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EFFECTS OF ANGLING REGULATIONS ON A WILD BROOK TROUT FISHERY

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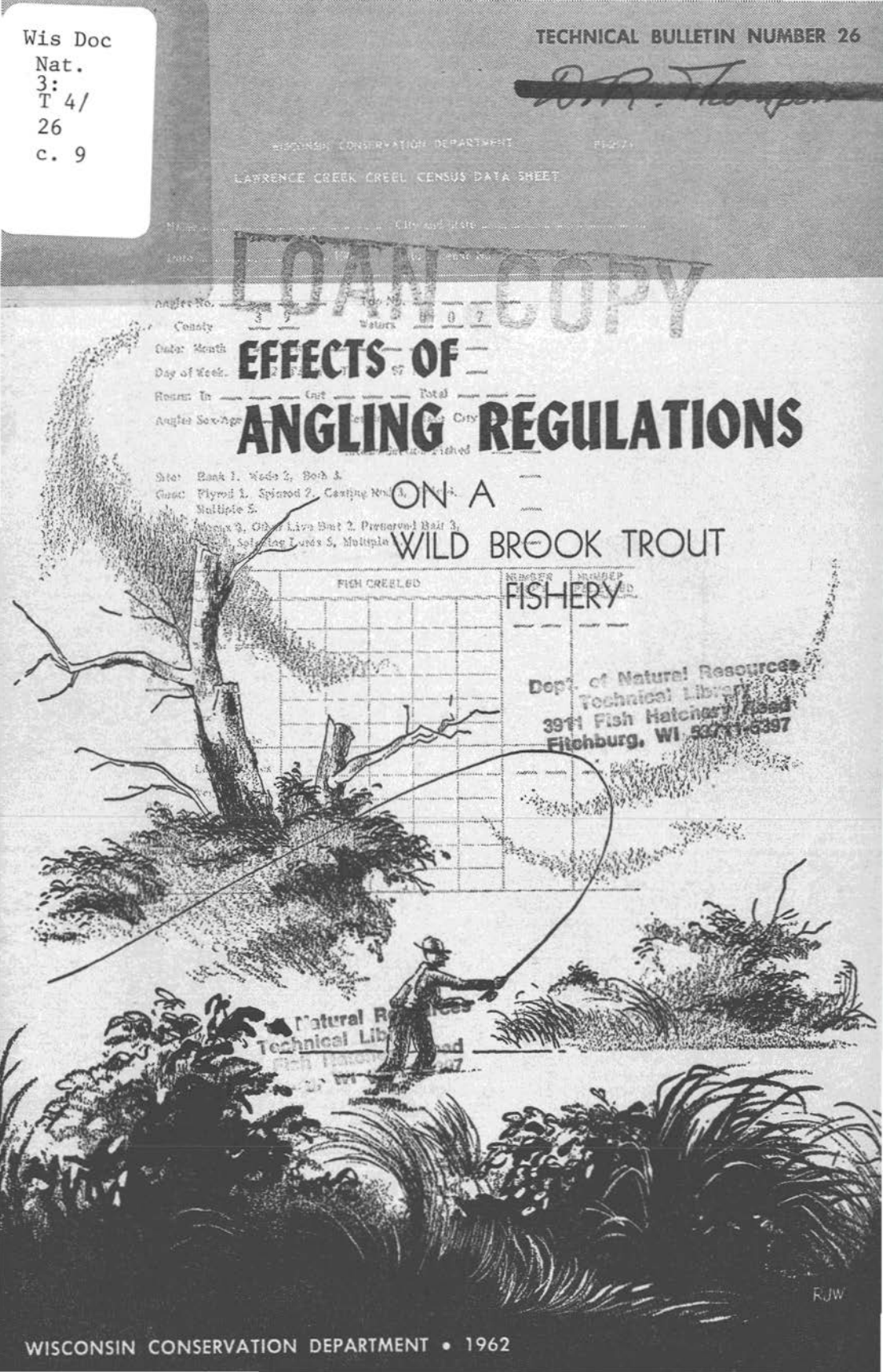

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EFFECTS OF ANGLING REGULATIONS ON A WILD BROOK TROUT FISHERY

by

Robert L. Hunt, Oscar M. Brynildson and
James T. McFadden
Fishery Biologists

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WISCONSIN CONSERVATION DEPARTMENT
Madison 1, Wisconsin

1962

ACKNOWLEDGMENTS

An investigation such as this one, which spanned eight years of electrofishing work and six years of complete creel census, necessarily involved the participation of many personnel in the Wisconsin Conservation Department. We are indebted to all these people for individual talents contributed so generously to this investigation.

Special acknowledgment is due the following personnel: Lyle Christenson critically reviewed the manuscript, encouraged its preparation from the start, and served as administrator of the project since 1957. John Brasch directed the administration of the project during the difficult period of its inception and the first three years of operation; Ray White ably assisted with electrofishing work and offered many valuable suggestions during the early phases of organizing the manuscript. Jack Mason supervised routine field work during an interim period between project leaders. Clarence Todd and Clifford Lodginski assisted with all phases of the work; Willis Fernholz, Elmer Simonson, Gerald Daley, Paul Downing, Gerald Wegner and Roger Worlund assisted in field work, creel census, and compilation of raw data; George Brader was responsible for preparation of IBM summaries of creel census data.

Lastly, we acknowledge the splendid cooperation of the thousands of trout fishermen who participated in this research project. Without their assistance, this study would not have been possible.

The cover picture was reproduced from a drawing by Ray White. Photographs are by Ray White and Robert Hunt. The present address of James T. McFadden is: Institute for Fisheries Research, University Museums Annex, Ann Arbor, Mich.

Edited by Ruth L. Hine

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ABSTRACT

The effects of different angling regulations on a wild brook trout population and fishery were studied at Lawrence Creek, which contains a dense population of this species and has a reputation for "good trout fishing".

During six years of continuous research, three sets of regulations were evaluated: a 6-inch minimum size limit and bag limit of 10 (1955 season), no size limit and no bag limit (1956–57 seasons), and a 9-inch minimum size limit and bag limit of 5 (1958–60 seasons). The first two sets of regulations were much alike in their effect upon angler harvests. Few anglers were skillful enough to catch 10 or more wild brook trout and few brook trout less than 6 inches were kept when it was legal to do so. We therefore concluded that the harvests observed in 1955, 1956, and 1957 were largely unaffected by the presence or absence of regulations as liberal as a 6-inch limit and bag of 10.

When the minimum size limit was raised to 9 inches during the 1958–60 seasons, the catch was dramatically reduced, angling success indices declined, and fishing pressure declined. Simultaneously the growth of trout declined and instances of higher-than-normal summer and winter mortality due to natural causes reduced the possibility of stockpiling enough Age Group II brook trout to provide a yield (in terms of both number and pounds) comparable to one which includes a significant percentage of Age Group I brook trout as well. Adoption of the 9-inch limit did improve the reproductive capacity of the brook trout population. In trout streams where spawning habitat is available but spawners are scarce, suitable size limits provide an appropriate management tool for increasing reproductive potential. However, in Lawrence Creek the 9-inch limit was not needed for this specific purpose because enough Age Group I brook trout usually survived the fishing season to provide adequate reproduction regardless of the angling regulations.

During two fishing seasons angling proved to be an efficient predatory activity. The catches of brook trout in 1956 and 1957 represented 59 per cent and 65 per cent of the respective preseason populations. Age Group II brook trout seemed especially vulnerable to angling.

Regulation of the harvest of wild brook trout from Wisconsin streams is both biologically sound and necessary to insure perpetuation of this fishery wherever sufficient angling activity exists. Furthermore, minimum size limits provide a more dependable method of controlling the harvest than do bag-limit restrictions. Reductions in harvest due to reduced bag limits are largely independent of brook trout population density. To protect sparse populations, bag limits would have to be so restrictive (perhaps as low as 2 trout per day) that desirable harvesting would be prevented when the same populations are at higher densities. On the other hand, harvests made under a 9-inch limit showed much reduced rates of exploitation at all levels of fishing intensity and trout population density encountered. A minimum size

limit adapted to the growth characteristics of the brook trout populations being managed would ameliorate angling mortality over a wide range of trout density and angling pressure.

Regardless of the bag limit or size limit in effect, the amount of angling mortality which occurred during the 1955–60 seasons was found to be a function of the relationship existing between angling intensity and density of trout. Angling mortality is an inverse density-dependent factor. If angling pressure remains constant, the rate of exploitation increases as the density of trout decreases. Or, any increase in angling pressure brings about a proportionately greater depletion of sparse trout populations than of dense trout populations.

INTRODUCTION

Mortality due to angling can constitute a serious limiting factor within a population of wild stream-dwelling brook trout *(Salvelinus fontinalis)*. However, angling mortality can be markedly altered by changes in the angling regulations governing a brook trout fishery. These two conclusions are based on six years of intensive research conducted on Lawrence Creek located in central Wisconsin in Adams and Marquette Counties. In this particular fishery, angling exploitation was influenced more by raising the legal minimum size limit from 6 inches to 9 inches than it was by complete removal of both size and bag restrictions.

The Lawrence Creek Trout Research Project was established by the Wisconsin Conservation Department in the spring of 1955 under the provisions of the Wisconsin statutes which authorized the Wisconsin Conservation Commission to initiate investigations relative to the supply of trout and methods used in managing trout populations in various streams in the state. Under the Wisconsin Trout Management Policy adopted in 1954, the Commission recognized that one of the responsibilities of the Conservation Department was to determine "the effects of different fishing restrictions on stocks of trout", and gave the Department authority to establish areas for appropriate experimental studies. The Lawrence Creek Station was established to partially fulfill this obligation.

The primary objective of the research at Lawrence Creek was to determine the effects of different angling regulations on a wild brook trout population and the fishery sustained by this population. Other objectives were to determine: (1) sex ratios and fecundity of wild brook trout, (2) characteristics of the environment of brook trout, (3) movement of brook trout in a stream, and (4) effects of a headwaters trout refuge.

In this report, the findings from these last four objectives are discussed only when they bear directly on the primary objective. However, our investigations into these aspects of trout biology have increased our understanding of the basic ecology of brook trout in addition to supplying information useful for management through angling regulations.

DESCRIPTION OF THE STREAM AND STUDY AREA

Lawrence Creek sustains a dense population of wild brook trout and a sparse population of wild rainbow trout, *Salmo gairdneri*. Its clear water, abundant springs, and extensive spawning habitat make it an excellent brook trout stream with a reputation for "good fishing" known throughout the state.

The Lawrence Creek project area includes approximately 3.3 miles of stream extending from the headwaters to its juncture with the upper end of the Lawrence Millpond. The stream has an average width of 23.5 feet and a total surface area of 9.4 acres. Discharge at the outlet approximates 25 c.f.s. at base flow. The physical dimensions of Lawrence Creek are summarized in Table 1.*

Lawrence Creek was selected for the pilot investigation of angling regulations because:

1. It was known to sustain an excellent population of wild brook trout, the species of stream trout thought to be in greatest danger of overexploitation by angling.
2. The stream was small enough to be "workable" with our present electrofishing gear and available manpower.
3. It was reasonably centrally located in the state and thus accessible to a large segment of the trout-angling public.
4. It was well bounded by roads so that posting of regulations and project area signs was simplified.
5. Since most of the land adjoining the stream is state owned, there was no trouble with trespass problems.

Lawrence Creek was divided into four sections beginning with section A at the headwaters through section D terminating at the millpond (Fig. 1). Portions of sections A and B have stronger gradients than are characteristic of the remainder of the stream. These two regions of increased gradient contain a high proportion of exposed gravel substrate and function as the chief spawning areas, although brook trout do reproduce successfully throughout the stream wherever gravel is exposed.

Most of section A is moderately shaded by alder or forest growth. The upper half of section B meanders through an attractive marsh-meadow. The stream then enters a second wooded region where the gradient increases. Below this woods the stream emerges into another marsh-meadow which includes all of section C and most of section D. At its lower extremity section D is relatively wide and shallow. This portion of the stream flows through privately-owned land, but fishermen are allowed access to the stream.

The entire stream is continually supplied with spring water from both lateral feeders and springs which bubble up through the stream bed. Variations in water temperature from source to mouth are minor. Water temperature and stream flow are relatively stable from year to year. Because it is supplied mainly by a deep aquifer, variations in annual rainfall or air temperature do not affect it to the same extent that most streams in central Wisconsin are affected.

A list of nongame fishes and sport fishes known to be present in Lawrence Creek is contained in Appendix D. Occasionally sport fishes other than trout enter the lower part of the stream from the millpond, but they apparently are not year-around residents.

* All numbered tables will be found in Appendix A.

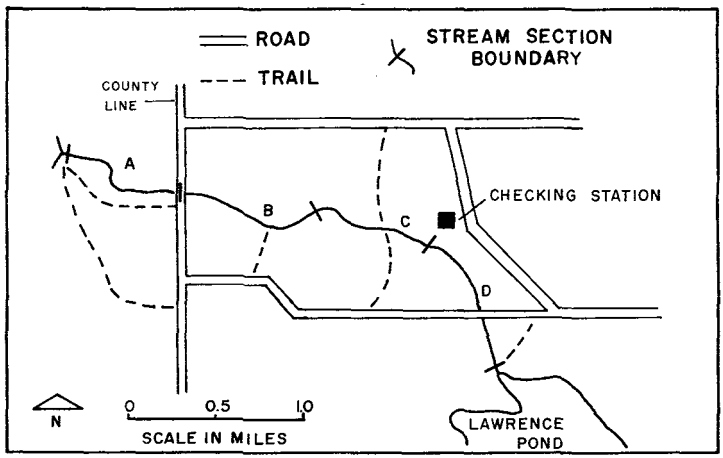


Figure 1. Map of Lawrence Creek trout research area.

METHODS

The effects of each set of angling regulations upon the brook trout population and the fishery were evaluated on the basis of concomitant changes in: (1) composition of the yield to anglers, (2) structure of the trout population before and after each fishing season (by size groupings, age composition, and densities), (3) angling pressure, angling methods and other variables descriptive of the anglers themselves, (4) rates of both natural and angling mortality, and (5) reproductive potential of the trout population.

Ideal measurements of yield to the anglers were obtained through a complete creel census. Anglers were required to obtain a free permit before each trip to the stream. Separate permits were issued for each section. Before leaving the project area anglers were required to return their permits and present their trout for examination.

Petersen-type (mark and recapture) estimates of the trout population were made each April, prior to the fishing season, and each September beginning the day after the fishing season ended. Electrofishing gear was employed. Much of the data for age analyses, growth, condition, mortality, and reproduction studies were also obtained during the semiannual electrofishing operations.

A more detailed explanation of the methods employed is presented in Appendix B.

McFadden (1961) has published a thorough account of the precision of the population statistics derived from our field data. Some typical examples are shown at the top of page 8.

These statistics were based on the September, 1956, population estimate. Since the fall trout population in Lawrence Creek is normally more dense than was the case in 1956, our estimates of various population parameters would usually be even more precise than those listed above.

Population Statistics	95 Per Cent Confidence Limits in Per Cent (±) of the Point Estimate
Total Number of Trout	2.9
Number by Age Group	
0	3.1
I	7.3
II	18.8
Total Number of Mature Females	9.1
Calculated Production of Eggs	12.1

EVALUATION OF STATE-WIDE REGULATIONS—1955

At Lawrence Creek, the investigation of angling regulations as one means of managing Wisconsin's wild brook trout resources has passed through three distinct phases to date.

During the first year of operation (1955), regulations in effect at Lawrence Creek were similar to the state-wide regulations for trout; namely, a 6-inch minimum size limit, a daily bag limit of 10 and a season length of 131 days. The only departure from the state-wide rules was the limitation of angling to the hours from 6:00 a.m. to 10:00 p.m. Except for short time periods prior to 6:00 a.m. and immediately after the 10:00 p.m. closing hour in midseason (when day length is maximum), this limitation probably did not alter the normal pattern of angling pressure.

The data pertaining to the 1955 creel census will be considered in detail because:

1. Our findings from the analysis of the 1955 creel census data provided the base line for comparisons with results to be obtained in subsequent years when regulations to be tested at Lawrence Creek would differ from those in effect on a state-wide basis.

2. Since the regulations in effect were the same as those pertaining to the state as a whole, their relationship to a known harvest was considered especially pertinent.

3. This was the first permit-only creel census ever conducted on a Wisconsin trout stream for an entire trout fishing season.

Creel Census Summary

The trout fishing season in 1955 opened on April 30 and closed September 7. During the 131-day season, 1,712 angling trips were made by 1,003 individual anglers. Some of the more important statistics derived from a complete creel census of these anglers are as follows:

Species	Total Catch for the Season				Hours of Effort		Catch Per Hour
	No.	No./Acre	Lbs.	Lbs./Acre	No.	No./Acre	
Brook	3,040	323.4	537.3	57.2	4,653.0	494.9	0.69
Rainbow	177	18.8	44.2	4.7			

At the end of a fishing trip each angler returns to the checking station and presents his catch for examination.

Statistics for hours of effort and catch per hour are related to the combined catches of brook trout and rainbow trout because rainbow trout are caught incidentally to the effort expended to catch brook trout. However, the catch of rainbow trout is so unimportant to the fishery that no elaboration of their contribution will be made other than a report of the number and pounds caught each year.

Periodicity of Fishing Pressure and Catch

Angling effort and number of brook trout caught followed similar trends throughout the trout fishing season (Fig. 2). Fishing pressure was very heavy the first week and then declined rapidly. On the opening day of the season, 17 per cent of the season's total catch and 9 per cent of the total trips were recorded. By the end of the first week, 27 per cent of the catch and 19 per cent of the trips were recorded (Table 2).* During the fifth week, which included Memorial Day, there was a rise in trips and catch. Angling interest increased again after the thirteenth week, but never approached the peak activity attained during the first few days of the season.

Fishing pressure was usually heavier on week ends. Saturdays and Sundays comprised only 29 per cent of the days in the season, but 2 per cent of all the trips were made on those days.

Qualitative Changes in the Catch

An abundant yearling group (Age Group I) of brook trout dominated the

* All numbered tables will be found in Appendix A.

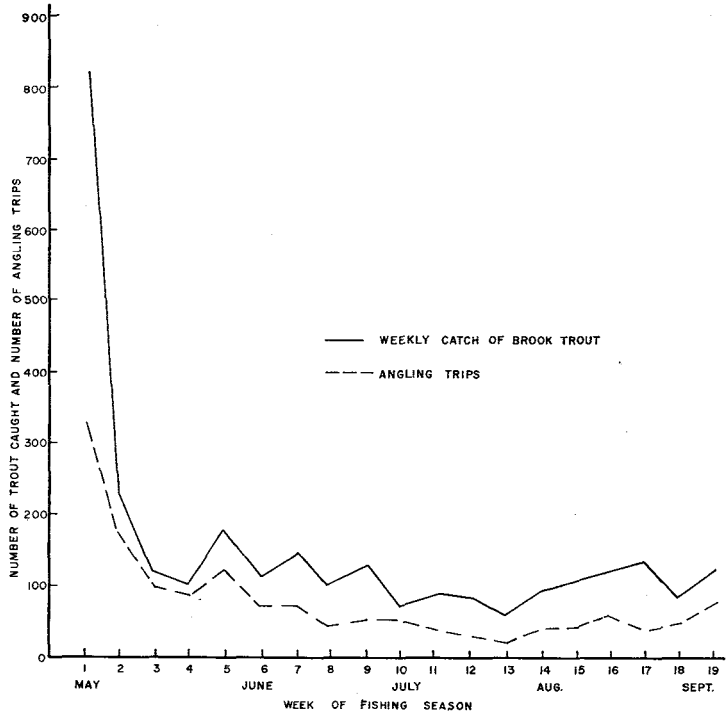


Figure 2. Distribution of angling pressure and catch of brook trout through the 1955 angling season.

1955 fishery, accounting for 62 per cent of the catch and 44 per cent of the total yield in pounds. Two-year-old brook trout (Age Group II) comprised 36 per cent of the catch and 49 per cent of the total weight of brook trout caught. All older brook trout combined contributed only 2 per cent of the trout removed and 7 per cent of the total weight removed (Table 3).

Two-year-old brook trout predominated in catches taken during the first week of the season after which their importance declined rapidly. The catch of yearling brook trout increased inversely to that of the two-year-old brook trout as the season progressed (Fig. 3).

Rapid exploitation of the larger brook trout caused marked changes in size distribution in the yield even during the first week of angling (Fig. 4). The supply of trout larger than 8.4 inches was rapidly depleted, and angling pressure was sufficient to prevent recovery of this group during the open season. This size group roughly corresponds to Age Groups II, III, and IV.

The 7.5- to 8.4-inch group included brook trout mostly of Age Group II during the early part of the season. The proportion of trout of this size in the catch decreased until the seventh week. After this initial decline, 7.5- to 8.4-inch brook trout comprised an increasingly larger proportion of the yield, and by the end of the season, approximately one-third of the catch was trout of this size. This increase was largely due to recruitment of Age Group I brook trout.

The 6.0- to 7.4-inch group, composed almost entirely of Age Group I brook trout, became the predominant size group in the catch during the third week of the season, but during the last five weeks of the season, the proportion of brook trout of this size in the catch decreased, as many Age Group I brook trout were recruited into the 7.5- to 8.4-inch group. However, even during the closing week of the season, 50 per cent of the brook trout creeled were 6.0- to 7.4 inches long.

Such periodic length-frequency samples illustrate the changes in average size of the yield resulting from depletion by angling, and growth and recruitment of smaller trout. The interaction between these two opposing activities is reflected in the average size of trout a particular stream produces.

Angling Intensity and Exploitation of the Trout Population

Angling intensity during the 1955 fishing season varied from 347 hours per acre in section D to 680 hours per acre in section C. The percentage of the preangling season population which was harvested varied from 19 per cent in section A to 48 per cent in section D (Table 4).

The preseason standing crop of brook trout in the entire stream weighed 703 pounds, or about 75 pounds per acre. The yield of 537 pounds (57 pounds per acre) represented 76 per cent of the weight of brook trout present at the beginning of the season. Weight of the postseason residual standing crop (excluding Age Group O) was 392 pounds

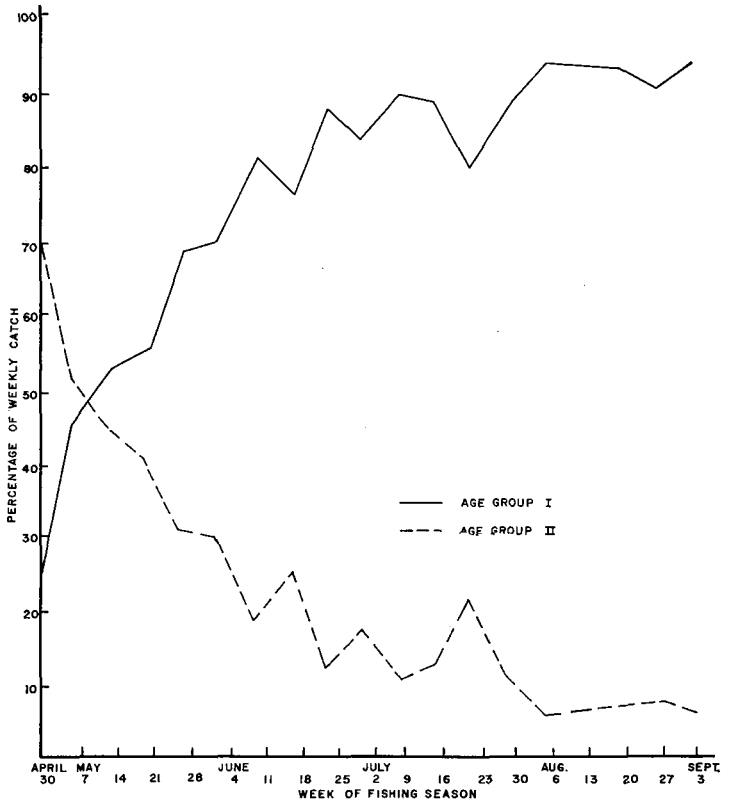


Figure 3. Percentage contribution of Age Groups I and II brook trout to the weekly catches during the 1955 fishing season.

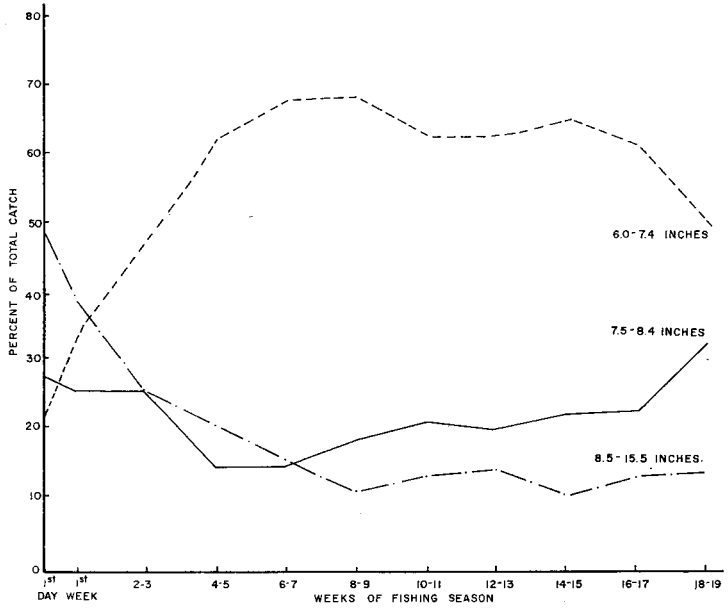


Figure 4. Seasonal variation in the size distribution of the brook trout in the anglers' catch during the 1955 season.

(42 pounds per acre), or an amount equal to 56 per cent of the preseason standing crop (Fig. 5). Except for occasional runts and cripples, this carry-over population consisted of legal-sized brook trout (under the existing 6-inch size limit).

Angling proved effective enough to remove 32 per cent of the number of adult (Age Group I and older) brook trout present when the season began, including 24 per cent of the yearling brook trout, 72 per cent of the two-year-old brook trout and 42 per cent of the brook trout three or more years old (Fig. 6).

Angling Characteristics

Angling Success. During the 1955 season, 75 per cent of the anglers fished only once, 13 per cent fished twice, 4 per cent fished 3 times and 8 per cent fished from 4 to 34 times. A total of 1,003 different individuals fished the stream. Percentage of successful trips and catch per hour were highest in section A and lowest in section C. Stream averages for these two indices were 47 per cent successful trips and 0.69 trout per hour (Table 5).

A large share of the catch was accounted for by a small proportion of the angling trips. Nearly one-third of the total catch was realized from only 6 per cent of all the trips, and half of the total catch was taken during 11 per cent of the trips (Fig. 7). On 53 per cent of the trips anglers failed to creel even one legal trout. Limit catches of 10 trout were made on only 3 per cent of the angling trips and accounted for 16 per cent of the total catch.

Angling success differed greatly among various groups of fishermen. Those anglers who fished the stream several times during 1955 made better catches per trip than those who fished only once or twice. Apparently the anglers who fished more often tended to be more skillful as indicated by the following data:

Trips Per Season	No. of Anglers	Per Cent of Anglers	Per Cent of Trips	Per Cent of Catch	Catch Per Trip
5+	49	4.9	26.7	49.7	3.31
3–4	73	7.3	14.5	18.9	2.32
1–2	881	87.8	58.8	31.4	0.95

Angling Methods. Much of Lawrence Creek can be easily fished with fly-casting and spinning gear. Nevertheless, natural baits, mainly worms, were used on 61 per cent of the angling trips and accounted for 68 per cent of the catch. Artificial flies were used on 25 per cent of the angling trips and accounted for 22 per cent of the catch. Spinning lures were used exclusively on 3 per cent of the angling trips and took 1 per cent of the catch. Both natural and artificial baits were employed on 11 per cent of the trips and took 9 per cent of the catch.

Anglers using live bait averaged 1.99 legal brook trout per trip; fly fishermen averaged 1.52 per trip; spin fishermen averaged 0.60 per trip; those resorting to multiple methods averaged 1.45 per trip.

Discussion

The 10-trout daily bag limit had no discernible effect in apportioning the catch among anglers. Reduction of the daily bag limit from 10 to 5 trout per day would have theoretically reduced the catch by only 18 per cent (Table 6).

Such a reduction would amount to a diversion of approximately 5.4 per cent of the preseason population from the more proficient anglers' creels, during a period when a 35 per cent natural mortality loss was being incurred. Assuming that natural mortality losses would have been the same for this 5.4 per cent as for the rest of the population, only an additional 3.5 per cent of the initial population would actually be available to the less skilled anglers. It is doubtful whether such a small increase in available trout would have improved the success of the unskilled anglers.

The number of Age Group II brook trout was rapidly depleted during the early weeks of the season. The fishing then became largely dependent upon Age Group I brook trout. Yearlings dominated the catch from the middle of May to the end of the season. This group was being heavily cropped before attaining a very desirable size. Angling, which tends to

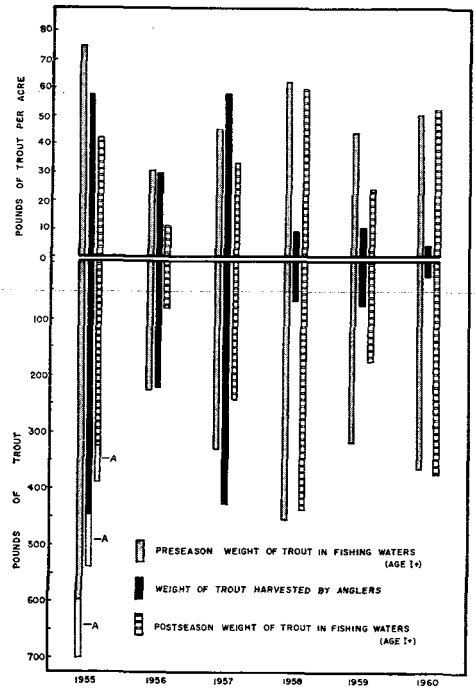


Figure 5. Pounds of brook trout comprising the preseason and postseason populations and the pounds of brook trout harvested under the special angling regulations tested at Lawrence Creek. (Data for Section A is included for the 1955 season only.)

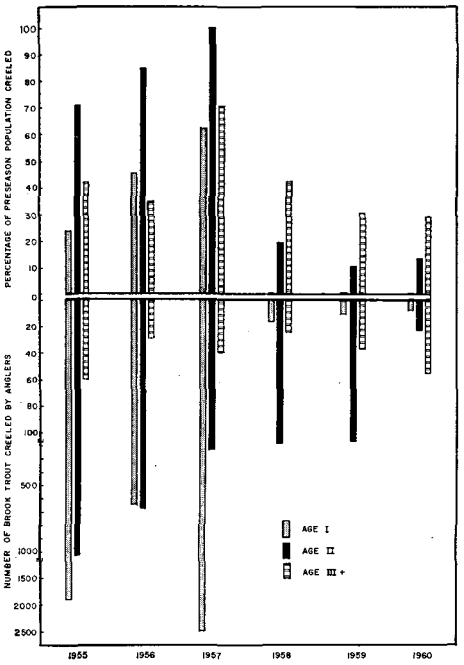


Figure 6. Age composition of the catch and rate of exploitation of the age groups in the catch during the 1955–1960 trout fishing seasons.

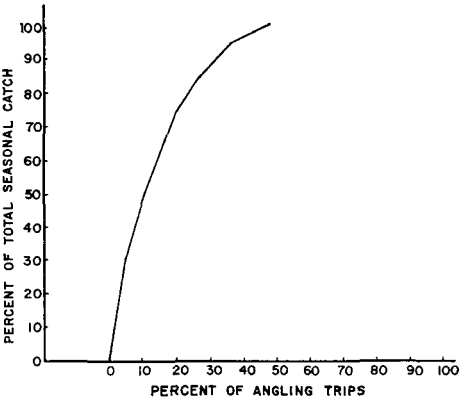
skim off the larger, faster-growing individuals of each age (Cooper, 1953a), was so effective that the average length of yearling brook trout cropped remained at 6.7 inches throughout the first seven weeks of the season.

Heavy early-season angling pressure and its resultant extensive exploitation of the larger trout undoubtedly affected the catch for the remainder of the season. Brook trout larger than 8.4 inches were uncommon in catches made after the third week. However, recruitment of smaller brook trout to legal size during the angling season compensated for the reduction of legal-size brook trout due to angling and natural mortality. The number of legal-size brook trout present when the fishing season closed approximated the number present when the fishing season began. Removal of 32 per cent of the available population representing a harvest equal in weight to 75 per cent of the preseason biomass did not appear to be excessive.

The consistency with which certain anglers made good catches while 53 per cent of the total angling trips were unsuccessful testifies to the skill of the individual fisherman as the single most important factor in determining how many trout he will catch. In relation to the state-wide brook trout fishery, this observation would indicate that a relatively few anglers of exceptional skill take a disproportionately large share of the brook trout caught in Wisconsin each year. So-called "angler's luck" can be largely discounted as a factor influencing the harvest of wild brook trout.

Hence, the success of even the best trout management program might easily be underestimated by those anglers who fail to recognize the relationship between fishing ability and trout in the creel.

Figure 7. Distribution of the catch of brook trout from the 1955 season among angling trips.



EVALUATION OF LIBERALIZED REGULATIONS—1956 AND 1957

The second phase of our investigation of angling regulations was conducted during the 1956 and 1957 trout fishing seasons. Anglers were allowed to keep all the trout they could catch. There were no minimum-size or bag-limit restrictions. Opening and closing dates of the trout fishing season were the same as the state-wide dates except that fishing was limited to the hours from 6:00 a.m. to 10:00 p.m. Fishing was continued under the free-permit system which required each angler to check in and check out and to present his catch for examination.

The principal objective in testing these liberalized regulations was to determine to what extent the state-wide regulations tested in 1955 had restricted the angler harvest.

Due to establishment of section A as an experimental fish refuge prior to the opening of the 1956 fishing season, the amount of available fishing water was reduced from approximately 9.4 acres to 7.4 acres. This reduction should be kept in mind when comparing angler harvests for 1956 and later years with the harvest during the 1955 season. Those statistics reduced to a "per acre" basis constitute the best basis for comparison.

Creel Census Summaries

During the 133-day 1956 trout fishing season, 1,313 angling trips were made by 997 individual anglers. Some statistics derived from the creel census of these anglers follow:

During the 130-day 1957 trout fishing season, 1,249 angling trips were made by 781 individual anglers. The 1957 season began on a Wednesday due to a state-wide trial conversion to an opening date of May 1. The 1955 and 1956 trout fishing seasons had both opened on the Saturday nearest May 1. Some of the statistics derived from the 1957 creel census are summarized at the top of page 16.

Periodicity of Fishing Pressure and Catch

There was no increase in fishing pressure due to removal of size and bag restrictions. In fact, about 25 per cent fewer trips were made in 1956 and in 1957 compared to the number made in 1955.

Fishing pressure and catch during 1956 followed a pattern similar to that observed during the 1955 season. On opening day of the trout fishing season, 25 per cent of the season's total catch of brook trout and 2 per cent of the total trips were recorded. Through the first week, 37 per cent of the catch and 19 per cent of the trips had been accounted for. By the end of the fifth week, 64 per cent of the season's catch was in and 52 per cent of the trips had been made (Table 2).

Fewer trips were made during the first five weeks of the 1957 trout fishing season compared to the same period in the preceding two seasons, but during the

Species	Total Catch for the Season				Hours of Effort		Catch Per Hour
	No.	No./Acre.	Lbs.	Lbs./Acre	No.	No./Acre.	
Brook	1,360	184.5	220.3	31.2	3,051.0	413.8	0.47
Rainbow	57	7.7	8.8	1.2			

Species	Total Catch for the Season				Hours of Effort		Catch Per Hour
	No.	No./Acre	Lbs.	Lbs./Acre	No.	No./Acre	
Brook	2,778	381.0	431.4	60.9	3,168.0	429.9	0.89
Rainbow	47	6.4	11.1	1.5			

closing weeks of the 1957 season angling interest increased to about the same level as in 1955 and heavier than that which occurred in 1956. During the first week of the 1957 season, only 13 per cent of the total trips and 22 per cent of the total catch of brook trout were recorded. Undoubtedly the catch and fishing pressure during the first week were reduced because of the change to a week-day opening date. By the end of the fifth week, 45 per cent of the catch had been taken on 36 per cent of the total trips (Table 2).

Qualitative Changes in the Catch

1956 Season. During 1956, the number of yearling brook trout was relatively low due to poor survival during the first 15 months of life. As a result brook trout of Age Groups I and II each comprised nearly half the catch. As in 1955, Age Group II constituted the bulk (60 per cent) of the weight of brook trout harvested (Table 3). This age group (mostly 7.5 to 8.4 inches long) dominated the catch during the first three weeks of the season after which their importance rapidly declined. The contribution of Age Group I brook trout (from 6.0 to 7.4 inches long) increased after the third week. During the last four weeks, Age Group I brook trout continued to predominate in the catch, but they were now largely in the 7.5- to 8.4-inch length range.

Brook trout less than 6 inches long comprised 20 to 25 per cent of the weekly catches during the period from May 5 to June 15. However, only during the May 5–13 period was the actual number (66 fish) of trout of this size in the catch of any magnitude. Over the entire season only 146 brook trout out of the total catch of 1,360 were less than 6 inches long, and most of these were at least 5.5 inches.

1957 Season. The number of yearling brook trout was relatively high in 1957, while the weak 1955 year class, now two-year-olds, had dwindled to a low number. Consequently, the 1957 fishery was largely dependent upon the yearling group throughout the entire season. Yearling brook trout accounted for 90 per cent of the total number and 83 per cent of the total weight of brook trout creeled. Two-year-old brook trout comprised 8 per cent of the number and 13 per cent of the weight of trout creeled (Table 3).

Brook trout 6.0 to 7.4 inches long were most common in the catches during the first 14 weeks of the season. During the remaining five weeks the bulk of the catch consisted of brook trout from 7.5 to 8.4 inches long. The proportion of brook trout in the catch more than 8.4 inches in length increased steadily from the seventh week to the end of the season.

Only 147 brook trout out of the total catch of 2,778 were less than 6 inches long. Such trout never comprised more than 20 per cent of any one week's catch and only 5 per cent of the total catch. Few trout smaller than 5.5 inches were kept.

Electrofishing crew shocking a deep hole in the middle of section B. After 100 yards of the stream have been shocked, all trout collected in that stretch are examined and marked.

Angling Intensity and Exploitation of the Trout Population

1956 Season. Angling intensity during the 1956 season averaged 414 hours per surface acre for the entire area of stream open to fishing. Within section C, angling effort was 666 hours per acre. This is the highest angling pressure recorded for an individual stream section during the six years of creel census covered by this report (Table 2).

The weight of the 1956 catch of brook trout, 30 pounds per acre, nearly equalled the 31 pounds per acre of adult brook trout available in April, 1956, just before the trout fishing season opened. Weight of the residual adult brook trout remaining after the fishing season closed in September averaged 11 pounds per acre. Within the portion of stream open to angling, 46 per cent of the yearlings, 85 per cent of the two-year-olds, 33 per cent of the three-year-olds, and 100 per cent of the four-year-olds were removed by

anglers (Fig. 6). For all ages combined, anglers harvested 59 per cent of the brook trout available in April.

1957 Season. For the third consecutive year fishing pressure on Lawrence Creek was heavy compared to that expended on other waters in Wisconsin (McFadden, 1956). During the 1957 season angling effort amounted to 430 hours per acre. Maximum effort recorded per section was 597 hours per acre in section B.

The total catch of brook trout representing 58 pounds per acre exceeded the preseason standing crop of 45 pounds per acre by 29 per cent. The weight of the remaining adult brook trout in September was 33 pounds per acre or 73 per cent of the weight of preseason standing crop. Angling was sufficiently effective to remove 65 per cent of the adult brook trout population from the fishing waters (Table 4). This is the highest over-all exploitation rate encountered during six years of creel census.

Angling Characteristics

Angling Success. Despite the fact that trout of any size could be kept, indices of angling success for the 1956 season were: 0.47 trout per hour and 34 per cent successful fishing trips. Section B provided the best fishing (Table 5). Of the 997 individual anglers registered, 83 per cent fished only once, 11 per cent made 2 trips, 3 per cent fished 3 times, and 3 per cent fished from 4 to 17 times during the 1956 season. The 4 individuals who each made 10 or more trips accounted for 4 per cent of the total trips and 12 per cent of the total catch of brook trout. The 61 anglers who each fished 3 or more times accounted for 21 per cent of the total trips and 53 per cent of the total catch (Table 7). One-third of the catch was taken on only 3 per cent of the total trips. Half the total catch was taken on only 7 per cent of the total trips.

The rate of catch for the 1957 season rose to an average of 0.89 trout per hour and on 44 per cent of the total trips at least one brook trout was creeled (Table 5). These improved indices reflect in part the greater number of trout present in 1957.

Of the 781 individuals who fished the stream, 77 per cent came only once, 14 per cent came twice, and 3 per cent fished from 4 to 28 times. The 11 anglers who each made 10 or more trips accounted for 32 per cent of the total catch during 16 per cent of the total trips. Catches of more than 10 trout were made on only 6 per cent of the total trips.

Angling Methods. In 1956, bait fishermen creeled 77 per cent of the total catch on 70 per cent of the total trips and averaged 0.80 brook trout per trip. Fly fishermen creeled 14 per cent of the catch on 16 per cent of the trips and averaged 0.64 brook trout per hour (Table 8).

In 1957, bait fishermen again predominated, taking 74 per cent of the catch on 65 per cent of the trips, while fly fishermen took 16 per cent of the catch on 19 per cent of the trips (Fig. 8). Bait fishermen, who averaged 2.5 brook trout per trip, were 39 per cent more efficient than fly fishermen who averaged 1.8 brook trout per trip.

Discussion

Evidence from our complete creel census in 1956 indicates that adherence to a daily bag of 10 trout would have reduced the catch by only 5 per cent. Catches of more than 10 trout were reported on only 14 (1 per cent) of the 1,313 angling trips (Table 9). If a minimum size limit of 6 inches had been in effect, the catch would have been reduced

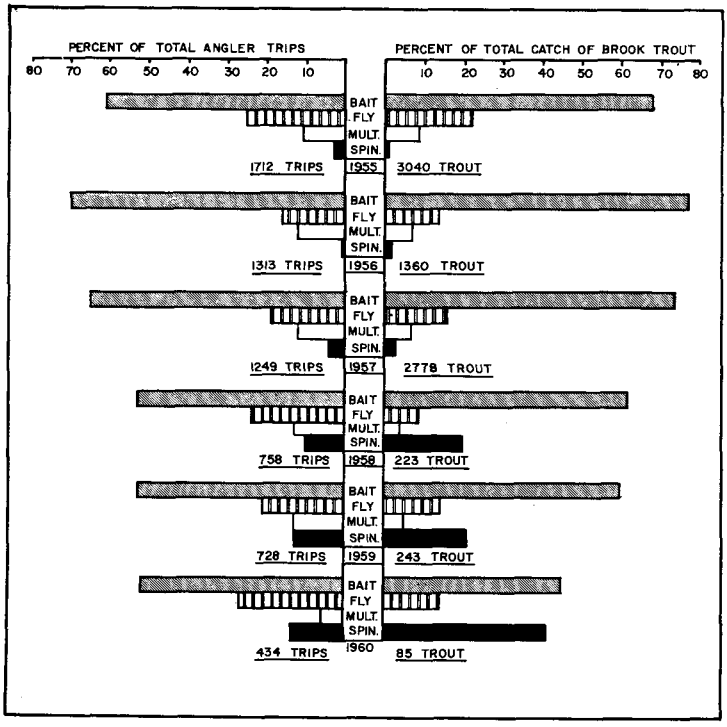


Figure 8. Percentage distribution of angler trips and catches of brook trout during the 1955–1960 seasons, based on the method of fishing.

by 11 per cent. The total catch of 1,360 brook trout included only 146 less than 6 inches. The size-limit and bag-limit restrictions in combination would have reduced the angler's harvest by 14 per cent. Reduction in catch due to the combined effects of bag and size limits are not the sum of the individual reductions, since some trout caught in excess of 10 per trip were also less than 6 inches long.

The foregoing calculations assume that any decrease in the catches of the better fishermen due to a 6-inch limit and bag limit of 10 would not automatically increase the catches of the less proficient anglers (Cooper, 1953b).

These calculations based on the 1956 creel census data apply to a brook trout fishery in which yearlings were less abundant than normal. This condition tended to minimize the effect of a bag limit. However, since yearlings in 1956 were smaller than average during the early weeks of the season, the probable effect of a 6-inch minimum size limit was maximized under the existing fishing pressure.

The 1957 fishery was largely sustained by a relatively high number of yearling brook trout exhibiting more normal rates of growth and recruitment. Creels of more than 10 trout were taken on only 72 (6 per cent) of the 1,249 angling trips (Table 9). These 72 trips were distributed among only 36 individual anglers, 3 of whom accounted for 24 of the 72 catches of more than 10 trout. A daily limit of 10 trout would have reduced the catch by 11 per cent while a minimum size limit of 6 inches would have reduced the catch by 5 per cent. Both restrictions operating simultaneously would have reduced the catch by 14 per cent.

Removal of the 6-inch minimum size limit did not materially alter the size composition of the catch. Length-frequency structures of the 1956 and 1957 catches of brook trout were similar to that of the 1955 catch (Fig. 9). Positioning of the 1955 and 1957 modes at the 6.5- to 7.4-inch interval are simply reflections of the predominance of yearlings in the catches during those years. The 1956 mode, positioned at the 7.5- to 8.4-inch interval, reflects the greater dependence of the fishery upon two-year-old trout.

Such natural changes in growth rates and age composition were more important in determining the size composition of the catch than was the presence or absence of a 6-inch minimum size limit. This observation should not be extended to other size limits or even to a 6-inch size limit in association with trout populations having growth rates very different from brook trout in Lawrence Creek. In streams where trout less than 6 inches are frequently creeled, growth rates are usually so slow that few trout larger than 6 inches are produced. For example, following removal of the 6-inch minimum size limit from some test streams in New Hampshire, approximately 60 per cent of the wild brook trout taken in 1957 and 75 per cent of those taken in 1958 were less than 6 inches long. Some 4-inch and even a few 3-inch brook trout were creeled. However, all of these small trout were more than one summer old. Most were Age Group I, but even some Age Group II and Age Group III brook trout were included (Seamans, 1959).

In the relatively fertile trout streams of Wisconsin, growth of brook trout is such that many in excess of 6 inches are available. Such trout are, naturally, preferred over smaller trout. If the behavior of anglers at Lawrence Creek during 1956 and

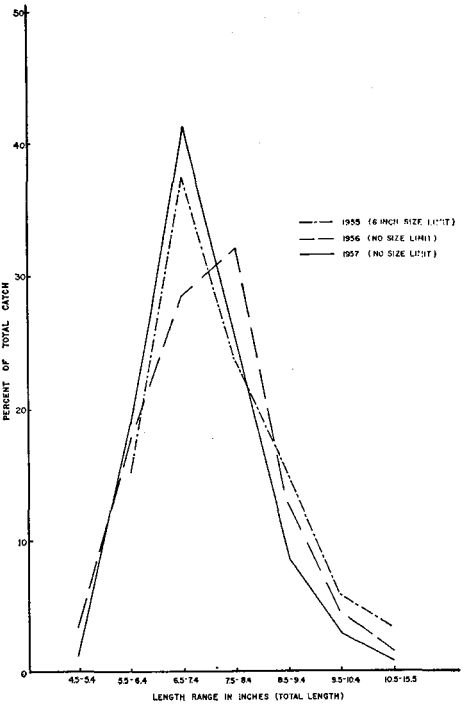


Figure 9. Length frequencies of the 1955, 1956, and 1957 catches of brook trout.

1957 is representative of the attitude prevailing throughout the state, it appears that trout fishermen in Wisconsin do not consider a trout less than 6 inches long worth keeping, even if it were legal to do so. This attitude could change, however, if trout fishing deteriorates.

When our findings from two years of liberalized regulations were related to our base line study in 1955, two observations were especially significant:

1. Catches of 10 or more wild trout were unusual.
2. Anglers kept few trout smaller than 6 inches.

Hence, the limitation upon the harvest observed in 1955 could not be attributed to the angling regulations in effect. Rather, the rate of exploitation for each stream section was largely a function of

the angling intensity and density of trout. The less dense population in section D was exploited more extensively than the denser populations in the other sections. Section A contained the most dense population but was only lightly fished, and rate of exploitation was low. In either case, the state-wide regulations being tested would not have prevented the trout population from being overharvested if sufficient angling effort had been applied.

In 1956, initial density of trout was moderate in section C, but angling intensity was very high. Consequently, exploitation was high. Three-fourths of the available trout were caught. In 1957, section C was again the hardest-fished section. It was fished almost as much as in 1956, but exploitation of the trout population was less severe because the number of trout present was much higher.

If we assume that regional (a single watershed or block of streams) or state-wide reductions in bag limits do not decrease fishing pressure, then the use of bag limits appears to be an inefficient technique in managing wild brook trout populations, based on our Lawrence Creek studies. Data from the 1955–57 fishing seasons, which include records of many individual anglers each making relatively few trips per season, indicate that bag limits would have to be very restrictive to achieve a substantial reduction in the total catch.

Large catches of wild brook trout per angling trip were relatively scarce. This observation was found to be true at brook trout densities ranging from 1,003 per acre in 1955 (a very high density) to 313 per acre in 1956 (a low density for Lawrence Creek but not in comparison to many trout waters). Therefore, since the limiting effect of bag limits appears to be largely independent of trout population density, their usefulness in trout management is impaired. In order to protect sparse brook trout populations, bag limits would have to be so restrictive that desirable harvesting may be prevented when the same populations are at higher densities.

A state-wide reduction of the bag limit from 10 to 5 would probably reduce the catch of brook trout by 20 per cent at best. If a 50 per cent reduction in catch were desired, a bag limit of 2 trout per day would be necessary (Fig. 10).

In theory, a bag limit sets an arbitrary upper limit to the efficiency of an individual fishing unit (Rounsefell and Everhart, 1953). The use of bag limits for trout has been advocated for a variety of reasons including:

1. Reducing the catch so that more trout survive to spawn, or be caught at larger sizes.
2. Distribute the catch more evenly among fishermen.
3. Provide a goal for the angler to aim at.
4. Prevent fish-hogging and waste, and encouragement of fishing for sport rather than meat for the table.

Our research at Lawrence Creek indicates that neither of the first two objectives is likely to be fulfilled by a bag limit applying to a wild brook trout fishery. Our research was not designed to investigate either of the last two objectives, although both merit further study.

Still another use of bag limits in reducing fishing pressure on selected streams is discussed following presentation of our findings during the 1958–60 period.

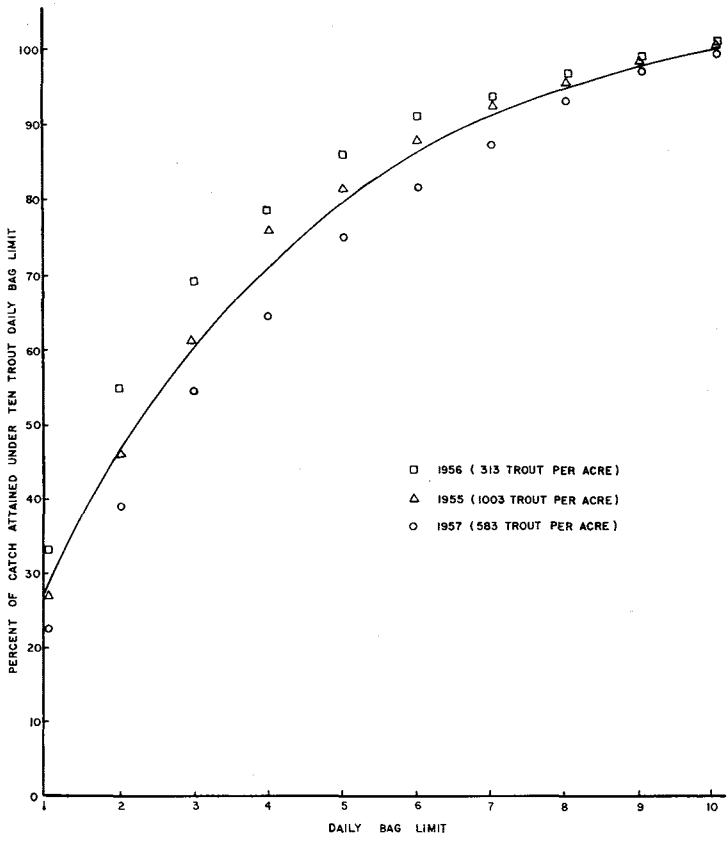


Figure 10. Theoretical reduction in seasonal catch of brook trout that could be expected due to bag limits of less than 10 trout. (The line is fitted to the composite data derived from the 1955–57 angling seasons, and the pre-angling season trout densities are shown in the legend for the figure.)

EVALUATION OF MORE-RESTRICTIVE REGULATIONS—1958–1960

The third phase of experimentation with angling regulations and their effects upon a wild brook trout population and angler harvests began with the 1958 trout fishing season and continued through the 1960 season. A minimum size limit of 9 inches and a daily bag limit of 5 were imposed. The system of issuing free permits was continued. Section A, the experimental trout refuge, remained closed to fishing. Angling hours remained unchanged from previous years, and opening and closing of the trout fishing season coincided with the state-wide dates.

Four guidelines were proposed to evaluate the effectiveness of these stringent regulations:

1. Alterations in the quantity, quality and composition of the yield were expected. Our knowledge of population structure and growth of brook trout in Lawrence Creek indicated that under a 9-inch limit approximately half the number but the same weight of trout could be creeled as under a 6-inch limit, provided angling pressure and growth of trout did not decline (McFadden, 1961).

2. Raising the minimum size limit and

lowering the bag limit should provide impetus for an increase in the number of larger trout in the population.

3. The catch of sublegal trout should increase in relation to the number of legal trout creeled. Would trout fishermen in Wisconsin be interested in this type of sport based on catching and releasing large numbers of medium-sized brook trout?

4. Because a 9-inch minimum size limit exceeds the length attained by most yearling brook trout in Lawrence Creek, this age group should go largely unharvested. Since most of these yearlings are sexually mature, an improvement in the reproductive capacity of the population was anticipated.

Creel Census Summaries

The May 1 opening date continued to apply to the 1958, 1959, and 1960 trout fishing seasons. Opening day was a Thursday in 1958, a Friday in 1959, and a Sunday in 1960. All three seasons covered 130 days. The creel census provided the following summary statistics:

seasonal distribution of pressure and catch in 1958 continued to follow the usual pattern of highest activity the first week, then a gradual falling off of pressure until the last few weeks when activity increased again but never approached that exhibited during the opening weeks.

Through the first week, 36 per cent of the total catch of brook trout and 15 per cent of the total trips were recorded. By the end of the third week 48 per cent of the catch and 24 per cent of the trips were recorded (Table 10).

Thirty fewer angler trips were made in 1959 than in 1958, and only one-third as many trips were made in comparison to the 1955 season, the year of highest angling activity. While fishing success improved slightly in 1959 over that of 1958, the catch-rate of legal trout per hour (0.16) and percentage of successful trips (19 per cent) both remained quite low.

Angling effort and catch declined drastically in 1960, and distribution of the catch was the most disproportionate ever encountered during six years of creel

Year	Species	Total Catch for the Season				Hours of Effort		Catch Per Hour
		No.	No./Acre	Lbs.	Lbs./Acre	No.	No./Acre	
1958:	Brook	223	30.3	67.9	9.2	1,847.0	250.4	0.13
	Rainbow	13	1.8	4.3	0.6			
1959:	Brook	243	33.0	76.5	10.4	1,559.5	214.5	0.16
	Rainbow	7	1.0	2.2	0.3			
1960:	Brook	85	11.5	27.3	3.7	1,007.0	136.6	0.09
	Rainbow	6	0.8	1.5	0.2			

Periodicity of Fishing Pressure and Catch

Angling pressure and catch for the 1958 season were markedly lower compared to all previous years. However, the census. By the end of the first week of a 19-week season, 54 per cent of the total catch had been taken. Only 15 per cent of the total trips were included, however (Table 10).

Qualitative Changes in the Catch

As expected, adoption of the 9-inch minimum size limit on an experimental basis in 1958 largely eliminated Age Group I brook trout from the legal-sized portion of the population. Few yearlings attained legal size until late summer by which time the majority of the angling trips had been made. Thus, the fishery was largely dependent upon the number of Age Group II brook trout present. This age group constituted 82 per cent of the number and 77 per cent of the weight of brook trout caught in 1958, and 80 per cent of the number and 81 per cent of the weight creeled in 1959.

Age Group II brook trout were relatively abundant in both 1958 and 1959 but scarce in 1960. This age group accounted for 27 per cent of the total number and 24 per cent of the total weight of brook trout taken during the 1960 fishing season. Age Group III brook trout made up 65 per cent of the catch in 1960, 15 per cent in 1959, and 10 per cent in 1958. Age Group I brook trout did not enter the catch in 1960 until the tenth week and accounted for only 8 per cent of the total catch for the season. In 1958 and 1959 yearlings entered the catch during the eleventh week and accounted for 7 per cent and 5 per cent of the seasonal catches respectively (Table 3). The yearling group was abundant in 1958, relatively few in number in 1959, and abundant again in 1960.

Length-frequency distributions of the catches during the 1958–60 seasons were similar (Fig. 11). The majority of the brook trout creeled exceeded the minimum legal size by less than one inch.

Angling Intensity and Exploitation of the Trout Population

The amount of angling effort expended per acre of fishing water declined to 251 hours in 1958, to 215 hours in 1959, and to 137 hours in 1960. Section C was fished hardest and section D was fished the least all three years.

The catch of legal brook trout in 1958 was 9.2 pounds per acre, or 30.3 trout per acre. This yield represented 15 per cent

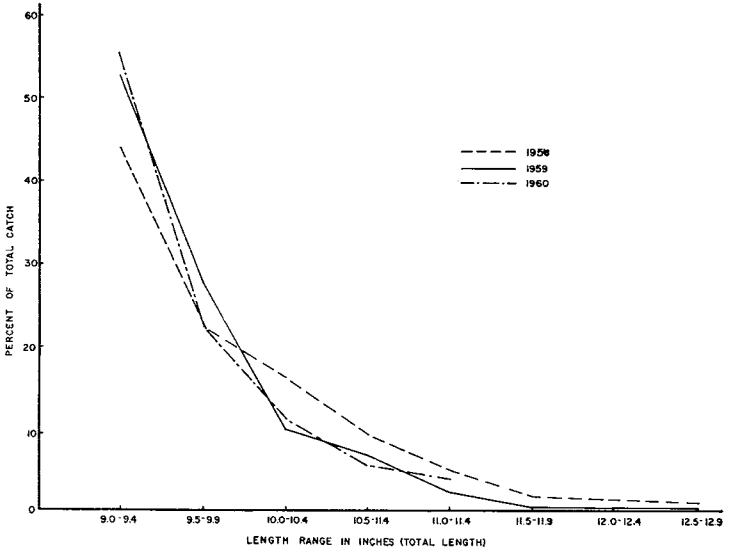


Figure 11. Length frequencies of the 1958, 1959, and 1960 catches of brook trout.

by weight and only 4 per cent by number of adult brook trout present just prior to the time the fishing season began.

The catch of brook trout in 1959 was 10.8 pounds per acre, or 33.9 trout per acre. This yield represented 24 per cent of the standing crop and 8 per cent of the number of adult brook trout present when the fishing season began.

Exploitation during the 1960 season was the lowest recorded during six years of creel census. Anglers removed only 3.7 pounds of brook trout per acre which represented 7 per cent of the preseason standing crop, while removal of 12.3 brook trout per acre represented a depletion of the preseason population by only 1 per cent (Table 11).

As expected, yearling brook trout were lightly exploited. Sixteen were taken in 1958, 11 in 1959, and only 7 in 1960. These catches represented only 0.3 per cent, 1.0 per cent, and 0.1 per cent of the number of yearlings present at the beginning of the 1958–60 trout fishing seasons. The maximum depletion of two-year-old brook trout for the three-year period was 29 per cent attained in 1958. Three-year-old brook trout were exploited at a maximum rate of 43 per cent during the three-year period (Fig. 6).

Angling Characteristics

Angling Success. The traditional measures of angling success, based upon the catch-rate of legal trout only, were quite low all three seasons in which the more restrictive angling regulations were tested. Rates of catch were 0.13 trout per hour during the 1958 season, 0.16 trout per hour during the 1959 season, and only 0.09 trout per hour during the 1960 season. The total catches of both legal brook trout and legal rainbow trout were included in these indices.

However, the adoption of the 9-inch minimum size limit provided conditions for catching and releasing large numbers of sublegal trout because yearling trout were largely eliminated from the harvest. The rates at which such trout were caught and released were high, averaging 2.00 per hour in 1958, 1.18 per hour in 1959, and 2.55 per hour in 1960. Anglers reported releasing 3,704 sublegal trout in 1958, a number equal to 65 per cent of the entire preseason adult population. In 1959, some 1,846 sublegal trout, representing 61 per cent of the adult population were caught and released. In 1960, anglers released 2,572 sublegal trout, or 36 per cent of the adult population.

1958 Season. The 758 angling trips made in 1958 were distributed among 429 individuals of whom 86 per cent fished 1 or 2 times, 9 per cent fished 3 or 4 times, and 1 per cent fished 10 or more times. The 61 anglers who fished 3 or more times during the season accounted for 42 per cent of the total trips and 66 per cent of the total catch (Table 7). It took only 7 per cent of the total angling trips to bring in 61 per cent of the total catch.

Limit catches were made 5 times during 1958 (Table 9). Anglers failed to catch a single "keeper" trout on 81 per cent of the total trips.

1959 Season. During the 1959 fishing season, 728 trips were distributed among 404 individuals of whom 73 per cent came only once during the season and creeled only 14 per cent of the catch. An additional 15 per cent of the anglers returned to fish a second time. This group accounted for 10 per cent of the catch. The 7 anglers who fished 10 or more times comprised 2 per cent of the total anglers, accounted for 16 per cent of the

total trips, and creeled 42 per cent of the catch (Table 7).

Limit catches of 5 trout were made 7 times during 1959. On 81 per cent of the total trips, no legal trout were caught.

One expert angler took 20 per cent of the trout in the total catch and 4 of the 7 limit catches on only 3 per cent of the total angling trips.

1960 Season. Our complete creel census in 1960 revealed that 318 individuals made 434 angling trips. Anglers making only one trip per season accounted for 82 per cent of the total trips and 20 per cent of the total catch. The group of anglers that fished at least 3 times during the season took 5 per cent of the total catch on 23 per cent of the total trips. Only one angler made more than 10 trips (Table 7).

Three limit catches were made in 1960. On 82 per cent of the 434 trips no legal trout were caught.

Angling Methods. Bait fishing, chiefly with worms, continued to be the most popular method throughout the three seasons of testing more restrictive regulations. Fly fishing was the second most popular method, but anglers using spinning lures proved to be by far the most proficient group as indicated by the following data:

Method	Per Cent of Trips	Per Cent of Catch	Average Seasonal Catches/Trip
Live bait (worms)	52–53	45–62	0.17–0.38
Flies	21–28	9–14	0.10–0.22
Spinning lures	10–14	21–41	0.55–0.71

This disparity between the angling success of fishermen using spinning lures compared to those using worms or flies was not evident during the fishing seasons prior to adoption of the 9-inch minimum size restriction (Fig. 8). Also, the apparent superiority of the bait-fishing group over that of the fly-fishing group noted during the previous years became even more pronounced under more restrictive angling regulations. Bait fishermen were approximately 70–80 per cent more successful at catching legal-sized trout than were fly fishermen during the 1958–60 seasons.

At least two possibilities could account for the disparity between the success rates of bait fishermen and fly fishermen. Either brook trout are more easily caught on worms than on artificial flies under most circumstances, or the group of anglers fishing with worms included a greater percentage of skillful individuals. Neither explanation can be endorsed until a more intensive analysis has been completed. Perhaps neither or both will be found pertinent, although the latter seems more reasonable. The few exceptionally skillful worm fishermen consistently made good catches, but so did the most skillful fly fishermen and spin fishermen.

These data from Lawrence Creek which demonstrate the greater efficiency of the bait fishermen as compared to the fly fishermen, stand in sharp contrast to a similar comparison published by Rupp (1955). He reported that fly fishermen were more than twice as efficient as bait fishermen in taking wild, legal-sized (6-inch) brook trout from Sunkhaze Stream, Maine. Two especially skillful anglers took 22 per cent of the total week-end and holiday catch one year and 20 per cent of the similar total the next year. If both these anglers used flies, their catches were probably sufficiently

important in the total catch to raise the efficiency of the entire group of fly fishermen above that of the worm fishermen.

Discussion

From the standpoint of efficient utilization of a wildlife resource, the number and pounds of brook trout creeled during the 1958–60 seasons were well below optimum levels. The restrictions which limited anglers to 5 trout at least 9 inches long resulted in more drastic reductions in yields than expected.

A summary of the composite data for the 1958–60 seasons revealed that anglers reduced the number of adult brook trout by less than 4 per cent. During this period, less than 1 per cent of the yearlings, 14 per cent of the two-year-olds, and 32 per cent of the brook trout three or more years old were harvested. The weight of brook trout removed in relation to the weight of the preseason standing crop was 15 per cent in 1958, 24 per cent in 1959, and 7 per cent in 1960. None of these yields approached that attained during 1955 under a 6-inch size limit and bag limit of 10. That year anglers removed 32 per cent of the adult brook trout including 24 per cent of the yearlings, 72 per cent of the two-year-olds, and 42 per cent of the older brook trout. The weight of the total catch was equal to 76 per cent of the preseason standing crop.

Despite the apparent increased protection provided by raising the size limit, by lowering the bag limit, and by the decrease in fishing intensity, there was no sustained increase in the number of legal-sized brook trout in the population during the 1958–60 period. The fishing water contained 163 brook trout over 9 inches at the close of the 1958 season compared to 140 at the close of the 1959 season, and only 78 at the termination of the 1960 season. The small number of legal brook trout in the fall of 1960 was partially due to the scarcity of two-year-old brook trout (the weak 1958 year class).

No single factor appeared to explain the lack of legal brook trout, or the failure of the 9-inch minimum size limit to provide a yield in pounds comparable to one attainable under a 6-inch minimum size limit. Rather, there appeared to be a number of possible contributing factors:

1. Where yearling brook trout are largely excluded from the catch because of the minimum size limit, mortality of yearlings due to natural causes (including hooking mortality of sublegal trout) may be high during the summer. For example, during the summer of 1960, natural mortality reduced the number of yearling brook trout by 56 per cent. It should be pointed out, however, that this generation was the strongest year class (1959) produced in Lawrence Creek during the investigation period.

Natural mortality of yearling brook trout during the three successive fishing seasons covered by the 9-inch limit appeared to be directly related to the density of yearlings, as indicated by the following data:

Fishing Season	Number of Yearling Brook Trout in Stream Sections B, C and D	Natural Mortality Rate (in Per Cent)
1958	4738	34
1959	1082	25
1960	6852	56

During the 1958 and 1959 fishing seasons, natural mortality of yearlings was approximately of the same magnitude as during the 1955 and 1956 fishing seasons. However, anglers removed an additional 25 per cent and 46 per cent of the yearlings during the respective 1955 and 1956 fishing seasons. While some of the yearlings caught by anglers would have died naturally, mortality due to angling and natural causes combined was approximately twice as great during the summers of 1955–57 as it was during the summers of 1958–60.

2. Natural mortality of yearling brook trout may be high during their second winter of life if the number of trout of this age group is high at the end of the fishing season. Since few yearling brook trout in Lawrence Creek attained lengths of 9 inches, they had to be carried through their second winter of life before they could directly benefit the creel. Two of the three yearling groups protected by the 9-inch limit suffered high mortality during the second winter of life. An 80 per cent loss occurred during the winter of 1959 and a 75 per cent loss during the winter of 1960, whereas losses of yearling brook trout during six previous winters approximated 54 per cent. Hence, stockpiles of yearling brook trout resulting from increased survival during the summer may not be successfully carried through the winter to benefit the fishing the following season.

3. Growth rates of yearling and two-year-old brook trout might decline if a sustained increase of such trout could be achieved. Increments of growth of yearling and older brook trout were 46 per cent below the 8-year mean for Lawrence Creek in 1958 and 12 per cent below the mean in 1959. These reduced growth rates could reflect "within-age-group" density effects, or 1958 and 1959 may have been poor years for growth for extrinsic reasons.

During 1960 growth of adult brook trout was 8 per cent above the eight-year mean, but the number of potential creelable trout (Age Group II, the weak 1958 year class) was so low that little benefit was realized from the improved growth.

4. Even if growth and survival favored a stockpiling of Age Group II brook trout, fishermen may not exert enough pressure throughout the season to harvest those trout over 9 inches long. If a minimum size limit restricts the yield to brook trout two or more years old (as the 9-inch limit did at Lawrence Creek), anglers must catch most of the legal-sized age group II brook trout produced each season if the yield is expected to approximate one which includes a significant percentage of the yearling group as well.

Fishing pressure during the 1958–60 seasons was low compared to the previous three seasons, and most of the angling trips during 1958–60 were made during the first month of each season. As stated previously, part of the decline in fishing pressure may have been due to the critical attitude of some anglers toward more-restrictive regulations as such.

At least these four elements, then, a weak year class, increased summer and/or winter mortality, below-average growth, and a decline in angling pressure, acted in various combinations each of three years to effectively nullify any sustained response of the brook trout population to the beneficial intent of an increased minimum size limit and reduced bag limit. No persisting increase in the number of legal brook trout occurred, and the yield was well below the capacity of the fishery.

Indices of angling success also declined considerably when the 9-inch limit was

instituted. Catch-rates declined from the 1955–57 average of 0.68 trout per hour to an average of 0.13 trout per hour during the 1958–60 seasons. The rate of successful trips decreased from 48 per cent in 1955 to 19 per cent in both 1958 and 1959 and to 12 per cent in 1960. Skill of the individual angler became increasingly important in determining the distribution of the catch when the size limit was raised.

Only 45 per cent as many angling trips were made during the three years of more-restrictive regulations as compared to the preceding three-year period. Anglers may have bypassed Lawrence Creek in favor of nearby streams having a 6-inch minimum size limit and bag limit of 10. Failure to catch a legal trout probably discouraged some anglers from returning that same year or again the following year as long as the same restrictions prevailed. We suspect even some good trout fishermen became discouraged as a result of the decrease in angling success from what they had experienced.

In the three seasons, approximately 8,700 trout were caught, but only 577 were big enough to keep. The ratio of sublegal trout hooked and released per legal trout creeled was 15:1. During the 1960 season when legal-sized trout were scarce but sublegal trout were abundant, fly fishermen as a group released 77 sublegal trout for every legal trout creeled.

Angling pressure on Lawrence Creek declined from a seasonal average of 13 trips per day in 1955, and approximately 10 trips per day in 1956 and 1957, to only 3 trips per day in 1960. Apparently the sport of catching and releasing large numbers of sublegal trout did not offset the decreased satisfaction due to fewer trout in the creel. Perhaps many trout fishermen in Wisconsin are not presently interested in "fishing for fun", even when fishing involves a catch rate of wild brook trout as high as 2.6 per hour on an easily fished, aesthetic stream such as Lawrence Creek. This disinterest may reflect the availability of high quality trout fishing in other Wisconsin streams. Anglers who disliked the regulations at Lawrence Creek could easily find other streams providing the kind of fishing they preferred.

Concerning our last guideline—improvement in reproductive capacity—the adoption of the 9-inch regulation did help to increase egg production. For example, egg production in the fall of 1958 reached a record high level of 110,666 eggs per acre of stream. The following September, the resultant generation of brook trout, then 9 months old, numbered 22,646, making it the strongest year class encountered.

Nearly 75 per cent of the eggs produced in the fall of 1958 were from yearling brook trout spawning for the first time. The number of these yearling trout was materially increased as a result of the negligible angler harvest of less than 1 per cent.

The reduced rates of angling mortality during the summers of 1959 and 1960 again benefited egg production of the respective spawning groups. Raising the minimum size limit allowed more brook trout to live long enough to spawn at least once. In Lawrence Creek the 9-inch limit was not needed for this specific purpose because enough Age Group I brook trout usually survived the fishing season to provide adequate reproduction regardless of the angling regulations. In streams where spawning habitat is available, but spawners are scarce, suitable size limits are an appropriate management tool for increasing the reproductive capacity of brook trout populations.

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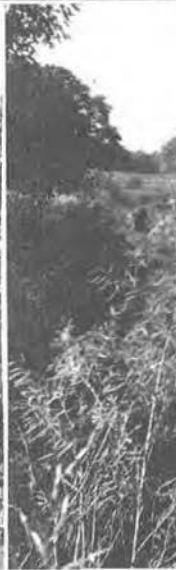
Stream section C meanders through a marsh meadow. A deep hole is usually found at each bend. The stream bottom is predominantly sandy.



Spring water, the life blood of a trout stream. Lawrence Creek has an abundant supply of both lateral feede. tributaries and bubbling springs such as this one.

Major spawning areas on Lawrence Creek. In section A (above) a luxuriant growth of water cress provides excellent habitat for young trout. The riffle portion of stream section B (left) provides several hundred yards of clean gravel, moderate water depth, moderate velocity and numerous feeder springs.

Middle stretch of section D, containing one of the deepest holes (8–10 feet) located at the bend, on the right bank (above).

The lower portion of section D, the widest part of the stream. (left).

FINAL DISCUSSION AND MANAGEMENT IMPLICATIONS

One of the basic assumptions underlying the regulations which govern trout fishing in Wisconsin is that angling is an effective predatory activity. If, in fact, predation by anglers were not important compared with other limiting factors, the concept of management through fishing regulations would have little biological value. The intensive investigations conducted at Lawrence Creek substantiate this premise that man is an effective predator upon brook trout. Anglers creeled 59 per cent of the brook trout population in 1956 and 65 per cent of the brook trout population in 1957. Age Group II brook trout seemed especially vulnerable 72–100 per cent of the brook trout in this age group were caught (Table 12); thus, few Age Group II brook trout survive to spawn for a second time. Regulation of the harvest of wild brook trout from Wisconsin streams, therefore, is both biologically sound and necessary to insure perpetuation of this fishery wherever sufficient angling activity exists.

Furthermore, our testing of three different sets of angling regulations, during six years of continuous research at Lawrence Creek, demonstrated that the type of regulations can markedly alter the catch of stream-dwelling brook trout (Fig. 12). to angling. During the 1955–57 seasons,

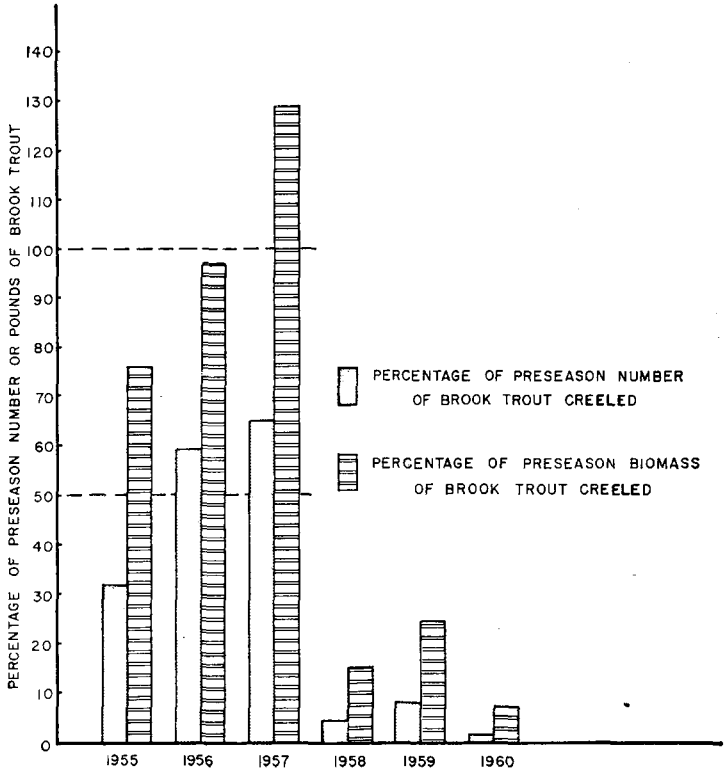


Figure 12. A comparison of harvest rates under various angling regulations tested at Lawrence Creek during the 1955–1960 trout fishing seasons.

Rates of angling exploitation ranged from 65 per cent to only 1 per cent of the number of adult brook trout and the catch ranged in weight from 129 per cent to only 7 per cent of the preseason standing crop.

Of the three sets of regulations tested, two proved to be much alike in their relation to the angler harvests. About the same catch would have occurred in 1955, 1956, and 1957 whether there had been no size or bag restrictions or whether a 6-inch size limit and bag of 10 had been in effect. However, if angling pressure had been sufficiently high, the existing state-wide regulations governing brook trout fishing (a minimum size limit of 6 inches and a daily bag of 10) would not have prevented excessive harvest.

The amount of angling mortality occurring during the 1955–57 seasons was found to be a function of the relationship existing between angling intensity and trout population density. Mortality due to angling is an inverse density dependent factor. If angling intensity remains constant, the rate of exploitation increases as the density of trout decreases. Or, any increase in angling intensity brings about a proportionately greater depletion of sparse trout populations than of dense trout populations.

This ecological relationship is illustrated in the three-dimensional Figure 13. The point of insertion of each pin is determined by the intercept of the value for angling trips per acre (angling intensity) and the value for number of brook trout per acre (population density). The length of each pin reflects the third and dependent variable—the rate of exploitation (mortality due to angling). The pins become shorter proceeding to the right (increasing population density) and down (decreasing angling intensity); the pins become longer proceeding to the left (decreasing population density) and up (increasing angling intensity).

Each season, each stream section provided an observation of these three variables. The seven observations represented in Figure 13 were chosen because they best illustrate the stated ecological principle.

Because of this inverse density-dependent nature of angling mortality, and because of the inadequacy of regulations as liberal as a 6-inch minimum size limit and bag limit of 10 to control the catch, it is evident that sparse populations of brook trout can be extensively cropped by even moderate angling effort. Such trout populations, without protection, would continue to be suppressed even if the carrying capacity of the stream were to improve.

An example of the effectiveness of angling at low population densities (for Lawrence Creek) is available from the 1956 fishing season. When the number of catchable brook trout in section C had been reduced to about 75 per acre, one expert angler continued to consistently creel about 10 brook trout per trip. Near the end of the season he was creeling more than 5 per cent of the adult brook trout each trip.

When brook trout densities are high and angling intensity is moderate, excessive harvest is circumvented by the outright number of trout present. However, under the existing regulations in Wisconsin, even very high densities of brook trout are not exempt from overexploitation if sufficient angling effort is expended.

When the minimum size limit was experimentally raised to 9 inches during the 1958–60 seasons, the catch was dramatically reduced, angling success indices

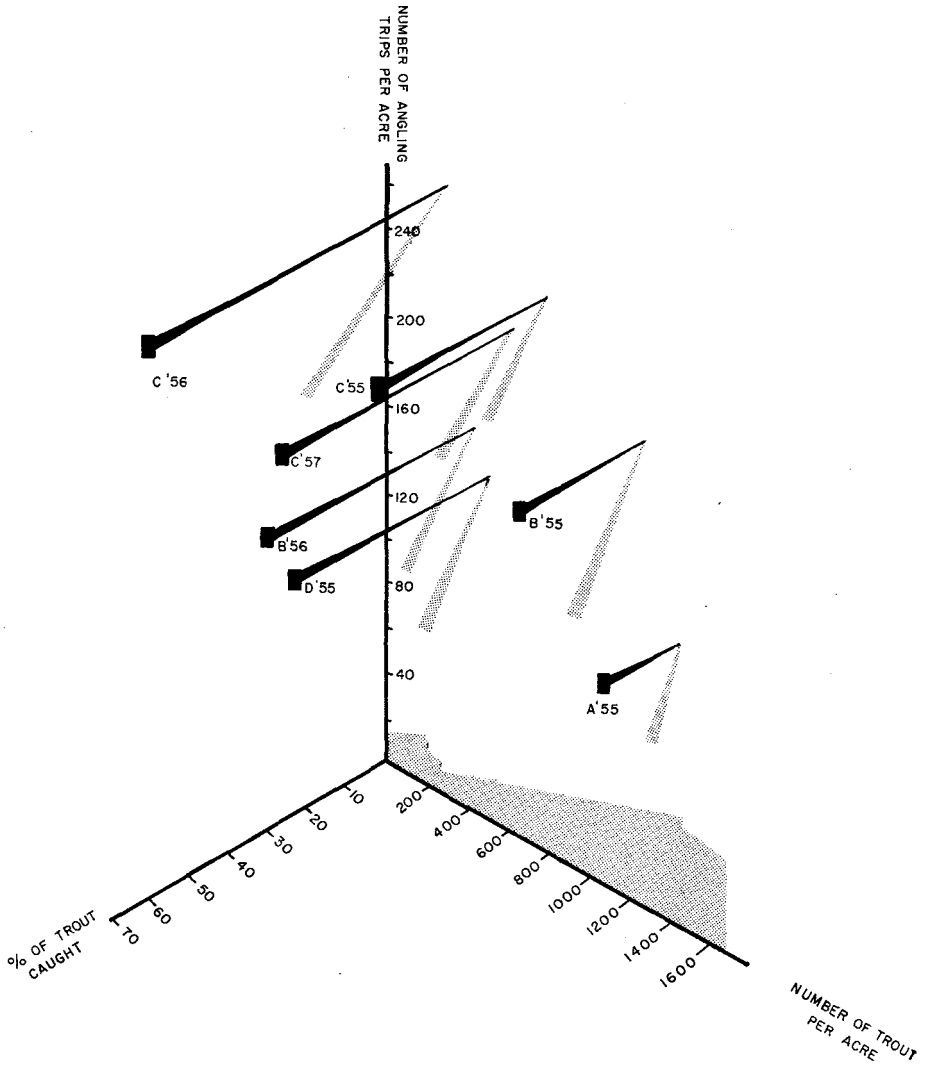


Figure 13. A three-dimensional portrayal of the inverse density dependent relationship of angling mortality to angling intensity and density of brook trout. (Observations are based on the 1955–57 trout fishing seasons.)

declined, and fishing pressure declined (Table 13). The catches in three successive seasons amounted to exploitations of only 4 per cent, 8 per cent, and 1 per cent of the preseason populations of adult brook trout. The greatest rate of harvest among the yearlings was 1 per cent. Among the three groups of two-year-olds, the maximum harvest was 20 per cent. The catch of legal brook trout per hour of effort declined to an average of 0.13 during the 1958–60 seasons, and 55 per cent fewer angling trips were recorded during this period than during the previous three-year period.

These reductions were attributed to the

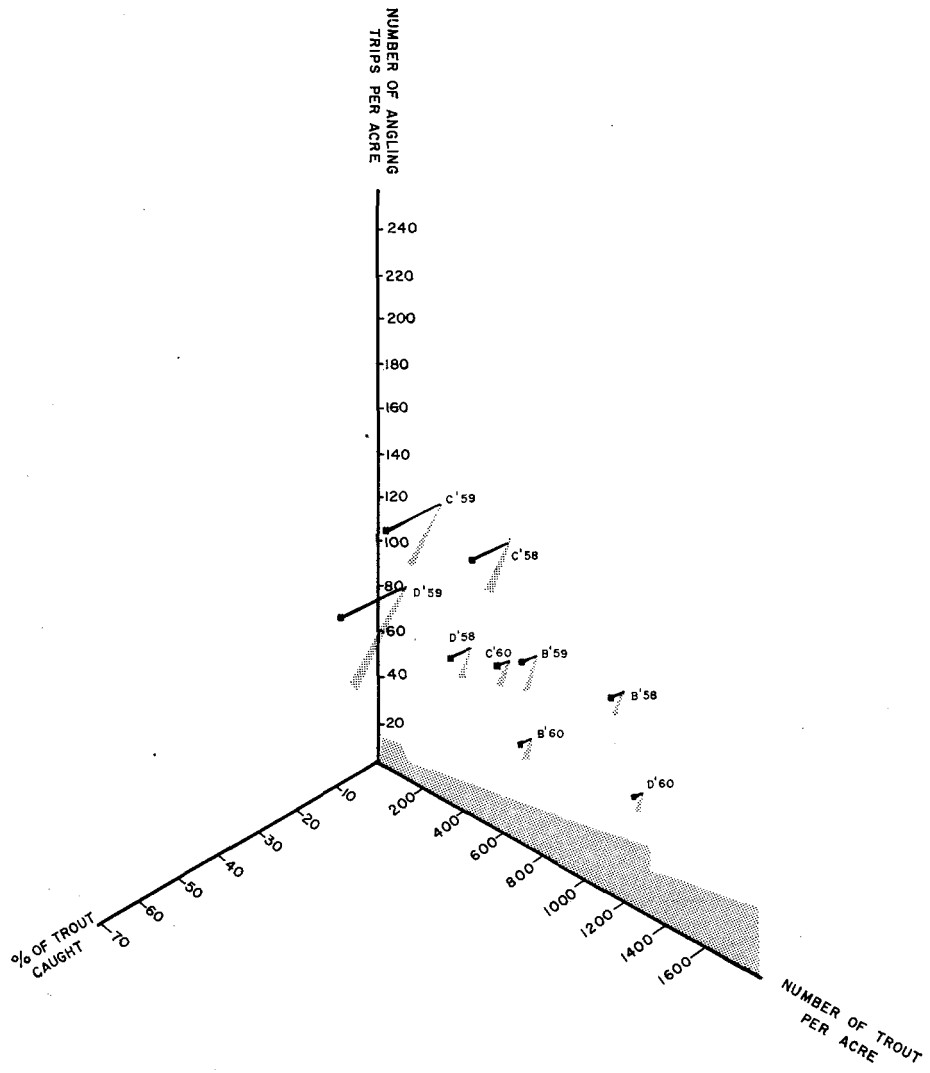


Figure 14. A three-dimensional portrayal of the inverse density dependent relationship of angling mortality to angling intensity and density of brook trout. (Observations are based on the 1958–1960 trout fishing seasons, when a 9-inch minimum size limit was in effect.)

size-limit restriction because the bag limit of 5 trout per day had no measurable effect upon the harvest. Limit catches were made on less than 1 per cent of the angling trips. It is possible that such a reduced bag limit reduced angling pressure through its psychological influences, although no data are available to substantiate this theory. Some anglers may have chosen to fish other streams simply because the law allowed them to keep 10 trout, provided they were skillful enough to catch them.

The assumption made earlier that a regional reduction in the bag limit would not decrease fishing pressure may be un-

warranted. Our experiences at Lawrence Creek during the 1958–60 trout fishing seasons suggest that some anglers might choose to avoid a stream (or streams) subject to a reduced bag limit even though they seldom attain such a bag limit. If this assumption were correct, catches of trout from certain streams could be altered by reducing the bag limit, but the reduced yield would come about because of reduced angling pressure. An appropriate experimental program should be initiated to adequately investigate the management potential of such regionally applicable regulations.

In practice the minimum size limit of 9 inches was too high for application to a dense brook trout population exhibiting moderate growth and adequate reproduction. However, testing of this regulation did demonstrate the effectiveness of size limits in altering angling exploitation.

This effectiveness is apparent if Figure 13 is compared to Figure 14. Both illustrate the same ecological relationship between fishing pressure, trout density and rate of exploitation. However, the observations in Figure 14 (taken from seasons in which the 9-inch limit was operative) show much reduced rates of exploitation at all levels of fishing intensity and population density encountered. Minimum size limits adapted to the growth characteristics of the brook trout populations being managed would ameliorate the rate of angling mortality over a wide range of trout density and angling intensity.

This report dealing with investigations conducted at the Lawrence Creek Trout Research Station from 1955 to 1960 has concerned itself with only three possible sets of angling regulations applicable to managing the brook trout fishery in Wisconsin streams. A fourth set of regulations currently being tested includes not only size and bag restrictions but limitations upon the method of fishing as well by restricting half the stream to "fly fishing only." However, it is apparent from our research to date that no one combination of angling regulations will ever be biologically suitable to statewide application even for a single species of trout. Taking into account the profound regional variations occurring in the thousands of miles of trout streams distributed throughout Wisconsin, plus the equally complex changes likely to occur within each trout population, we strongly advocate a trout management program which embraces flexible angling regulations.

When "The world is ours and ours alone" . . .

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APPENDIX A

Supplementary Tables Referred to in the Text

TABLE 1

Summary of the Physical Dimensions of Lawrence Creek

Dimension	Section of Stream				Stream Total
	A	B	C	D	
Length in Feet	5,495	4,307	3,881	3,713	17,396
Average Width in Feet	16.1	23.7	25.7	23.8	23.5
Surface Area in Acres	2.03	2.28	2.29	2.80	9.40

TABLE 2

Periodicity of Fishing Pressure and Catch of Brook Trout

(1955, 1956, and 1957)

Week of Season	1955				1956				1957			
	Angling Trips		Trout Caught		Angling Trips		Trout Caught		Angling Trips		Trout Caught	
	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total
1	324	18.9	824	27.1	252	19.2	508	37.4	165	13.3	597	21.5
2	176	29.2	227	34.6	160	31.4	190	51.3	113	22.4	269	31.2
3	103	35.2	122	38.6	115	40.1	75	56.8	73	28.2	217	39.0
4	90	41.5	98	41.8	84	46.5	50	60.5	50	32.2	106	42.8
5	131	48.1	188	48.0	72	52.0	47	64.0	53	36.4	67	45.2
6– 7	158	57.4	270	56.9	69	57.3	42	67.1	112	45.4	285	55.5
8– 9	116	64.1	238	64.7	81	63.4	100	74.4	116	54.7	179	61.9
10–11	119	71.1	172	70.4	133	73.6	91	81.1	102	62.8	156	67.5
12–13	75	75.5	158	75.6	98	81.0	58	85.3	126	72.8	209	75.1
14–15	118	82.4	231	83.2	76	86.8	52	89.2	104	81.1	177	81.4
16–17	138	90.4	282	92.4	97	94.2	67	94.1	119	90.6	214	89.1
18–19	164	100.0	230	100.0	76	100.0	80	100.0	118	100.0	302	100.0
Total	1,712		3,040		1,313		1,360		1,249		2,778	

TABLE 3

Percentage of Total Number and Total Weight of the Yield of Brook Trout Contributed by Various Age Groups

(1955–1960)

Year	Age Group I		II		III		IV+	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
1955	62.5	44.4	35.5	49.0	1.9	5.9	0.1	0.7
1956	47.9	33.5	50.0	59.9	1.9	5.2	0.2	1.4
1957	89.9	82.6	8.2	13.3	1.3	3.6	0.1	0.5
1958	7.2	6.2	82.0	76.7	9.9	13.7	0.9	3.4
1959	4.5	3.8	79.8	81.1	15.2	14.6	0.5	0.5
1960	8.2	7.0	27.0	23.7	64.8	69.3	0.0	0.0

TABLE 4

Angling Intensity and Exploitation of the Brook Trout Population

(1955, 1956,* and 1957*)

Stream Section	1955					1956				1957			
	A	B	C	D	Avg.	B	C	D	Avg.	B	C	D	Avg.
Angling trips/acre	124.6	206.1	247.2	151.1	182.1	168.4	268.1	112.5	178.2	217.5	222.7	86.8	169.5
Angling hours/acre	374.9	612.5	662.2	349.5	494.9	405.0	666.2	214.8	413.8	592.5	597.4	160.4	429.9
Preseason population (no./acre)	1512	1308	852	510	1003	464	354	155	313	877	653	288	583
Yield (no./acre)	285.7	421.9	357.2	242.9	323.4	241.2	266.8	71.1	184.5	609.6	387.3	178.6	376.9
Preseason population present after season (no./acre)	438	443	368	128	330	70	67	28	53	267	136	107	166
Preseason population caught (per cent)	18.9	32.2	41.9	47.7	32.2	52.0	75.3	45.8	59.0	69.5	59.3	62.0	64.6
Preseason standing crop (lbs./acre)	99.7	86.0	60.8	58.9	74.8	38.1	34.7	21.9	30.9	61.8	47.7	30.1	45.4
Yield (lbs./acre)	47.0	68.0	60.1	53.3	57.2	37.8	43.5	15.8	30.0	91.8	58.7	31.3	58.5
Yield (percent of preseason standing crop)	47.1	79.1	98.8	90.5	76.5	99.2	125.4	72.1	97.1	148.5	123.1	104.1	128.8
Preseason population present after season (lbs./acre)	------	------	-----	-----	41.7	-----	-----	-----	11.2	-----	-----	-----	33.0

*Data for section A excluded because no fishing was permitted in that section.

TABLE 5

Indices of Angling Quality in the Various Sections of Lawrence Creek Open to Fishing

(1955–60)

Year	Index	Stream Section A	B	C	D	Stream Average
1955	Per cent successful trips	55.7	55.3	38.2	47.0	46.7
	Catch per hour	0.91	0.64	0.54	0.70	0.69
1956	Per cent successful trips	-----	43.0	30.3	28.3	33.5
	Catch per hour	-----	0.65	0.40	0.33	0.47
1957	Per cent successful trips	-----	52.0	35.1	47.3	44.2
	Catch per hour	-----	1.06	0.66	1.11	0.89
1958	Per cent successful trips	-----	17.7	16.6	23.9	19.0
	Catch per hour	-----	0.13	0.10	0.20	0.13
1959	Per cent successful trips	-----	18.9	16.9	21.1	18.8
	Catch per hour	-----	0.15	0.12	0.26	0.16
1960	Per cent successful trips	-----	11.5	12.9	10.5	11.6
	Catch per hour	-----	0.08	0.10	0.09	0.09

TABLE 6

Theoretical Catch of Brook Trout at Daily Bag Limits of One to Ten Trout, Based on Empirical Creel Census Data from 1955

	Daily Bag Limit									
	1	2	3	4	5	6	7	8	9	10
Number of trout caught	800	1,771	1,866	2,319	2,477	2,672	2,808	2,912	2,992	3,040
Per cent of total catch	26.3	45.1	61.4	76.3	81.5	87.9	92.3	95.8	98.4	100.0
Average number of trout/trip	0.47	0.80	1.09	1.35	1.45	1.56	1.64	1.70	1.75	1.78

TABLE 7

Distribution of Trips and Catch of Brook Trout

(1955–60)

Year	Trips per Season	Number of Anglers	Percentage of Anglers	Percentage of Total Trips	Percentage of Total Catch	Catch per Trip
1955	1–2	881	87.8	58.8	31.4	0.95
	3–4	73	7.3	14.5	18.9	2.32
	5–9	32	3.2	12.2	20.5	2.98
	10+	17	1.7	14.5	29.2	3.58
1956	1–2	936	93.9	78.9	46.9	0.62
	3–4	45	4.5	11.1	21.9	2.04
	5–9	12	1.2	5.8	18.8	3.37
	10+	4	0.4	4.2	12.4	3.05
1957	1–2	711	91.0	65.6	36.9	1.25
	3–4	45	5.8	12.3	16.3	2.94
	5–9	14	1.8	6.5	15.0	5.15
	10+	11	1.4	15.6	31.8	4.53
1958	1–2	368	85.8	57.8	33.7	0.17
	3–4	38	8.8	16.6	15.2	0.27
	5–9	17	4.0	13.7	16.6	0.36
	10+	6	1.4	11.9	34.5	0.86
1959	1–2	355	87.9	56.8	24.3	0.14
	3–4	26	6.4	12.2	7.7	0.21
	5–9	16	4.0	15.2	26.3	0.58
	10+	7	1.7	15.8	41.7	0.88
1960	1–2	297	93.4	77.0	42.9	0.12
	3–4	12	3.8	9.0	6.6	0.15
	5–9	8	2.5	11.5	31.9	0.58
	10+	1	0.3	2.5	18.7	1.54

TABLE 8

Distribution of Angling Trips and Catch of Brook Trout, Based on the Method of Fishing

(1955–60)

Year	Method of Fishing	Percentage of Total Trips	Percentage of Total Catch	Catch per Trip
1955	Bait	60.6	68.1	1.99
	Fly	25.4	21.7	1.52
	Multiple	11.2	9.2	1.45
	Spin	2.8	1.0	0.60
1956	Bait	70.5	76.7	0.80
	Fly	15.7	13.8	0.64
	Multiple	12.4	7.3	0.44
	Spin	1.4	2.2	1.12
1957	Bait	64.7	73.9	2.54
	Fly	19.4	15.5	1.76
	Multiple	12.2	7.4	1.36
	Spin	3.7	3.2	1.91
1958	Bait	53.0	61.9	0.34
	Fly	23.5	9.4	0.12
	Multiple	13.3	4.0	0.09
	Spin	10.2	24.7	0.71
1959	Bait	52.6	59.7	0.38
	Fly	21.4	14.4	0.22
	Multiple	13.1	4.5	0.12
	Spin	12.9	21.4	0.55
1960	Bait	52.1	44.7	0.17
	Fly	27.6	14.1	0.10
	Multiple	6.7	0.0	0.00
	Spin	13.5	41.2	0.59

TABLE 9

Frequency of Various-Sized Catches of Brook Trout

(1955–60)

Catch per Trip	Frequency					
	1955	1956	1957	1958	1959	1960
0	912	882	683	614	588	383
1	188	153	136	88	80	32
2	156	96	91	31	34	7
3	103	55	58	12	9	6
4	94	37	50	3	10	3
5	63	32	44	5 [2]	7	3
6	58	15	28			
7	33	8	31			
8	24	5	22			
9	31	8	18			
10	50 [1]	8	16			
More than 10		14	72			

[1]Daily bag limit of 10 in effect during 1955.
[2]Daily bag limit of 5 in effect during 1958, 1959, and 1960.

TABLE 10

Periodicity of Fishing Pressure and Catch of Brook Trout

(1958–60)

Week of Season	1958				1959				1960			
	Angling Trips		Trout Caught		Angling Trips		Trout Caught		Angling Trips		Trout Caught	
	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total	Number	Cumulative Percentage of Total
1	112	14.8	81	36.3	186	25.5	87	35.8	67	15.4	46	54.1
2	38	19.8	8	40.0	31	29.8	20	44.0	10	17.7	2	56.5
3	31	23.9	17	47.5	46	36.1	15	50.2	31	24.9	9	67.0
4	16	26.0	6	50.2	26	39.7	22	59.2	24	30.4	0	67.0
5	47	32.2	12	55.6	37	44.8	1	59.7	21	35.2	6	74.1
6– 7	49	38.7	19	64.1	45	51.0	2	60.5	38	43.1	6	81.2
8– 9	74	48.4	21	73.5	34	55.6	12	65.4	40	53.2	3	84.7
10–11	99	61.5	6	76.2	64	64.2	16	72.0	59	66.8	1	85.9
12–13	70	70.7	4	78.0	51	71.4	10	76.1	36	75.1	0	85.9
14–15	32	74.9	14	84.3	53	78.7	23	85.6	32	82.5	3	89.4
16–17	96	87.6	12	89.7	83	90.1	19	93.4	43	92.4	3	92.9
18–19	94	100.0	23	100.0	72	100.0	16	100.0	23	100.0	6	100.0
Total	758		223		728		243		434		85	

TABLE 11

Angling Intensity and Exploitation of the Brook Trout Population

(1958–60)

Stream Section	1958				1959				1960			
	B	C	D	Avg.	B	C	D	Avg.	B	C	D	Avg.
Angling trips/acre	108.7	131.4	74.6	102.8	86.0	128.8	84.6	100.1	49.6	77.7	51.1	58.9
Angling hours/acre	297.4	326.9	150.0	250.5	195.6	326.0	131.1	214.5	119.3	194.3	103.6	136.6
Preseason population (no./acre)	1249	684	467	776	805	326	208	427	792.1	682.5	1375.7	979.8
Yield (no./acre)	32.5	30.1	28.6	30.3	29.4	38.0	33.2	33.9	9.2	18.8	9.6	12.3
Preseason population present after season (no./acre)	907	171	158	394	235	213	72	166	356	528	356	410
Preseason population caught (per cent)	2.6	10.7	6.1	3.9	3.7	14.5	16.2	8.2	1.2	2.8	0.7	1.2
Preseason standing crop (lb./acre)	89.2	51.0	48.5	61.8	73.5	33.2	31.1	45.9	29.5	32.9	81.0	50.1
Yield (lbs./acre)	7.9	5.8	13.0	9.2	9.4	12.4	10.7	10.8	2.5	6.0	3.0	3.7
Yield (per cent of preseason standing crop	8.8	11.4	26.8	14.9	12.8	37.3	34.4	23.5	8.5	18.2	3.7	7.4
Preseason population present after season (lbs./acre)	-----	-----	-----	59.4	-----	-----	-----	24.0	-----	-----	-----	51.6

TABLE 12

Percentage of the Preseason Population of Brook Trout Harvested According to Age Group

(1955–60)

Year	Age Group			Stream Total for All Adult Trout (I+)
	I	II	III+	
1955	24.4	71.7	42.2	32.2
1956	45.6	85.2	35.4	59.0
1957	62.0	100.0	72.2	64.6
1958	0.3	19.8	42.8	3.9
1959	1.0	11.2	30.6	8.2
1960	0.1	12.8	29.1	1.2
1956–57 Avg.	57.7	91.7	50.0	62.7
1958–60 Avg.	0.6	14.1	31.7	3.5

TABLE 13

Angler Harvests of Trout Under Various Angling Regulations Tested

(1955–60)

Year[1]	Yield		Yield per Acre		Hours of Effort		Catch per Hour
	Number	Pounds	Number	Pounds	Number	Number/ Acre	
1955	3,217	581.5	342.2	61.9	4,653	494.9	0.69
1956	1,417	229.1	192.2	32.4	3,051	413.8	0.47
1957	2,825	442.5	387.4	62.4	3,168	429.9	0.89
1958	236	72.2	32.1	9.8	1,847	250.4	0.13
1959	250	78.7	34.0	10.7	1,560	214.5	0.16
1960	91	28.8	12.3	3.9	1,007	136.6	0.09

[1]1955: 6-inch minimum size limit and bag limit of 10.
1956–57: No size limit and no bag limit.
1958–60: 9-inch minimum size limit and bag limit of 5.

APPENDIX B

Methods Used in the Lawrence Creek Investigations

While the complete creel census is the foundation of the Lawrence Creek investigations, a biologically sound evaluation of angling regulations requires more than just knowledge of the angling harvest. Before we can attempt to determine how many trout can safely be cropped, we must know how many trout are in the stream, how many are produced by natural reproduction, how many die from natural causes, and how fast the trout grow and mature. It was the aim of our annual work plans to investigate this complex of interrelated problems.

Population Estimates

Censuses of the trout population were made each April, prior to the fishing season, and in September beginning the day after the fishing season closed. A gasoline-powered generator (230 volt, 10 ampere D.C.) was employed. The population estimates were based on the mark and recapture method of Petersen, using the formula:

$$PE = \frac{M(R + U)}{R}$$

Where PE = estimated population
M = number of trout captured and marked with a temporary mark on the first run and then released.
R = number of trout having a temporary mark that are captured on the second run.
U = number of trout captured on second run which have no temporary mark.

Total population estimates were made for each stream section and for trout in each one-inch length group; i.e., 1.5–2.4 inches, 2.5–3.4 inches, etc. In the spring estimates only Age Group I and older trout were included, since Age Group 0 trout (from hatching stage to following January 1) were still too small to sample effectively with our electrofishing gear.

During the 1955–58 period, marking of Age Group 0 trout to provide known-age fish in the population was done in September as part of the post-fishing season census. Only trout less than 4.5 inches were given permanent year-class marks in order to assure not marking any slow-growing Age Group I trout. Beginning in 1959, however, it has been our practice to conduct a June population census as well. All brook trout of Age Group 0 in June can be marked. At that time at least a one-inch length gap exists between even the faster growing young-of-the-year and the slow growing yearlings.

During each census the entire stream was shocked twice. Generally two crews of men were used, the first crew being at least one day ahead of the second crew. Shocking was done by 100-yard stations. After 100 yards of stream had been covered, the motor was stopped and the trout collected were processed. All trout captured by the first crew were measured to the nearest 0.1 inch (total length) and weighed to the nearest gram on a 500-gram-capacity scale. All permanent markings were recorded. These trout were then floated back 100 yards downstream in a large perforated garbage pail and released.

Through a series of experimental trials we found that this procedure of carrying the trout back to the lower end of the station in which they were captured has proven to be a beneficial practice. Trout

displaced downstream from their point of capture returned to their home pool faster than trout displaced upstream.

On the second run, lengths and markings were again recorded on all trout handled, but weights were taken only on those trout not captured on the first run.

Creel Census

Ideal measurements of the angler harvests were obtained through a complete creel census. Anglers were required to obtain a free permit before each trip to the stream. Separate permits were issued for each stream section. Before leaving the project area, anglers were required to return their permits and present their catches for examination.

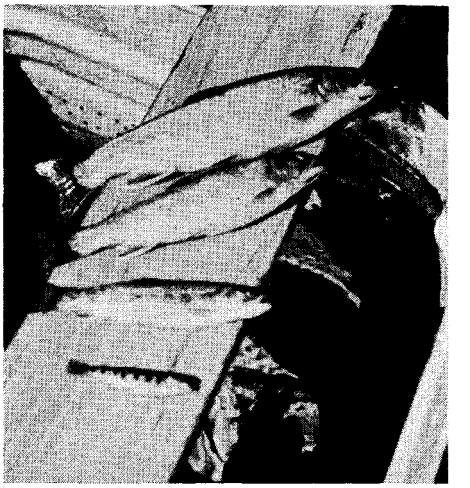
All legal-sized trout creeled were measured and weighed. Anglers were required to bring in their trout whole and uncleaned. Those trout not having identifying year-class marks were scale-sampled. Sex and state of maturity of the gonads were also noted on the creel census form (see sample card in Appendix C). Data were also gathered from anglers regarding amount of time spent fishing, methods employed, and number of trout caught and released.

Age, Growth and Condition Studies

Estimates of age structure of the population, rates of growth, and condition factor calculations were based primarily upon data gathered during routine electrofishing operations.

Age analyses of the 1953–57 trout populations were based on length frequency distributions and large collections of scale samples. Sampling was carefully stratified by stream sections and one-half-inch length intervals.

Since 1958, calculations of age composition have been based primarily on known-age trout. Scale samples were collected only in those cases where insufficient known-age trout were encountered in any inch group, or as a check against questionable markings.



Four generations of brook trout from Lawrence Creek. In mid-June young of the year are inventoried for the first time and permanently marked when they are approximately 2.5 inches long. The older trout (Age I, II and III) have already been marked.

The average total length of each age group at the time of each census of the trout population has been determined by two methods: (1) From the size-age distribution of the entire population. This method assumes that the average length of all the trout included in a given size grouping is the midpoint of that size grouping. For example, if there is estimated to be 200 trout in the 7.5- to 8.4-inch size group, then it is assumed that the average length of these 200 trout is 8.0 inches. (2) From averages of the individual measurements of known-age trout when large samples of such measurements were available. Where the two methods have been compared on the same lot of trout essentially similar growth characteristics were derived.

Coefficients of condition (R) were determined from a standard Wisconsin Conservation Department table, which is based on the formula:

$$R = 10 \times W / L^3$$

Where R = coefficient of condition
W = weight in grams
L = total length in inches

Average condition factors were normally computed for trout in each inch grouping comprising the spring and fall populations. In addition, a more intensive condition study was undertaken based on monthly samples collected from February, 1956, through March, 1957. Trout of Age Groups 0, I, and II were collected with electrofishing gear from the same segment of stream each month. McFadden (1961) has reported the results of this intensive investigation of monthly condition factors.

Mortality and Reproduction Studies

Rates of natural and angling mortality of brook trout were calculated from the egg stage to the time the trout leave the fishery.

Since success of natural reproduction is one component of total mortality, we attempted to measure this factor as it affected each new generation. Each fall, following the onset of spawning activity, the stream was patrolled regularly, and each probable brook trout redd was counted and marked with a wire rod. Marking was done to prevent counting the same redd twice, and also to allow us to return at a later date to sample some of the redds. Determination of mortality during the incubation period was based on direct counts of viable and dead eggs obtained from the excavated redds. Each redd to be sampled was dug up with a

Each winter after the brook trout have finished spawning, some of the redds are sampled to determine the percentage of viable eggs or sac-fry.

shovel, and its gravel and contents sifted back into the water. The dislodged eggs floated downstream to collect on a specially constructed wire-screen frame. The contents of the redd were immediately examined on the screen to determine egg fertility and probable hatching success. The eggs or sac-fry were then returned to the stream by washing them onto a fresh shovel of gravel which was deposited in the same location as the original redd.

In order to determine the amount of mortality from the egg stage to an age of 6 or 9 months (when a new generation was first included in a population estimate), it was necessary to first estimate the egg production by each year's spawning stock. Fecundity data for such calculations were obtained by dissecting sexually mature female brook trout collected from six streams in the Lawrence Creek vicinity and making direct counts of the number of eggs in relation to the length of the trout. These fecundity data were used in conjunction with each September population census, sex ratios, and data on size and age at sexual maturity to obtain an estimate of each year's total production of eggs. The proportion of the eggs produced which survived as 6- or 9-month-old fingerlings was determined from the number of such trout present at the time of the following June or September population estimate.

For trout older than 9 months, mortality data were handled separately for the seven-month "winter period" extending from mid-September to mid-April, and the five-month "summer period" extending from mid-April to mid-September. The beginning and end of these periods coincide with the approximate dates of the pre- and post-fishing season population estimates.

Mortality statistics were based on the number of trout of each age group present at the beginning and end of a given time period as determined through our population estimates. For the summer period the contribution of angling mortality to total mortality was determined through the complete creel census.

APPENDIX C

Lawrence Creek Creel Census Form

(Most of the data are coded for later processing by IBM methods)

WISCONSIN CONSERVATION DEPARTMENT Fi-257a

LAWRENCE CREEK CREEL CENSUS DATA SHEET

Name ..... City and State .....

Date ..... 196 ..... Auto License No. .....

Angler No. ____ Trip No. ____

County 3 9 Waters 0 0 7

Date: Month Day Year ____

Day of Week: S1 M2 T3 W4 T5 F6 S7 H8 ____

Hours: In ____ Out ____ Total ____

Angler Sex-Age ____ Residence: State City ____

Stream Section Fished ____

Site: Bank 1, Wade 2, Both 3. ____

Gear: Flyrod 1, Spinrod 2, Casting Rod 3, Pole 4, Multiple 5. ____

Bait: Worms 1, Other Live Bait 2, Preserved Bait 3, Fly 4, Spinning Lures 5, Multiple 6. ____

SPECIES CAUGHT		FISH CREELED					NUMBER KEPT	NUMBER RELEASED
	Length - inches						____	____
	Weight - grams							
BROOK 043	Marks							
	Age							
	Sex							
	Scale sample							
	Length - inches						____	____
	Weight - grams							
RAIN-BOW	Marks							
042	Age							
	Sex							
	Scale sample							

APPENDIX D

Common and Scientific Names of Sport Fishes and Non-Game Fishes Occurring in Lawrence Creek

Sport Fishes

Common Name	Scientific Name
*Brook trout	*Salvelinus fontinalis*
Rainbow trout	*Salmo gairdneri*
Largemouth bass	*Micropterus salmoides*
Bluegill	*Lepomis macrochirus*
Green sunfish	*Lepomis cyanellus*
Northern pike	*Esox lucius*

Nongame Fishes

Blacknose dace	*Rhinichthys atratulus*
*Brook stickleback	*Eucalia inconstans*
*Mottled sculpin	*Cottus bairdi*
Creek chub	*Semotilus atromaculatus*
Central mudminnow	*Umbra limi*
**White sucker	*Catostomus commersonnii*

* Abundant at all ages.

** Abundant as young-of-the-year and occasionally abundant as adults during the spawning period.

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