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EFFECTS OF A SLOTTED SIZE LIMIT ON THE BROWN TROUT FISHERY OF THE AU SABLE RIVER, MICHIGAN[1]

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Abstract

Fishing regulations for brown trout were changed from a 12-inch minimum to a slotted size limit. The slotted limit allowed harvest of trout between 8 and 12 inches and over 16 inches. Abundance of brown trout smaller than 8 inches decreased by 8%, abundance of 8- to 12-inch brown trout decreased by 32%, and abundance of brown trout over 12 inches decreased by 47%. Growth rate did not change significantly. Annual fishing mortality rate between ages 2 and 3 increased from near zero to about 30%, and this reduced the number of fish surviving to older ages and larger sizes. However, unfavorable changes in environmental conditions contributed to decreases in abundance also. Total numerical harvest of brown trout increased nearly five times but consisted of smaller fish. Fishing pressure probably increased somewhat, but the increase in harvest was due primarily to the change in size limits. Voluntary release of legal-sized trout appeared to increase independent of our regulations. We concluded that the greatest effect of the slotted limit was in reshaping man's use of the trout populations. Biological effects were comparatively unimportant except for their influence on satisfying desires of different factions within the angling community.

Introduction

The Au Sable River of north central Michigan is considered by many to be one of the best trout streams in America. Wild, self-sustaining populations of brown, brook, and rainbow trout coexist in many areas of the river where their abundance, along with the scent of pines and the flight of the giant mayfly, help give the river a special appeal. In April 1979, experimental fishing regulations were imposed on what is probably the most famous stretch of the river from Burton's Landing to Wakeley Bridge on the Mainstream. The primary element of these regulations was a slotted size limit which allowed harvest of trout between 8 and 12 inches and over 16 inches (Fig. 1).

We will describe the effects of the slotted limit and make some general observations concerning its potential as a fishery management tool. We will not give an indepth description of data collection methods or statistical analyses used to evaluate the new regulation but, for those interested, these technical details will be contained in a research report available by early 1985 from Michigan Department of Natural Resources (Clark and Alexander 1985).

The River

The Au Sable is relatively young for a river, having developed after the last ice age about 12,000 years ago. Its name was given by early French explorers and means "River of Sands". The 1,800 square mile Au Sable Basin contains over 100 miles of blue-ribbon trout water. The river consists of three major branches, the North Branch, the Mainstream (or Middle Branch), and the South Branch, and has three major tributaries, the East Branch, and two different Big Creeks. The soils in the basin are light, composed of much sand and gravel, and are very pervious to water infiltration. As a result, a large part of about 30 inches of annual precipitation goes to groundwater recharge, and the influx of this groundwater to the stream throughout the year helps provide cold temperatures and relatively stable flow conditions for trout.

The exceptional quality of the Au Sable River began attracting hundreds of anglers as early as 1873 when the railroad line to the town of Grayling was completed. In those days, they came to catch the Michigan grayling which was the only member of the salmon-trout family native to the river. But the grayling disappeared from the Au Sable by the mid-1880's. Use of the river for log running, overfishing, and competition from the newly introduced trout were all suspected of contributing to its demise. By the 1870's rainbow trout and probably brook trout were being planted in the Au Sable River by private individuals, and in 1885 the State of Michigan began planting the river with brook trout. Brown trout were the last to be introduced, but today they dominate the river, making up 80% to 90% of the total weight of trout collected in recent biological surveys (Gowing and Alexander 1980).

The first "quality" fishing regulation was established on the Au Sable River in 1901 when the size limit on trout was raised to 8 inches from the 6-inch limit then in effect statewide. The first fly-fishing-only rule was adopted in 1907 on the North Branch. Currently, 44 miles of the river are restricted to flies-only fishing and another 14 miles to fishing with artificial lures only.

There has been a long history of trout research on the Au Sable River and other rivers nearby. The first trout fishery research station in the United States was established by the Michigan Department of Natural Resources, then known as the Department of Conservation, on nearby Hunt Creek in 1939. For about 40 years, the Department has conducted scientifically designed studies to determine effects of various fishing regulations on trout fisheries (see Clark et al. 1981 for a synopsis). As a result of these studies and continuous fisheries management surveys, the Department has accumulated what may be the most extensive and longest series of data on trout streams anywhere in the world. For example, growth, mortality, and birth rates for trout have been estimated for periods of years on different sizes of streams, different trout species combinations, different stocking rates (including no stocking), and different fishing intensities (including no fishing). Furthermore, it is possible to obtain more accurate population data from the streams of this region than from those of most other regions of the country. The relative efficiency of the primary stream sampling device, the dc electroshocker, is extremely high here. This is due to the nature of the streams themselves. They are easy to wade because they have low gradients (about 5.5 feet/mile) and gravel-sand bottoms, and they are high in electrical conductivity because they have hard water (about 190 ppm total alkalinity).

Another point of interest concerning trout research is the fact that some of the first hooking mortality studies were conducted here on the North Branch of the Au Sable River and Hunt Creek (Shetter and Allison 1955, 1958). They showed that death rates of trout caught and released on natural bait were far greater than death rates of trout caught and released on artificial lures or flies. It is largely on these results and those of later supporting studies that today's flies-only and artificial-lures-only regulations can be justified.

The Problem

Nine miles of river from Burton's Landing to Wakeley Bridge on the Mainstream is one of the best stretches of the Au Sable River. All trout in this stretch are wild fish; trout have not been planted here since 1954. By the early 1970's anglers of this stretch were complaining that the large brown trout which helped give the area its reputation were gone. At the time, it was thought an increase in fishing pressure might be causing the decline in big browns through overharvest, but this could not be determined with certainty because neither trout population surveys nor creel surveys had been conducted there since 1963. Nonetheless, in response to angler complaints the minimum size limit on brown and rainbow trout was increased from 10 to 12 inches in 1973, and the daily creel limit was reduced from 5 to 3 trout per day. Also, the size limit on brook trout was increased from 7 to 8 inches in 1974. At the same time, annual trout population surveys were resumed so the effects of the 12-inch size limit could be studied in detail.

By 1977, it became apparent that the 12-inch size limit and 3-trout creel limit were not working. Trout population surveys were producing clear evidence that these regulations had failed to bring back the numbers of large trout observed in similar surveys in the 1960's. The most important reason for the failure appeared to be a significant decline in the growth rate of brown trout (Alexander et al. 1979). Mean lengths of brown trout of all ages were considerably less in the 1970's than in the 1960's (Fig. 2). For example, the average 3-year-old brown trout was more than 2 inches smaller (11.3 inches versus 13.6 inches). This change in growth had a great impact on the fishery. The estimated number of brown trout larger than 12 inches in the population and the estimated number of these large fish harvested per hour of fishing both decreased by two and one-half times.

The 12-inch size limit did succeed in increasing the number of 10- to 12-inch brown trout in the population by about 40% over the number present under the 10-inch limit in the 1960's. However, it appeared that these fish were only adding to the problem. The size structure of the population seemed to be out of balance; too many mid-sized fish and not enough large fish. One line of thinking suggested that harvesting these "overabundant" mid-sized fish and protecting the rarer, more valuable large fish might solve the problem. It might allow the remaining fish in the population to obtain more food per individual, so they could grow faster. Similar "thinning" operations were known to be effective in increasing growth rates of trout, bluegills, and other fishes in lakes. The big question was: Would it work in a trout stream? To find the answer, a slotted size limit was designed to thin the numbers of 8- to 12-inch brown trout by allowing their harvest and to protect 12- to 16-inch brown trout by requiring their release. On April 28, 1979, the slotted size limit went into effect on the Burton-to-Wakeley section.

The Controversy

Not everyone was convinced the slotted limits would improve brown trout growth. In fact, not all biologists agreed that the 12-inch size limit was to blame for the decline in brown trout growth. Several alternative hypotheses were advanced to explain the decline. Alexander et al. (1979) described the complexity of the problem in more detail. Briefly, no single factor was identified as the cause for the decline in growth, but there were two leading hypotheses. The first was a considerable decrease in productivity of the river. This came about when two sources of nutrient enrichment at the town of Grayling, about 6 miles upstream of Burton's Landing, were curtailed. The State of Michigan phased out fish production, with its related waste discharge, at the Grayling Hatchery in the mid-1960's and the town stopped putting sewage effluent into the river in 1971. Large amounts of sewage can kill a river, but limited amounts can have the same effect as fertilizer on a garden. It stimulates the growth of aquatic plants, which feed aquatic insects and crustaceans, which feed trout.

The second hypothesis was based on population genetics theory. Favro et al. (1979) suggested fishing under a minimum size limit might reduce the genetic growth potential of brown trout by killing most of the larger trout and leaving behind the smaller trout to reproduce. Cooper (1952) expressed this same concern earlier with regard to Michigan brook trout, and more recently, Ricker (1981) gave convincing evidence that the commercial fishery in the North Pacific had reduced the average size of salmon through genetic selection.

Studies were designed by the Department of Natural Resources to test both sewage enrichment and population genetics hypotheses. Merron (1982) studied the decline in productivity due to sewage diversion. He calculated growth of brown trout from the 1960's through the 1970's on three branches of the Au Sable, the Mainstream, the North Branch, and the South Branch. He used scale samples that were collected during the period from other research and management surveys. Each of the branches had a different history of nutrient enrichment. Sewage effluent was discharged into the Mainstream from the town of Grayling and into the South Branch from the town of Roscommon, but these discharges were stopped in different years, 1971 on the Mainstream and 1974 on the South Branch. The North Branch never received any effluent. Merron found growth rates of brown trout were significantly slower in both the Mainstream and the South Branch after termination of sewage discharges, and that the timing of these decreases in growth corresponded to the timing of sewage diversion. He found no change in growth for the same time intervals on the North Branch. Thus, the results of Merron's study strongly supported the idea that growth of brown trout in the Burton-to-Wakeley section of the Mainstream had decreased in the 1970's because the river was no longer being "fertilized" by municipal sewage and hatchery effluent.

To test the genetics hypothesis, samples of young-of-the-year brown trout were taken from streams in northern Michigan which varied in fishing pressure from light to heavy. The Mainstream of the Au Sable was one of those selected. These fish were marked so their stream origins could be identified, and then they were planted together in the same experimental lakes. The idea was to see if their growth in these common environments was correlated with the degree of exploitation in their home streams. This study has not been completed yet.

Meanwhile, Clark et al. (1980) predicted the slotted size limit would have no effect on the growth of brown trout. They cited a number of examples in which changes in fishing regulations or other management activities had significantly changed trout population densities in streams but had not significantly changed trout growth rates. Numerous scientific references and trout population data in the Department files indicated trout populations in streams adjusted their numbers through density-dependent movement and mortality. That is, trout compete with one another for favorable positions in streams. The relative quality of these positions is related in part to food abundance and to the nearness of cover for protection against predators. When the trout population size exceeds the number of favorable positions, the largest, most aggressive individuals take the best positions and force the others to move to other areas where they have less food and protection. Over time, it appears that starvation and/or predation are effective in removing these excess fish. Clark et al. (1980) developed a population dynamics model based in part on these density-dependent mortality relationships and used it to predict that the slotted size limit would actually reduce, and not increase, the number of large brown trout in the Burton-to-Wakeley section. The primary basis for this prediction was the assumption that growth and natural mortality rates of trout would not change enough to compensate for the added fishing mortality on the 8- to 12-inch fish. In other words, anglers would remove enough 8- to 12-inch trout so as to reduce the number surviving to the larger sizes.

Experimental Methods

The experiment to evaluate the slotted size limit spanned a period of 10 years, 1974 through 1983. Data were collected on the trout populations and angler use of the study section (Burton's Landing to Wakeley Bridge on the Mainstream) from 1979 through 1983 under the slotted size limit and compared to identical data taken from 1974 through 1978 under the 12-inch size limit. Also, identical data were collected on a similar section of the North Branch where no changes in fishing regulations occurred during the period of study. Thus, the North Branch was used as a control. We assumed that any large-scale trout population changes caused by natural phenomenon would be reflected in this control section. Then we would know that similar changes occurring in our study section were not due to the regulations but to environmental effects.

Changes in population and catch statistics observed after the slotted size limit went into effect were tested at the 90% level of significance. The 95% level is often used for statistical testing in scientific experiments, but we thought 95% was too restrictive given the inherent variability in natural fisheries. Henceforth, when we say things have changed significantly or are significantly different, we mean that a statistically significant difference has been detected at the 90% level.

The study section on the Mainstream was discussed earlier. The control section on the North Branch was about 14 miles long, from Sheep Ranch Public Access Site to Kellogg's Bridge near the community of Lovells. At its farthest point, it is only 15 miles from the study section on the Mainstream. Regulations on this section from 1974 through 1983 were artificial flies only, minimum size limits of 8 inches on brook trout and 10 inches on brown trout, creel limit of 5 trout per day from the last Saturday in April to October 31. One of the major differences between this section and the study section was that no rainbow trout were present. However, brown and brook trout populations in the North Branch compared very well with those in the Mainstream.

Limited time and manpower prevented detailed sampling of trout populations in the entire 9-mile study section and 14-mile control section, so two sampling stations, about 1/4 mile long each, were defined within the study section and three within the control section. These stations were considered as index stations in which the trout population dynamics could be studied in detail. We assumed the regulations would affect the trout populations in the study section as a whole similar to how they affected the trout in these smaller sampling areas. Electroshocking gear was used to estimate trout abundance each fall within the boundaries of the sampling stations. Scales were taken from some of the fish at this time also. Later these scales were used to determine the age of trout of various sizes and species. By estimating the age and size of the fish over a period of time, we determined the average growth and survival rates of the population in our index areas.

Creel surveys were conducted on both the study and control sections in 1976, before the slotted size limit, and from 1979 through 1983, after the slotted size limit. These surveys were designed to estimate the total hours of fishing and the total catch of trout, both harvested and released, of each species. Stratified, random sampling methods were used, as described in more detail by Alexander and Shetter (1967) or Malvestuto (1983). Briefly, total hours of fishing were estimated by making progressive instantaneous counts. A clerk floated each section in a canoe, counting the number of anglers on the river at specified times of the day. Catch per hour was obtained by interviewing anglers on the river, usually after their fishing trip was completed. Anglers were asked the length of the fishing trip and also how many trout of each species they had caught and released. Of course, this means that our estimates of trout caught and released were dependent on the honesty of the anglers; their ability to distinguish between brown, brook, and rainbow trout; and their ability to recall the exact number and species and approximate sizes of trout they caught and released that day. To help test the accuracy of these catch-and-release reports from the general public, we recruited a small group of knowledgeable fishermen to keep accurate records of sizes and species of trout they caught. We plan to compare the size and species composition reported by these cooperators to those reported by the general public, but comparisons are not complete at this time. Also during the interviews, trout in the angler's possession (those harvested) were counted, identified to species, and scale sampled for age analysis. Finally, we estimated total catches by multiplying the total hours fished per day times the average catch per hour per day.

Results and Discussion

The slotted limit was designed primarily for brown trout, and we will concentrate on them in this report. We could not detect any effect from the regulation on brook or rainbow trout (Clark and Alexander 1985).

Earlier research demonstrated that changes in daily possession limits did not affect trout populations while size limits had strong effects (Shetter 1969; Hunt 1970; Latta 1973). The ineffectiveness of possession limits was due primarily to the rarity of anglers catching their limit of trout. Size limits were effective because they applied to every single trout caught. Therefore, even though our daily possession limit increased from 3 to 5 trout, we assumed any effects found were caused by the change in size limits.

We defined the before period as 1974 through 1978 and the after period as 1980 through 1983. This allowed a 2-year transition period (1978 to 1980) for the population to adjust from the 12-inch limit to the slotted limit.

Trout population statistics

We compared the size structure of brown trout before and after the slotted limit was applied and found the average abundance of fish of all sizes decreased significantly in both study and control sections (Table 1). In the Mainstream, trout smaller than 8 inches decreased 8%, trout between 8 and 12 inches decreased 32%, and trout larger than 12 inches decreased 47%. In the North Branch, the respective decreases were 19%, 24%, and 44%. The average number of trout larger than 16 inches also decreased in both sections, but due to small sample sizes, reliable confidence bounds could not be calculated for these larger trout.

We expected to find reductions in brown trout abundance in the Mainstream because of the increased harvest permitted under the slotted limit, but we did not expect to find similar reductions in the North Branch where regulations remained constant. Despite the relative stability of the Au Sable River as trout habitat, environmental conditions did change in some way, and we were faced with the problem of separating effects of changing fishing regulations from effects of changing environmental conditions.

To accomplish this separation of effects, we examined how the observed size structures were formed through the biological processes of recruitment, survival, and growth. We use the word "recruitment" here to mean the annual number of young fish born and surviving to age 0 (6 months old). Age structure and annual survival of brown trout populations in before and after periods are presented in Table 2. We did not include an exceptionally large 1978 year class in these calculations. This year class was twice as large as any other year class in both study and control sections. Including it in the calculations would have inflated mean numbers at age and misrepresented the effects of the regulation.

We found a significant decrease in annual recruitment in both study and control sections but no change in annual survival rates, except at older ages where survival was influenced by changes in fishing mortality (Table 2). Environmental factors most often affect fish populations through fluctuations in annual recruitment of young fish (Cushing 1977; Backiel and Le Cren 1978), and our data showed that environmental conditions must have been less favorable for recruitment of brown trout in the after period. Average recruitment of age-0 fish decreased 10% in the Mainstream and 23% in the North Branch.

Even without changes in regulations, reduced recruitment alone would have led to reductions in abundance of older, larger trout in both streams. However, regulations did change in the Mainstream causing additional mortality of 8- to 12-inch trout through harvest. This harvest mortality added to the environmental effect to reduce the number of larger, older trout even further. More specifically, the survival rate from age 0 to 1 in the Mainstream did not change. Trout at this age were smaller than 8 inches and not affected by harvest. (This is illustrated by growth data given later.) Survival from age 1 to 2 decreased significantly from 0.70 under the 12-inch limit to 0.54 under the slotted limit. Some trout at this age reached 8 inches and were harvested under the slotted limit. Thus, fishing mortality added to the existing natural mortality from age 1 to 2 and reduced the survival rate.

Survival from age 2 to 3 decreased significantly in the Mainstream from 0.65 to 0.44 (Table 2). Almost all trout at this age were between 8 and 12 inches. They received the full effect of harvest under the slotted limit but were still protected under the 12-inch limit. This means the difference between instantaneous total mortality rates at this age, measured before and after the regulation change, can be used as an estimate of the instantaneous fishing mortality on the Mainstream brown trout (assuming natural mortality remained constant--see Ricker 1975). In this manner, we estimated the instantaneous fishing mortality rate to be 0.39, and this estimate is only slightly higher than estimates made earlier using other methods (Clark et al. 1980 used a conditional fishing rate of 0.30 which corresponds to an instantaneous fishing rate of 0.36).

Survival from age 3 to 4 did not change significantly in the Mainstream (Table 2). About half the trout at this age were smaller and half larger than 12 inches, so about the same proportion of fish in the age group were vulnerable to harvest under each regulation; the smaller half under the slotted limit and the larger half under the 12-inch limit.

In the North Branch, survival of brown trout did not change significantly in the after period until age 2, the age they began to exceed the minimum size limit of 10 inches. Here survival decreased from 0.49 to 0.35 (Table 2). This decrease was not due to any change in regulations but was probably due to a slight increase in fishing pressure to be discussed later in this report. One result which seemed unrealistic was an apparent increase in survival rate from age 3 to 4 (0.05 to 0.15). We expected a decrease in survival at this age for the same reason it decreased at age 2--increased fishing pressure. It is our opinion that these survival rates estimated for age 3 to 4 were unreliable due to small sample sizes of trout at age 4. The number of age-4 brown trout averaged only 1 per acre before and 2 per acre after. Therefore, we based our interpretation of results solely on abundance and survival rates of fish age 3 or younger.

While fishing and environmental factors combined to reduce abundance of brown trout in both study and control streams, this did not lead to an increase in growth rates. Growth of brown trout did not change significantly in the Mainstream (Fig. 3), and in the North Branch a slight, but statistically significant decrease in growth was detected (Fig. 4). Thus, the classical inverse relationship between growth and abundance which has been observed in pond and lake fisheries was not observed in our trout streams. However, decreased growth in the North Branch suggested environmental conditions might have acted to reduce growth, along with recruitment, in the after period. If so, the additional reduction in abundance caused by the slotted limit in the Mainstream could have increased growth there; just enough to balance the negative environmental effect and to result in no net change in growth. But even if the regulation did cause this slight improvement in growth, the relatively larger increase in mortality it caused between ages 1 and 3 was clearly the more important effect in determining the abundance of trout larger than 12 inches.

In summary, the growth rate of brown trout did not change significantly as a result of the slotted size limit. Abundance of brown trout of all sizes in the Mainstream decreased 10% in the after period due to lower recruitment of young fish, but this was caused by some unknown change in environmental conditions. Abundance of 8- to 12-inch fish was reduced an additional 22% (32% in total) from angler harvest under the slotted limit. Abundance of fish larger than 12 inches was reduced an additional 15% (47% in total) by further angler harvest. Notice that it took about 2 years (from age 1 to 3 on the average) for brown trout to grow through the harvest slot from 8 to 12 inches, so they were subjected to 2 years of angler harvest before they reached 12 inches. Once fish reached 12 inches, they were protected under the slotted limit but fewer trout reached this size because they were harvested at 8 to 12 inches.

Creel survey statistics

No confidence bounds were calculated in the 1976 creel survey and bounds for the 1980 through 1983 surveys were not nearly as narrow as the bounds for the trout population surveys. Nonetheless, it was obvious that total harvest of brown trout from the Mainstream study section changed significantly (Table 3). It increased from an estimated 440 brown trout per year under the 12-inch minimum limit to an average of 2,090 brown trout per year under the slotted limit. In terms of harvest per hour of fishing, this was 0.014 brown trout per hour versus 0.061 brown trout per hour. Total fishing pressure did not change significantly, but a slight increase is suggested by the estimated means. Of course, numbers of fish were not the only difference in the total harvest. The size of fish harvested under the slotted size limit was much smaller than under the 12-inch minimum limit. Almost all the former were between 8 and 12 inches, while the latter were all over 12 inches.

For the same time periods, no significant change was observed in the total harvest of brown trout in the North Branch control section (Table 3), although a slight decrease was suggested by the means, 1,600 brown trout before versus 1,440 brown trout after. In terms of harvest per hour, this was 0.066 brown trout per hour versus 0.054 brown trout per hour. Total fishing pressure did not change significantly in the North Branch, but again, a slight increase was suggested by the means.

There were only two other creel survey statistics we can confidently say changed significantly, and those were the changes mandated by law. The number of 8- to 12-inch brown trout harvested increased from near zero under the 12-inch limit to 2,060 under the slotted limit, and the number of 12- to 16-inch brown trout harvested decreased from 410 under the 12-inch limit to near zero under the slotted limit (Table 3). We made no deliberate effort to estimate the illegal harvest, but our creel census clerks did observe a small harvest of illegal-sized fish during the study. We can only hope this illegal harvest was negligible or that it was no more severe under the slotted limit than the 12-inch limit.

Even though effects of the slotted limit on other creel survey statistics could not be verified statistically, some effects suggested by the data were interesting to think about. For example, the estimated catch of 12- to 16-inch brown trout, that is, the sum of harvest and catch and release, was nearly the same in the after period as the before period in both study and control sections--930 before versus 1,050 after. Yet, we know the number of brown trout of this size in the population decreased by over 40% (Table 1). Thus, it appears anglers caught the same number of fish, even though fewer fish were available. Either they improved their fishing skills over the years, or they caught, released, and recaptured the average brown trout from one and one-half to two times. The former explanation is flattering, but difficult to accept by those of us who have observed the behavior of anglers over the years. The latter explanation makes the most sense because an increase in the release rate of brown trout in this size category was mandated by the slotted limit on the Mainstream. In the North Branch, it appears in general that the release rate of trout has increased over the years, even though the fish may be legal to harvest. Anglers reported releasing about 41% of the legal-sized brown trout on the North Branch in 1976 and about 57% in the 1980's. This increase in release rate was probably responsible for maintaining a relatively constant catch of 12- to 16-inch trout in the North Branch (730 before versus 830 after), while abundance declined.

Fisheries Management Implications

The greatest effect of the slotted size limit was not in the trout population itself, but in the change in man's use of the trout population. In the Mainstream, anglers traded the harvest of 12- to 16-inch brown trout for about a five-fold increase in the total number of brown trout harvested, although the new harvest consisted of smaller fish (8 to 12 inches). At the same time, they still caught at least as many 12- to 16-inch brown trout, but had to release them.

Is harvesting five trout between 8 and 12 inches worth as much as harvesting one trout larger than 12 inches? Fenske (1984) surveyed the opinions of Michigan trout anglers and found a nearly even split on a question very similar to this one. Of those questioned, 45% thought it was better to catch five 8-inch trout, while 39% thought it was better to catch one 12-inch trout. Is catching and releasing a 12-inch trout worth as much as catching and harvesting a 12-inch trout? We suspect most anglers would answer no to this question, yet there is no doubt catching and releasing a trout has considerable value. The main point of these questions was to suggest that beyond protecting trout populations from extermination, the primary function of fishing regulations is to satisfy different, and often competing, angler preferences. From this standpoint, slotted size limits have the desirable feature of being able to compromise between those who prefer to harvest many small trout and those who prefer to catch fewer larger trout. However, it should also be recognized that this same compromise could be achieved more simply by dividing a stream into two smaller sections; one section having an 8-inch minimum limit for the first group of anglers and one having a 12-inch minimum limit for the second group of anglers. Likewise, a similar compromise could be achieved with a 10-inch minimum limit applied to the whole area (see

Clark 1981).

With regard to the fishery in the Burton-to-Wakeley study section, it appears that no change in fishing regulations is capable of returning the number of large brown trout observed there in the past. Brown trout growth has declined, and short of fertilizing the river with sewage again, we doubt if growth can be returned to former levels. However, this part of the river continues to produce large numbers of medium-sized trout and still produces a few trophy-sized trout for fly fishermen.

Slotted limits were not as good as a 12-inch minimum size limit in producing larger trout in the Au Sable River, and this is probably true in general for trout stream fisheries. The reason was that harvest mortality had a more significant effect in reducing survival of trout to older ages and larger sizes than it had on increasing growth rate to larger sizes. If harvest of mid-sized trout had any effect on growth rate of brown trout in our study, the effect was minor, and results of other studies indicated growth rates of trout in streams were independent of relatively large changes in population density and fishing intensities (Cooper 1949; McFadden el al. 1967; McFadden 1969; Bachman 1984). Thus, it appears that the following "rules of thumb" for trout streams regulated under simple minimum size limits will also apply for slotted limits (Clark 1981):

1. If the minimum limit is set at a small size, for example 6 to 8 inches, a large number of trout can be harvested, but the average trout caught will be smaller and the number of trophy-sized trout both in the population and the harvest will be fewer than for higher size limits. In the case of slotted limits, the catch of trophy-sized trout will be inversely related to the width of the harvest slot.

2. If the minimum limit is set at a large size, for example 12 to 15 inches, the total number of trout harvested will be small, but the average trout caught will be larger and the number of trophy-sized trout in the populations will be greater than for lower size limits. Catch-and-release regulations, or a closure of the fishery, will produce the maximum number of trophy-sized trout in the population.
3. The higher the existing fishing mortality is, the more noticeable any change in size limits will be.

This also means the effects of slotted limits can be predicted about as well as those of simple minimum size limits, at least on a per-recruit basis. Our predictions for the Mainstream brown trout in 1979 (Clark et al. 1980) were fairly accurate on a per-recruit basis, but we could not have predicted the change in environmental conditions and its effect on recruitment of young fish.

Finally, results of this study demonstrated the importance of an experimental control. Without a control it is impossible to determine to what degree observed changes were caused by management actions versus environmental effects. Although the Au Sable River is known for its stability in environmental conditions for trout, changes in conditions had a relatively large effect on annual recruitment of juvenile trout during our study. Annual brown trout recruitment decreased about 23% and brook trout recruitment increased by about 40% in the North Branch where fishing regulations remained constant. Such population changes might also be interpreted as natural cycles in the competitive struggles of two ecologically similar species (Hutchinson 1978), and we think competition between brook and brown trout must be playing at least some part in observed population changes. However, relative sizes of year classes produced in both branches of the river were in phase, and this is more indicative of environmental influences. We think subtle changes in average temperatures during the growing seasons for young trout might have been the cause. Colder temperatures correlated with poor brown trout year classes and good brook trout year classes in our data set, and the average temperature in our after period was colder.

What is the future of the slotted size limit in the Au Sable River? We think this should depend on the popularity of the regulation among anglers. The slotted limit is just one of many regulations that could be used to protect Au Sable brown trout from extinction due to overfishing. Other biological effects of regulations are comparatively unimportant, except for their influence on satisfying the desires of different factions within the angling community.

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Figure 1. Description of slotted size limits posted at entrance of study section at Wakeley Bridge on the Mainstream of the Au Sable River, Michigan.

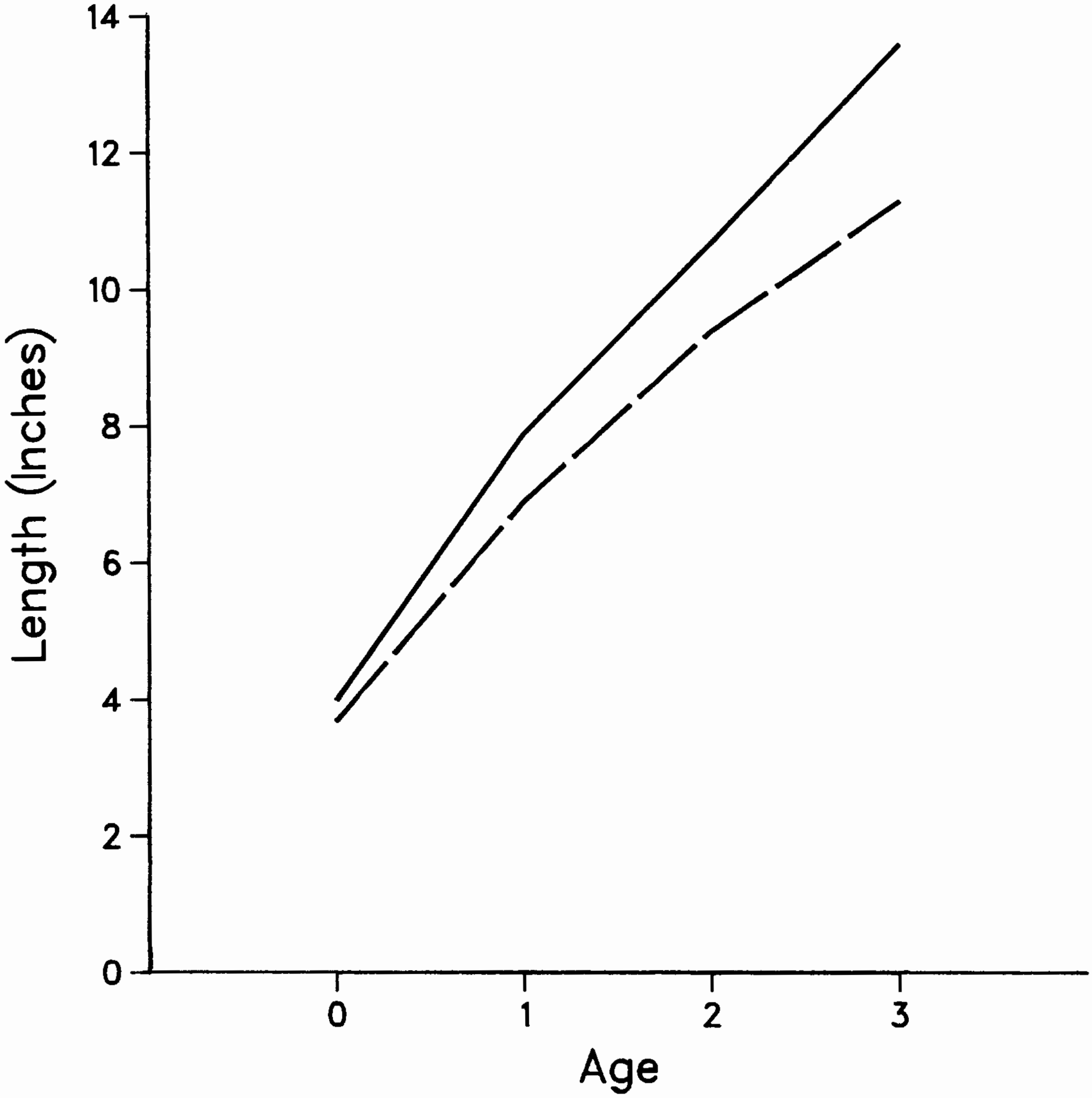

Figure 2. Brown trout growth in the Mainstream in the period from 1959 to 1963 (solid line) compared to the period from 1974 to 1978 (dashed line).

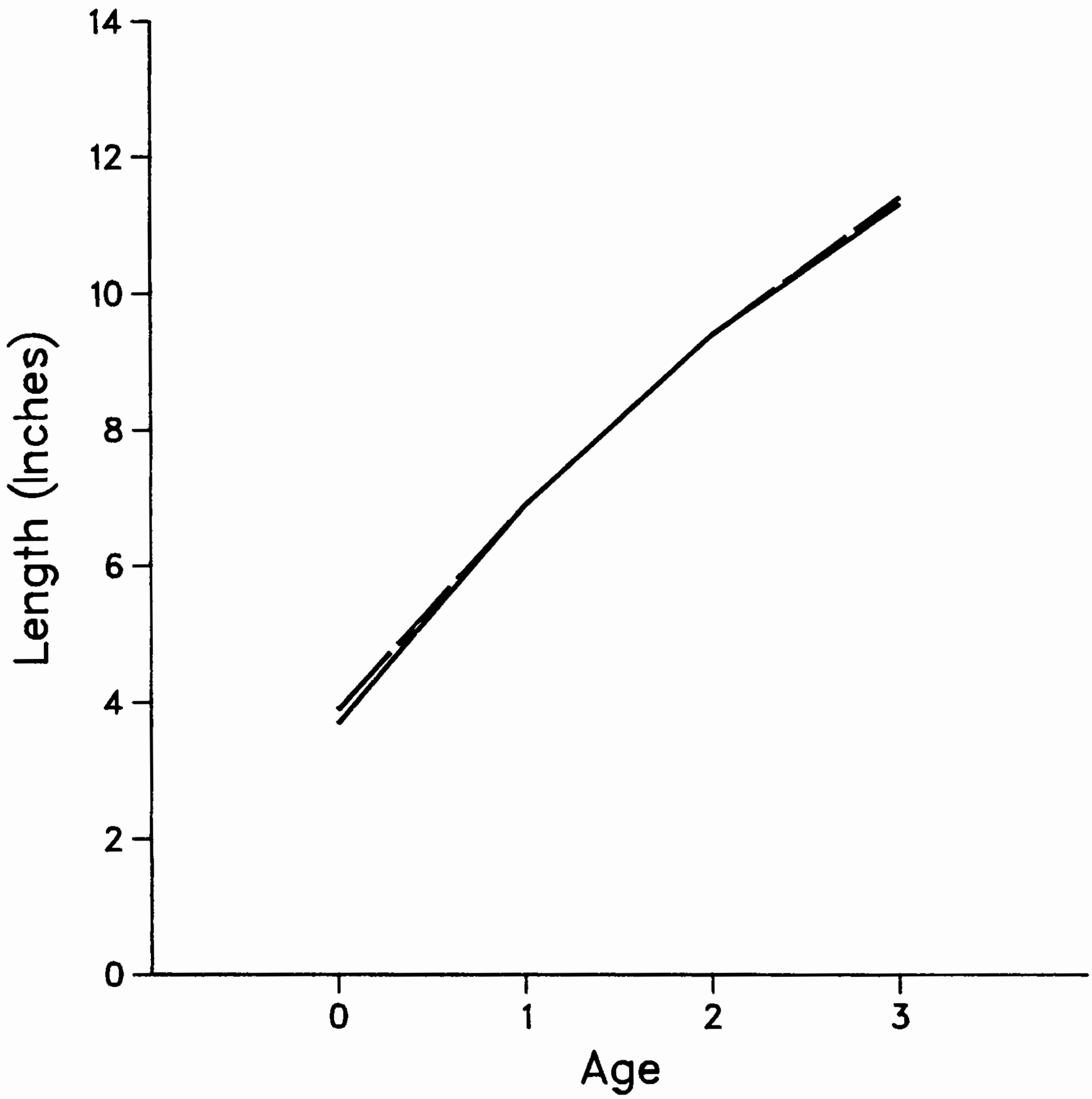

Figure 3. Brown trout growth in the Mainstream in the period from 1974 to 1978 (solid line) compared to the period from 1980 to 1983 (dashed line).

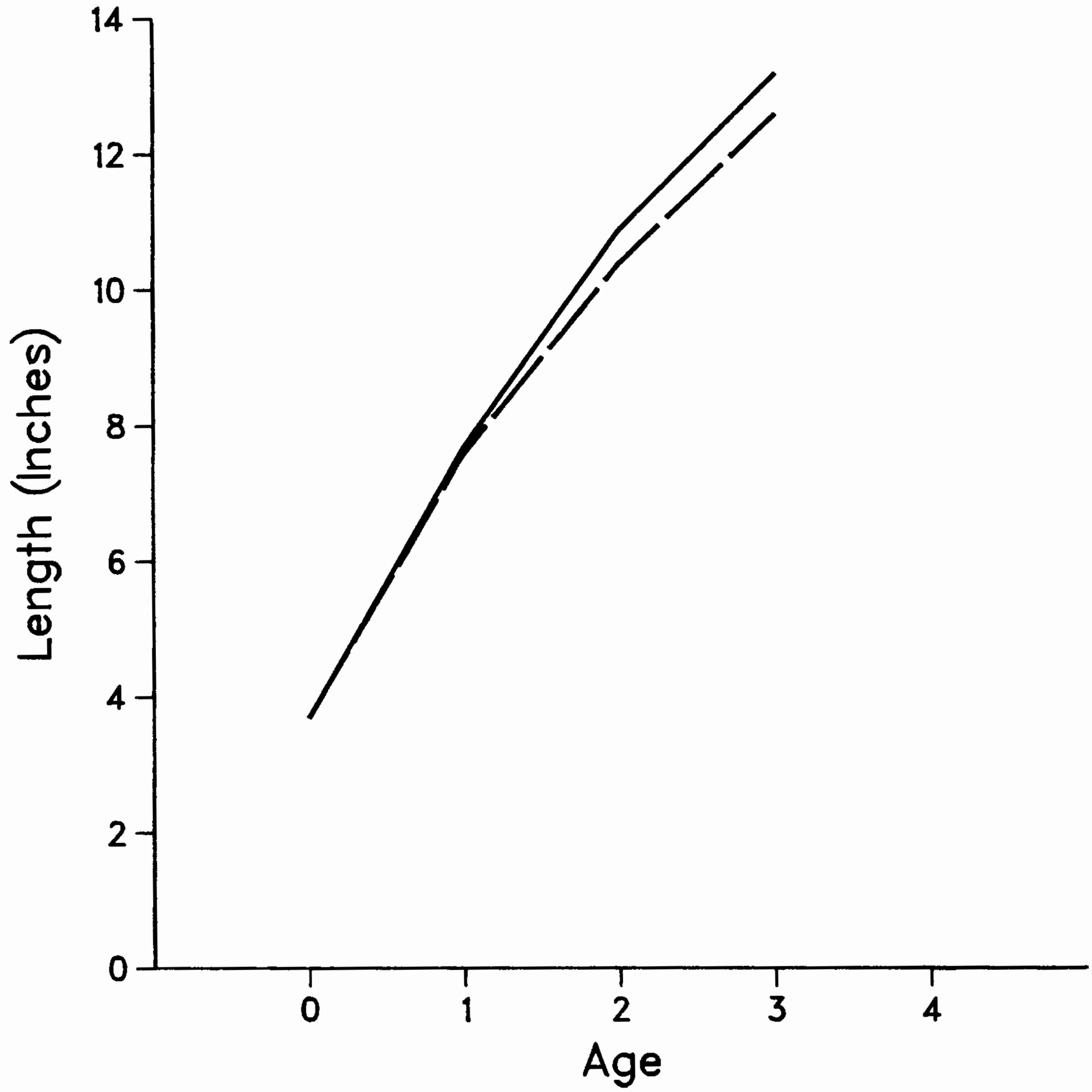

Figure 4. Brown trout growth in the North Branch in the period from 1974 to 1978 (solid line) compared to the period from 1980 to 1983 (dashed line).

Table 1. Mean number of brown trout per acre in fall populations by selected size categories. Confidence bounds for the 90% level of significance are in parentheses.

Stream, time period (size limit)	Size of trout: Trout smaller than 8 inches	8- to 12-inch trout	12- to 16-inch trout	Trout 16 inches or larger
Mainstream				
1974-1978 (12-inch minimum)	600 (±21)	189 (±6)	18 (±2)	1 (-)
1980-1983 (Slotted)	555 (±19)	128 (±5)	10 (±1)	<1 (-)
North Branch				
1974-1978 (10-inch minimum)	525 (±9)	86 (±5)	23 (±1)	2 (-)
1980-1983 (10-inch minimum)	425 (±11)	65 (±2)	13 (±1)	1 (-)

Table 2. Mean number of brown trout by age and annual survival for fall populations. Confidence bounds for the 90% level of significance are in parentheses.

Stream, time period, (size limit)	Age of trout				
	0	1	2	3	4
<u>Mainstream</u> 1974-1978 (12-inch minimum)					
Number	450 (±21)	164 (±8)	114 (±8)	74 (±7)	4 (±1)
Survival rate	0.36 (±0.02)	0.70 (±0.06)	0.65 (±0.07)	0.05 (±0.02)	
1980-1983 (Slotted)					
Number	405 (±19)	148 (±9)	80 (±11)	35 (±6)	1 (±1)
Survival rate	0.37 (±0.03)	0.54 (±0.08)	0.44 (±0.09)	0.02 (±0.01)	
<u>North Branch</u> 1974-1978 (10-inch minimum)					
Number	478 (±9)	92 (±3)	43 (±4)	21 (±2)	1 (±1)
Survival rate	0.19 (±0.01)	0.47 (±0.04)	0.49 (±0.06)	0.05 (±0.01)	
1980-1983 (10-inch minimum)					
Number	366 (±9)	78 (±3)	33 (±3)	12 (±2)	2 (±1)
Survival rate	0.21 (±0.01)	0.42 (±0.05)	0.35 (±0.07)	0.15 (±0.07)	

Table 3. Mean numbers per year of brown trout harvested and caught and released in selected size categories. Confidence bounds for the 95% level of significance are in parentheses. No confidence bounds were calculated for the 1976 survey.

Stream, time period, (size limit)	Size categories								Total fishing pressure (hours)
	8 to 12 inches[1]		12 to 16 inches		Over 16 inches		Total[1]		
	Harvested	Released	Harvested	Released	Harvested	Released	Harvested	Released	
Mainstream									
1976 (10-inch minimum)	-- (--)	-- (--)	410 (--)	520 (--)	30 (--)	40 (--)	440 (--)	-- (--)	30,500 (--)
1980-1983 (Slotted)	2,060 (±900)	5,440 (±2,230)	-- (--)	1,050 (±710)	30 (±60)	70 (±160)	2,090 (±910)	5,510 (±2,250)	34,500 (±6,400)
North Branch									
1976 (10-inch minimum)	1,110 (--)	770 (--)	430 (--)	300 (--)	60 (--)	40 (--)	1,600 (--)	1,110 (--)	24,300 (--)
1980-1983 (10-inch minimum)	1,030 (±440)	1,360 (±720)	360 (±210)	470 (±310)	50 (±70)	60 (±90)	1,440 (±577)	1,890 (±965)	26,800 (±4,900)

[1]For North Branch this includes only trout larger than 10 inches because a 10-inch minimum size limit was in effect.

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