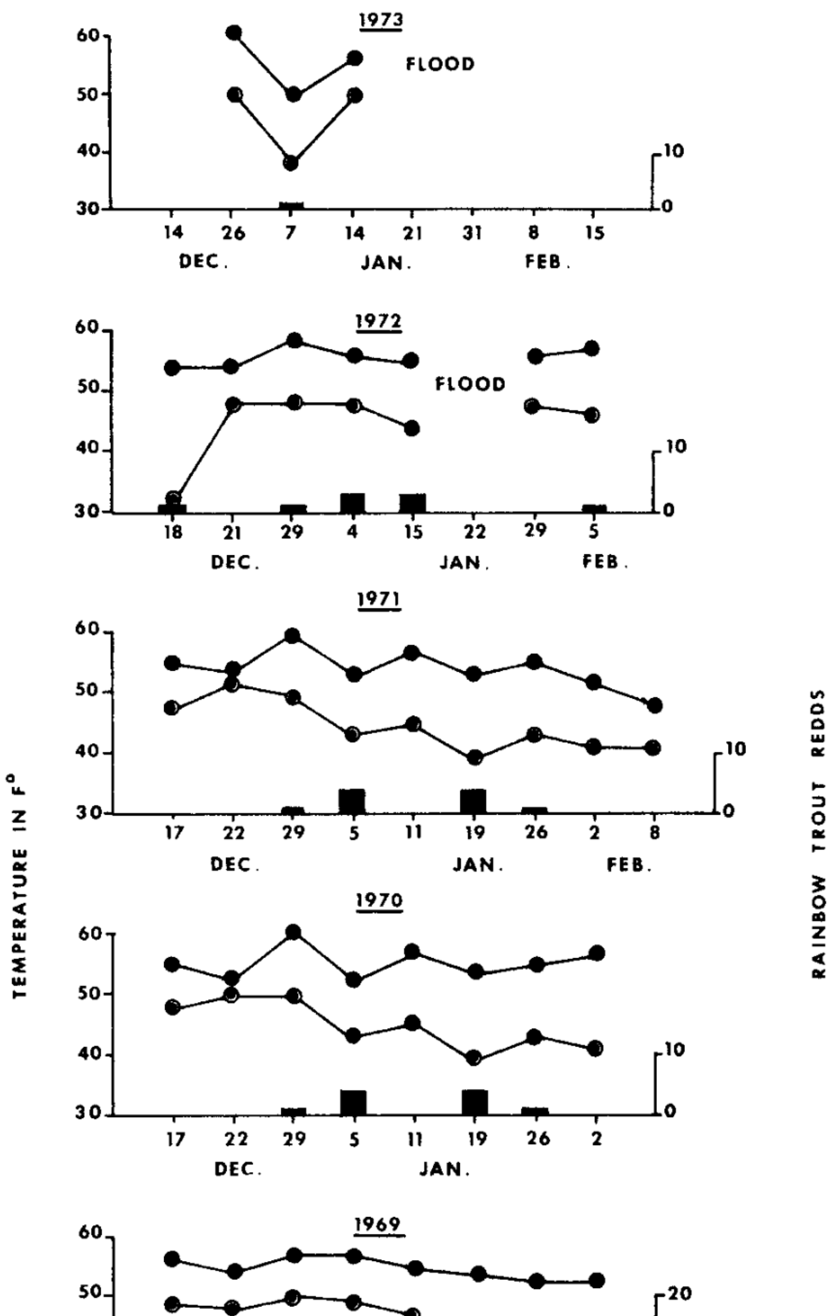
the third week of January, after a rapid decrease of approximately 10° F in the minimum water temperature from 52° F to 42° F (Figure 8). Spawning was first observed each year in the upper section above the confluence of Lane Spring and 90% of all redds were found in this section. The minimum water temperature fluctuated more in this section, and more adult trout were usually present. The earliest date that the trout spawned was December 2 and the latest was February 5.

Mill Creek study area

Trout standing crops in Mill Creek during most years were highest (29.6 pounds per acre) in the middle section and lowest (8.8 pounds per acre) in the campground section. Standing crops increasing substantially in the refuge and campground sections in 1973 (Table 4 and Figure 9). Trout numbers and weight increased 162% and 221% respectively in the refuge section after the section was closed to fishing in 1972. The number of age-group 0 trout in this section increased 176% and the number of age-group II and older trout increased 325%. The number of trout in the campground section during the same period decreased approximately 20% while the weight increased 238%. The difference between this study section and the preceding was a slight decrease in the number of age-group 0 trout and an increase in the number of age-group II and older trout which greatly increased the weight. The middle section in 1972 and 1973 and the refuge section in 1973 which were closed to fishing contained approximately 60% more trout than the campground section.

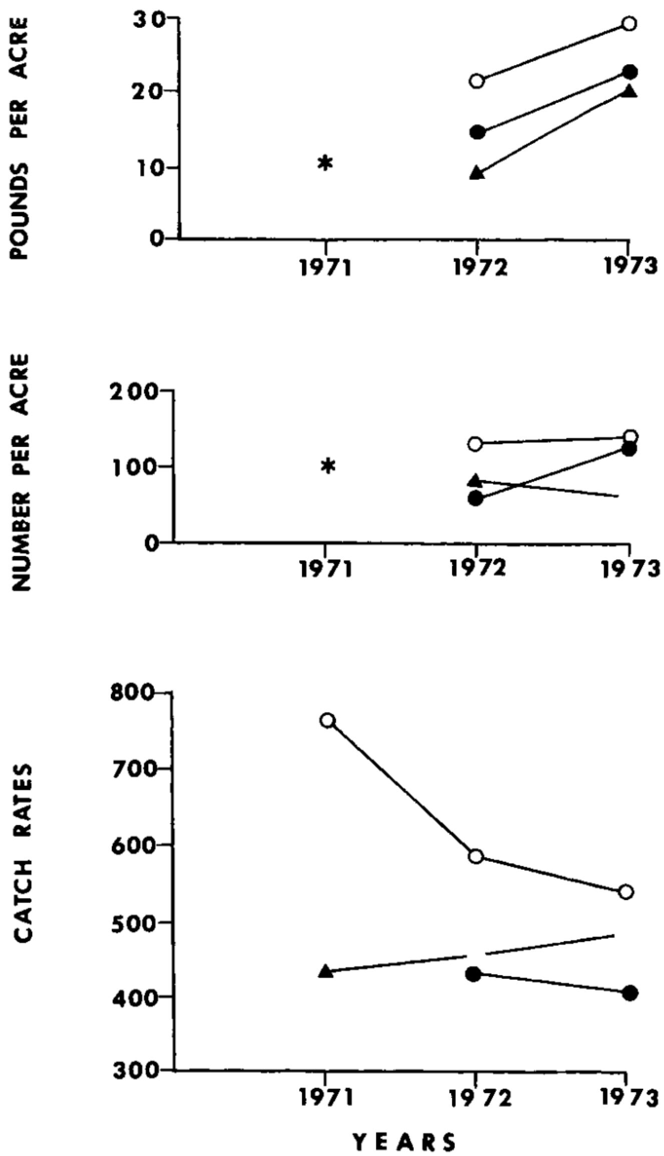
The numbers and weight of warm-water fishes increased progressively downstream from Wilkins Spring. Warm-water fishes were most abundant



1973
FLOOD
DEC.
JAN.
FEB.
1972
FLOOD
DEC.
JAN.
FEB.
1971
DEC.
JAN.
FEB.
1970
DEC.
JAN.
1969
TEMPERATURE IN F°
RAINBOW TROUT REDDS

Table 4. Rainbow trout population estimates and catch rates (number and pounds) per 10 shocker hours in the Mill Creek study area, 1971 to 1973 (October samples). Asterisks (*) indicate when a section was not sampled or when population estimates were not made. Actual shocking time in hours is in parenthesis.

Year and size group	Refuge Section: Catch rate No.	Refuge Section: Catch rate lbs.	Refuge Section: Population estimate No./A	Refuge Section: Population estimate lbs./A	Middle Section: Catch rate No.	Middle Section: Catch rate lbs.	Middle Section: Population estimate No./A	Middle Section: Population estimate lbs./A
1971					(0.9 hr)			
--- 6.9	*	*	*	*	422	28.1	*	*
7.0-10.0	*	*	*	*	233	58.8	*	*
10.1 ---	*	*	*	*	111	77.0	*	*
Total					766	163.9		
1972	(2.2 hr)				(2.6 hr)			
--- 6.9	188	11.5	49	3.0	186	13.1	70	4.4
7.0-10.0	202	40.3	23	4.6	342	68.3	53	10.3
10.1 ---	40	29.7	4	2.8	61	57.7	7	6.4
Total	430	81.5	76	10.4	589	139.1	130	21.1
1973	(2.5 hr)				(2.6 hr)			
--- 6.9	178	17.5	87	8.6	217	14.5	76	5.1
7.0-10.0	142	32.3	23	5.2	179	42.5	35	8.3
10.1 ---	99	70.0	13	9.2	148	104.5	23	16.2
Total	419	119.8	123	23.0	544	161.5	134	29.6



POUNDS PER ACRE
30
20
10
0
*
1971
1972
1973
NUMBER PER ACRE
200
100
0
*
1971
1972
1973
CATCH RATES
800
700
600
500
400
300
1971
1972
1973
YEARS

in the campground section (52.4 and 52.6 pounds per acre) in 1972 and 1973, and least abundant in the refuge and middle sections (19.5 and 19.1 pounds per acre, respectively) in 1973 (Table 5). Fish numbers and weight in the middle section decreased by approximately 50% from 1972 to 1973. This decrease may have been a result of the 1972 flood which removed some of the brush and logs from the creek. Rock bass, smallmouth bass, and longear sunfish were the predominent fishes in this study area.

Rainbow trout survival rates in Mill Creek from 1972 to 1973 were highest in the refuge and middle sections (0.47 and 0.45, respectively) and lowest in the campground section (0.38). Therefore, of every 10 trout present at the end-of-the-year, five trout in the refuge and middle sections and four in the campground section survived to the end of the next year. Age-group I and older trout had a higher survival rate (0.56) in the refuge section than in the middle section (0.43). Survival rates for age-group 0 trout in the refuge, middle, and campground sections were 0.46, 0.50, and 0.26, respectively.

Trout spawned in Mill Creek usually between the third week o

December and the third week in January, after a rapid decrease in the minimum water temperature of approximately 10° F (Figure 10). The earliest date that trout were observed spawning was December 18 in 1972 and the latest was February 8 in 1973. In 1971 and 1972, all of the spawning activity was in the middle section, but in 1973 several redds were observed in the refuge section, downstream from the confluence of the spring branch with Mill Creek.

Length frequency histograms and recaptured marked rainbow trout

Table 5. Warm-water fish population estimates and catch rates (number and pounds) per 10 shocker hours in the Mill Creek study area, 1971 to 1973 (October samples). Asterisks (*) indicate when a section was not sampled or when population estimates were not made. Actual shocking time in hours is in parenthesis.

Year and Species	Refuge Section Catch rate No.	lbs.	Population estimate No./A	lbs./A	Middle Section Catch rate No.	lbs.	Population estimate No./A	lbs./A
1971					(0.9 hr)			
Rock bass	*	*	*	*	355	70.4	*	*
Smallmouth bass					33	9.2		
Longear sunfish					11	0.9		
Green sunfish					44	5.4		
Total					443	85.9		
1972	(2.2 hr)				(2.6 hr)			
Rock bass	157	24.9	56	8.9	448	98.1	123	26.8
Smallmouth bass	9	3.0	1	0.4	19	7.8	4	1.4
Longear sunfish	5	0.6	5	0.7	53	2.8	23	1.2
Green sunfish	63	5.7	43	3.9	122	14.4	37	4.3
Bluegills	27	3.5	17	2.2	38	5.2	7	0.5
Largemouth bass	9	12.0	2	3.3	19	3.3	4	1.7
Hybrid sunfish	5	0.4	1	0.1	8	21.3	4	0.6
Total	275	325.1	125	19.5	707	152.9	202	36.5

Table 5. (Continued.)

Year and Species	Refuge Section Catch rate No.	Catch rate lbs.	Population estimate No./A	Population estimate lbs./A	Middle Section Catch rate No.	Catch rate lbs.	Population estimate No./A	Population estimate lbs./A
1973	(2.5 hr)				(2.6 hr)			
Rock bass	156	27.1	82	14.3	201	43.1	61	13.1
Smallmouth bass	12	2.0	2	0.3	15	3.9	6	1.6
Longear sunfish	23	4.5	11	2.2	38	2.5	13	0.9
Green sunfish	8	1.3	2	0.3	15	1.8	14	1.7
Bluegills	31	2.9	7	0.7	46	6.0	12	1.6
Largemouth bass	8	12.9	1	1.6	0			
Hybrid sunfish	12	0.8	2	0.1	4	0.3	2	0.2
Total	250	51.5	107	19.5	319	57.6	108	19.1

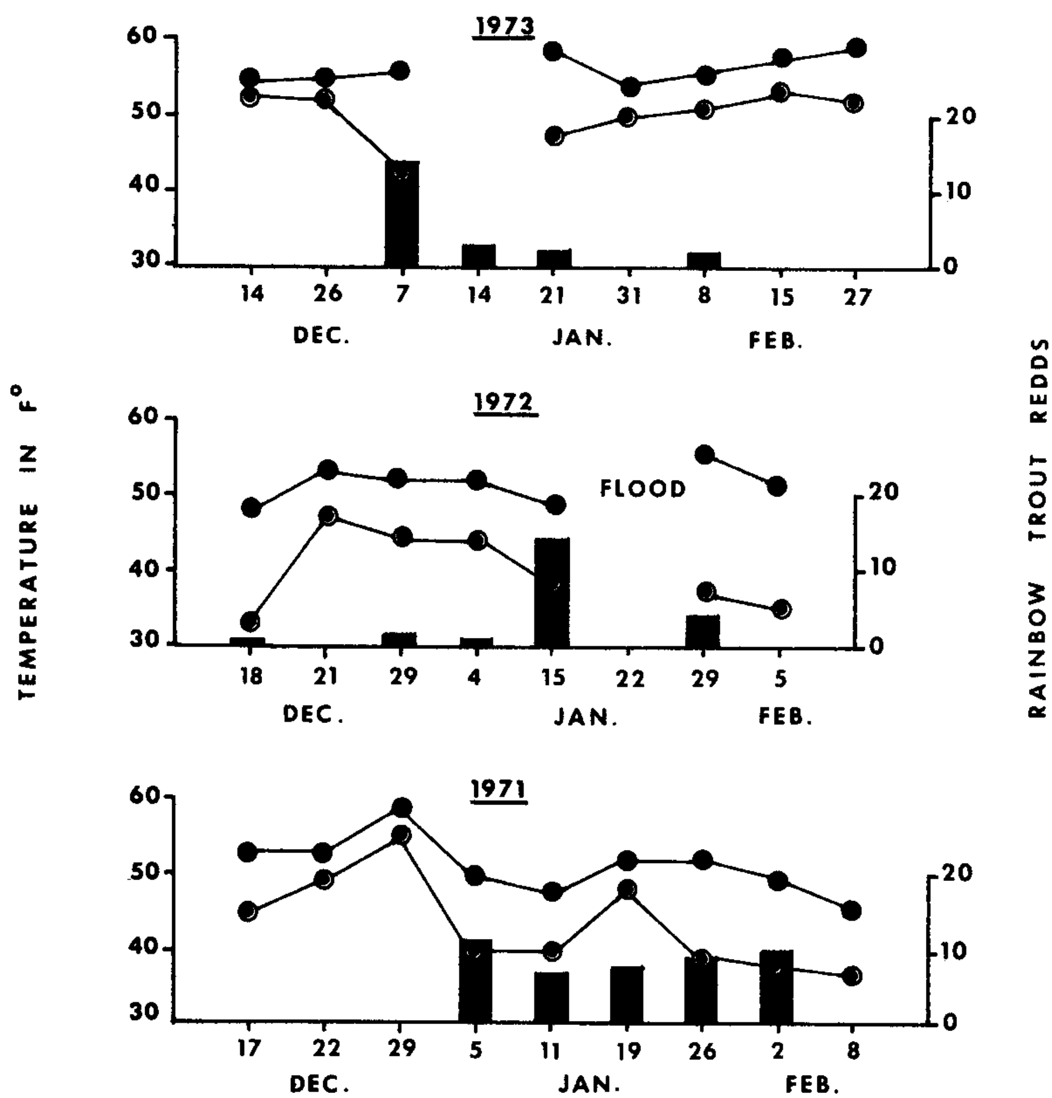


Figure 10. The number of rainbow trout redds observed in the Mill Creek during three spawning seasons, 1971 to 1973. Circles connected by lines indicate maximum and minimum water temperatures (F°) and solid bars indicate number of trout

indicated that there were at least four age-groups of trout in Mill Creek, but the size range of age-group II and older trout could not be determined (Figure 11). Rainbow trout averaged 5.7 inches (range 3.3 to 7.0 inches) in total length the first year, and 8.5 inches (range 7.0 to 10.0 inches), the second year. The length-weight relationship of rainbow trout in Mill Creek indicated that a 5.7 inch trout (age-group 0) weighed approximately 1.3 ounces and an 8.5 inch trout (age-group I) weighed approximately 3.5 ounces (Figure 12).

Discussion

Trout fishing in Missouri traditionally has been maintained almost entirely by periodic stockings in large spring branches and major Ozark streams near springs because salmonids are not native to Missouri and most of our waters are too warm for them. It was commonly thought that stocked rainbow trout would not reproduce. And, although some trout spawning has been observed, we were still unsure if the rainbow trout populations in Missouri could be or were self-sustaining. This study proved that some of Missouri's spring-fed rivers and creeks do support self-sustaining rainbow trout populations.

The streams sampled contained low standing crops of trout, less than 30 pounds per acre, which suggests that even though they were self-sustaining, the environment was less than optimum for trout. Furthermore, the standing crops of warm-water fish in the study streams equaled or exceeded the weight of trout and there was a progressive increase in the standing crops downstream from the springs. It is very apparent that large portions of our streams lacked suitable trout

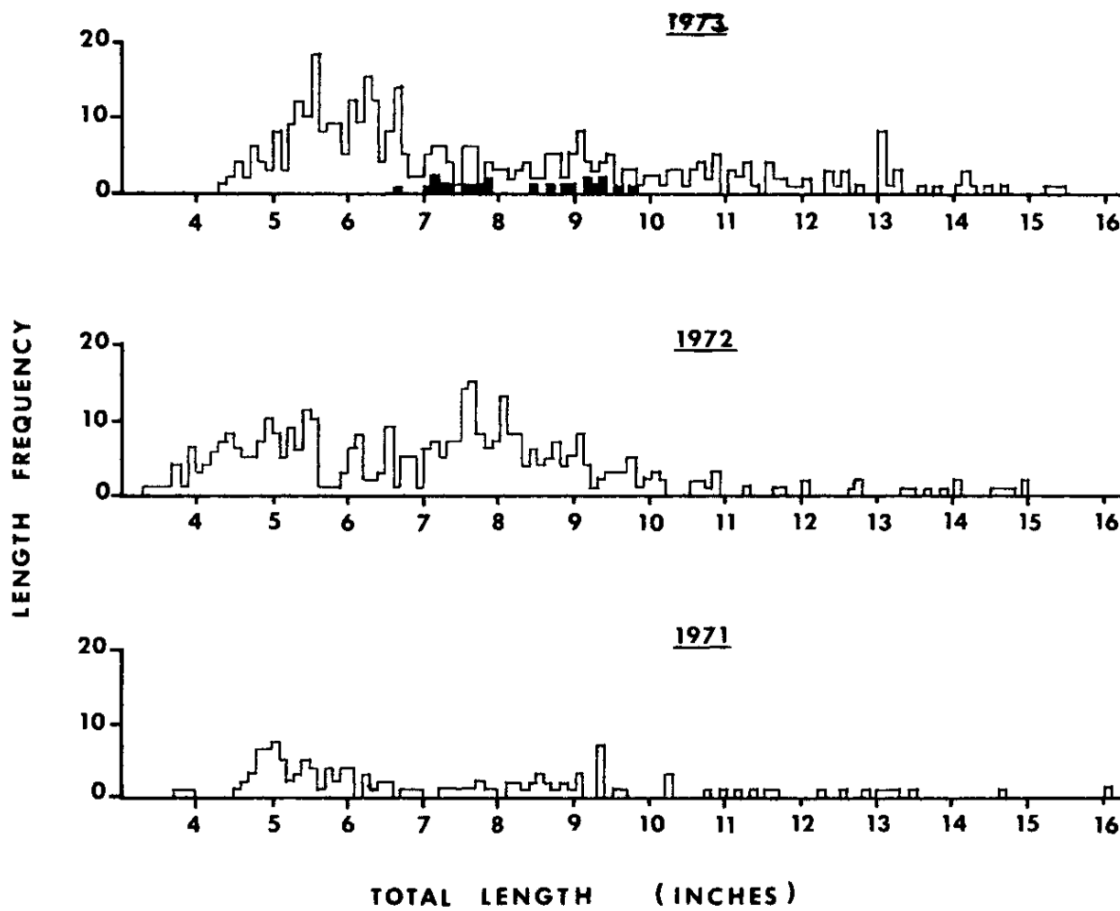
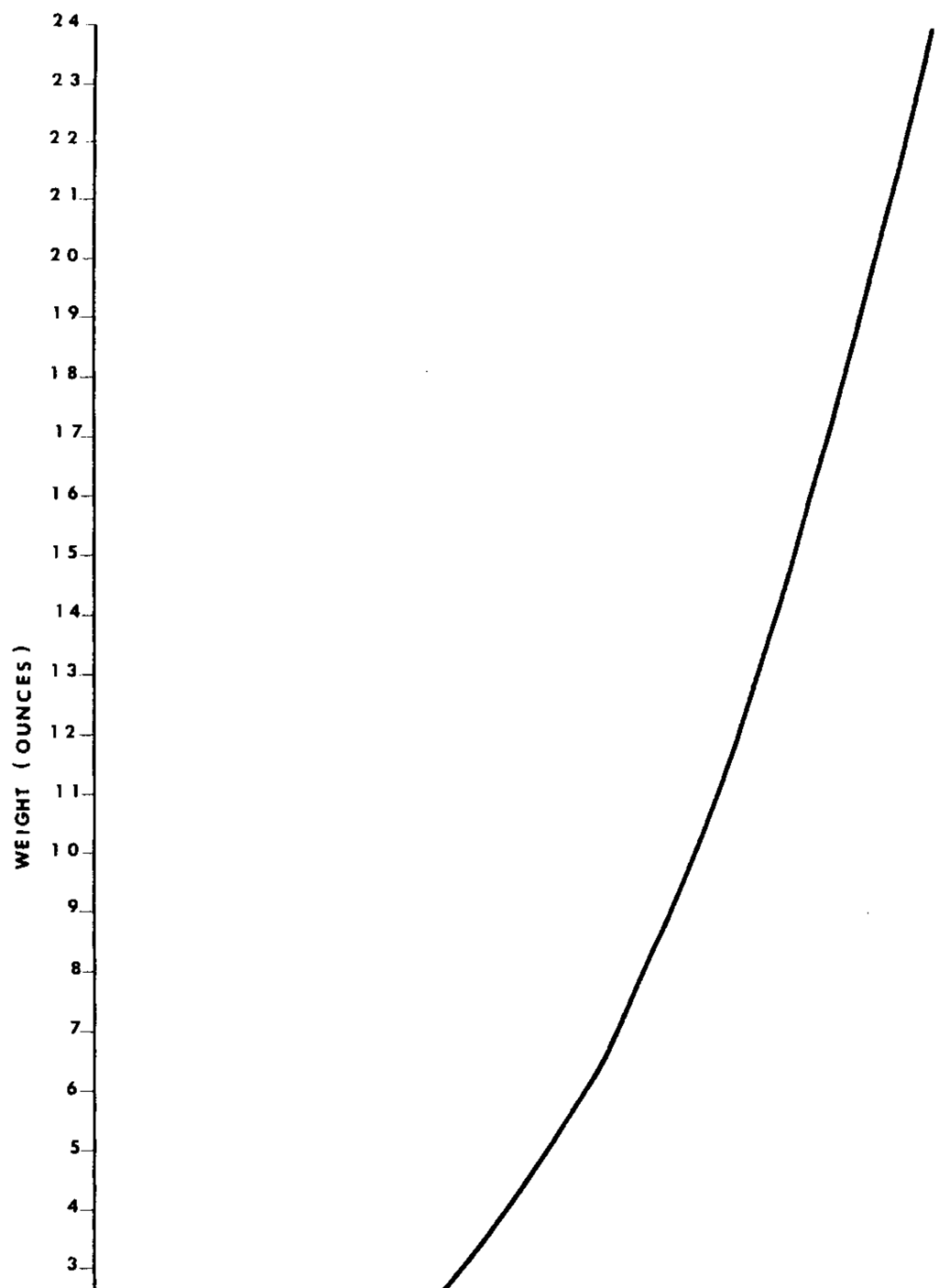


Figure 11. Length frequency of rainbow trout in the Mill Creek study ar
samples). Solid bars indicate recaptured young-of-the-year


WEIGHT (OUNCES)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3

habitat. Chapman (1966) postulates, with considerable evidence, a space-food mechanism regulating stream salmonid populations. Trout are very specific in their spatial needs. They require cover and current. Usually, the characteristics and number of riffles determines the amount of suitable trout habitat. Our low gradient trout streams usually have gravelly, shallow riffles separated by deeper pools and very little cover which supports only limited numbers of trout. As the individuals in the population compete for this limited space, the loosers are forced into the less desirable areas of the stream and become much more vulner able to predation, cannibalism, and disease. To further complicate survival, Missouri trout streams all have numerous predatory centrachids such as smallmouth bass and rock bass which are not usually present in more traditional trout streams.

The rather constant cool water temperature environment in which these trout live does not provide a well defined spawning stimulus. It also influences the size attained by young-of-the-year trout and probably their survival. The trout we studied in Spring Creek and Mill Creek were of unknown origin, but those in the Little Piney River were progeny of a fall spawning hatchery strain. They all spawned at approx imately the same time each year, but the exact time varied yearly depend ing on when the water temperature decreased sharply enough to stimulate spawning. This suggests that they were all genetically similar and were from a fall spawning strain. Originally, wild rainbow trout spawned during rising water temperature and increasing day length, in late winter or early spring (Breder and Rosen, 1966). Fish culturists, to facilitate easier and more efficient hatchery operation, selectively bred a strain of fall spawning rainbow trout which in the hatchery are spawned in October and November. Apparently, progeny of this hatchery strain surviving under natural conditions such as in Mill Creek and the Little Piney River may be ready to spawn earlier in the fall, but did not because the water was to warm and they lacked a stimulus. We found that the water temperature must decrease sharply, approximately 10° from 52° to 42° F, before the trout would spawn. In some instances after spawning started, the water warmed and spawning ceased until another sharp reduction occurred.

Missouri's climate during the fall and winter is usually mild. Even in December and January, the air temperature seldom drops below 0° F except for short periods. We found that unless the air temperature, drops to 0° F or below and remains there 6 to 8 hours or longer the water temperature does not decrease enough to stimulate spawning.

This variation in spawning time also influenced the size attained by young-of-the-year trout. Those trout, stimulated to spawn in mid-December or earlier, produced young ranging in size from approximately 5.5 to 7.0 inches or larger by October because they had a longer growing period. Those that were delayed until January or later produced young of-the-year that were considerably smaller ranging from 3.5 to 5.5 inches in October. As we indicated earlier, these streams contain many predators. Small trout are less able to compete with larger individuals and may become more vulnerable to predation.

Floods during spawning have the potential to completely eliminate one or more year classes of trout. The 1972 flood was not severe, but it did eliminate young-of-the-year in the Little

Piney River by destroying

redds constructed before the flood and by filling those constructed after the flood with sand and gravel. In Mill Creek, the damage was not as evident because of the better substrate, but if the flood magni tude had been greater, several age-groups of trout might have been elim inated. Elwood and Waters (1965) reported severe flooding eliminated two year classes of brook trout by destroying eggs and fry in redds and increased the mortality of older trout by destroying suitable habitat. They also reported slow growth the year following the flood because of a reduction in food production. Extreme floods in Missouri could cause as much damage.

Rainbow trout growth in the study streams appeared rapid during their first year of life (5.7 inches average length), but slowed drasti cally the second year (8.5 inches average length). The average length of wild stream rainbow trout at the ends of their first and second years of life (calculated from Carlander's, 1969 Life history of rainbow trout) was 3.5 inches and 7.0 inches, respectively. Natural rainbow trout in Missouri are larger the first year because they are spawned earlier and have a longer growing period, but they do not maintain this advantage. I believe that warm water in the summer slows or stops growth. We found scale annuli forming during the summer which indicates that growth prac tically ceases. Brown (1946c) found that brown trout activity and body maintenance requirements increased and growth slowed in water tempera tures above 20° C (68° F). Water temperature in our study streams pro bably exceeded 70^0 F for short periods during the summer. This causes trout to expend most, if not all, of their energy for body maintenance, growth slows or stops. Also, larger trout have higher maintenance, requirements and thus are affected more by high water temperature than small trout.

Fishing pressure was not measured in our study streams, but our data suggests that fishing greatly reduced the number of adult trout and the total biomass. Those areas open to fishing had fewer trout and lower survival rates. Furthermore, after the refuge study section in Mill Creek was closed to fishing the biomass, the number of adult trout, and the number of young-of-the-year increased substantially. These natural trout populations even under optimum conditions are small and exist in a very complicated ecological system. Any factor, that appreciably reduces the number of adults affects the entire population by eliminating reproduction and recruitment. In native trout streams, trout are the predominate fish species. When adult populations decline fishing pres sure also declines. This allows enough adult trout to spawn each year to provide a new year class. Trout are not the only game species sought by fishermen in Missouri's trout streams and fishing pressure does not decline when the trout population declines. Trout continue to be caught along with the other sport fishes. Consequently, heavy fishing pressure could decimate these trout populations.

A literature review (Turner, 1972) indicated that the same biologi cal and physical factors which regulated trout spawning and survival in native trout streams affected trout in Missouri. Spawning time was controlled by a complex of factors including genetics, water temperatures, volume, and length of the photoperiod. None of the authors indicated the necessity of the sudden temperature drop which our study revealed stimulated spawning, although Figures 2 and 3 in Dodge and MacCrimmon's (1971) paper suggested that spawning was stimulated by a sharp reduction

in water temperature. The authors stated that rainbow trout were adapted to a wide range of climatic conditions and made maximum use of the environment available for reproduction. Survival rates ranged from 0.13 to 0.90, and the greatest mortality occurred after trout left the redd. Stonefly nymphs, mergansers, herons, bitterns, kingfishers, bullfrogs, oligochaete worms, sculpins, juvenile salmonids, and adult salmonids were all reported as trout predators. The greatest egg loss occurred from floods scouring the redds, and from silt and sand deposition in the redds smothering the eggs.

This research has demonstrated the very fragile nature of Missouri's self-sustaining trout populations. They are small and can support only a very limited harvest, but if trout fishermen numbers continue to increase, these streams could become very important if managed as "fish for-fun" areas. Harvest would have to be very light, but the quality of the experience would be high. In addition, these natural trout popula tions are also a very important reservoir of disease free trout that Missouri's trout hatcheries may need in the future.

Summary

Reproduction, survival, and growth of self-sustaining rainbow trout populations were studied in three Missouri streams. Standing crops ranged from 1.2 to 29.6 pounds per acre and were largest in areas closed to fishing. Production was limited by interspecific competition for space and food, lack of suitable habitat, and warm water in the summer which slowed or stopped growth.

Rainbow trout usually spawned after the third week of December and

before the third week of January. Spawning was stimulated by a rapid decrease in water temperature of approximately 10° F from 52° to 42° F.

Survival rates ranged from 0.25 to 0.38 in areas open to fishing to 0.45 to 0.47 in areas closed to fishing. Fishing pressure appeared to be the most important cause of death of large trout. Floods during spawning reduced annual recruitment by scouring redds or by filling them with sand and gravel.

Rainbow trout grew approximately 5.7 inches the first year and 2.8 inches the second year. Growth beyond the second year could not be calculated.

Management Recommendations

1. The location and the relative size of all the self-sustaining rain-bow trout populations in Missouri should be determined.
2. Representative areas should be acquired as natural areas by the Missouri Department of Conservation and fishing should be restricted to fish-for-fun with no harvest.

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