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FISHERIES DIVISION
RESEARCH REPORT

Number 1987 December 1, 1992

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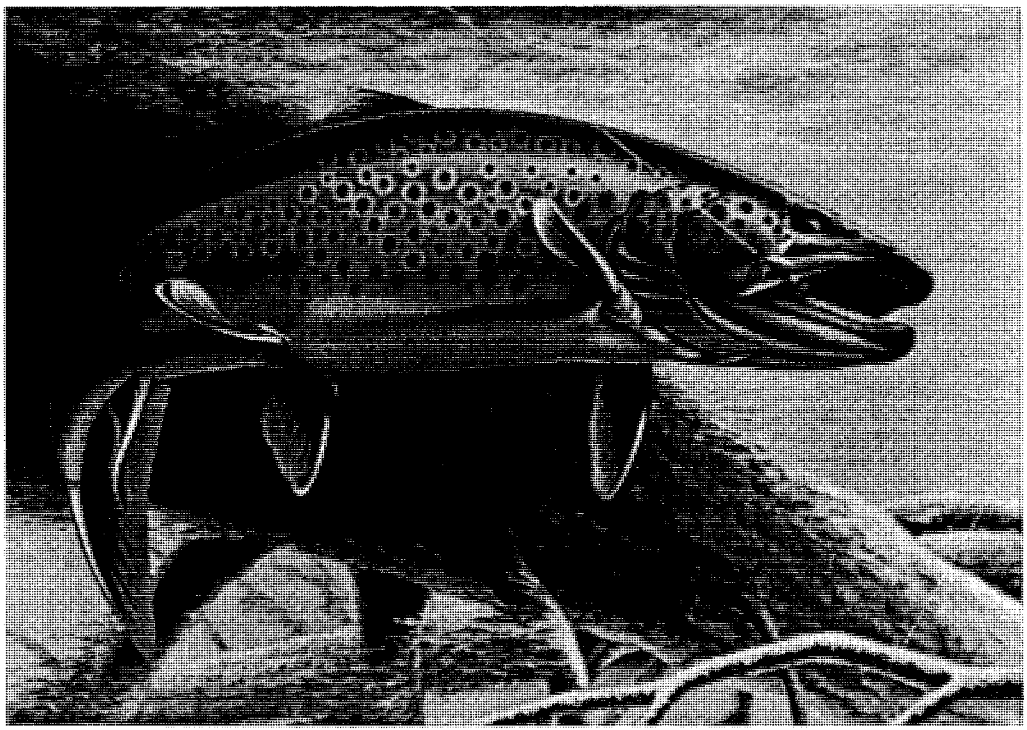

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STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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EVALUATION OF CATCH-AND-RELEASE TROUT FISHING REGULATIONS ON THE SOUTH BRANCH OF THE AU SABLE RIVER, MICHIGAN

Richard D. Clark, Jr.
and
Gaylord R. Alexander

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Michigan Department of Natural Resources

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Evaluation of Catch-and-Release Trout Fishing Regulations on the South Branch of the Au Sable River, Michigan

Richard D. Clark, Jr.

Michigan Department of Natural Resources
Institute for Fisheries Research
212 Museums Annex Building
Ann Arbor, Michigan 48109-1084

Gaylord R. Alexander

Michigan Department of Natural Resources
Hunt Creek Research Station
Route #2, Box 2299
Lewiston, Michigan 49756

Abstract.— Flies-only, catch-and-release (no-kill) trout fishing regulations were established on a 4.7-mi-long section of the South Branch of the Au Sable River, Michigan. The former regulations restricted terminal tackle to flies only but allowed harvest of brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* 10 in or larger and brook trout *Salvelinus fontinalis* 8 in or larger. The primary objective of the new regulation was to produce higher standing stocks of larger trout and higher catch rates of all trout, but particularly larger ones. We evaluated the effectiveness of the regulation in achieving this objective. We compared before (1974-82) and after (1985-90) trout populations, catch, and fishing effort in the catch-and-release section and in two separate control sections where fishing regulations remained constant. Rainbow trout were rare in all study sections, so we concentrated our efforts on brown trout and brook trout.

In general, the condition of brown trout populations improved in the catch-and-release section but deteriorated in both control sections. Total abundance of brown trout increased significantly in the catch-and-release section and decreased significantly in the control sections. Relative to the control sections, total abundance in the catch-and-release section increased by from 41% to 59%. Abundance of brown trout larger than 12 in did not change significantly in the catch-and-release section but decreased significantly in both control sections. Survival rates of brown trout did not change significantly in the catch-and-release section, but decreased significantly for age-1 and older fish in both control sections. Thus, the catch-and-release regulation produced a better population of larger trout than would have existed otherwise. Mean lengths at age of brown trout did not change significantly in catch-and-release or control sections. No change in condition factor (length-weight relation) of brown trout could be attributed to the catch-and-release regulation.

We found no detectable effect of the catch-and-release regulations on the brook trout population. Brook trout abundance remained constant in the catch-and-release section,

increased significantly in one control section, and decreased significantly in the other control section. We detected no effect on brook trout survival or growth.

The catch-and-release regulation was probably responsible for a significant decrease in fishing effort in the catch-and-release section, but we cannot be certain because fishing effort also decreased in one of the control sections. Other than eliminating the harvest, catch-and-release had no detectable effect on the total catch of brown trout. This may have been due to high variances on catch estimates, because changes in mean catch estimates were generally consistent with changes in estimates of trout abundance. Catch-and-release had essentially the same effect on the catch of brook trout as the catch of brown trout. The harvest was eliminated, but no other measurable effect was detected. We observed an increasing trend in voluntary release of trout in the control sections. During the mid-1970s, anglers released about 40% of the trout they caught, but by 1990, the release rate was up to 80-90%. This increase in voluntary release could have reduced the apparent effects of mandatory catch-and-release in the catch-and-release section, because the catch-and-release section was evaluated relative to the control sections.

We conclude that catch-and-release regulations had a positive impact on the brown trout population in the catch-and-release section, but "improvements" observed were modest. These improvements seem to take on a secondary importance considering the general decline observed in brown trout populations in the Au Sable River over the last 20 years. We should focus future research and management efforts on identifying and controlling, if possible, the factor(s) causing brown trout to decline. Based on our analysis, exploitation from fishing is not responsible for the general decline.

Catch-and-release or no-kill fishing regulations require anglers to release all the fish they catch unharmed. This type of regulation is gaining popularity among trout anglers nationwide, including those in Michigan. The popular literature is full of glowing testimonies and ethical promotions of catch-and-release fishing.

In 1983, catch-and-release fishing regulations were established for brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, and rainbow trout *Oncorhynchus mykiss* on a 4.7-mi-long section of the South Branch of the Au Sable River, Michigan. Because rainbow trout are rare in this section, this report is focused on brown trout and brook trout. The primary objective of the regulations was to produce higher standing stocks of larger trout and higher catch rates of all trout, but particularly larger ones. The purpose of our study was to evaluate the effectiveness of catch-and-release in achieving its objective and to monitor other aspects of the fishery, such as fishing effort and recruitment, mortality, growth, and body condition of trout.

While Michigan has had much experience with other types of special trout fishing regulations (see for example, Clark et al 1981; Clark and Alexander 1984, 1985), this was the first catch-and-release regulation to be placed on a wild trout fishery in the State. In the early 1980s, when this study was initiated, reports from other areas of the country showed mixed and sometimes conflicting results concerning the effects of catch-and-release. The catch-and-release program for cutthroat trout *Oncorhynchus clarki* and Montana grayling *Thymallus arcticus* in Yellowstone National Park, appeared to be highly successful in both increasing the number of larger fish in the population and increasing the catch rate of larger fish (Anderson 1977). However, rainbow trout *O. mykiss* and brown trout fisheries within the Park did not respond in the same way. While the number of older, larger trout increased in the population, the catch rate of larger trout did not improve, except for the expert angler. This suggested that catch-and-release regulations may stockpile large, uncatchable fish.

In Pennsylvania, a 20-in minimum size limit (essentially a catch-and-release fishery) for brown trout in Penns Creek appeared to increase the density but decrease the condition factor of trout. These results suggested the regulation increased abundance of fish in the 12- to 16-in size range, but produced fewer fish over 20 in than a lower minimum size limit (Graff and Hollender 1977).

Both of the above references (Anderson 1977; Graff and Hollender 1977) were in the form of management reports and not meant to be taken as rigorous research studies. A review of the literature in 1980 revealed that no rigorous studies had been published describing the impact of catch-and-release regulations on trout fisheries.

Since the early 1980s, management reports and other accounts of catch-and-release trout fishing have been common (for example, see Behnke 1989; Richardson and Hamre 1984; Barnhart and Roelofs 1987), but rigorous research reports are still rare. However, some relevant research studies have been published, including several that were associated with this study. Anderson and Nehring (1984) studied catch-and-release regulations on a mixed brown trout and rainbow trout fishery in the South Platte River, Colorado. They found the regulations to be highly successful. They compared a river section under catch-and-release to a "control" section under "standard" regulations (8 trout per day, no size limit). In the catch-and-release section, 50% of the trout in the population were greater than 12 in compared to only 17% in the control section. Overall catch rates averaged 48% greater in the catch-and-release section, and the catch rate of trophy-sized trout (greater than 15 in) was 28 times greater. Catch-and-release was popular with the anglers. Fishing effort averaged 1,300 and 1,600 hours per acre per year in the catch-and-release and control sections, respectively. This Colorado study was a good comparative study, but the study design did not eliminate the possibility that the catch-and-release section was simply better trout habitat. If so, the better habitat could have been responsible for, or contributed to the final results.

Another notable evaluation of catch-and-release was conducted by Orciari and Leonard (1990) on a brown trout fishery in the Housatonic River, Connecticut. This was not a wild trout fishery. Natural reproduction of brown trout was "virtually nonexistent," and the fishery was maintained entirely by stocking. The catch-and-release regulation was imposed as a public health measure, because the brown trout were contaminated with PCBs. The study showed that trout anglers would continue to fish in traditional areas, even if fish were chemically contaminated and could not be eaten. Fishing effort averaged about 110 hours per acre per year, and catch rates were maintained throughout the fishing season. An average of 38% more trout by number were caught than were originally stocked, suggesting many trout were caught more than once. This Connecticut study was also a comparative study whose design suffered the same problems as the Colorado study. The design of our study avoids these problems, because we sampled both before and after catch-and-release was imposed, as well as, comparing study and control sections.

Two other studies were conducted in conjunction with ours. Clapp et al (1990) and Regal (1992) placed radio transmitters in brown trout within our catch-and-release section to determine the extent of their movements in relation to the size of the restricted area. Clapp et al (1990) monitored large fish from 17 to 25 in long, which are the "trophies" the regulations were meant to produce and protect. They found these large brown trout moved widely. Mean total ranges were 3 mi during spring/summer and 7 mi during fall/winter. At some time during the year, six of eight fish moved out of the catch-and-release section, even though none were tagged and released closer than 1 mi from its boundaries. However, their longer movements generally occurred in fall/winter. They spent 87% of their time within the catch-and-release section during the height of the fishing season. None of the fish were reported caught by anglers, either inside or outside the protected section. Thus, we think the 4.7-mi-long section afforded a large degree of protection to these largest individuals in the trout population.

Regal (1992) tracked mid-sized brown trout in the same reach of the catch-and-release section as Clapp et al. Regal's fish moved much smaller distances than those of

Clapp et al. Regal concluded that total range of movement was related to the size of the trout. He found that the average total range during spring/summer was only 43 ft for 10- to 12-in brown trout and 140 ft for 12- to 14-in brown trout. These size-dependent differences in the range of movement were probably related to feeding behavior. The smaller trout were more likely to take feeding stations and feed on drifting insects and the larger trout were more likely to cruise the stream to forage on small fish. Whatever the reason, it was clear that the catch-and-release section was large enough to protect brown trout smaller than 14 in.

Methods

Catch-and-release fishing regulations were established for trout on April 30, 1983 on a section of the South Branch of the Au Sable River, Michigan (Figure 1). Terminal tackle was restricted to artificial flies, and fishing was permitted from the last Saturday in April through September 30. Anglers were not allowed to possess trout on this section of river. All trout caught were to be released unharmed.

The regulation was evaluated by comparing trout populations and fishery statistics from this *treated* section with those of two *untreated* control sections, the treatment being the catch-and-release fishing regulation. Periods before (1974-82) and after (1985-90) the start of the catch-and-release regulation were used for comparison. To help ensure the trout populations were at equilibrium under the catch-and-release regulation, a two year transition period (1983 and 1984) was allowed prior to after-period sampling.

Fishing regulations in the treated section and both control sections were identical during the 1974-82 before period and remained constant in both control sections during the 1985-90 after period. Those regulations restricted terminal tackle to flies only, minimum size of harvest to 10 in for brown trout and rainbow trout and 8 in for brook trout, and daily bag limits to 5 trout per day from the last Saturday in April to September 30.

The primary control section (control 1) was 5.4 mi of the South Branch of the Au Sable River directly downstream of the treated section, Highbanks Public Access Site to Smith Bridge. The secondary control section (control 2) was 13.3 mi of the North Branch of the Au Sable River from Sheep Ranch Public Access Site to Kellogg Bridge (Figure 1). We considered the Highbanks-to-Smith section the best experimental control for gaging possible changes in trout populations, because it was part of the same river as the treated section. However, its proximity to the catch-and-release section aroused concern that large numbers of anglers who wanted to harvest trout might be displaced downstream, and thus, cause a *treatment effect* in the control section. The secondary control section (Ranch-to-Kellogg) was selected to guard against this possible problem. At its nearest point, the Ranch-to-Kellogg section is over 10 mi from the study section, and probably would be less prone to any such treatment effect. All three river sections contain good populations of brown trout and brook trout, with brown trout comprising from 60% to 80% by weight of the total trout standing stock. The sections also contain similar trout habitat.

In an ideal experiment, statistics from the control population would not change from before to after treatment (imposing catch-and-release regulations). Any difference observed in the treated population from before to after can then be considered the *treatment effect*. Unfortunately, all experiments conducted in natural settings are subjected to confounding factors. That is, the investigator cannot control all the factors affecting the populations under study, and furthermore, the factors cannot be identified *a priori*. The investigator is forced to assume that any unknown, uncontrollable factors will have identical effects on both treated and control populations. If the control population changes significantly from before to after period, it becomes necessary to compare *relative* differences in treated and control populations to isolate the *treatment effect*. We compared *relative* differences in our trout population statistics by comparing the ratios of treated/control between before and after periods.

Trout population sampling

Trout populations were sampled annually at seven index stations. Two stations were within the Chase-to-Highbanks section on the South Branch (treated section), Chase Bridge and Marlabar at 1.3 acres and 1.4 acres, respectively. Two stations were within the Highbanks-to-Smith section on the South Branch (control 1 section), Dogtown and Smith Bridge at 1.8 acres and 1.5 acres, respectively. Three stations were within the Ranch-to-Kellogg section on the North Branch (control 2 section), Twin Bridge, Eamon's Landing, and Dam 4 at 3.3, 2.5, and 3.0 acres, respectively (Figure 1). These population stations covered approximately 9%, 6%, and 4% of the surface area in treated, control 1, and control 2 sections, respectively. They were selected for ease of access for electrofishing crews, but they also appeared to contain habitat types which were fairly representative of the total study sections. We used them only as index stations and made no attempt to expand population estimates to cover the entire treated or control sections.

Abundance and survival -- A detailed description of procedures and formulas for estimating abundance and survival was presented in our earlier report on the evaluation of slotted size limits (Clark and Alexander 1985). We used the same methods in this study. Briefly, we used dc-electrofishing gear and mark-and-recapture techniques to estimate abundance of trout each fall by species, size, and age groups. We used Bailey formulas (Bailey 1951) to compute estimates and variances. We collected trout scales during the marking run to estimate age composition. We estimated age-specific annual survival and its variance from two successive age groups.

We assumed annual estimates were replicate samples taken from populations at equilibrium under their respective regulations and grand means (and variances) were computed for before and after periods. We calculated 95% confidence intervals for before and after means and any differences observed were considered statistically significant if confidence intervals did not overlap.

The population sampling stations were open ended, that is, no blocking nets were set during population estimates. Fish movement in and out of sections was assumed to be negligible for the short time (one day) between marking and recapture runs. This assumption was supported by the recapture rates which ranged from 30% to 60%, and tended to increase with fish size (Figure 2). If a significant number of trout were leaving or entering the population areas, recapture rates probably would have been lower.

Growth - Mean total lengths at age of trout by species were calculated for each year and station using population estimates and age information from scale samples. The mean total length (L_i) of age *i* trout was computed as:

$$L_i = \frac{\sum_j [n_{ij} \ (j+0.5)]}{\sum_j n_{ij}},$$

where n_{ij} is the estimated number of trout of age *i* within in group *j*.

We assumed mean lengths at age for each year were replicate samples taken from populations at equilibrium under their respective regulations and grand means (and variances) were computed for before and after periods. We calculated 95% confidence intervals for before and after means and any differences observed were considered statistically significant if confidence intervals did not overlap.

Length/weight relationship -- We thought the catch-and-release regulation could cause a change in the physical condition of the trout. Such a change, if it occurred, could have biological significance and might be easier to detect statistically than a change in growth in length. Therefore, we collected samples of trout taken within or near each population index station one year before (1981) and four years after (1984, 1985, 1987, and 1988) the catch-and-release regulations were imposed. We measured total lengths and wet weights of each individual in the sample. We were careful to sample the full range of sizes for each species present. We assumed that the slope of the regression (B) between length and weight (transformed to natural logarithm) gave a good indication of the general condition of trout in the population (Carlander 1977). The length/weight relationship was developed as a linear regression of the form:

$$\ln(W) = A + B\ln(L),$$

where L was length in millimeters and W was weight in grams and A and B were the intercept and slope parameters, respectively. We calculated 95% confidence intervals for B and differences observed were considered statistically significant if confidence intervals did not overlap (Netter and Wasserman 1974).

Catch and effort surveys

Annual surveys of catch and effort were conducted for two years before the catch-and-release regulation (1981-82), and six years after (1985-90). The two years of 1983 and 1984 were considered transition years and no surveys were conducted.

These surveys were designed to estimate total catch of trout, both harvested and released, and total hours of fishing effort. Stratified, random sampling methods were used (Alexander and Shetter 1967; Malvestuto 1983). A clerk made progressive instantaneous counts by floating each section in a canoe and counting the number of anglers 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 their trip and how many trout of each species they had caught and released. Trout in the angler's possession (those harvested) were counted and identified to species. Finally, we estimated total catch by multiplying the total hours fished per day by the average catch per hour per day.

As with the trout population estimates, we computed grand means for before and after periods with 95% confidence intervals. Differences between before and after were considered statistically significant if confidence intervals did not overlap.

Results and Discussion

Trout Populations

Brown trout - In general, brown trout abundance increased under catch-and-release regulations in the Chase-to-Highbanks section (treated section), while it decreased in both control sections. However, somewhat different results were found for different size groups (Table 1). Estimates of abundance by age group (Table 2) were essentially parallel with estimates by size group, so we will focus our discussion on the latter. In the treated section, statistically significant increases were detected in numbers of brown trout within size groups smaller than 12 in, but the number larger than 12 in did not change significantly. Numbers of brown trout of all sizes decreased significantly in both control sections, except that numbers of 4.0- to 7.9-in trout in the Highbanks-to-Smith (control 1) section remained constant.

Examining relative changes using the ratio method confirmed that catch-and-release regulations were responsible for increasing abundance of brown trout in the Chase-to-Highbanks section. The ratios of (Chase-to-Highbanks)/(Highbanks-to-Smith) increased significantly for all size groups smaller than 12 in. However, the ratio did not increase significantly for trout larger than 12 in. The ratios of (Chase-to-Highbanks)/(Ranch-to-Kelloggs) significantly increased for all size groups. Thus, brown trout abundance increased in the treated section relative to the control sections.

Survival rates of brown trout in the Chase-to-Highbanks section did not change significantly, but survival rates decreased significantly for age-1 and older brown trout in both control sections (Table 3).

The catch-and-release regulation had no detectable effect on brown trout growth. Mean lengths at age of brown trout did not change significantly between before and after periods for either treated or control sections (Table 4). The coefficient of condition of brown trout remained constant in the Chase-to-Highbanks treated section and decreased in the Highbanks-to-Smith control section (Table 5). The exception was a significant increase in condition in both sections in 1988. We doubt if the catch-and-release regulations were responsible for these changes in condition. We would expect condition to decrease, if anything, in response to increased abundance under catch-and-release. Most likely, these changes in condition were caused by weather or other environmental factors. For example, exceptionally hot, dry weather prevailed in the entire region during 1988.

These results have two important implications. First, the catch-and-release regulations did increase trout abundance, but only modestly. Estimates of the total abundance of all brown trout increased 17% in the Chase-to-Highbanks section and decreased 24% and 42% in the Highbanks-to-Smith and Ranch-to-Eamons sections, respectively (Table 1). Assuming brown trout numbers would have decreased the same amount in the treated section as the control sections had it not been for the opposing effect of the regulations, then the regulations caused total brown trout numbers to increase by from 41% (17%+24%) to 59% (17%+42%). However, the most disappointing aspect of these findings was the relatively minor effect the regulations had on the numbers of brown trout larger than 12 in (Table 1). One of the main objectives of the regulations was to increase the number of larger trout.

The second implication was that some unknown factor(s) was acting to decrease brown trout abundance between before (1974-82) and after (1985-90) years. The effect of this factor(s) on trout abundance was nearly as large as the effect of the catch-and-release regulation. The factor(s) appeared to affect abundance by decreasing reproduction and increasing mortality of brown trout populations. Both control sections exhibited significant decreases in numbers of age-0 brown trout (Table 2), suggesting a reduction in reproductive success. Both control sections exhibited significant decreases in the survival of age-1 and older brown trout, suggesting an increase in mortality rate of older fish. Brown trout growth and condition did not change significantly.

Brook trout - The catch-and-release regulations had no measurable effect on brook trout populations. Brook trout abundance did not change significantly in the Chase-to-Highbanks section (Tables 6 and 7). At the same time, abundance increased in one control section (Highbanks-to-Smith) and decreased in the other (Ranch-to-Kelloggs).

We could not find any effect of the catch-and-release regulation when examining brook trout survival rates. With the exception of age-0 fish, survival rates of brook trout did not change significantly in any of the stream sections (Table 8). And we doubt if catch-and-release regulations could be responsible for the changes observed in age-0 survival.

The catch-and-release regulation had no detectable effect on brook trout growth. Mean lengths at age of brook trout did not change significantly between before and after periods for either treated or control sections (Table 9). The coefficient of condition of brook trout tended to decrease in both study and control sections (Table 10). However, a similar increase in the coefficient of condition occurred in 1988, as it did for brown trout. And as with brown trout, it was probably an anomaly caused by unusual weather in 1988.

Our results for brook trout are

equivocal, but this is not surprising. The potential direct effect of the catch-and-release regulation on brook trout appears small. The previous regulation (8-in minimum size limit and flies only) was already highly restrictive. Relatively few brook trout attain lengths greater than 8 within in the South Branch of the Au Sable River due to the high natural mortality rate and low growth rate, so there was little potential for the 8-in size limit to have much of a population-level effect. Consequently, changes in the brook trout population occurring between an 8-in minimum size limit and catch-and-release regulations would be difficult to measure.

Catch and Effort

The catch-and-release regulation was probably responsible for a significant decrease in the mean fishing effort in the Chase-to-Highbanks section. Mean effort decreased from 10,797 (±1,902) hours per year to 7,393 (±878) hours per year. However, we cannot attribute this change in effort to the regulations with certainty, because fishing effort also decreased significantly in the Ranch-to-Kelloggs section (Table 11).

Brown trout - Other than eliminating the harvest, catch-and-release regulations had no statistically significant effect on the total catch of brown trout. However, the changes in point estimates of mean catch and mean catch per hour were consistant with corresponding changes in the trout population data. This suggests the regulation actually did increase catch and catch-per-hour of brown trout, but that our catch survey methods were too imprecise to measure it. In the Chase-to-Highbanks section, brown trout harvest went from 868 (±259) 10-in-plus trout per year to zero (Table 11). Undoubtedly, some fish were harvested illegally, but overall angler compliance was considered excellent (Gigliotti 1989). In general, the mean catches of 10-in-plus brown trout (Table 11) were consistent with estimates of trout population abundance (Table 1). That is, mean catch from Chase-to-Highbanks section was relatively constant, while mean catches appeared to decrease (though not significantly) in the control sections. In fact, no statistically significant differences occurred in brown trout catches in any of the sections monitored.

Mean catch per hour of 10-in-plus brown trout, counting both harvested and released fish, did not change significantly in any of the sections monitored. It was 0.1480 (±0.0539) before and 0.1453 (±0.0808) after in the Chase-to-Highbanks section, 0.1165 (±0.0658) before and 0.0581 (±0.0241) after in the Highbanks-to-Smith section, and 0.1311 (±0.1195) before and 0.0973 (±0.0543) after in the Ranch-to-Kelloggs section.

Brook trout - Catch-and-release had essentially the same effect on the catch of brook trout as the catch of brown trout. The harvest of brook trout was eliminated in the Chase-to Highbanks section, but no other measurable effect on catch was detectable (Table 12).

Mean catch per hour of 8-in-plus brook trout, counting both harvested and released fish, did not change significantly in any of the sections monitored. It was 0.0882 (±0.0518) before and 0.1290 (±0.0682) after in the Chase-to-Highbanks section, 0.1034 (±0.0649) before and 0.0903 (±0.0280) after in the Highbanks-to-Smith section, and 0.1446 (±0.1189) before and 0.1286 (±0.0695) after in the Ranch-to-Kelloggs section.

Voluntary release - We can document that the rate of voluntary release of trout has increased over the years by combining the results of this study with our previous study on slotted size limits (Clark and Alexander 1985). A 15-year record (1976-90) of catches from the Ranch-to-Kelloggs section demonstrates that the release rate of legal-sized trout has increased. Recall that this section was used as the control section for both studies and that fishing regulations were constant during the period. During the mid-1970s, anglers released about 40% of the trout they caught, but by 1990, the release rate was up to 80-90% (Figure 3). While release rates would vary in other fisheries, this increasing trend in voluntary release of fish is probably ubiquitous (Clark 1983). This increase in voluntary release could have reduced the apparent effects of mandatory catch-and-release in the treated section, because the treated section was evaluated relative to the control sections. Obviously, in terms of impact on trout populations, there would be little difference between a fishery with 90% voluntary release of fish and one with mandatory release of fish.

Relative effects of fishing versus other factors

The "improvements" observed in the trout populations due to the catch-and-release regulations were modest. They seem to take on a secondary importance when one considers the general decrease observed in brown trout populations in the Au Sable River over the last 20 years (Clark and Alexander 1985). At best, it could be said that reducing exploitation to near zero only balanced the general decrease in trout abundance. We are nearing the point now where the effects of fishing on the populations cannot be reduced any further without prohibiting the sport entirely. The small amount of hooking mortality caused by catch and release would then be avoided. Obviously, it would be much better to identify and control, if possible, the factor(s) causing brown trout to decline. Based on our analysis, exploitation from fishing is not a factor in this general decline. Fishing effort in the Ranch-to-Kelloggs section decreased along with brown trout populations (Tables 1 and 11). We need to search for a factor(s) impacting the success of reproduction, the mortality of juvenile fish, and the mortality of adult fish.

Acknowledgments

The work involved in this study was completed by the combined effort of management and research sections in Michigan Department of Natural Resources, Fisheries Division. Many people employed by those sections played important roles in the study, but we would especially like to thank Fisheries Division employees of District 7. They performed essentially all the field work involved with trout population estimates and were frequent helpers with catch surveys.

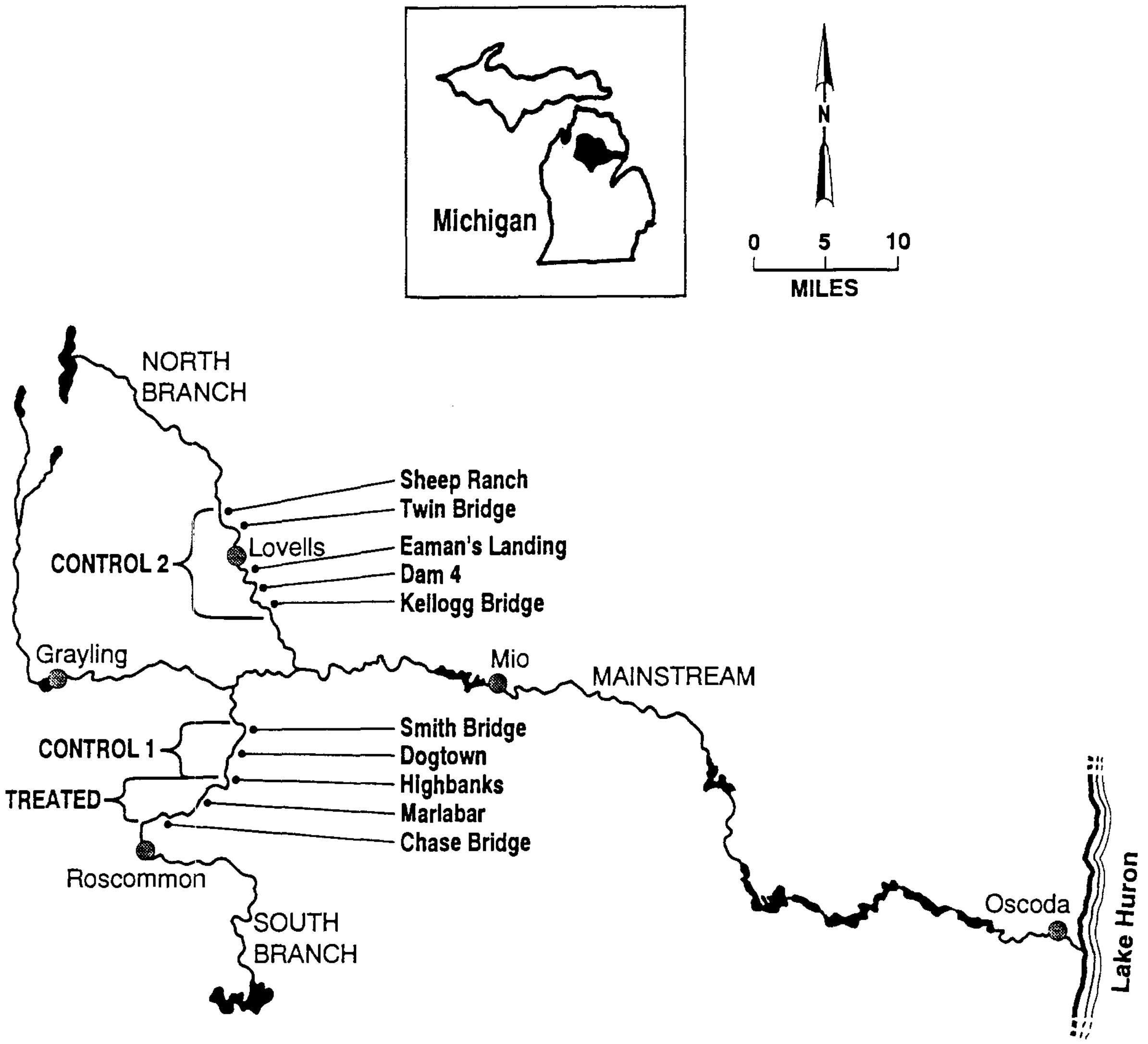

Figure 1.—The treated section, control sections 1 and 2, and trout population sampling areas are shown on this map of the Au Sable River and its major tributaries, the South Branch and the North Branch. Insert shows location of Au Sable River in Michigan.

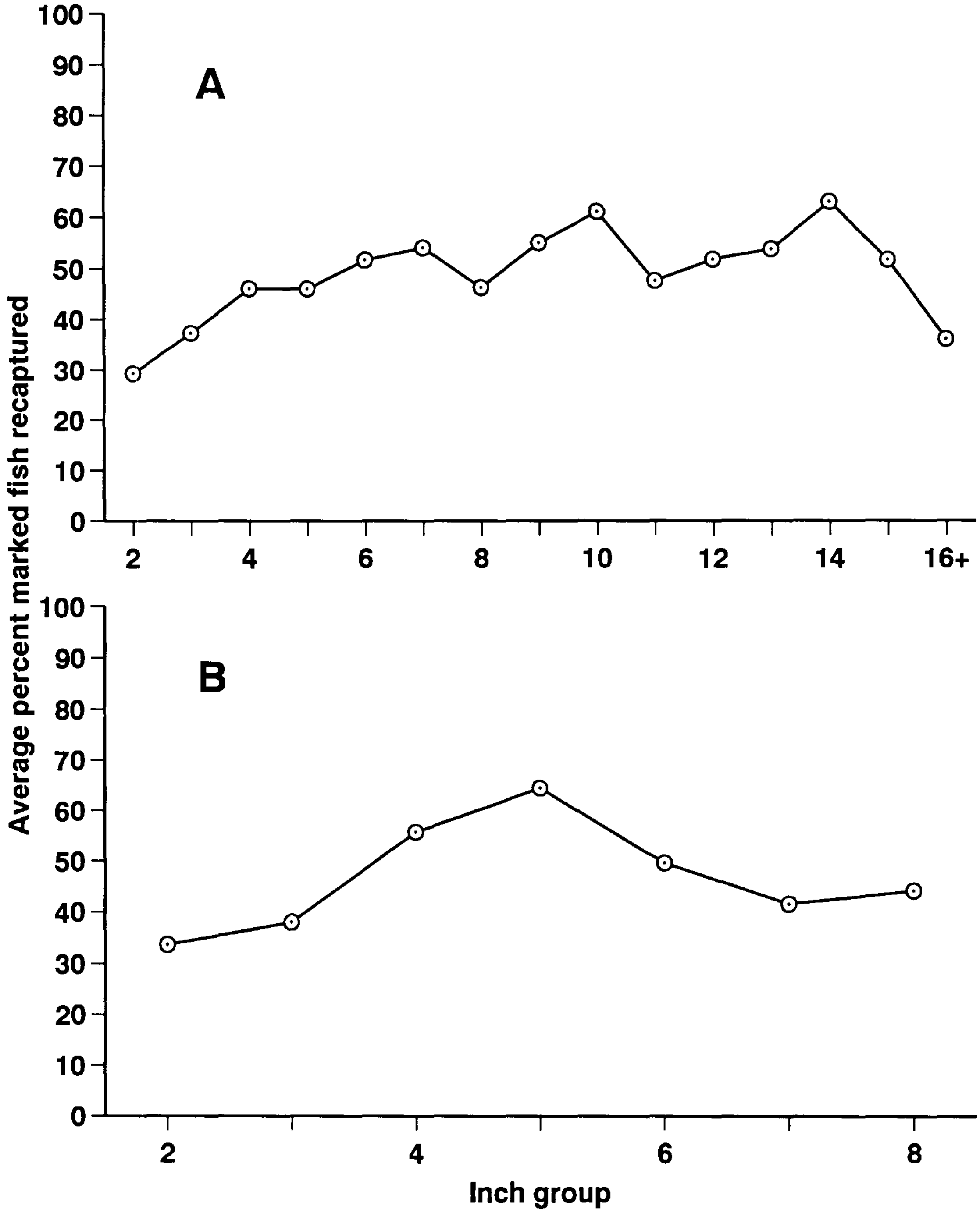

Figure 2.—Average recapture rates by inch group of marked (A) brown trout and (B) brook trout in population estimates at Marlabar station. Thirteen years of population estimates during 1974-90 were used to derive averages. Recapture rates were similar at all other stations.

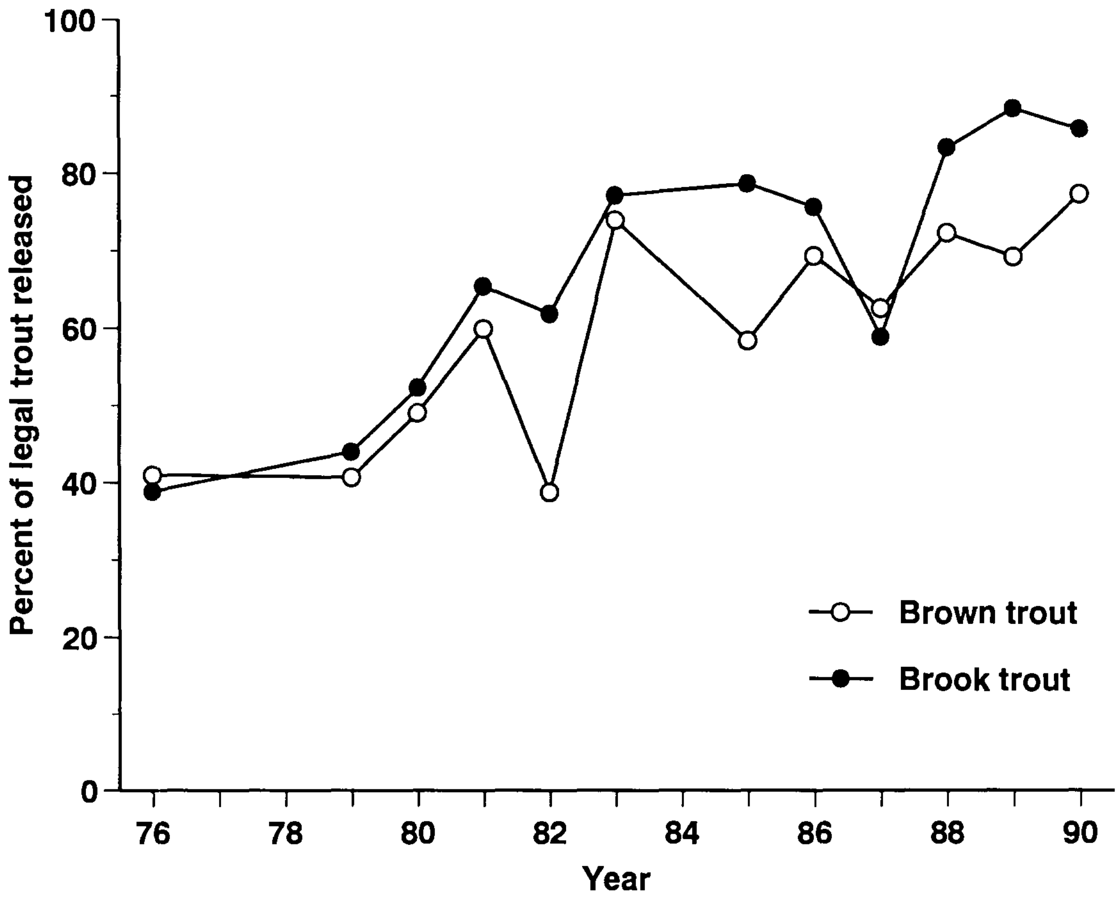

Figure 3.—Trend in voluntary release of legal-sized trout in the Ranch-to-Kelloggs section of the North Branch of the Au Sable River. No changes in fishing regulations occurred during the period. The minimum size limits were 10 inches for brown trout and 8 inches for brook trout.

Table 1.— Mean number of brown trout per acre in fall populations by selected size categories. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" row indicates if trout abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Size category of trout (in)			
	< 4.0	4.0-7.9	8.0-11.9	12.0 +
Chase Bridge - Highbanks				
1974-82 (10-in minimum)	113.1 (±9.6)	153.1 (±8.3)	57.8 (±5.4)	29.1 (±3.1)
1985-90 (No-kill)	144.4 (±15.2)	174.9 (±10.5)	67.7 (±4.5)	25.8 (±2.3)
Significance	(+)	(+)	(+)	(0)
Highbanks - Smith Bridge				
1974-82 (10-in minimum)	114.4 (±7.1)	77.5 (±5.0)	34.1 (±3.9)	12.0 (±1.7)
1985-90 (10-in minimum)	83.0 (±13.6)	67.8 (±7.4)	20.9 (±3.3)	7.4 (±1.4)
Significance	(-)	(0)	(-)	(-)
Ranch - Kellogg Bridge				
1974-82 (10-in minimum)	297.8 (±7.2)	199.4 (±4.3)	80.2 (±2.5)	23.3 (±1.7)
1985-90 (10-in minimum)	201.3 (±11.7)	101.8 (±4.0)	36.4 (±1.6)	8.2 (±0.8)
Significance	(-)	(-)	(-)	(-)

Table 2.— Mean number of brown trout per acre by age for fall populations. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Age 0	1	2	3	4	5
Chase Bridge - Highbanks						
1974-82	220.2	71.7	31.3	14.7	4.1	1.0
(10-in minimum)	(±12.0)	(±5.7)	(±3.0)	(±2.2)	(±1.7)	(±0.8)
1985-90	244.2	93.8	43.0	20.8	5.7	0.3
(No-kill)	(±17.3)	(±6.6)	(±4.0)	(±2.4)	(±1.0)	(±0.4)
Significance	(0)	(+)	(+)	(+)	(0)	(0)
Highbanks - Smith Bridge						
1974-82	157.2	41.4	20.6	10.0	0.9	0.2
(10-in minimum)	(±7.9)	(±3.8)	(±2.6)	(±1.2)	(±0.4)	(±0.0)
1985-90	119.9	42.6	10.0	3.1	2.4	0.0
(10-in minimum)	(±16.0)	(±8.7)	(±1.9)	(±0.5)	(±0.8)	(±0.0)
Significance	(-)	(0)	(-)	(-)	(+)	
Ranch - Kellogg Bridge						
1974-82	449.9	86.5	42.3	20.1	0.4	0.0
(10-in minimum)	(±8.4)	(±2.8)	(±2.5)	(±1.9)	(±0.0)	(±0.0)
1985-90	261.5	59.3	21.2	5.6	2.0	0.0
(10-in minimum)	(±13.4)	(±2.6)	(±1.6)	(±0.6)	(±0.3)	(±0.0)
Significance	(-)	(-)	(-)	(-)		

Table 3.— Mean survival rate of brown trout by age for fall populations. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if survival changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Age		
	0	1	2
Chase Bridge - Highbanks			
1974-82 (10-in minimum)	0.326 (±0.032)	0.437 (±0.055)	0.469 (±0.085)
1985-90 (No-kill)	0.384 (±0.039)	0.459 (±0.055)	0.484 (±0.072)
Significance	(0)	(0)	(0)
Highbanks - Smith Bridge			
1974-82 (10-in minimum)	0.263 (±0.028)	0.499 (±0.079)	0.486 (±0.086)
1985-90 (10-in minimum)	0.355 (±0.088)	0.235 (±0.066)	0.308 (±0.078)
Significance	(0)	(-)	(-)
Ranch - Kellogg Bridge			
1974-82 (10-in minimum)	0.192 (±0.007)	0.489 (±0.034)	0.475 (±0.055)
1985-90 (10-in minimum)	0.227 (±0.016)	0.357 (±0.031)	0.263 (±0.038)
Significance	(+)	(-)	(-)

Table 4.— Mean lengths at age for brown trout in fall populations. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Mean lengths (in) at age:				
	0	1	2	3	4
Chase Bridge - Highbanks					
1974-82 (10-in minimum)	4.0 (±0.5)	7.7 (±0.8)	10.9 (±1.3)	14.2 (±3.1)	16.9 (±6.1)
1985-90 (No-kill)	3.9 (±0.4)	7.4 (±0.7)	10.4 (±1.2)	13.0 (±1.9)	15.8 (±3.7)
Significance	(0)	(0)	(0)	(0)	(0)
Highbanks - Smith Bridge					
1974-82 (10-in minimum)	3.6 (±0.3)	7.3 (±0.9)	10.7 (±1.4)	13.2 (±2.9)	15.1 (±8.0)
1985-90 (10-in minimum)	3.8 (±0.5)	7.5 (±1.4)	10.8 (±1.5)	13.1 (±2.2)	16.2 (±2.9)
Significance	(0)	(0)	(0)	(0)	(0)
Ranch - Kellogg Bridge					
1974-82 (10-in minimum)	3.8 (±0.1)	7.8 (±0.3)	10.7 (±0.9)	13.0 (±1.5)	15.5 (±9.3)
1985-90 (10-in minimum)	3.7 (±0.3)	7.5 (±.5)	10.3 (±1.0)	13.1 (±2.3)	15.6 (±2.9)
Significance	(0)	(0)	(0)	(0)	(0)

Table 5.— Coefficients of condition (B) for brown trout. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" column indicates if changes in condition were statistically significant between the *before* year (1981) and each *after* year, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, sample dates, (regulation)	B	R^2	Sample size	Length range (in)	Significance
Chase Bridge - Highbanks					
Oct 14-15, 1981 (10-in minimum)	3.045 (±0.035)	0.99	161	4.0-24.9	
Oct 22, 1984 (No-kill)	3.055 (±0.045)	0.99	113	3.0-24.6	(0)
Oct 14, 1985 (No-kill)	2.998 (±0.040)	0.99	128	3.3-23.6	(0)
Oct 15, 1987 (No-kill)	3.008 (±0.078)	0.98	114	3.2-23.3	(0)
Oct 10-12, 1988 (No-kill)	3.299 (±0.060)	0.99	147	3.7-23.8	(+)
Highbanks - Smith Bridge					
Oct 14-15, 1981 (10-in minimum)	3.114 (±0.035)	0.99	170	4.0-25.0	
Oct 23, 1984 (10-in minimum)	3.000 (±0.071)	0.99	89	3.0-16.7	(-)
Oct 15, 1985 (10-in minimum)	2.905 (±0.078)	0.99	77	3.3-22.5	(-)
Oct 16, 1987 (10-in minimum)	2.922 (±0.053)	0.99	114	3.2-21.0	(-)
Oct 11, 1988 (10-in minimum)	3.217 (±0.040)	0.99	120	3.5-21.1	(+)

Table 6.— Mean number of brook trout per acre in fall populations by selected size categories. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" row indicates if trout abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Size category of trout (in)		
	< 4.0	4.0-7.9	8.0-11.9
Chase Bridge - Highbanks			
1974-82 (8-in minimum)	76.9 (±7.4)	76.2 (±6.4)	3.0 (±1.3)
1985-90 (No-kill)	86.9 (±9.4)	64.7 (±6.5)	4.6 (±1.3)
Significance	(0)	(0)	(0)
Highbanks - Smith Bridge			
1974-82 (8-in minimum)	147.5 (±6.8)	90.4 (±6.6)	3.6 (±1.7)
1985-90 (8-in minimum)	252.5 (±14.3)	109.0 (±7.4)	4.7 (±1.3)
Significance	(+)	(+)	(0)
Ranch - Kellogg Bridge			
1974-82 (8-in minimum)	524.3 (±8.1)	173.2 (±4.3)	20.4 (±1.6)
1985-90 (8-in minimum)	432.4 (±14.3)	144.2 (±7.4)	11.9 (±1.3)
Significance	(-)	(-)	(-)

Table 7.— Mean number of brook trout per acre by age for fall populations. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Age 0	Age 1	Age 2
Chase Bridge - Highbanks			
1974-82 (8-in minimum)	123.3 (±8.7)	24.2 (±2.6)	0.6 (±0.2)
1985-90 (No-kill)	117.2 (±13.5)	32.5 (±7.1)	1.5 (±1.5)
Significance	(0)	(0)	(0)
Highbanks - Smith Bridge			
1974-82 (8-in minimum)	184.1 (±7.6)	50.2 (±5.2)	3.0 (±1.0)
1985-90 (8-in minimum)	298.7 (±9.6)	60.9 (±3.8)	4.4 (±0.4)
Significance	(+)	(+)	(+)
Ranch - Kellogg Bridge			
1974-82 (8-in minimum)	608.5 (±9.5)	102.8 (±4.8)	10.0 (±1.7)
1985-90 (8-in minimum)	500.1 (±13.4)	88.1 (±4.2)	6.3 (±1.1)
Significance	(-)	(-)	(-)

Table 8.— Mean survival rate of brook trout by age for fall populations. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if survival changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Age 0	Age 1
Chase Bridge - Highbanks		
1974-82 (8-in minimum)	0.197 (±0.026)	0.027 (±0.011)
1985-90 (No-kill)	0.277 (±0.040)	0.045 (±0.015)
Significance	(+)	(0)
Highbanks - Smith Bridge		
1974-82 (8-in minimum)	0.273 (±0.031)	0.059 (±0.021)
1985-90 (8-in minimum)	0.204 (±0.023)	0.072 (±0.021)
Significance	(-)	(0)
Ranch - Kellogg Bridge		
1974-82 (8-in minimum)	0.169 (±0.008)	0.098 (±0.017)
1985-90 (8-in minimum)	0.176 (±0.010)	0.072 (±0.014)
Significance	(0)	(0)

Table 9.— Mean lengths at age for brook trout in fall populations. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, time period, (regulation)	Age 0	Age 1	Age 2
Chase Bridge - Highbanks			
1974-82 (8-in minimum)	3.9 (±0.4)	6.8 (±1.2)	9.8 (±3.6)
1985-90 (No-kill)	3.7 (±0.5)	6.6 (±1.1)	9.1 (±3.1)
Significance	(0)	(0)	(0)
Highbanks - Smith Bridge			
1974-82 (8-in minimum)	3.6 (±0.3)	6.5 (±0.9)	8.5 (±1.8)
1985-90 (8-in minimum)	3.5 (±0.3)	6.2 (±0.8)	9.0 (±1.7)
Significance	(0)	(0)	(0)
Ranch - Kellogg Bridge			
1974-82 (8-in minimum)	3.4 (±0.1)	6.9 (±0.5)	8.8 (±2.1)
1985-90 (8-in minimum)	3.4 (±0.1)	6.7 (±0.4)	8.8 (±1.6)
Significance	(0)	(0)	(0)

Table 10.— Coefficients of condition (B) for brook trout. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" column indicates if changes in condition were statistically significant between the *before* year (1981) and each *after* year, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

Section, sample dates, (regulation)	B	R^2	Sample size	Length range (in)	Significance
Chase Bridge - Highbanks					
Oct 14-15, 1981 (8-in minimum)	3.365 (±0.147)	0.98	35	4.0-7.8	
Oct 22, 1984 (No-kill)	3.073 (±0.238)	0.94	49	3.4-10.4	(0)
Oct 14, 1985 (No-kill)	2.797 (±0.247)	0.91	53	3.2-9.5	(-)
Oct 15, 1987 (No-kill)	2.914 (±0.221)	0.95	41	3.1-12.1	(-)
Oct 10-12, 1988 (No-kill)	3.878 (±0.314)	0.95	38	3.8-10.0	(+)
Highbanks - Smith Bridge					
Oct 14-15, 1981 (8-in minimum)	3.169 (±0.144)	0.97	53	2.9-7.6	
Oct 23, 1984 (8-in minimum)	3.150 (±0.156)	0.97	60	2.3-9.9	(0)
Oct 15, 1985 (8-in minimum)	2.925 (±0.124)	0.95	122	2.9-9.8	(0)
Oct 16, 1987 (8-in minimum)	2.768 (±0.124)	0.97	56	3.1-10.2	(-)
Oct 11, 1988 (8-in minimum)	3.443 (±0.125)	0.97	82	4.0-9.6	(+)

Table 11.— Mean fishing effort and numbers of brown trout harvested and caught and released. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

			Legal-size brown trout:		
Section, time period, (regulation)	Fishing effort (hours)	Rel- eased (<10 in)	Harv- ested (≥10 in)	Rel- eased (≥10 in)	Total catch (≥10 in)
Chase Bridge - Highbanks					
1981-82	10,797	2,199	868	730	1,598
(10-in minimum)	(±1,902)	(±1,025)	(±259)	(±440)	(±510)
1985-90	7,393	1,819	0	1,319	1,319
(No kill)	(±878)	(±1,098)	(±0)	(±858)	(±858)
Significance	(-)	(0)	(-)	(0)	(0)
Highbanks - Smith Bridge					
1981-82	13,128	2,109	590	925	1,515
(10-in minimum)	(±2,119)	(±1,351)	(±271)	(±765)	(±811)
1985-90	13,266	2,063	289	499	788
(10-in minimum)	(±1,542)	(±933)	(±210)	(±282)	(±352)
Significance	(0)	(0)	(0)	(0)	(0)
Ranch - Kellogg Bridge					
1981-82	30,462	7,755	1,760	2,234	3,994
(10-in minimum)	(±5,129)	(±3,778)	(±864)	(±1,498)	(±1,729)
1985-90	22,241	6,919	711	1,453	2,164
(10-in minimum)	(±2,000)	(±2,082)	(±301)	(±494)	(±578)
Significance	(-)	(0)	(0)	(0)	(0)

Table 12.— Mean fishing effort and numbers of brook trout harvested and caught and released. Confidence bounds for the 95% level of significance are in parentheses. The "Significance" rows indicate if abundance changes were statistically significant between time periods, where (+) indicates an increase and (-) indicates a decrease. Non-significant differences are indicated by (0).

			Legal-size brook trout:		
Section, time period, (regulation)	Fishing effort (hours)	Rel- eased (<8 in)	Harv- ested (≥8 in)	Rel- eased (≥8 in)	Total catch (≥8 in)
Chase Bridge - Highbanks					
1981-82	10,797	5,829	304	650	954
(8-in minimum)	(±1,902)	(±2,210)	(±194)	(±493)	(±530)
1985-90	7,393	4,641	0	1,055	1,055
(No-kill)	(±878)	(±1,674)	(±0)	(±679)	(±679)
Significance	(-)	(0)	(-)	(0)	(0)
Highbanks - Smith Bridge					
1981-82	13,128	9,572	221	1,140	1,361
(8-in minimum)	(±2,119)	(±2,477)	(±159)	(±778)	(±794)
1985-90	13,266	10,215	181	1,030	1,211
(8-in minimum)	(±1,542)	(±1,815)	(±123)	(±368)	(±388)
Significance	(0)	(0)	(0)	(0)	(0)
Ranch - Kellogg Bridge					
1981-82	30,462	20,910	1,546	2,860	4,405
(8-in minimum)	(±5,129)	(±6,246)	(±846)	(±1,608)	(±1,817)
1985-90	22,241	16,952	643	2,217	2,860
(8-in minimum)	(±2,000)	(±3,235)	(±330)	(±609)	(±693)
Significance	(-)	(0)	(0)	(0)	(0)

References

Alexander, G. R., and D. S. Shetter. 1967. Fishing and boating on portions of the Au Sable River in Michigan, 1960-63. Transactions of the American Fisheries Society 96:257-267.

Anderson, J. A. 1977. The Yellowstone Park experience with catch-and-release fishing. Pages 7-9 *in* R. A. Barnhart and T. D. Roelofs, editors. Catch-and-release fishing as a management tool. Humboldt State University, Arcata, California.

Anderson, R. M., and R. B. Nehring. 1984. Effects of a catch-and-release regulation on a wild trout population in Colorado and its acceptance by anglers. North American Journal of Fisheries Management 4:257-265.

Bailey, N. J. J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38:293-306.

Barnhart, R. A., and T. D. Roelofs, editors. 1987. Catch-and-release fishing: a decade of experience. Proceedings of National Sport Fishing Symposium. Humboldt State University, Arcata, California.

Behnke, R. J. 1989. We're putting them back alive. Trout Magazine. Autumn 1989. Vienna, Virginia.

Carlander, K. D. 1977. Handbook of freshwater fishery biology, Volume 2. Iowa State University Press, Ames, Iowa.

Clapp, D. F., R. D. Clark, Jr. and J. S. Diana. 1990. Range, activity, and habitat of large, free-ranging brown trout in a Michigan stream. Transactions of the American Fisheries Society 119:1022-1034.

Clark, R. D., Jr. 1983. Potential effects of voluntary catch and release of fish on recreational fisheries. North American Journal of Fisheries Management 3:306-314.

Clark, R. D., Jr., and G. R. Alexander. 1984. Effects of a slotted size limit on the brown trout fishery of the Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1927, Ann Arbor, Michigan.

Clark, R. D., Jr., and G. R. Alexander. 1985. Effects of a slotted size limit on a multispecies trout fishery. Michigan Department of Natural Resources, Fisheries Research Report 1926, Ann Arbor, Michigan.

Clark, R. D., Jr., G. R. Alexander, and H. Gowing. 1981. A history and evaluation of regulations for brook trout and brown trout in Michigan streams. North American Journal of Fisheries Management 1:1-14.

Gigliotti, L. M. 1989. No-kill fishing regulations: an assessment of the social and recreational characteristics and behaviors of Michigan stream trout anglers with special consideration of anglers on selected sections of the Au Sable River. PhD dissertation, Michigan State University, East Lansing, Michigan.

Graff, D. R., and B. A. Hollender. 1977. Catch-and-release fishing - the Pennsylvania experience. Pages 137-150 *in* R. A. Barnhart and T. D. Roelofs, editors. Catch-and-release fishing as a management tool. Humboldt State University, Arcata, California.

Malvestuto, S. P. 1983. Sampling the recreational fishery. Pages 397-420 *in* L. A. Nielsen and D. L. Johnson, editors, Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Netter, J., and W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc., Homewood, Illinois.

Orciari, R. D., and G. H. Leonard. 1990. Catch-and-release management of a trout stream contaminated with PCBs. North American Journal of Fisheries Management 10:315-329.

Regal, G. E. 1992. Range of movement and daily activity of wild brown trout in the South Branch Au Sable River, Michigan. Master's thesis, The University of Michigan, Ann Arbor, Michigan.

Richardson, F., and R. H. Hamre, editors. 1984. Wild trout III, proceedings of the symposium. Trout Unlimited, Vienna, Virginia.

Report approved by R. D. Clark, Jr.
Richard D. Clark, Jr., Editor
Andrew J. Nuhfer, Editorial Board Reviewer
Alan D. Sutton, Graphics
Barbara A. Champion, Word Processor