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A History and Evaluation of Regulations for Brook Trout and Brown Trout in Michigan Streams

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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. Those studies indicated that a minimum size limit was the most effective regulation for controlling exploitation of trout.

In this study, minimum size limits for brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) in Michigan streams were evaluated through mathematical modeling. Minimum size limits ranging from 152 to 229 mm were tested for brook trout and from 152 to 305 mm for brown trout. Catch-and-release (no-kill) regulations were also simulated for both species. Maximum yield in numbers and weight of trout harvested (legal-size fish killed) was obtained at a 152-mm minimum limit for both species. Yield in numbers and weight of trout caught and released (sublegal fish returned to water alive) 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.

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 et al. (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 idea of maximum yield, 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.

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 trout in less than an hour, while another person may prefer to spend all day on the stream and can be satisfied only by catching trout larger than 457 mm. Optimum yield must be defined through analysis of such angler preferences. 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 trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) populations in Michigan streams. The objectives of the study were to: (1) review the history and past research regarding effects of different regulations on stream trout fisheries; and (2) use mathematical modeling techniques and other pertinent information to help evaluate various alternative regulations, particularly the statewide minimum size limit.

History of Trout Stream Regulations

In 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 nonobservance 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 minimum limit on Arctic grayling (*Thymallus arcticus*) 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 on the Au Sable River. In 1903, the statewide size limit was raised to 178 mm for brook trout, brown trout, rainbow trout (*Salmo gairdneri*), landlocked salmon (*Salmo salar*), and grayling. Fifty fish per day with 100 fish in possession were permitted. The first flies-only rule was adopted with a 203-mm 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 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.

Clearly, the trend in regulations during this early period was toward more restrictive laws. No quantitative biological data are available, but one must assume that the reason for this trend was a real or perceived reduction in the quality of fishing. At least one author from that period, Mershon (1923), testified to such a decline in trout-fishing quality in Michigan from 1900 to 1920.

In 1922, one year after the Department of Conservation was created, a 203-mm limit was again placed on the North Branch of the Au Sable River 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.

The Michigan legislature passed the Discretionary Powers Act (Act 230) in 1925 giving the 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 beginnning 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 1930, 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. This closing order was terminated, however, at the end of 1933. The long-term trend toward more restrictive regulations continued, and in 1942 the creel limit on brook trout, brown trout, and rainbow trout was 15 fish or 10 pounds and one fish. In 1952, it was 10 fish or 10 pounds and one fish, and in 1969, the creel limit for brown trout was only five fish. A statewide minimum size limit of 178 mm was maintained for both species until 1969 when it was raised to 254 mm for brown trout.

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 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 those studies were conducted in trout research areas established on Hunt Creek, Montmorency County, in 1939; Rifle River, Ogemaw County, in 1945; and Pigeon River, Otsego County, in 1949. In those 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 minimum limit on brook trout in Hunt Creek between the years 1945 and 1950. The objective was to determine the results of reducing the statewide size limit (178-mm) on a small stream with slow-growing brook trout. Shetter and Proshek (1953) summarized this experiment as follows: (1) successful angler trips and catch per hour increased under the 152-mm 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 limit. They suggested that a 152-mm limit would adversely affect reproduction, and that it may have a detrimental effect on population genetics by creating a selective pressure against larger fish. To support their concern about genetics, they cite Cooper (1952) who demonstrated that angling continually removes faster-growing members of a brook trout population. Finally, their opinion was that the 152-mm size limit did not provide fishing of a type that could be classed as sporting, and they concluded that the regulation should not be considered for widespread use by management.

Apparently, 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 minimum limit.

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) concluded 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 his studies suggested that more restrictive fishing regulations for brook trout should be investigated.

At the same time, D. S. Shetter and L. N. Allison conducted 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 16 years (1950–1965) which evaluated the impact of higher size limits, lower creel limits and fly-fishing-only regulations (Shetter et al. 1954; Gowing 1954; Schultz 1957a, 1957b; Shetter 1957a, 1957b; Cooper et al. 1959; Cooper et al. 1961, 1962, 1963; Shetter and Alexander 1965, 1966; Shetter 1969; Latta 1973; 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." Shetter added, "to evaluate the special regulations (higher size limit, flies only) on the North Branch [Au Sable River], one must consider abstract values as well as the catch of trout. Anglers have the fun of catching many sublegal trout (7" to 9") [178–229 mm] which they must release, and this is of real value, especially when highly prized large fish can be kept for the creel."

Cooper et al. (1959) summarized the results of special angling restrictions on the North Branch, South Branch, and the main Au Sable rivers, Little South Branch of the Pere Marquette River, 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 also appeared to have 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 River. 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 overwinter mortality of trout was extremely high. They surmised that predation by mergansers was the primary cause of the winter loss. Cooper et al. (1961) wrote in their progress report. "The problem we now face is to see if the overwinter loss can be prevented, and, if so, this might enhance any positive effects of the special regulations." In 1962, Alexander started an intensive investigation on food habits of vertebrate predators on the North Branch (Alexander 1977a, 1977b).

The studies of the 1960's continued to test 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 that occurred 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 trout and brown trout fishery. His results indicated that neither of these regulations met their proposed objectives. Concerning the flies-only rule, he reported that no biological gain could be demonstrated, but that the regulation operated in a sociological manner to create a limited-entry fishery. With regard to the creel-limit regulation, he could find neither a biological nor a sociological impact.

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."

Recent Studies of Regulations

The 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: northern pike (*Esox lucius*) by Latta (1972), bluegills (*Lepomis machrochirus*) by Schneider (1973), largemouth bass (*Micropterus salmoides*) by Latta (1974), smallmouth bass (*Micropterus dolomieui*) by Latta (1975), and walleyes (*Stizostedion vitreum*) by Schneider (1978). Field studies continued to be the basis for management decisions, but mathematical modeling studies enhanced and expanded the interpretation of field results.

All analyses of regulations for the sport fishes mentioned above 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 that would otherwise take years of fieldwork.

However, analyses with Ricker's yield equation are not without problems and disadvantages. The type of data 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, while the model was designed to calculate yield in weight from a fish population, it does not directly calculate other types of fisheries outputs. 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 that 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 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 et al. (1980). In this study we used the simulators to predict statewide effects of imposing different minimum size limit regulations.

Simulation Analysis of Minimum Size Limits

Three types of brook trout 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 poor reproduction. Most trout streams in Michigan can be assigned to one of these categories. Brook trout and brown trout population data (Table 1), including growth, mortality, fecundity, and sexual maturity information were taken from the North Branch of the Au Sable River (Shetter 1969; Alexander

TABLE 1.—*Annual natural mortality rates* (n) *and length parameters on October 1 of each year for each age group of brown trout and brook trout in the quality-main-stream category.*

Age	*n*	Length (mm) Mean	Shortest	Modal	Longest
Brown trout					
0		97	48	97	147
1	0.53	203	114	206	305
2	0.70	295	147	300	401
3	0.75	341	292	340	419
4	0.84	419	343	419	533
5	0.34	518	373	518	607
6	0.86	579	399	579	661
7	0.90	605	424	605	690
8	0.95	610	450	630	710
Brook trout					
0		89	58	86	155
1	0.74	169	110	167	263
2	0.85	208	147	205	312
3	0.92	261	204	261	343
4	0.95	317	254	315	381
5	0.98	342	279	339	432

1974, 1977b) for the main-stream simulations. Population data (Table 2) for tributary brook trout simulations were obtained 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).

TABLE 2.—*Annual natural mortality rates* (n) *and length parameters on October 1 of each year for each age group of brown trout and brook trout in the quality-tributary category.*

Age	*n*	Length (mm) Mean	Shortest	Modal	Longest
Brown trout					
0		85	51	84	145
1	0.20	156	109	150	259
2	0.54	213	145	203	358
3	0.87	271	191	264	406
4	0.87	319	249	318	462
5	0.92	387	330	384	470
6	0.92	419	356	419	508
7	0.95	465	406	462	559
8	0.95	489	457	490	607
Brook trout					
0		82	51	79	147
1	0.67	135	76	133	229
2	0.78	176	114	173	279
3	0.97	253	196	254	287
4	0.98	281	241	279	318
5	0.99	314	264	315	366

TABLE 3.—*Annual natural mortality rates* (n) *and length parameters on October 1 of each year for each age group of brown trout and brook trout in the marginal-stream category.*

Age	*n*	Length (mm) Mean	Shortest	Modal	Longest
Brown trout					
0	0.70[a]	144	118	144	169
1	0.53	262	186	262	338
2	0.70	368	216	368	495
3	0.75	452	300	452	605
4	0.84	518	417	518	610
5	0.34	571	495	571	622
6	0.86	584	533	584	634
7	0.90	597	546	597	648
8	0.95	610	560	610	660
Brook trout					
0	0.70[a]	87	56	86	154
1	0.74	169	110	167	263
2	0.85	208	147	205	312
3	0.92	261	203	261	343
4	0.95	317	254	315	381
5	0.98	342	279	339	432

[a] Mortality rate from time of stocking in early April to October 1.

The population parameters of growth and mortality for these streams were judged to be representative of other Michigan streams in their size category, but natural reproduction and recruitment in the North Branch of the Au Sable River is probably above average for main-stream fisheries. However, this above-average recruitment should not affect the accuracy of the analysis if one assumes recruitment, at whatever level found in a fishery, remains relatively constant for the fishing regulations tested.

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

The original model, TROUT·DYNAMICS, was modiifed to simulate trout stocking. The modified version was named STOCKED·TROUT. First- and second-year survival rates were constant in STOCKED·TROUT, rather

TABLE 4.—*Predicted length frequencies of brown trout caught from a quality main-stream fishery at different minimum size limits (mm). Numbers caught and released appear in parentheses. Fishing rate (m) was 0.50.*

Length range (mm)	Number per hectare caught at size limit						
	152	178	203	229	254	305	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)

than density dependent as in TROUT· DYNAMICS. The stocked population was seeded each year with an appropriate number of 127- to 152-mm fingerlings in lieu of reproduction.

Size limits from 152 to 229 mm were tested for brook trout; from 152 to 305 mm 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, 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 of Simulation Analysis

Quality trout streams

As size limits *increased,* the following general relationships occurred for all quality trout fisheries: (1) catch of trout in numbers and weight harvested *decreased*; (2) catch and release of

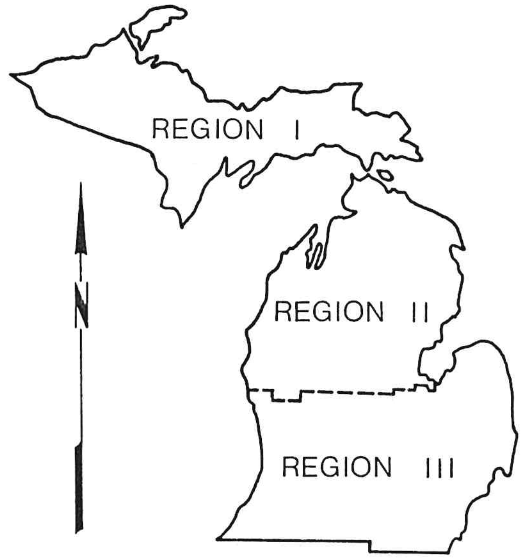

FIGURE 1.—*Fisheries management regions in Michigan.*

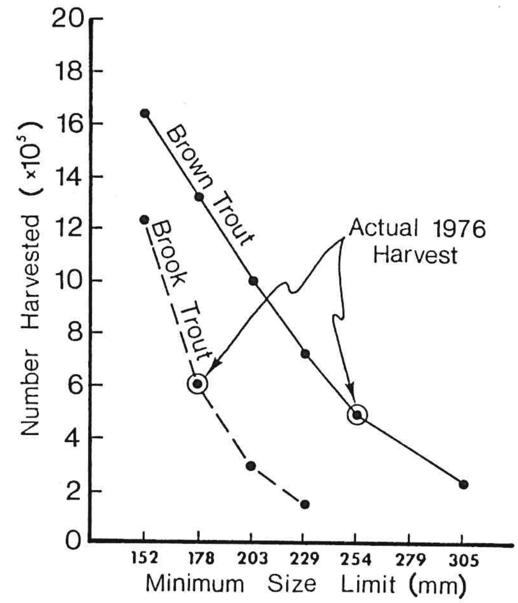

FIGURE 2.—*Annual harvest of brook trout and brown trout expected from fisheries management Region II under different minimum size limits.*

trout in numbers and weight *increased*; (3) 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*; and (4) numbers of larger trout harvested *increased*. 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 4–7.

TABLE 5.—*Predicted length frequencies of brook trout caught from a quality main-stream fishery at different minimum size limits (mm). Numbers caught and released appear in parentheses. Fishing rate* (m) *was 0.85.*

Length range (mm)	Number per hectare caught at size limit				
	152	178	203	229	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 6.—*Predicted length frequencies of brown trout caught from a quality tributary fishery at different minimum size limits (mm). Numbers caught and released appear in parentheses. Fishing rate* (m) *was 0.30.*

Length range (mm)	Number per hectare caught at size limit						
	152	178	203	229	254	305	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)
381+	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)

Marginal trout streams

Catch and yield statistics for marginal brook trout and brown trout fisheries are presented in Tables 8 and 9. Trends in catch and yield were similar to those for quality streams, assuming stocking rates were maintained. Stocking rate used for these simulations was 740 fingerlings per hectare per year. The percentages of stocked fish harvested under each size limit were estimated by dividing mean annual catches predicted for each age group by the numbers stocked (Table 10). As one might expect, a greater proportion of the planted fish were harvested under lower size limits.

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 11). For example, if the size limit on brown trout was reduced to 178 mm from the 254 mm in effect in 1978, harvest in numbers 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 harvest of brown trout, the catch should increase by 274% (Table 11).

Estimates of the 1976 harvest of brook trout and brown trout from Michigan streams were obtained from Department of Natural Resources mail surveys. 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 management regions (Fig. 1). Projections of numbers harvested un-

TABLE 7.—*Predicted length frequencies of brook trout caught from a quality tributary fishery at different minimum size limits (mm). Numbers caught and released appear in parentheses. Fishing rate* (m) *was 0.85.*

Length range (mm)	Number per hectare caught at size limit				
	152	178	203	229	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 (1,224.0)	172.5 (1,384.8)	22.2 (1,448.8)	0.0 (1,504.1)
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)

der different minimum size limits (Figs. 2–4) were obtained by multiplying the 1976 harvest by mean percentage changes (divided by 100) predicted for each species (Table 11).

Changes in size limits produced radically different effects on total trout harvest for the different management regions. For example, if a uniform size limit of 203 mm were adopted for both brook trout and brown trout the total trout harvested for Regions II (northern Lower Peninsula) and III (southern Lower Peninsula) would increase by 207,800 and 85,400 trout, respectively. The reduction of brook trout harvest due to increasing the limit from 178 to 203 mm is more than compensated by an increase in brown trout harvest due to reducing the brown trout limit from 254 to 203 mm (Figs. 2 and 3). However, the total trout harvest in Region I (Upper Peninsula) was comprised primarily of brook trout (Fig. 4). Adoption of a

TABLE 8.—*Catch and yield values predicted by STOCKED·TROUT for brown trout fisheries in marginal streams*[a] *with a conditional fishing rate of 0.70.*

Minimum size limit (mm)	Catch in numbers per hectare			Yield in kilograms per hectare		
	Harvested	Caught and released	Total catch[b]	Harvested	Caught and released	Total catch[b]
152	512.5	0.0	512.5	81.7	0.0	81.7
178	502.8	17.6	520.4	81.2	1.1	82.3
203	408.4	175.2	583.6	80.3	12.9	93.2
229	309.7	316.8	626.5	75.9	24.9	100.8
254	200.0	470.3	670.3	67.0	46.6	113.6
305	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

[a] The stream was stocked each year in early April with 740 fingerlings per hectare, ranging from 127 to 152 mm in length.
[b] 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.

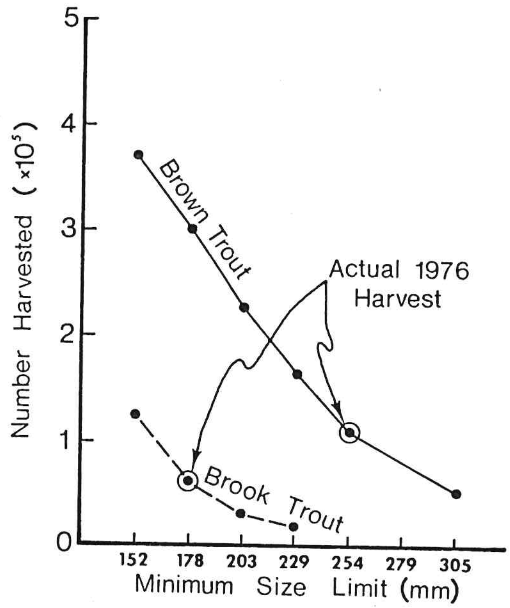

FIGURE 3.—*Annual harvest of brook trout and brown trout expected from fisheries management Region III under different minimum size limits.*

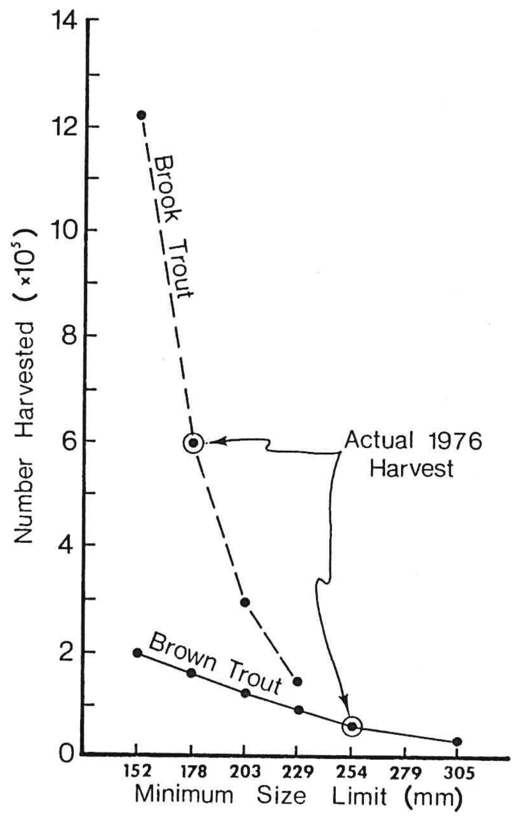

FIGURE 4.—*Annual harvest of brook trout and brown trout expected from fisheries management Region I under different minimum size limits.*

203-mm 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 the total number of trout harvested in Region I would be reduced by nearly 40% or 243,000 fish.

Other Considerations

Biological factors alone cannot define an optimum set of regulations for Michigan trout streams. They merely place constraints upon the magnitude of fishing benefits that trout streams can provide. Our simulation results indicated that minimum size limits of 152 mm and above prevented brook and brown trout

TABLE 9.—*Catch and yield values predicted by STOCKED·TROUT for brook trout fisheries in marginal streams*[a] *with a conditional fishing rate of 0.85.*

Minimum size limit (mm)	Catch in numbers per hectare: Harvested	Caught and released	Total catch[b]	Yield in kilograms per hectare: Harvested	Caught and released	Total catch[b]
152	301.9	494.1	796.0	15.1	11.9	27.0
178	141.8	751.0	892.3	10.6	22.7	33.3
203	63.2	877.3	940.5	6.6	30.2	36.8
229	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

[a] The stream was stocked each year in early April with 740 fingerlings per hectare, ranging from 127 to 152 mm in length.
[b] 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.

TABLE 10.—*The predicted percentages of stocked fish harvested for different size limits in marginal streams. Fishing rate (m) was 0.70 for brown trout and 0.85 for brook trout.*

Minimum size limit (mm)	Percent harvested at age I	II	III	IV	Total
Brown trout					
152	56.6	10.6	1.7	0.3	69.2
178	55.2	10.6	1.7	0.2	67.7
203	41.2	11.5	2.1	0.3	55.1
229	26.7	12.5	2.2	0.3	41.7
254	9.4	14.6	2.5	0.3	26.8
279	0.0	13.1	3.2	0.5	16.8
Brook trout					
152	30.6	9.4	0.7	<0.1	40.7
178	6.9	10.7	1.4	<0.1	19.0
203	0.4	5.9	2.1	0.1	8.5
229	0.0	1.6	2.0	0.2	3.8

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 these objectives are defined, then the best minimum size limits can be established.

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 determining possible effects of factors not directly addressed by the model. For example, TROUT·DYNAMICS is a single-species model; thus, effects of regulations on species interactions are left open for debate. Most Michigan trout streams are multi-species fisheries with either brook trout and brown trout occurring together or with other salmonids such as rainbow trout, chinook salmon (*Oncorhynchus tshawytscha*), and coho salmon (*Oncorhynchus kisutch*). Concern has been expressed that brook trout may be declining in Michigan streams because of competition with brown trout (Coopes 1974; Alexander et al. 1979). Problems of this type must be considered, along with model results, when evaluating fishing regulations.

Minimum size limits of 178 mm on brook trout and 254 mm on brown trout in Michigan streams were changed in 1979. Uniform size limits for both species of 203 mm in Lower Peninsula streams and 178 mm in Upper Peninsula streams were adopted by the Michigan Natural Resources Commission. Some of the reasons for adopting the new size limits were that they: (1) allowed better utilization of the tributary brown trout resource than the former 254-mm limit on brown trout; (2) provided a reasonable compromise between total numbers harvested and production of trophy-sized trout; (3) reduced possible competitive advantages brown trout might have had over brook trout under old regulations; and (4) were simple for anglers to understand and conservation officers to enforce.

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TABLE 11.—*Estimated percent of the number of trout creeled at size limits in effect in 1978 (brook trout—178 mm and brown trout—254 mm) which would be creeled at other size limits.*

Minimum size limit (mm)	Brown trout: Quality Main-stream	Brown trout: Quality Trib-utary	Brown trout: Marginal stream	Brown trout: Mean	Brook trout: Quality Main-stream	Brook trout: Quality Trib-utary	Brook trout: Marginal stream	Brook trout: Mean
152	278	474	256	336	188	212	213	204
178	221	351	251	274	100	100	100	100
203	162	251	204	206	50	52	45	49
229	120	173	155	149	23	30	20	24
254	100	100	100	100				
305	53	26	62	47				

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