 95 kg per hectare for the 14 other trout streams.

Hatchery trout.--Hatchery brown trout at the age of 19 months were planted at the rate of about 286 fish per hectare each spring from 1965 through 1975. Average stocks of hatchery fish present by size class, both fall and spring, can be found in Tables 1 and 2. On the average about 90 hatchery trout per hectare were present in the fall and only 56 in the spring. Total trout present averaged 829 in the fall and 582 in the spring. Hatchery fish comprised about 11% of the total trout present.

The survival rate of hatchery brown trout in Newton Creek was significantly lower for age I to III than for wild brown trout (Fig. 6). However, little difference in survival rate was evident after age III. Note that the hatchery trout survivorship curve does not have the typical convex arch found for wild trout, but is instead straight. This is caused by the higher mortality rates of hatchery fish a year or so after stocking. Cooper (1959) pointed out that much of the available published literature indicates that survival of hatchery fish is somewhat less than that for wild fish of comparable size and species. Miller (1953, 1958), and Butler (1980) reported poor survival

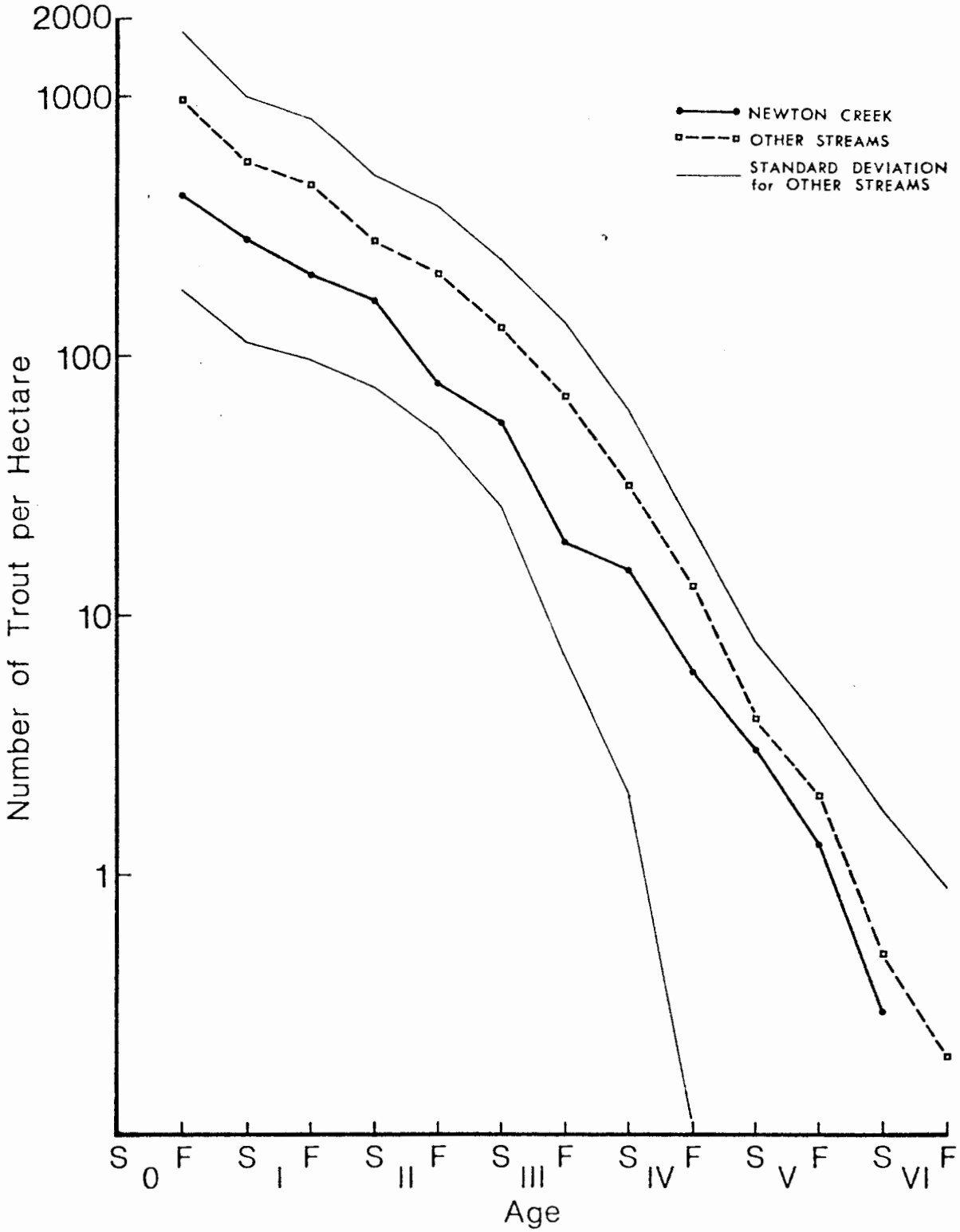

Figure 4.--Survival of wild brown trout, spring (S) and fall (F), in Newton Creek compared to the average curve of 14 other streams.

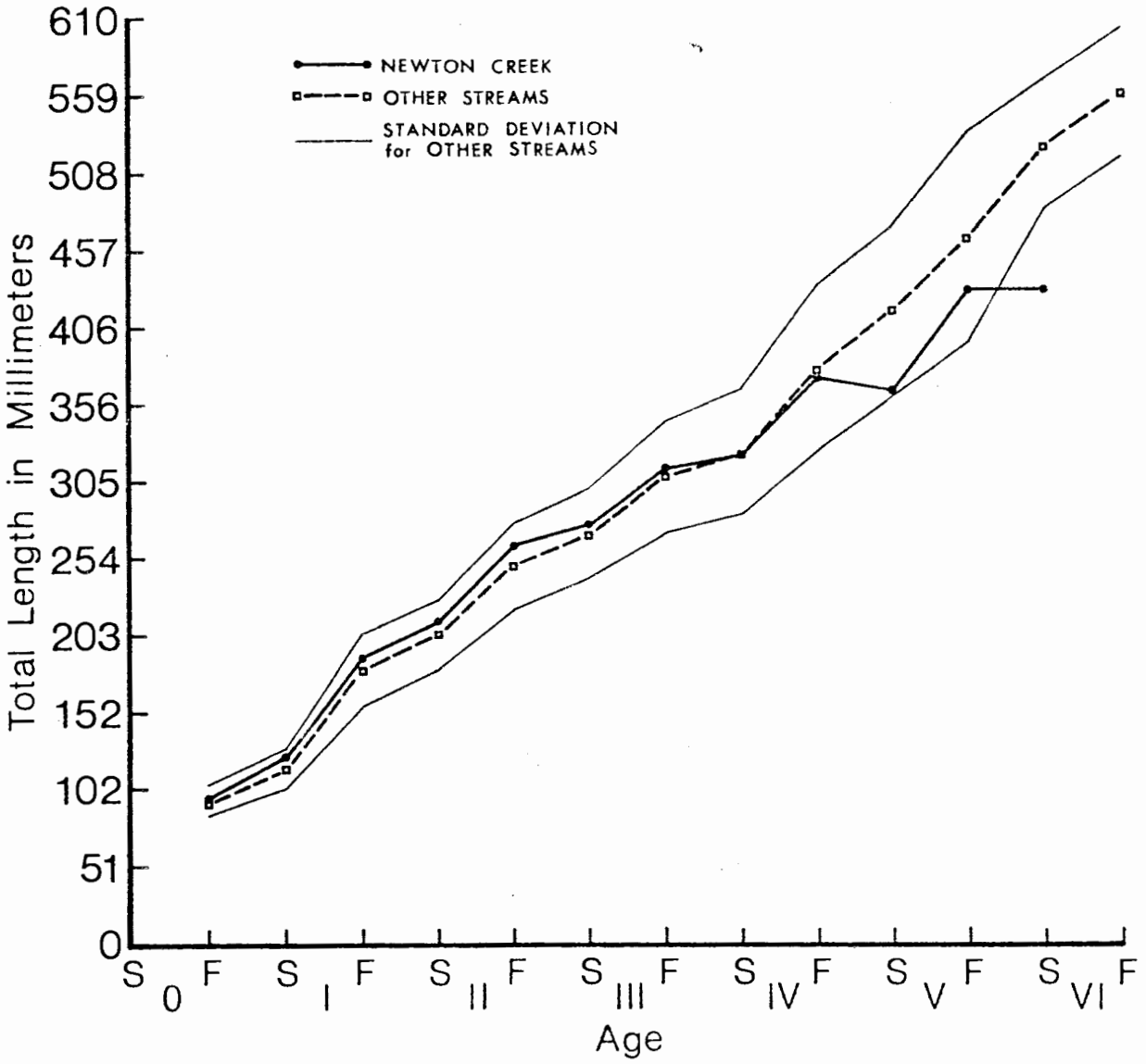

Figure 5.--Growth of wild brown trout, spring (S) and fall (F), in Newton Creek compared to the average for 14 other streams.

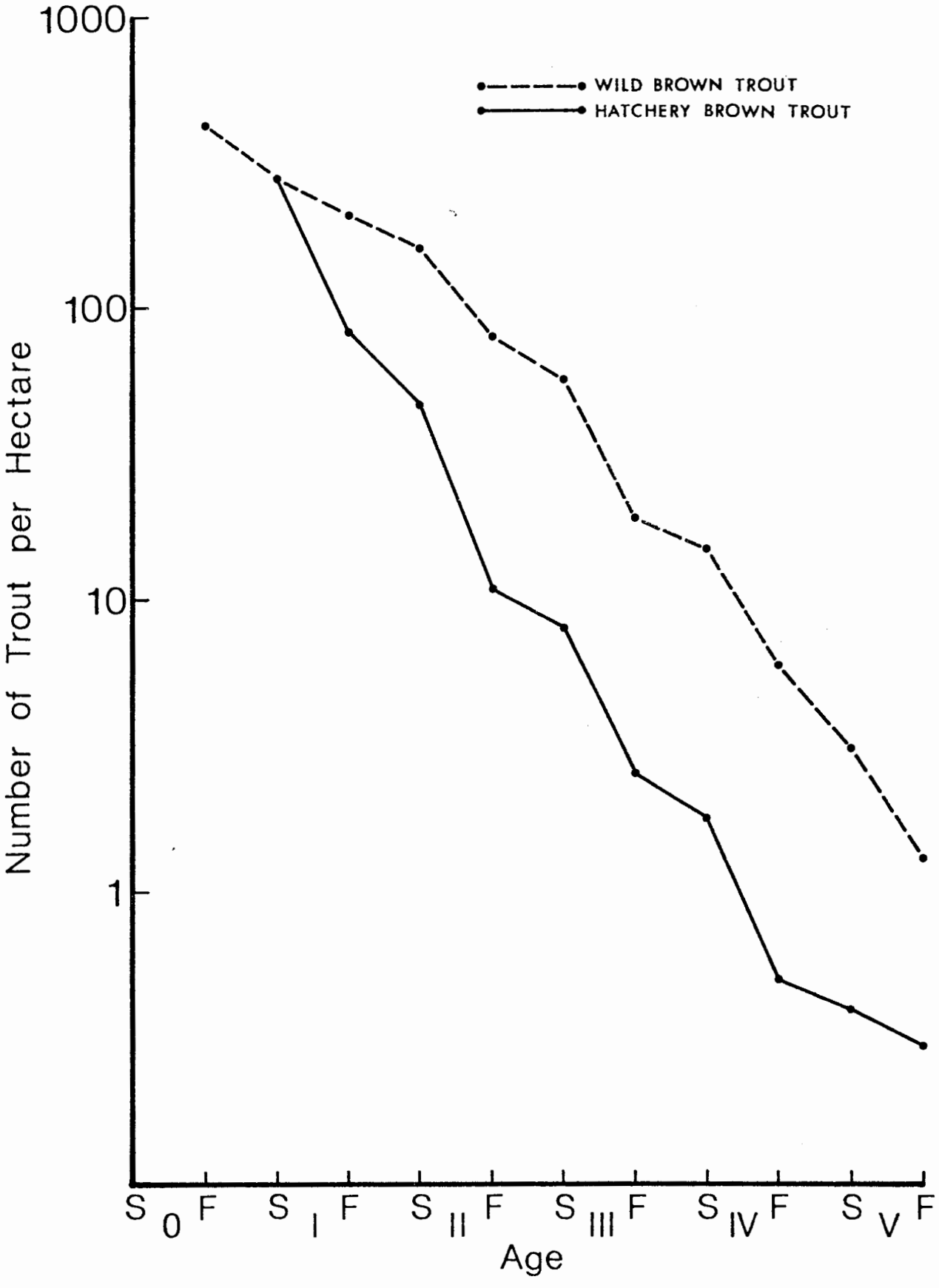

Figure 6.--Survivorship curves for wild and hatchery brown trout in Newton Creek.

of hatchery trout because they cannot compete well with wild trout stocks. Thus, the survival of hatchery fish in Newton Creek was as expected.

Hatchery-released brown trout appeared to grow at slower rates than wild brown trout in Newton Creek. They were significantly smaller at ages II through VI (Fig. 7). However, we believe that part of the difference in the apparent growth rate was caused by the greater cropping rate of hatchery trout by anglers. This, coupled with the greater chance of the larger fish of a cohort being caught (Cooper 1952) resulted in the divergent growth rates. Annual production of hatchery trout was about 9 kg per hectare and represented 16% of the total trout production.

Hatchery and wild trout interaction.--The stock size, survival rate, growth rate, and production of wild brown trout were compared for the years when hatchery trout were present (fall 1969 to spring 1976) and when only a few residual hatchery fish were present (fall 1976 to spring 1979). All of these population parameters were essentially the same for the two periods. Thus, stocking hatchery fish at the rates used in Newton Creek did not adversely affect the resident wild brown trout population, in fact, it appeared that hatchery fish were strictly additive in effect on the total trout stock. The total trout stock of age I and older fish increased from 566 to 701 trout per hectare on the average with trout stocking. This 24% improvement in Newton Creek is not typical. According to most literature as reviewed by Cooper (1959) hatchery fish do not generally increase the total trout stock for any significant period of time, nor do they normally add to total trout production.

Brook trout.--As can be seen in Tables 1 and 2, the brook trout population was sparse in Newton Creek. Only 5 or 6 trout per hectare were estimated to be present. Wild brook trout survival and growth appeared to be normal based on the few fish observed. Lack of recruitment of wild brook trout appeared to be responsible for the low stock levels.

Fishing.--One census was made of angling effort and success on Newton Creek during the study. This census was conducted in 1975 (McClain 1976) when the stream was fished under a 254-mm (10-inch) size limit for brown trout and 178-mm (7-inch) size limit for brook trout. The census showed the catch was composed of 65% wild brown trout, 23% hatchery brown trout, and 12% brook trout. The composition of the catch differed considerably from legal-size trout available in the population. From the spring and fall population data we estimated that the legal-size trout available to the angler was composed of about 87% wild brown trout, 12% hatchery brown trout, and only 1% brook trout.

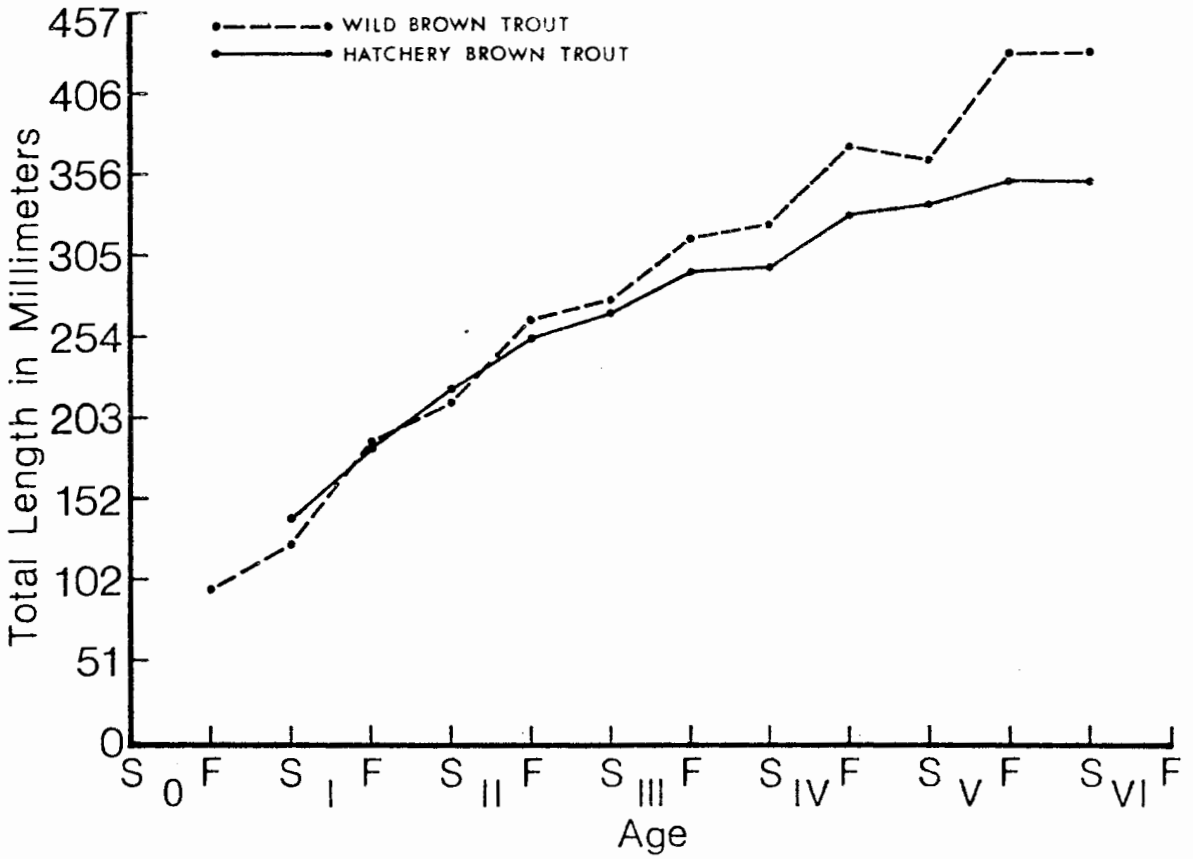

Figure 7.--Growth of wild and hatchery brown trout in Newton Creek.

Thus, hatchery brown trout appeared to be more vulnerable to angling than wild brown trout, and brook trout were considerably more vulnerable than either wild or hatchery brown trout. It is commonly accepted by biologists and anglers (Schuck 1941; Cooper 1951, 1952) that brook trout are more vulnerable to anglers than brown trout. However, views on the relative catchability of wild versus hatchery strains of trout are varied. Green (1952), Cooper (1959 and 1970), and Boles and Borgeson (1966) indicated that hatchery strains are more catchable than wild strains but Schuck (1941) found no difference. Using McClain's 1975 data, we estimated the total angler harvest from Newton Creek to be about 22.0 trout per hectare per year or by species 14.1 wild brown trout, 5.4 hatchery brown trout, and 2.5 brook trout. Fishing pressure was determined to be about 135 angler hours per hectare per year.

The return to anglers of 5.4 hatchery trout per hectare per year amounts to a 1.9% recovery of the 286 per hectare stocked each year. This return is not particularly low considering that fishing was under a 254-mm (10-inch) size limit. By comparison the catch of wild brown trout was only 14.1 trout per hectare per year. This amounts to only a 4.9% harvest of the age I trout present in the spring, the age of hatchery fish when planted.

Fishing regulations.--The fishing regulations from 1969 to 1979 were a 254-mm (10-inch) size limit, 5 fish creel limit for brown trout, but with a 178-mm (7-inch) size limit on brook trout and a total creel limit of 10 trout. Prior to 1969, the regulations were a 178-mm (7-inch) size limit and 10 fish creel limit, for all trout. Some data were available prior to 1969 on Newton Creek so we made an appraisal of the impact of the different regulations on the trout population. Data presented earlier in this report deal solely with trout populations when fished under the 254-mm (10-inch) size limit.

The standing crop of wild brown trout, both in the spring and fall, were substantially larger under the 254-mm (10-inch) size limit (Tables 1 and 2) than under the 178-mm limit (7-inch) (Tables 3 and 4). The number of wild brown trout present in the fall was 52% higher with weight being 96% higher. Spring values were 30% greater for numbers and 66% greater for weight. An increase is to be expected and, in fact, is the goal of the regulation, particularly those of fish 7.0 to 9.9 inches long. However, the population of trout larger than 10 inches and smaller than 7 inches as well as 7.0- to 9.9-inch fish increased more than expected based upon our past studies of regulations in Michigan (Shetter and Alexander 1965; Alexander and Ryckman 1976; Clark et al. 1979, 1980). We believe that fishing pressure and cropping rate (angler fishing rate) declined drastically under the more restrictive regulations on small streams like

Table 3.--Average number (per hectare) and weight (grams per hectare) of trout in Newton Creek, by species and size class, in the fall 1967-68.

Size class (mm)	Wild brown		Hatchery brown		Brook		Total trout	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
51-75	7.2	18	0.0	0	2.1	5	9.3	23
76-101	153.5	976	0.0	0	1.8	12	155.3	988
102-126	81.7	1,151	1.4	19	0.3	4	83.4	1,174
127-151	34.3	889	15.2	394	0.3	9	49.8	1,292
152-177	93.5	3,866	19.1	790	1.0	43	113.6	4,699
178-202	45.2	2,982	28.4	1,869	0.3	19	73.9	4,870
203-228	27.2	2,595	11.8	1,128	0.6	61	39.6	3,784
229-253	13.7	1,805	3.4	447	0.0	0	17.1	2,252
254-278	9.2	1,624	3.6	642	0.0	0	12.8	2,266
279-304	9.1	2,112	0.6	139	0.0	0	9.7	2,251
305-329	2.6	801	0.0	0	0.0	0	2.6	801
330-355	1.7	664	0.0	0	0.0	0	1.7	664
356-380	0.7	317	0.0	0	0.0	0	0.7	317
381-405	0.0	0	0.0	0	0.0	0	0.0	0
406+	2.0	1,347	0.0	0	0.0	0	2.0	1,347
Totals	481.6	21,147	83.5	5,428	6.4	153	571.5	26,728

Table 4.--Average number (per hectare) and weight (grams per hectare) of trout in Newton Creek, by species and size class, in the spring 1967-69.

Size class (mm)	Wild brown		Hatchery brown		Brook		Total trout	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
51-75	0.3	1	0.0	0	0.0	0	0.3	1
76-101	26.2	167	0.0	0	1.0	7	27.2	174
102-126	151.6	2,136	0.0	0	1.7	25	153.3	2,161
127-151	83.6	2,166	1.5	39	0.8	22	85.9	2,227
152-177	19.4	804	3.2	131	0.6	28	23.2	963
178-202	25.4	1,672	5.5	364	0.6	40	31.5	2,076
203-228	35.2	3,363	11.3	1,079	0.3	32	46.8	4,474
229-253	22.2	2,920	10.2	1,341	0.4	54	32.8	4,315
254-278	14.9	2,645	6.6	1,170	0.0	0	21.5	3,815
279-304	9.9	2,290	1.7	390	0.0	0	11.6	2,680
305-329	5.4	1,623	0.2	51	0.0	0	5.6	1,674
330-355	1.1	435	0.0	0	0.0	0	1.1	435
356-380	0.9	411	0.0	0	0.0	0	0.9	411
381-405	1.2	670	0.0	0	0.0	0	1.2	670
406+	2.2	1,499	0.0	0	0.0	0	2.2	1,499
Totals	399.5	22,802	40.2	4,565	5.4	208	445.1	27,575

Newton Creek. This could, in part, result in much higher than expected populations of legal-size (254-mm) and larger fish. Further, the much larger stock of spawning size fish could result in more egg deposition and a larger hatch, thus, greater recruitment of young fish than expected could occur. This usually does not happen but in streams like Newton Creek with suspected poor spawning, or fry rearing conditions or both, more egg deposition could result in more young fish as noted.

Regression analysis of the wild brown trout numbers by age class demonstrated that the populations were significantly larger for age 0 to age II fish under the 254-mm size limit. Trout older than age II appeared more abundant also, but a statistically significant difference could not be demonstrated. The average survival rates of trout age 0 and older were similar under the two different size limits. Thus the effect of the 254-mm (10-inch) size limit in Newton Creek was an increased trout stock of all age classes because more young fish were produced. No evidence was found to indicate a change in the growth rate of wild brown trout during the entire study period.

The annual production of wild brown trout was found to average 45.5 kg/ha under the 254-mm (10-inch) size limit, but only 28.3 kg/ha under the 178-mm (7-inch) size limit.

The residual stocks of hatchery brown trout were higher under the 254-mm size limit, mostly for trout larger than 178 mm (Tables 1-4). Because the hatchery stock size was small and the variation between years was high, a statistically significant difference in stock size could not be demonstrated. Survival rates were not found to be different under the two regulations. The production of hatchery fish was calculated to be 9.3 kg/ha under the 254-mm (10-inch) size limit and only 7.0 kg/ha under the 178-mm (7-inch) size limit.

The combined population levels of wild brown trout, hatchery brown trout and brook trout are given in Tables 1-4, for years with different regulations. The total trout population was much larger under the 254-mm (10-inch) size limit. Standing crops averaged 49 kg/ha in the fall and 45 kg/ha in the spring under the 254-mm limit, compared to only 27 kg/ha in the fall and 28 kg/ha in the spring under the 178-mm limit. Total annual trout production showed large differences. Production of all trout combined amounted to 55.1 kg/ha under the higher size limit, compared to only 35.6 kg/ha under the lower size limit.

Discussion

Newton Creek appears to have adequate water quality, fertility, stability of flow, channel morphometry, gravel spawning substrate, and cover to be an average or better trout stream. However, the trout population, even with the stocking of hatchery fish which increased the trout stock, was only about half as large as the average stock found in an array of other streams. Low recruitment is believed to be the factor limiting the trout stock in Newton Creek for the following reasons: (1) the number of fall fingerling trout per hectare is much lower in Newton Creek compared to other trout populations; (2) the survival rate of wild brown trout older than fall fingerlings in Newton Creek, is comparable to that found in other streams; (3) the growth rate of wild brown trout is comparable to growth found in other streams; (4) stocks increased substantially under more restrictive fishing rules, in part presumably, because of greater egg deposition made by the larger population of adult trout; (5) the survival rate of yearling hatchery trout for the number planted here is normal for such stockings and adds directly to the total trout stock without adverse impact on wild trout stocks.

We can only hypothesize as to the reasons why recruitment is below average. One possibility is that egg incubation, fry development, and/or fry emergence from the streambed gravel is poor because of bedload sediments. Two ongoing studies of bedload sediment show adverse effects on trout (Alexander and Hansen, unpublished). Further, poor recruitment of trout has been noted in the streams of the Great Smoky Mountains due mainly to entrapment of fully developed fry by bedload sediment (Harshbarger, unpublished).

Another possible cause for low recruitment is that pesticide, herbicide or some other contaminant exist at levels in Newton Creek that affects adversely egg development and/or fry survival. However, tests of pesticide levels in adult wild brown trout taken from Newton Creek in October 1979, revealed no hazardous concentration. Pesticides checked for were DDE, DDD, DDT, PBB, and PCB. A scan was also run for other persistent chlorinated hydrocarbons which turned out negative. The possibility exists, however, that other contaminants not detected are present or that contaminants may adversely affect eggs and fry at very low concentrations.

Future research efforts on Newton Creek should first determine: (1) is egg deposition normal; (2) is egg development in the redd normal; and (3) is escapement normal from the redd? With the above knowledge, the problem limiting the stock in Newton Creek could be narrowed to either the: (1) egg to fry stage, or (2) fry to age-0 fall fingerling stage of the life cycle.

If we could determine the cause for poor recruitment the fisheries manager may be able to correct it. This would be important to trout fishermen because we believe Newton Creek is representative of many trout streams in central Michigan. However, if it is not feasible to enhance the population via natural recruitment, then this study indicates that the trout stock can be improved by stocking hatchery reared fish, contrary to other studies (Cooper 1959). However, the stock of wild trout in Newton Creek is low. Likewise, other fish competition appears to be low, thus stocking can be successful. Stocking rates would have to be higher than in the past, however, to approach an average trout population.

Acknowledgments

Michigan Department of Natural Resources fisheries personnel from District 8 conducted the trout population inventories and collected field data on stream morphology under the guidance of Leo E. Mrozinski. Howard Gowing calculated the trout production estimates. James R. Ryckman made the statistical analysis of the data sets. Otis H. Williams and Jack D. Rodgers did the trout age analyses and tabulated much of the data. James W. Merna and personnel of the Environmental Services Laboratory made the trout contaminant analyses. Editorial assistance was received by our colleagues Howard Gowing, Richard D. Clark, and William C. Latta. Margaret McClure typed the manuscript and Alan D. Sutton drafted the figures.

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Report approved by W. C. Latta

Typed by M. S. McClure

Appendix Table 1.--Estimated number of wild brown trout per hectare by age in the spring (S) and the fall (F) in Newton Creek 1967-1979.

Year	Age group							
	0		I		II		III	
	S	F	S	F	S	F	S	F
1967	-	168.9	187.4	247.3	40.7	19.7	22.3	4.8
1968	-	319.1	219.1	151.6	187.1	43.4	23.7	5.2
1969	-	443.4	374.3	273.4	84.2	64.5	35.8	16.1
1970	-	199.7	250.1	153.5	184.0	87.3	49.3	17.7
1971	-	388.9	180.5	169.2	110.1	53.6	37.2	13.6
1972	-	373.7	201.0	159.3	126.8	102.1	33.3	20.8
1973	-	498.2	312.2	244.7	144.0	88.6	110.7	27.4
1974	-	643.8	444.7	161.3	248.1	77.6	79.1	21.3
1975	-	349.2	393.0	227.6	123.6	82.3	54.8	20.8
1976	-	516.8	267.8	284.7	172.3	93.7	62.4	19.1
1977	-	361.4	335.4	219.5	272.9	88.2	60.7	18.8
1978	-	429.5	136.4	164.2	122.1	60.3	36.5	15.6
1979	-	-	333.1	-	128.0	-	41.3	-

	Age group					
	IV		V		VI	
	S	F	S	F	S	F
1967	4.3	3.0	4.4	1.5	1.5	0.0
1968	4.6	0.4	2.4	0.5	1.3	0.0
1969	4.0	3.4	0.7	1.1	0.4	0.0
1970	7.0	1.9	0.9	0.4	0.0	0.0
1971	7.6	2.8	2.2	0.0	0.0	0.0
1972	9.1	5.3	1.9	0.0	0.0	0.0
1973	20.7	11.9	5.1	3.5	0.4	0.0
1974	21.3	7.0	5.9	0.8	0.8	0.0
1975	13.6	7.9	3.6	1.1	0.0	tr
1976	12.1	6.4	4.6	1.5	0.0	0.0
1977	13.0	7.2	3.3	1.9	0.4	0.0
1978	5.9	6.3	1.9	2.2	0.5	tr
1979	7.4	-	2.3	-	0.5	-

Appendix Table 2.--Estimated number of hatchery brown trout per hectare by age in the spring (S) and the fall (F) in Newton Creek 1967-1976.

Year	Age group 0		I		II		III	
	S	F	S	F	S	F	S	F
1967			285.9	94.4	18.1	6.6	1.0	1.1
1968			285.9	55.3	47.4	8.9	4.5	0.7
1969			285.9	98.3	35.3	11.8	11.5	5.0
1970			285.9	103.8	63.4	9.3	10.0	2.5
1971			285.9	165.9	54.2	15.6	17.5	2.6
1972			285.9	36.8	36.5	11.4	6.6	3.4
1973			285.9	94.0	21.9	9.3	6.7	1.7
1974			285.9	67.9	79.3	9.3	5.6	1.9
1975 [a]			285.9	40.7	43.4	16.0	5.0	2.4
1976			-	-	14.5	3.6	5.6	1.1

	Age group IV		V		VI	
	S	F	S	F	S	F
1967	-	-	-	-	-	-
1968	0.9	0.0	-	-	-	-
1969	1.6	0.7	0.1	0.0	-	-
1970	2.2	0.8	0.7	0.6	0.1	0.0
1971	2.8	0.7	1.5	0.5	0.8	0.0
1972	0.8	0.4	0.0	0.1	0.0	0.0
1973	2.8	0.5	1.0	0.3	0.1	0.0
1974	1.1	0.5	1.1	0.5	0.5	0.5
1975 [a]	1.3	0.2	0.1	0.0	0.0	0.0
1976	1.6	0.5	1.7	0.4	0.8	0.0

[a] Hatchery trout stocked each May 1965-1975.

Appendix Table 3.--Estimated number of wild brown trout per hectare by inch group in the fall for Newton Creek 1967-1978.

Year	Inch group								
	2	3	4	5	6	7	8	9	10
1967	13.0	92.1	62.8	62.8	119.5	50.5	20.5	6.5	3.5
1968	1.3	214.8	102.6	77.8	67.4	40.0	33.9	20.9	14.8
1969	6.1	424.3	12.1	16.5	72.1	126.9	56.5	32.1	8.7
1970	14.0	176.5	8.7	10.9	54.0	21.3	49.6	67.4	22.6
1971	76.4	259.1	53.0	7.4	76.1	57.8	23.5	21.3	20.0
1972	3.5	242.1	127.8	7.0	32.1	46.5	73.1	25.6	56.5
1973	0.0	272.1	224.7	27.4	60.4	104.8	52.6	23.0	30.0
1974	47.3	468.7	127.4	11.3	42.1	56.1	40.8	46.5	21.3
1975	4.0	235.1	109.5	13.0	74.3	33.4	51.3	35.6	33.5
1976	0.0	231.7	284.3	17.0	124.6	96.0	35.6	44.0	46.9
1977	4.2	236.0	120.4	17.4	60.0	79.1	55.2	42.6	41.7
1978	24.8	326.0	78.3	8.3	45.2	56.9	49.1	33.0	20.0

	Inch group					
	11	12	13	14	15	16+
1967	8.7	1.3	3.5	1.3	0.0	3.0
1968	9.5	4.0	0.0	0.0	0.0	0.9
1969	23.5	11.3	7.8	1.7	0.0	2.1
1970	13.5	14.0	7.4	0.0	0.0	0.9
1971	14.8	9.5	7.0	0.9	1.3	0.0
1972	20.9	8.7	12.6	3.5	1.3	0.0
1973	31.3	17.0	14.8	5.2	4.0	7.0
1974	19.1	11.3	11.3	5.2	1.7	1.7
1975	17.4	10.5	12.1	3.0	4.0	2.1
1976	13.5	13.0	7.3	2.1	3.0	3.0
1977	11.3	10.8	8.3	4.4	1.7	4.0
1978	10.5	8.7	8.7	3.5	0.9	4.4

Appendix Table 4.--Estimated number of wild brown trout per hectare by inch group in the spring for Newton Creek 1967-1979.

Year	Inch group								
	2	3	4	5	6	7	8	9	10
1967	0.0	44.8	116.1	27.9	1.3	5.6	14.8	17.4	8.3
1968	0.0	21.7	143.0	49.1	49.6	57.4	67.4	21.3	7.4
1969	0.9	12.1	195.6	173.8	7.4	13.0	23.5	27.8	29.1
1970	0.0	6.1	160.9	85.4	14.8	34.8	67.4	71.7	23.5
1971	0.0	0.0	50.3	133.0	27.0	23.5	26.9	26.1	24.8
1972	0.0	0.0	80.8	119.5	44.4	14.8	43.0	24.3	17.4
1973	0.0	6.1	141.7	172.8	5.6	17.9	31.3	48.7	126.9
1974	0.0	3.5	365.2	78.3	12.6	60.8	139.1	32.1	24.4
1975	0.0	29.5	226.0	143.4	11.7	26.5	32.1	45.6	28.3
1976	0.0	5.2	123.9	141.3	31.7	29.5	50.0	57.0	35.6
1977	0.0	6.5	170.8	156.0	65.6	97.4	63.5	47.3	30.8
1978	0.0	0.9	75.6	61.7	9.5	40.0	31.3	38.3	25.6
1979	0.0	4.0	212.6	122.6	4.4	23.5	60.0	31.3	31.3

	Inch group					
	11	12	13	14	15	16+
1967	10.0	7.0	0.9	0.0	3.5	3.0
1968	10.9	3.5	1.7	2.6	0.0	2.6
1969	8.7	5.6	0.9	0.0	0.0	0.9
1970	13.0	10.0	3.0	0.9	0.0	0.0
1971	13.5	6.5	4.8	0.0	1.3	0.0
1972	14.0	6.1	7.0	0.9	0.0	0.0
1973	14.8	9.5	13.0	3.0	0.9	0.9
1974	44.0	20.9	14.0	2.1	1.3	1.7
1975	17.3	15.6	6.1	5.6	0.9	0.0
1976	20.0	14.8	6.3	0.0	4.0	0.0
1977	20.9	16.5	7.0	1.7	0.9	0.9
1978	10.9	4.4	3.5	0.0	0.9	0.9
1979	10.9	5.2	4.4	0.9	0.9	0.9

Appendix Table 5.--Estimated number of hatchery brown trout per hectare by inch group in the fall for Newton Creek 1967-1976.

Year	Inch group								
	2	3	4	5	6	7	8	9	10
1967	0.0	0.0	2.8	29.9	35.2	22.8	4.0	2.8	3.5
1968	0.0	0.0	0.0	0.5	3.0	33.9	19.6	4.0	3.8
1969	0.0	0.0	0.0	1.5	31.1	49.2	18.3	3.5	2.8
1970	0.0	0.0	0.0	1.5	36.1	55.6	11.5	5.8	2.0
1971	0.0	0.0	0.7	7.2	66.7	77.5	14.8	10.1	4.6
1972	0.0	0.0	0.0	1.0	11.0	14.6	11.0	3.8	5.0
1973	0.0	0.0	1.0	10.1	27.6	38.1	19.1	2.6	5.0
1974	0.0	0.0	0.0	9.0	22.6	26.3	10.8	4.8	3.2
1975	0.0	0.0	0.0	0.5	2.0	15.0	24.6	9.1	5.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0

Year	Inch group					
	11	12	13	14	15	16+
1967	1.2	0.0	0.0	0.0	0.0	0.0
1968	0.0	0.0	0.0	0.0	0.0	0.0
1969	6.3	3.2	0.0	0.0	0.0	0.0
1970	1.2	1.2	2.0	0.0	0.0	0.0
1971	1.2	0.7	1.7	0.0	0.0	0.0
1972	4.8	0.5	0.5	0.0	0.0	0.0
1973	0.5	1.2	0.0	0.5	0.0	0.0
1974	2.3	0.0	0.7	0.5	0.0	0.0
1975	2.0	1.0	0.0	0.0	0.0	0.0
1976	1.0	0.5	0.5	0.5	0.0	0.0

Appendix Table 6.--Estimated number of hatchery brown trout per hectare by inch group in the spring for Newton Creek 1967-1976.

Year	Inch group								
	2	3	4	5	6	7	8	9	10
1967	0.0	0.0	0.0	0.0	0.5	4.5	8.3	5.2	0.5
1968	0.0	0.0	0.0	4.6	9.0	10.6	16.0	6.8	2.8
1969	0.0	0.0	0.0	0.0	0.0	1.5	9.5	18.5	16.5
1970	0.0	0.0	0.0	0.0	1.7	10.3	28.1	22.3	7.5
1971	0.0	0.0	0.0	0.0	0.0	2.6	11.0	32.1	25.4
1972	0.0	0.0	0.0	0.0	0.0	2.8	16.1	16.0	7.5
1973	0.0	0.0	0.0	0.0	0.0	6.5	10.1	4.6	2.6
1974	0.0	0.0	0.0	1.5	24.1	15.0	25.1	13.0	5.0
1975	0.0	0.0	0.0	0.0	6.0	16.0	14.6	6.5	2.0
1976	0.0	0.0	0.0	0.0	0.5	0.5	3.5	8.5	4.6

Year	Inch group					
	11	12	13	14	15	16+
1967	0.0	0.0	0.0	0.0	0.0	0.0
1968	3.0	0.0	0.0	0.0	0.0	0.0
1969	2.0	0.5	0.0	0.0	0.0	0.0
1970	3.8	2.0	0.5	0.0	0.0	0.0
1971	2.0	1.5	1.0	1.2	0.0	0.0
1972	1.5	0.0	0.0	0.0	0.0	0.0
1973	4.6	3.8	0.5	0.0	0.0	0.0
1974	1.5	0.7	1.2	0.5	0.0	0.0
1975	4.0	0.5	0.0	0.0	0.0	0.0
1976	3.2	0.5	2.0	0.7	0.0	0.0