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A HISTORY AND EVALUATION OF REGULATIONS FOR BROOK AND BROWN TROUT IN MICHIGAN STREAMS [1]

By Richard D. Clark, Jr., Gaylord R. Alexander, and Howard Gowing

ABSTRACT

Since establishment of the Board of Fish Commissioners in 1873, the trend in Michigan trout fishing regulations has been toward more restrictive and complex laws. Major scientific investigations concerning the effectiveness of various types of regulations began in 1945. They determined that a minimum size limit was the most effective regulation for controlling exploitation of trout.

In this study minimum size limits for brook and brown trout in Michigan streams were evaluated through mathematical modeling. Minimum size limits ranging from 152 to 229 mm (6 to 9 inches) were tested for brook trout and from 152 to 305 mm (6 to 12 inches) for brown trout. Catch-and-release (no-kill) regulations were also simulated for both species. Maximum yield in numbers and weight of trout harvested was obtained at a 152-mm (6-inch) minimum limit for both brooks and browns. Yield in numbers and weight of trout caught and released increased as size limit increased and was maximum with a no-kill regulation. Total yield (defined as weight of trout caught and harvested plus weight of trout caught and released) increased as size limit increased and was maximum with a no-kill regulation. As size limit increased, the number of larger trout harvested increased, but at the same time, total number of trout harvested declined.

[1] Contribution from Dingell-Johnson Project F-35-R, Michigan.

Introduction

The primary purpose of trout fishing regulations is to control the impact of fishing on trout populations. Fishing regulations were originally imposed to prevent excessive fishing pressure from driving trout populations to extinction. More recently, it has been recognized that the types and combinations of regulations which successfully protect trout populations are very numerous, yet each set of regulations has a different effect on a trout fishery.

Faced with many acceptable possibilities, early fishery managers decided the best set of regulations would be those which provided the maximum yield of fish flesh without harming the population. This maximum yield concept was very appealing to managers because it assured (theoretically, at least) the utilization of fish populations to their fullest capacity, and it gave each angler the opportunity to harvest the maximum weight of fish.

Fisheries were managed for many years under the maximum yield philosophy, and according to Bennett, Hampton, and Lackey (1978), most fisheries are still managed for maximum yield. However, fisheries management philosophies are changing. Many recreational fishermen have made it clear that they do not fish for food, but for a multitude of other reasons. Most anglers agree that catching fish is the most important aspect of fishing, but they are not necessarily interested in eating the fish. Furthermore, the makeup of their catch, with respect to size, numbers, and species, is often critical to their angling enjoyment. Many of these desires are in direct conflict with the maximum yield idea, so fisheries managers are urged to seek more appropriate management goals. The goal which currently dominates fisheries management thinking, if not practice, is the optimum yield concept.

But optimum yield from a fishery is difficult to define. Under this management philosophy, the term "yield" can have a much broader connotation than simply a quantity of fish flesh. It is sometimes defined in terms of recreational benefits or fishing quality indices, and these quantities mean different things to different people. One person's idea of a quality trout fishing trip may be to catch his limit of 178-mm (7-inch) trout in less than an hour, while another person may prefer to spend all day on the stream and can only be satisfied by catching trout of larger than 457 mm (18 inches) long. Optimum yield must be defined through analysis of such angler preferences, and in the end, statewide regulations must be set which maintain the integrity of the trout resource and serve as the best compromise between competing angler preferences.

Our specific concern in this study was to reevaluate regulations on brook and brown trout populations in Michigan streams. The objectives of the study were: (1) to review the history and past research regarding effects of different regulations on stream trout fisheries; and (2) to use mathematical modeling techniques and other pertinent information to help evaluate various alternative regulations, but particularly the statewide minimum size limit.

History of trout stream regulations

In the year 1873, the Michigan legislature passed Act 124 which established the first Board of Fish commissioners. Their original charge was "to increase the product of the fisheries." Their primary means of achieving this goal was through fish culture and stocking. However, Michigan's first Superintendent of Fisheries, George H. Jerome, described the condition of the State's fishery resource and the need for regulations in his first report to the Governor (Jerome 1875):

> That waters once abounding with fish can become barren by excessive, or ill-timed, or barbarous fishing, or all together, is too obviously, painfully true. Too many lines and rods and anglers behind them, from every part of the country, tell the one story in verification of the fact, -- a class of witnesses not easily impeached. Go where we will, lakes streams and rivers, which scarcely a generation ago gave great joy and profit to riparian owner and general angler, now scarcely excite their thought or notice. . . .
>
> Laws, too, prescribing closure times and regulating the utensils and methods of capture, whether by seine or weir, or spear or hook, grow out of the very necessities of the case and can no more be dispensed with than can the rudder be detached from the ship and

> she ride on in safety. It is absence or non-observance of these laws that has depleted many a stream and river, pond and lake, of all their finny wealth and beauty.

The first minimum size limit for trout in Michigan streams, adopted in 1881, established a 152-mm (6-inch) minimum limit on grayling and brook trout. In 1889, the fishing season for all trout was set to extend from May through August. Our first "special regulation" was established in 1901 when the size limit was raised to 203 mm (8 inches) on the Au Sable River. In 1903, the statewide size limit was raised to 178 mm (7 inches) for brook, brown, and rainbow trout, landlocked salmon, and grayling. Fifty fish per day with 100 fish in possession were permitted.

The first flies-only rule was adopted with a 203-mm (8-inch) minimum size limit on the North Branch of the Au Sable River in 1907, but it was repealed in 1913 (Borgeson 1974). Also in 1913, anglers saw the minimum size limit reduced to 178 mm (7 inches) on the Au Sable River, the statewide daily creel limit reduced to 35 fish per day, and the statewide possession limit reduced to 50 fish per person.

An account of the quality of trout fishing in North Branch of the Au Sable River around the turn of the century was given by Mershon (1923). He testified to a decline of brook trout fishing quality over the period between 1900 to 1920.

> After the grayling were nearly all gone [from Lower Peninsula], the only remaining ones being in the Black River, we began fishing on the North Branch of the Au Sable, the most wonderful trout stream in the world in its day, and it would be yet if it were not fished to death. It has been advertised and commercialized until at the present time during the trout season one can not make a cast without hooking someone on his back cast. They fish with spinners, trolling hooks, worms and minnows, as well as flies, and it just can not stand it any more, but when I first knew it, it was a wonder.
>
> There wasn't a rainbow or anything else in there; it was before the days of the cannibal of all cannibals

> -- the German brown trout. When Avery appeared on the bank and hollered to me I had just landed a 16-inch [406-mm] brook trout, and at the cast before that had put into my creel one 14-inch [356-mm] in length. Think of that now, ye anglers of the North Branch. What would you give for two such fish in one afternoon, or in one season, for that matter. ...There was no limit as to the number one might take, the only limit being how many one could carry or wanted. The state law said that anything under 6 inches [152 mm] must be put back, but on the North Branch we rarely got anything under 8 inches [203 mm]. Later on an 8 inch [203 mm] law was put into effect, and fly fishing only allowed on that stream. A splendid law, and it should have been maintained, for while it was in operation the trout increased tremendously. Native trout had a chance to spawn and reproduce and we were not dependent entirely upon hatcheries for stocking the stream, but our legislators couldn't let well enough alone, and after a few years of practical demonstration of trout streams regulated in this way, they repealed the law, and it is as I stated a while back, no longer worth fishing.

In 1922, a year after the Department of Conservation was created, a 203-mm (8-inch) limit was again placed on the North Branch of the Au Sable with a creel limit of 20 fish. In the following year the statewide creel limit was reduced from 35 to 25 fish and the possession limit decreased from 50 to 40 fish.

Michigan legislature passed the Discretionary Powers Act (Act 230) in 1925 giving Conservation Commission authority to impose more restrictive regulations if necessary to preserve a species. Under this act most trout streams were closed to the taking of brook trout for 5 years beginning May 1, 1926. However, a few streams remained open, and on those the creel limit was 15 fish per day with a possession limit of 25 trout. In 1929, the creel and possession limits were reduced to 15 trout. The 5-year closing order on brook trout which was supposed to terminate in 1931 was reinstated for an additional 5 years. The closing order was terminated early, however, at the end of 1933. The long-term trend toward more restrictive regulations continued, and in 1945 the creel limit on brook, brown, and rainbow trout became 15 fish or 10 pounds and 1 fish.

Early field investigations

The Discretionary Powers Act (Act 230) of 1925 was amended in 1945 to give the Conservation Commission authority to designate as many as 20 lakes and 10 streams of the state for experimental fishing regulations. The 1945 amendment was the start of an era lasting about 20 years in which different "special" regulations were imposed on a number of Michigan trout streams while their fisheries were monitored by state research biologists. Most of these studies were conducted in trout research areas which were established on Hunt Creek, Montmorency County, in 1939; Rifle River, Ogemaw County, in 1945; and Pigeon River, Otsego County, in 1949. In these areas, anglers were required to report all fish creeled, and population analyses were conducted to determine the impact of the harvest.

The first experimental size limit studied under the Discretionary Powers Act was a 152-mm (6-inch) minimum limit on brook trout in Hunt Creek between the years 1945 and 1950. The objective was to determine the results of reducing the size limit on a small stream with slow-growing brook trout from a 178-mm (7-inch) limit, then in effect statewide. Shetter and Proshek (1953) summarized this experiment as follows: (1) successful angler trips and catch per hour increased under the 152-mm (6-inch) limit; (2) total annual numbers of trout harvested increased by 245%; and (3) total annual yield in weight increased by 166%. In spite of these seemingly favorable results, Shetter and Proshek made it very clear that they were not in favor of the 152-mm (6-inch) limit. First, it was thought that a 152-mm (6-inch) limit would adversely affect reproduction:

> Heavy angling pressure under such a limit could make inroads on this stock, and reduce the number of eggs laid down, which in turn could eventually lower the numbers of creel-sized fish available for angling.

They cite Cooper (1952) and credit him with demonstrating that angling continually removes faster growing members of a brook trout population:

> E. L. Cooper's studies (1952, in press) on the Pigeon River indicate strongly that even a 7-inch [178-mm] size limit is probably too low. ... Reduction of the size limit an additional inch merely aggravates the situation, and protects only the slowest-growing runts with less egg-producing capacity.

Finally, they make these recommendations:

> The 6-inch [152-mm] regulation did not provide fishing of a type that would be classed as sporting. It attracted novice anglers, and to some degree the "meat-hunters." Where a brook trout stream has a reasonable capacity to grow fish, such a regulation should not be considered. Only where growth and population studies combined with creel census data demonstrate conclusively that a high percentage of population goes unharvested should lowering the minimum size limit to 6 inches [152 mm] be utilized as a management tool.

It appeared that E. L. Cooper's work (Cooper 1949) set the stage for a movement toward more restrictive regulations (i.e., higher size limits and more gear restrictions). He maintained that the quality of brook trout fishing had declined in recent years (1940's) under the 178-mm (7-inch) minimum limit. Presumably this was a further decline from the one mentioned earlier by Mershon (1923).

Cooper (1952) demonstrated that brook trout in Gangle Lake, Montmorency County, and Pigeon River, Otsego County, exhibited Lee's phenomenon. The most logical explanation for this phenomenon was that the larger individuals in each age group experienced a higher mortality rate than the smaller individuals. Cooper went on to show that angling was probably the factor responsible for the phenomenon in these populations. His data showed that angling was selective in cropping the larger individuals of each age group. However, Lee's phenomenon and selective cropping by anglers was not significant for the Pigeon River brown trout population.

Cooper (1952) said that if selective breeding applies to wild fish as it does to hatchery fish, then wild brook trout are being continually selected for slow growth under present laws. The results of Cooper's studies suggested that more restrictive fishing regulations for brook trout should be investigated.

During the same period as E. L. Cooper's studies, D. S. Shetter and L. N. Allison were conducting their classic studies on hooking mortality. They found that trout hooked with artificial flies experienced far lower mortality after being released than trout hooked with natural bait (Shetter and Allison 1955). Their results combined with Cooper's were the impetus for the many studies conducted over the next 15 years (1950-65) which evaluated the impact of higher size limits, lower creel limits, and fly-fishing-only regulations (Shetter, Whalls, and Corbett 1954; Gowing 1954; Schultz 1957a and 1957b; Shetter 1957a and 1957b; Cooper, Shetter, and Hayne 1959; Cooper, Shetter, and Alexander 1961, 1962, and 1963; Shetter and Alexander 1965 and 1966; Shetter 1969; Latta 1973; and Alexander and Ryckman 1976). Shetter (1957a) stated that the objective of these special regulations was, "to provide the maximum sporting opportunities, over a stock of wild trout, for the greatest possible number of anglers." In his results for that year Shetter adds, "to evaluate the special regulations (higher size limit, flies only) on the North Branch [Au Sable], one must consider abstract values as well as the catch of trout. Anglers have the fun of catching many sublegal trout (7" to 9") [178 to 229 mm] which they must release, and this is of real value, especially when highly prized large fish can be kept for the creel."

Cooper, Shetter, and Hayne (1959) summarized the results of special angling restrictions on the North Branch, South Branch, and Mainstream of the Au Sable, Little South Branch of the Pere Marquette, Pigeon River, and Hunt Creek. They concluded that a flies-only restriction with higher size limits greatly reduced fishing pressure; and that more trout seemed to be present in the special-regulation waters, but those waters appeared to be better trout habitat. They were unable to determine if the greater trout numbers were due to regulations or to the seemingly better habitat in these areas. To answer this question they recommended reversing the special and normal regulation sections on the North Branch of the Au Sable. This recommendation was followed in 1961 and a new study was conducted to evaluate the results.

During the study on the North Branch, spring population estimates were obtained for the first time in 1961. Biologists were greatly concerned about the results of spring estimates. Data seemed to indicate that over-winter mortality of trout was extremely high. They surmised that predation by mergansers was the primary cause of the winter loss. Cooper, Shetter, and Alexander (1961) wrote in their progress report, "The problem we now face is to see if the over-winter loss can be prevented, and, if so, this might enhance any positive effects of the special regulations." The next year (1962) G. R. Alexander started an intensive investigation on food habits of vertebrate predators on the North Branch (Alexander 1977a and 1977b).

In general, the studies of the 1960's continued testing the effects of three basic types of angling restrictions: (1) flies-only rules, (2) reduced creel limits, and (3) increased minimum size limits. Interpretation of experimental results were often confounded by variations in trout abundance which were unrelated to the regulation changes. Also, many of the experiments tested two or more types of regulation changes simultaneously (e.g., increased size limits plus flies-only rules). Thus, it was not obvious which type of regulation was responsible for changes occurring in the fisheries.

However, several investigators did separate the effects of the different types of regulations. Shetter and Alexander (1962) and Hunt (1964) tested flies-only rules without changing creel or size limits. Latta (1973) tested flies-only rules and changes in creel limits separately on the Pigeon River brook and brown trout fishery. His results indicated that neither of these regulations met their proposed objectives. Concerning the flies-only rule he reported:

> The primary objective of a flies-only regulation
> is to reduce hooking mortality of trout smaller
> than the legal minimum size and thus through

> increased recruitment, increase future catch. The secondary objective is to increase the number of undersized fish available to be caught and released during the fishing season. This did not happen in Section C plus D at the Pigeon River. ... In all three experiments [referring to Shetter and Alexander (1962), Hunt (1964), and Latta (1973)] the most obvious change, with imposition of the flies-only regulation, was a dramatic decrease in fishing pressure. It appears that at the present time the flies-only regulation is operating in a sociological manner to create a limited entry fishery. No biological gain has yet been demonstrated. ... Of necessity, fishery managers practice a great deal of sociology, but they should acknowledge and not ignore the underlying biology.

Concerning the reduced creel limit Latta (1973) wrote:

> Limits to the number of fish that an angler may have in his possession (or creel) are imposed (1) to distribute the catch more equally among the anglers; and (2) to limit the total catch. In the present study neither of these objectives was attained in changing the creel limit from 2 to 5 fish.

In contrast to flies-only rules and reduced creel limits, changes in minimum size limits were shown to be effective in lowering angling and total mortality in trout populations (Shetter 1969; Hunt 1970). Hunt (1970) concluded from his studies of brook trout in Lawrence Creek, Wisconsin:

> The size limit, if wisely applied is the best single regulation for preventing excessive angler harvest of brook trout populations. The size limit applies to every trout caught, and it can be related to a rather stable biological parameter, growth rates of the trout populations.

Recent studies of regulations

The field studies on trout streams yielded a large fund of biological data concerning the effects of fishing regulations, and investigations on other sport fishes produced similar information concerning their fisheries. There was a need to assimilate all this information so that it could be used for improving fisheries management. One method of incorporating the information into a usable framework was through mathematical modeling. Size limit regulations were shown to be an effective means by which management could achieve the maximum benefit from a fishery resource, and mathematical modeling studies were conducted for several important sport fisheries in Michigan beginning in the early 1970's to determine which size limits were best for them: northern pike (Latta 1972), bluegills (Schneider 1973), largemouth bass (Latta 1974), smallmouth bass (Latta 1975), and walleyes (Schneider 1978). Field studies continued to be the basis for management decisions, but mathematical modeling studies enhanced and expanded the interpretation of field results.

Analyses of regulations for the sport fishes mentioned above all used Ricker's yield equation (Ricker 1975) which was incorporated into a computerized simulation model by Paulik and Bayliff (1967). This general fisheries model has a strong theoretical base and a fairly good record for reliability. It requires compilation and integration of quantitative data from many independent studies on the species of interest (i.e., studies measuring growth, mortality, exploitation, fecundity, and recruitment rates). In a matter of minutes with a computer this model enables simulation of experiments with fishing regulations which would otherwise take years of field study.

However analyses with Ricker's yield equation are not without problems and disadvantages. Data of the type required by the model may be incomplete or unavailable for the species of interest. An equilibrium state must be assumed for the simulated fishery, that is, a static system with constant growth, mortality, and recruitment. But perhaps the major disadvantage for its use on trout stream fisheries is that the model was developed primarily for commercial fisheries. As a result, the main purpose of the model is to predict yield in weight from a fish population exploited at different rates and size limits. Yield in weight is a major output of any fishery, but recent studies of recreational fishing have shown that many anglers consider other aspects of the fishing experience just as important as either yield in weight or numbers (Moeller and Engelken 1972; Hoagland and Kennedy 1974). Despite these findings, most recreational fisheries are managed on a maximum yield basis (Bennett et al. 1978). The reason may be that few quantitative models address other types of fisheries outputs, such as catch-and-release frequency.

In view of these disadvantages and the enormous value of Michigan's trout stream fishery, a project was undertaken to design and develop a quantitative model which would specifically address statistics of interest in recreational fisheries (e.g., hooking mortality and catch-and-release frequency), as well as numbers and weight of trout harvested. Two computerized trout population simulators were developed: (1) TROUT.DYNAMICS which simulated wild trout fisheries; and (2) STOCKED.TROUT which simulated fisheries maintained by stocking. Details of model development were reported by Clark, Alexander, and Gowing (1979). In this study we used the simulators to predict statewide effects of imposing different minimum size limit regulations.

Simulation analysis of minimum size limits

Methods

Three types of brook and brown trout fisheries were defined and simulated--quality main streams with fast growth and good natural reproduction, quality tributary streams with slow growth and good natural reproduction, and marginal streams with extremely fast growth but insignificant reproduction. Most trout streams in Michigan can be assigned to one of these categories. Both brook and brown trout population data including growth, mortality, fecundity, and sexual maturity information were taken from North Branch of the Au Sable River for main stream simulations (Shetter 1969; Alexander 1974, 1977b). Population data for tributary brook trout simulations were taken from Hunt Creek (McFadden et al. 1967; Shetter 1969), and data for tributary brown trout simulations were obtained from Gamble Creek (Gowing 1975) and Platte River (Taube 1976).

Little quantitative data were found for marginal trout stream fisheries. Reasonable estimates for growth and mortality were made based on information available. Characteristics of the "typical" marginal trout fishery were defined as: (1) insignificant reproduction--fishery maintained by annual stocking of 127- to 152-mm (5- to 6-inch) fingerlings in early April; (2) rapid growth rates; and (3) high natural mortality from planting time to first fall (70% dying) and average natural mortality thereafter (Fig. 1).

It was necessary to modify the original model, TROUT.DYNAMICS (Clark, Alexander, and Gowing 1979), in order to simulate trout stocking. The modified version was named STOCKED.TROUT. First and second year survival rates were constant in STOCKED.TROUT, rather than density dependent as in TROUT.DYNAMICS. Each year the stocked population was seeded with an appropriate number of 127- to 152-mm (5- to 6-inch) fingerlings in lieu of reproduction.

Size limits ranging from 152 to 229 mm (6 to 9 inches) were tested for brook trout and from 152 to 305 mm (6 to 12 inches) for brown trout. Catch-and-release (no-kill) regulations were also simulated for both species. Conditional fishing rates (m as defined by Ricker 1975) were applied as follows: (1) main stream, brook trout = 0.85, brown trout = 0.50; (2) tributary stream, brook trout = 0.85, brown trout = 0.30; and (3) marginal stream, brook trout = 0.85, brown trout = 0.70. Hooking mortality rates used were 0.30 for brook and 0.20 for brown trout. Based on published and unpublished data from across the state, we believe these fishing rates and hooking mortality rates are typical for Michigan, but if incorrect, they probably err on the high side of the actual rates. Estimates of numbers harvested, numbers caught and released, weight yielded to creel, and weight caught and released were made for each species and fishery type.

Results

Quality trout streams.--The following general relationships occurred for all quality trout fisheries: (1) as size limit increased, catch of trout in numbers and weight harvested decreased; (2) as size limit increased, catch and release of trout in numbers and weight increased; (3) as size limit increased, total catch in numbers (i.e., number harvested plus number caught and released) and total yield in weight (i.e., weight harvested plus weight released) increased; (4) as size limit increased, numbers of larger trout harvested increased; (5) total catch and yield were greatest with catch-and-release (no-kill) regulations. Catch and yield predictions for each species and fishery type are presented in Tables 1 through 4.

Marginal trout streams.--Catch and yield statistics for marginal brook and brown trout fisheries are presented in Tables 5 and 6. Trends in catch and yield were similar to those for quality streams, assuming stocking rates were maintained. Stocking rate used for simulations was 740 fingerlings per hectare per year.

Percent of stocked fish returned to creel for each size limit was estimated by dividing mean annual catches predicted for each age group by the numbers stocked (Table 7).

Statewide projections.--Using the size limits in effect in 1978 as a baseline, percent changes in harvest for each of the three fishery types and their simple, unweighted means were calculated from model projections (Table 8). For example, if the size limit on brown trout was reduced to 178 mm (7 inches) from the 254 mm (10 inches) in effect in 1978, harvest would be expected to increase by 221% in quality main streams, 351% in quality tributaries, and 251% in marginal streams. If one assumes that each fishery type contributes equally to the statewide brown trout harvest, it would be expected to increase by 274% (Table 8).

Estimates of present harvest of brook and brown trout from Michigan streams were obtained from Department of Natural Resources mail surveys for 1976. These estimates were based on a sample of 1% of Michigan anglers and are believed to be fairly accurate for areas the size of Michigan's fishery management regions (Table 9, Fig. 2). Projections of numbers harvested under different minimum size limits were obtained by multiplying present harvest (Table 9) by mean percentage changes predicted for each species (Table 8).

Changes in size limits produced radically different effects on total trout harvest for the different management regions (Figs. 3-5). For example, adopting a uniform size limit of 203 mm (8 inches) for both brook and brown trout would increase total trout harvest for Regions II (north lower Peninsula) and III (south lower Peninsula) by 207,800 and 85,400 trout, respectively. Reduction of brook trout harvest due to increasing the limit from 178 to 203 mm (7 to 8 inches) would be more than compensated by an increase in brown trout harvest due to reducing brown trout limit from 254 to 203 mm (10 to 8 inches) (Figs. 4 and 5). However, total trout harvest in Region I (Upper Peninsula) was comprised primarily of brook trout (Table 8). Adoption of a 203-mm (8-inch) limit in Region I would cause a much greater loss in brook trout harvested than would be gained in brown trout harvested. The net result is that total trout harvested in Region I would be reduced by nearly 40% or 243,000 trout (Fig. 3).

Discussion

Biological factors alone cannot define an optimum set of regulations for Michigan trout streams. They merely place constraints upon the magnitude of benefits trout streams can provide. Our simulation results indicated that all minimum size limits 152 mm (6 inches) and above prevented brook and brown trout populations from being fished to extinction. Within these rather broad biological constraints, sociological criteria (e.g., traditions, angler preferences, economic factors, or regulation simplicity) must be used to define the objectives of trout management. When the objectives are defined then the best minimum size limits can be defined.

Model results seem fairly consistent with empirical data from field investigations in Michigan and elsewhere. One of the major problems with interpreting and using these results is in determining possible effects of factors not directly addressed by the model. For example, TROUT.DYNAMICS is a single species model, so effects of regulations on species interactions are left open for debate. Most Michigan trout streams are multi-species fisheries with brook and brown trout occurring together or with other salmonids such as rainbow trout, chinook salmon, and coho salmon. Concern has been expressed that brook trout may be declining in Michigan streams as a result of competition with brown trout (Coopes 1974; Alexander et al. 1979). Problems of this type must be considered, as well as model results, when evaluating fishing regulations.

Minimum size limits for Michigan trout streams were changed in 1979. Size limits of 203 mm (8 inches) for Lower Peninsula streams and 178 mm (7 inches) for Upper Peninsula streams were adopted by the Michigan Natural Resources Commission. The major reasons for adopting the new size limits were: (1) they allowed better utilization of tributary brown trout resource; (2) they provided a reasonable compromise between total numbers harvested and production of large ("trophy") trout; (3) they reduced possible competitive advantages brown trout may have over brook trout; and (4) they were simple for anglers to understand and conservation officers to enforce.

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Table 1.--Length frequencies of brown trout caught from a quality mainstream fishery at different minimum size limits (millimeters; inches in parentheses). Numbers caught and released appear in parentheses. Fishing rate (m) was 0.50.

Length range (millimeters)	Number per hectare caught at size limit 152(6)	178(7)	203(8)	229(9)	254(10)	305(12)	No kill
102-126	0.0 (6.8)	0.0 (7.1)	0.0 (7.3)	0.0 (7.5)	0.0 (7.6)	0.0 (7.8)	0.0 (7.9)
127-151	0.0 (12.6)	0.0 (13.5)	0.0 (14.0)	0.0 (14.4)	0.0 (14.6)	0.0 (14.9)	0.0 (15.1)
152-177	12.6 (0.0)	0.0 (13.7)	0.0 (14.6)	0.0 (15.0)	0.0 (15.2)	0.0 (15.5)	0.0 (15.6)
178-202	12.0 (0.0)	13.2 (0.0)	0.0 (14.4)	0.0 (15.1)	0.0 (15.3)	0.0 (15.5)	0.0 (15.6)
203-228	8.0 (0.0)	9.1 (0.0)	10.1 (0.0)	0.0 (10.8)	0.0 (11.1)	0.0 (11.3)	0.0 (11.3)
229-253	4.7 (0.0)	5.4 (0.0)	6.2 (0.0)	6.7 (0.0)	0.0 (7.2)	0.0 (7.6)	0.0 (7.6)
254-278	3.5 (0.0)	4.0 (0.0)	4.7 (0.0)	5.3 (0.0)	5.8 (0.0)	0.0 (6.4)	0.0 (6.6)
279-304	2.8 (0.0)	3.2 (0.0)	3.8 (0.0)	4.4 (0.0)	4.9 (0.0)	0.0 (5.8)	0.0 (6.1)
305-329	2.0 (0.0)	2.3 (0.0)	2.7 (0.0)	3.1 (0.0)	3.5 (0.0)	4.4 (0.0)	0.0 (5.0)
330-355	1.0 (0.0)	1.2 (0.0)	1.4 (0.0)	1.6 (0.0)	1.9 (0.0)	2.5 (0.0)	0.0 (3.2)
356-380	0.3 (0.0)	0.4 (0.0)	0.4 (0.0)	0.5 (0.0)	0.6 (0.0)	0.8 (0.0)	0.0 (1.3)
381-405	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	0.2 (0.0)	0.3 (0.0)	0.0 (0.5)
406+	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	0.2 (0.0)	0.2 (0.0)	0.3 (0.0)	0.0 (0.9)
Total catch	47.1 (19.4)	39.0 (34.3)	29.6 (50.3)	22.0 (62.8)	17.1 (71.0)	8.3 (84.8)	0.0 (96.7)
Yield in weight (kg/ha)	5.1 (0.4)	5.2 (1.0)	5.1 (1.9)	4.8 (3.0)	4.4 (4.0)	3.0 (6.6)	0.0 (11.0)

Table 2.--Length frequencies of brook trout caught from a quality main-stream fishery at different minimum size limits (millimeters; inches in parentheses). Numbers caught and released appear in parentheses. Fishing rate (m) was 0.85.

Length range (millimeters)	Number per hectare caught at size limit 152(6)	178(7)	203(8)	229(9)	No kill
102-126	0.0 (72.5)	0.0 (72.8)	0.0 (71.7)	0.0 (70.9)	0.0 (70.3)
127-151	0.0 (122.2)	0.0 (128.6)	0.0 (127.4)	0.0 (125.5)	0.0 (124.3)
152-177	81.8 (0.0)	0.0 (90.8)	0.0 (92.3)	0.0 (91.7)	0.0 (90.8)
178-202	32.1 (0.0)	38.2 (0.0)	0.0 (42.4)	0.0 (43.9)	0.0 (44.0)
203-228	8.1 (0.0)	11.1 (0.0)	13.9 (0.0)	0.0 (15.7)	0.0 (16.3)
229-253	1.6 (0.0)	2.5 (0.0)	3.7 (0.0)	4.5 (0.0)	0.0 (5.4)
254+	0.3 (0.0)	0.5 (0.0)	0.9 (0.0)	1.3 (0.0)	0.0 (2.2)
Total catch	123.9 (194.7)	52.3 (292.2)	18.5 (333.8)	5.8 (347.7)	0.0 (353.3)
Yield in weight (kg/ha)	6.4 (4.0)	3.8 (7.9)	1.9 (10.4)	0.8 (11.8)	0.0 (12.8)

Table 3.--Length frequencies of brown trout caught from a quality tributary fishery at different minimum size limits (millimeters; inches in parentheses). Numbers caught and released appear in parentheses. Fishing rate (m) was 0.30.

Length range (millimeters)	Number per hectare caught at size limit 152(6)	178(7)	203(8)	229(9)	254(10)	305(12)	No kill
102-126	0.0 (34.5)	0.0 (35.2)	0.0 (35.6)	0.0 (35.8)	0.0 (35.8)	0.0 (35.9)	0.0 (35.8)
127-151	0.0 (72.0)	0.0 (75.4)	0.0 (76.0)	0.0 (76.0)	0.0 (75.8)	0.0 (75.5)	0.0 (75.3)
152-177	63.3 (0.0)	0.0 (66.9)	0.0 (68.2)	0.0 (68.4)	0.0 (68.2)	0.0 (67.6)	0.0 (67.3)
178-202	46.4 (0.0)	50.0 (0.0)	0.0 (52.3)	0.0 (53.5)	0.0 (53.6)	0.0 (53.2)	0.0 (52.9)
203-228	33.0 (0.0)	36.6 (0.0)	39.1 (0.0)	0.0 (40.7)	0.0 (41.3)	0.0 (41.4)	0.0 (41.2)
229-253	21.8 (0.0)	24.5 (0.0)	26.8 (0.0)	27.9 (0.0)	0.0 (29.5)	0.0 (30.1)	0.0 (30.0)
254-278	13.1 (0.0)	14.9 (0.0)	16.5 (0.0)	17.9 (0.0)	18.8 (0.0)	0.0 (19.8)	0.0 (19.8)
279-304	6.9 (0.0)	7.8 (0.0)	8.7 (0.0)	9.6 (0.0)	10.3 (0.0)	0.0 (11.2)	0.0 (11.4)
305-329	3.0 (0.0)	3.4 (0.0)	3.8 (0.0)	4.3 (0.0)	4.7 (0.0)	5.2 (0.0)	0.0 (5.5)
330-355	1.1 (0.0)	1.3 (0.0)	1.5 (0.0)	1.6 (0.0)	1.8 (0.0)	2.1 (0.0)	0.0 (2.3)
356-380	0.4 (0.0)	0.5 (0.0)	0.5 (0.0)	0.6 (0.0)	0.7 (0.0)	0.8 (0.0)	0.0 (1.0)
406+	0.2 (0.0)	0.2 (0.0)	0.3 (0.0)	0.3 (0.0)	0.3 (0.0)	0.4 (0.0)	0.0 (0.5)
Total catch	189.2 (106.5)	139.2 (177.5)	97.2 (232.1)	62.2 (274.4)	36.6 (304.2)	8.5 (334.7)	0.0 (343.0)
Yield in weight (kg/ha)	22.9 (4.3)	20.6 (9.2)	17.5 (14.3)	13.4 (19.8)	9.4 (24.7)	3.1 (31.6)	0.0 (34.8)

Table 4.--Length frequencies of brook trout caught from a quality tributary fishery at different minimum size limits (millimeters; inches in parentheses). Numbers caught and released appear in parentheses. Fishing rate (m) was 0.85.

Length range (millimeters)	Number per hectare caught at size limit 152(6)	178(7)	203(8)	229(9)	No kill
102-126	0.0 (373.6)	0.0 (415.3)	0.0 (430.2)	0.0 (435.9)	0.0 (443.1)
127-151	0.0 (480.7)	0.0 (558.1)	0.0 (583.4)	0.0 (591.9)	0.0 (601.1)
152-177	199.5 (0.0)	0.0 (250.6)	0.0 (270.9)	0.0 (276.8)	0.0 (281.1)
178-202	60.6 (0.0)	85.6 (0.0)	0.0 (100.3)	0.0 (105.4)	0.0 (107.4)
203-228	15.6 (0.0)	26.1 (0.0)	34.1 (0.0)	0.0 (38.8)	0.0 (41.0)
229-253	4.6 (0.0)	8.8 (0.0)	13.6 (0.0)	18.2 (0.0)	0.0 (23.5)
254+	0.8 (0.0)	1.6 (0.0)	2.7 (0.0)	4.0 (0.0)	0.0 (6.9)
Total catch	281.1 (854.3)	122.1 (1224.0)	172.5 (1384.8)	22.2 (1448.8)	0.0 (1504.1)
Yield in weight (kg/ha)	14.0 (14.7)	9.1 (26.1)	5.4 (33.2)	3.1 (37.3)	0.0 (42.1)

Table 5.--Catch and yield values predicted by STOCKED. TROUT for brown trout fisheries in marginal streams with a conditional fishing rate of 0.70. Total catch was defined as the number caught and harvested plus the number caught and released. Total yield was similarly defined, but was measured in units of weight. The stream was stocked with 740 fingerlings per hectare ranging from 127 to 152 mm (5 to 6 inches) in length each year in early April.

Minimum size limit		Catch in numbers per hectare			Yield in kilograms per hectare		
mm	inches	Harvested	Caught and released	Total catch	Harvested	Caught and released	Total catch
152	6	512.5	0.0	512.5	81.7	0.0	81.7
178	7	502.8	17.6	502.4	81.2	1.1	82.3
203	8	408.4	175.2	583.6	80.3	12.9	93.2
229	9	309.7	316.8	626.5	75.9	24.9	100.8
254	10	200.0	470.3	670.3	67.0	46.6	113.6
305	12	124.4	579.2	703.6	58.9	67.8	126.7
No kill		0.0	782.7	782.7	0.0	185.8	185.8

Table 6.--Catch and yield values predicted by STOCKED. TROUT for brook trout fisheries in marginal streams with a conditional fishing rate of 0.85. Total catch was defined as the number caught and harvested plus the number caught and released. Total yield was similarly defined, but was measured in units of weight. The stream was stocked with 740 fingerlings per hectare ranging from 127 to 152 mm (5 to 6 inches) in length each year in early April.

Minimum size limit		Catch in numbers per hectare			Yield in kilograms per hectare		
mm	inches	Harvested	Caught and released	Total catch.	Harvested	Caught and released	Total catch
152	6	301.9	494.1	796.0	15.1	11.9	27.0
178	7	141.8	751.0	892.3	10.6	22.7	33.3
203	8	63.2	877.3	940.5	6.6	30.2	36.8
229	9	28.3	928.5	957.0	4.1	34.6	38.7
No kill		0.0	970.0	970.0	0.0	40.2	40.2

Table 7.--Percent of stocked fish returned to the creel as predicted for different size limits in marginal streams.

Minimum size limit		Age				Total return
mm	inches	I	II	III	IV	
Brown trout						
152	6	56.6	10.6	1.7	0.3	69.2
178	7	55.2	10.6	1.7	0.2	67.7
203	8	41.2	11.5	2.1	0.3	55.1
229	9	26.7	12.5	2.2	0.3	41.7
254	10	9.4	14.6	2.5	0.3	26.8
279	12	0.0	13.1	3.2	0.5	16.8
Brook trout						
152	6	30.6	9.4	0.7	<0.1	40.7
178	7	6.9	10.7	1.4	<0.1	19.0
203	8	0.4	5.9	2.1	0.1	8.5
229	9	0.0	1.6	2.0	0.2	3.8

Table 8.--Estimated percent of the number of trout creeled at size limits in effect in 1978, brook trout--178 mm (7 inches) and brown trout-- 254 mm (10 inches), which would be creeled at other size limits.

Minimum size limit		Brown trout				Brook trout			
		Top quality		Mar-ginal stream	Mean	Top quality		Mar-ginal stream	Mean
mm	inches	Main-stream	Trib-utary			Main-stream	Trib-utary		
152	6	278	474	256	336	188	212	213	204
178	7	221	351	251	274	100	100	100	100
203	8	162	251	204	206	50	52	45	49
229	9	120	173	155	149	23	30	20	24
254	10	100	100	100	100				
305	12	53	26	62	47				

Table 9.--Michigan Department of Natural Resources mail survey estimates of numbers of brook and brown trout harvested from Michigan streams in 1976.

Management region	Number of trout		
	Brook	Brown	Total
I (Upper Peninsula)	596,800	58,240	655,040
II (North Lower Peninsula)	604,160	486,720	1,090,880
III (South Lower Peninsula)	61,280	110,080	171,360
State total	1,262,240	655,040	1,917,280

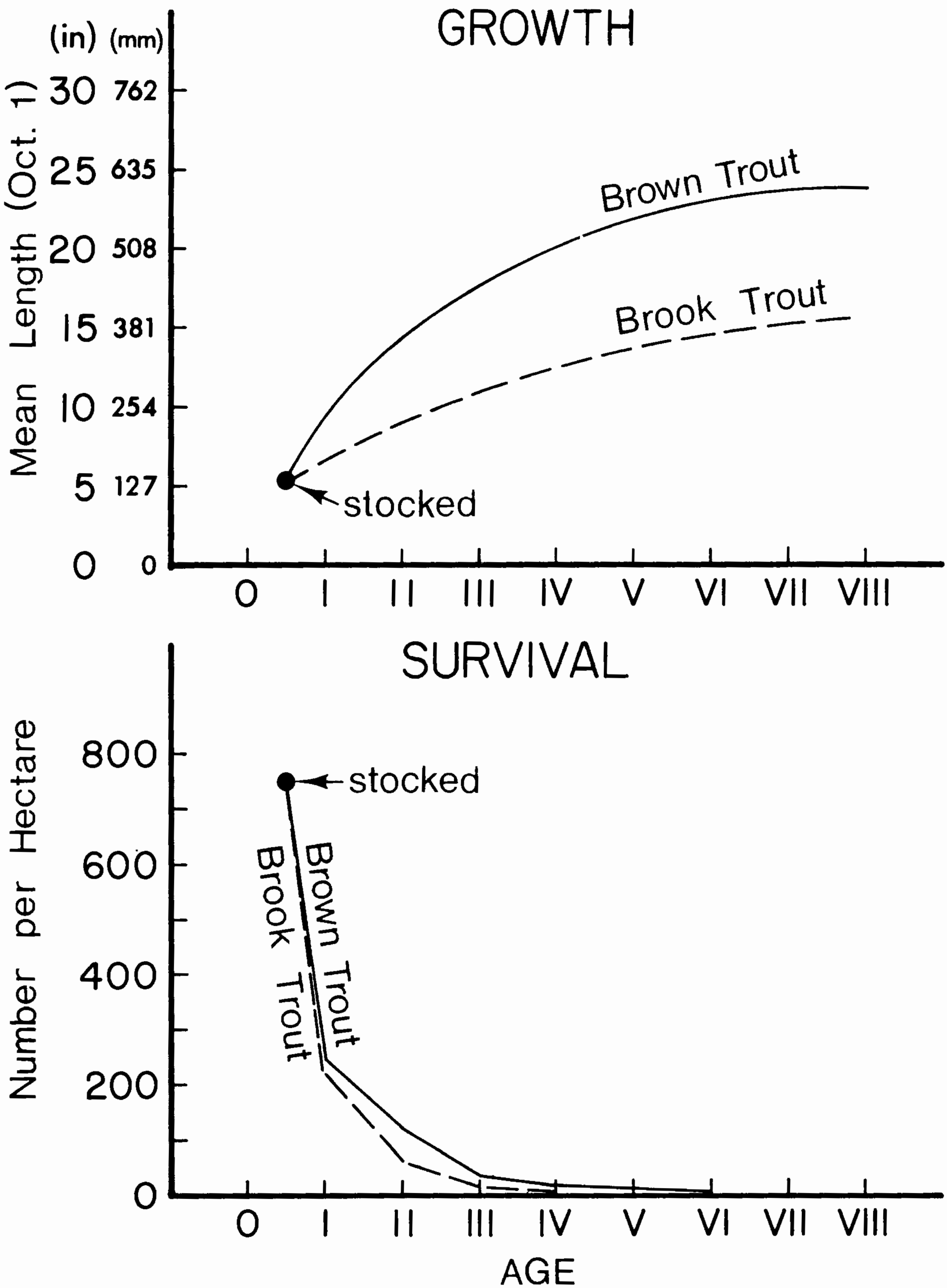

Figure 1.--Growth and survival of trout used for simulation of marginal streams in the analysis of minimum size limits.

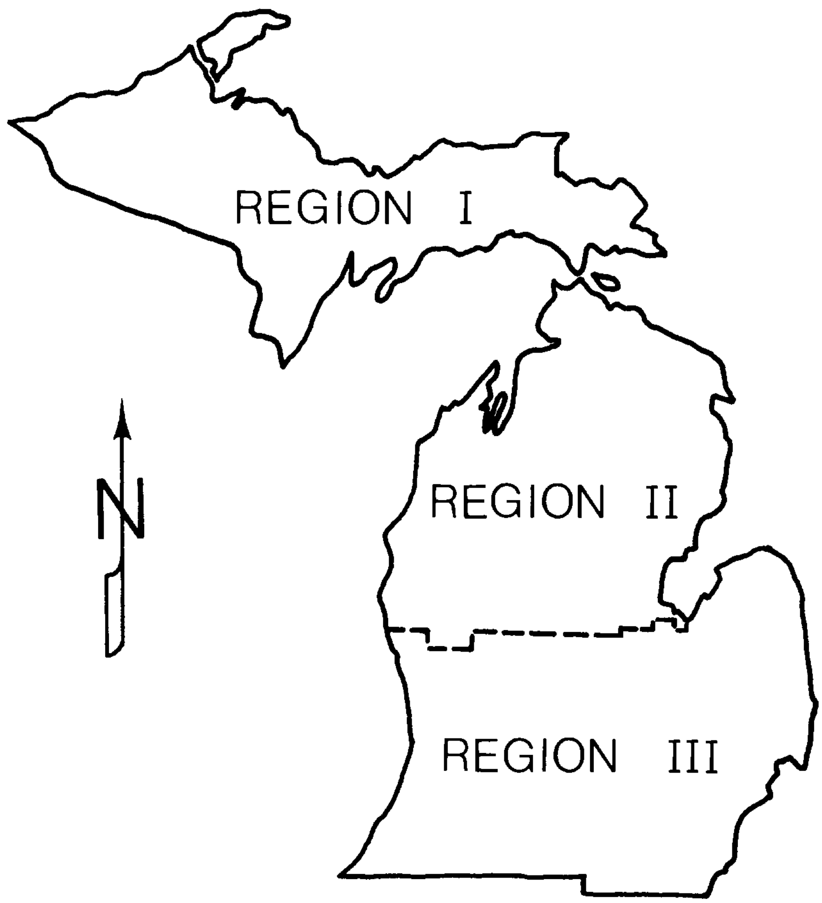

Figure 2.--Fishery management regions in Michigan.

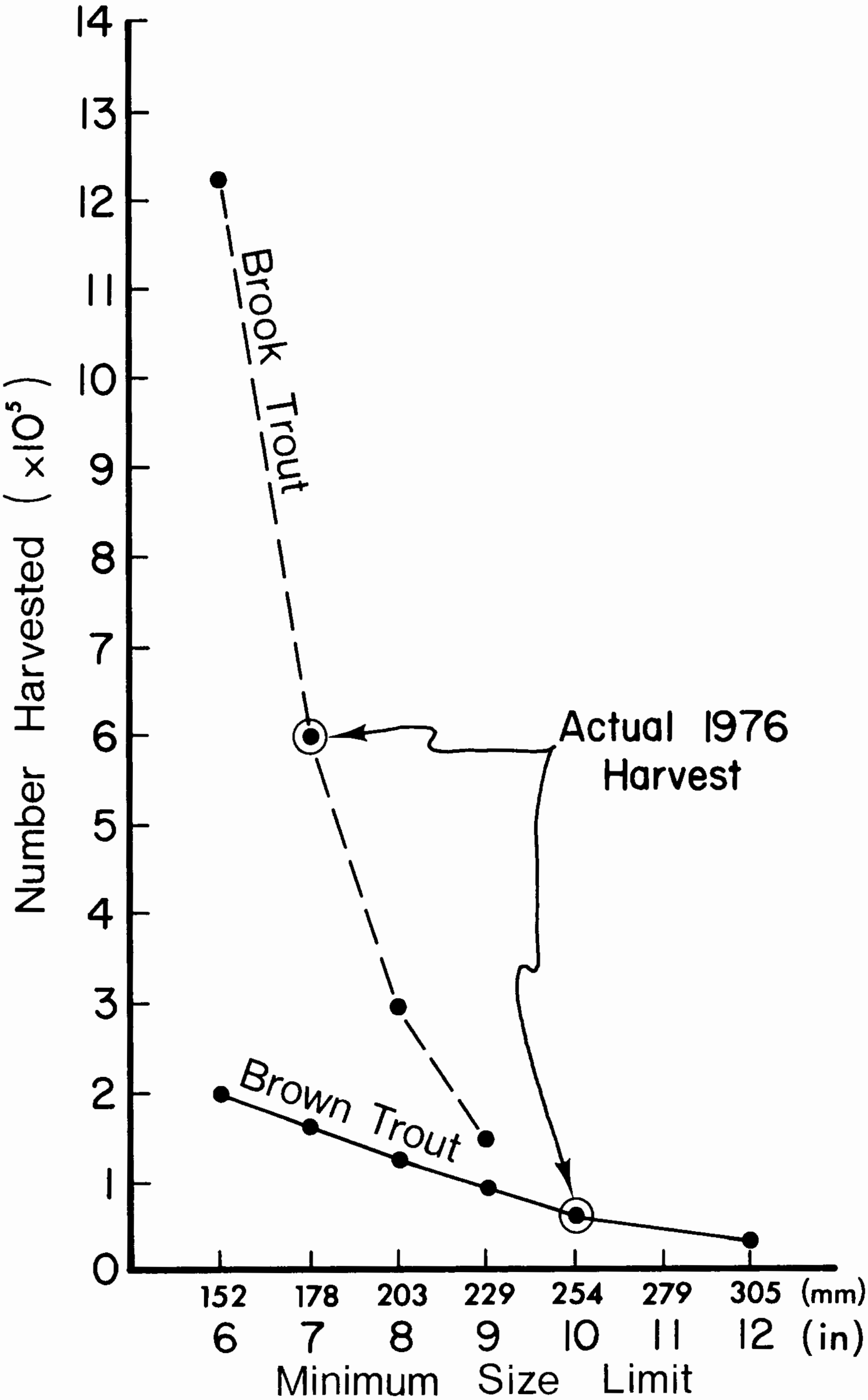

Figure 3.--Annual harvest of brook and brown trout expected from fisheries management Region I under different minimum size limits.

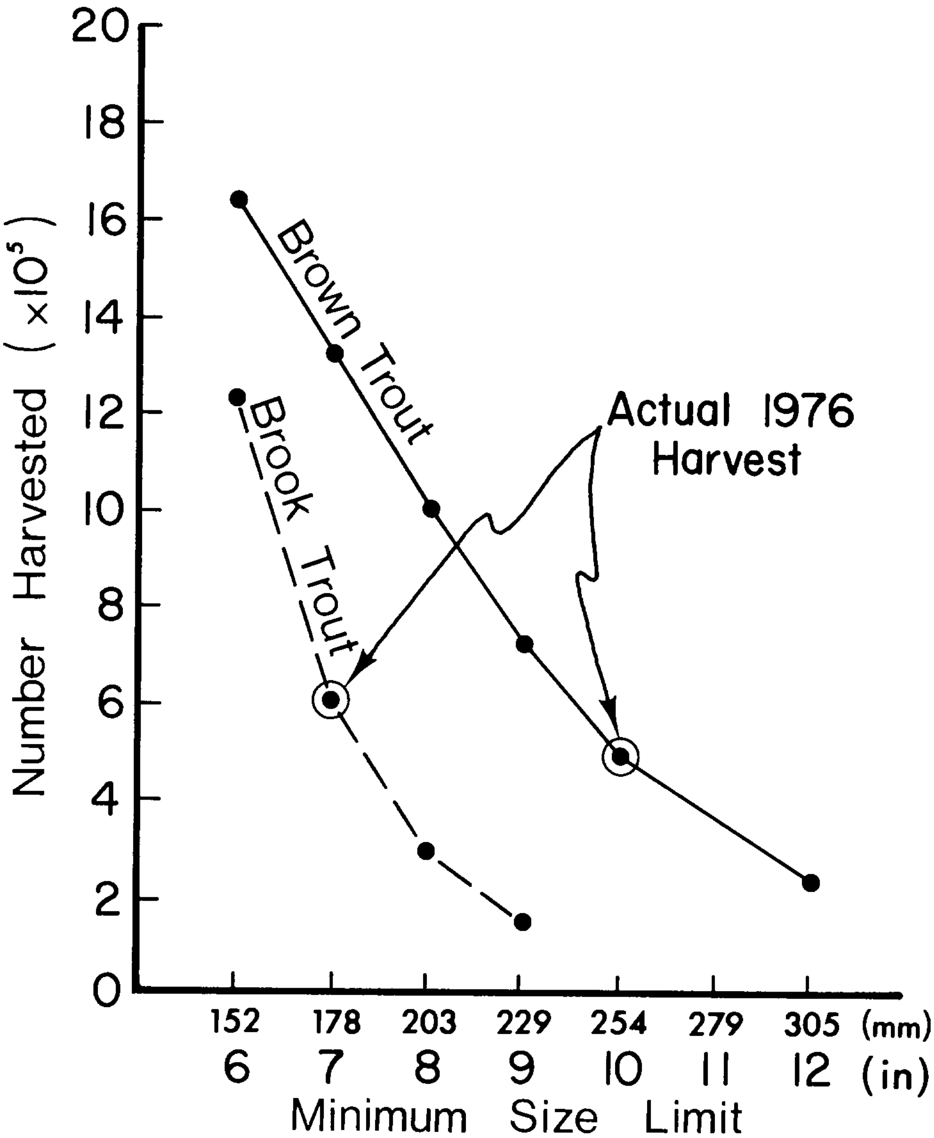

Figure 4.--Annual harvest of brook and brown trout expected from fisheries management Region II under different minimum size limits.

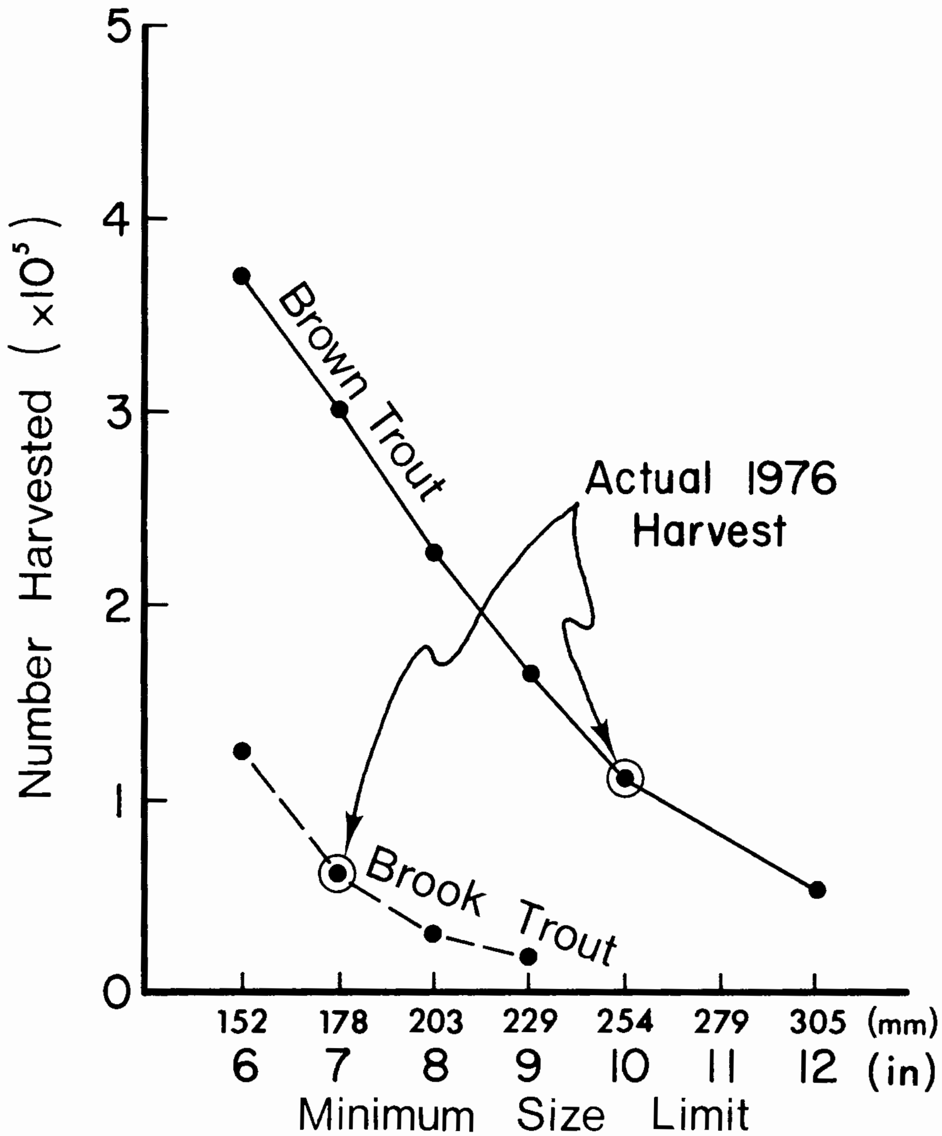

Figure 5.--Annual harvest of brook and brown trout expected from fisheries management Region III under different minimum size limits.

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