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THE TROUT FISHERY IN SHENANDOAH NATIONAL PARK

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By

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ABSTRACT

Populations of brook trout in streams of Shenandoah National Park were reduced drastically early in the past decade by a succession of unusually severe droughts and floods. The drying of stream beds, predation, and scouring were principal factors in the loss of fish. The park was closed to fishing in 1954 and 1955 to protect survivors.

The small numbers of survivors quickly repopulated the streams after drought conditions abated. The stocking of hatchery-reared fingerling trout in selected waters failed to augment the recovery of populations. Survival and growth of young, wild trout were especially good. Their redistribution through miles of previously dry streams was rapid. The park was opened again to fishing in 1956 under regulations which restrict the take but afford an increase in sporting opportunity. Two streams were placed under fishing-for-fun-only regulations in 1961.

The welfare of the trout populations is dependent mostly on the weather cycle. Fish may be abundant in wet years but very scarce in dry ones. Thus, the stream must be managed as marginal for trout.

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The brook trout (Salvelinus fontinalis, Mitchill) is the principal sport fish in Shenandoah National Park. Its numbers may fluctuate drastically, however, due to factors other than fishing regulations and fishing pressures. Within the past decade the fish has ranged from abundant to very scarce and back to abundant again.

The National Park Service has endeavored on several occasions to evaluate the trout populations and to define the factors which so strongly affect them. Brief studies were made on the fish and the streams by King (1936), Taylor (1941), Chamberlain (1951), and Henderson (1950)*. The results were conflicting, due to reasons which are explained later in this report. Continuing problems in the sport fishery indicated the need for a comprehensive investigation. Accordingly, the National Park Service requested the Fish and Wildlife Service to conduct a long-term study which began in 1952 and continued through 1959. It was opportune in that it included one of the more critical periods with respect to the fishery since the establishment of the park in 1930.

THE STREAMS

The park is located within the State of Virginia and lies along the crest and slopes of the Blue Ridge Mountains between Front Royal on the north and Rockfish Gap on the south. It is approximately 80 miles long and 1 to 13 miles wide. The steep ridges and peaks rise 1,000 to 3,000 feet above the Piedmont Plateau to the east and the Shenandoah Valley to the west. The highest peak in the park is 4,049 feet above sea level.

The 46 trout streams are short, steep, and small to medium in size. Their fishable

* Typewritten reports to the National Park Service.

lengths range from 0.5 to 7 miles (average: 2.4 miles) and total 108.5 miles. The streams on the east slopes drain into the Rappahannock and James rivers. Those on the west slopes drain into the Shenandoah River. In general, they cease to be trout streams within a short distance from the park.

The sandstone and shale stream beds scour badly. The waters are clear, colorless, and very soft. Tests I made at various times have ranged as follow: 6.0 to 7.0 in pH; 22,000 to 58,000 ohms in resistivity at 77° F.; 19 to 40 ppm in total dissolved solids; and 0 to 10 ppm in methyl orange alkalinity.

Twenty-one species of fish occur in the streams, but the distribution of some is limited (table 1). All but the rainbow trout are native to the park.

Some of the waters were stocked with hatchery-reared brook trout or rainbow trout up to 1950, and with brook trout again in 1955. No stocking has been done since that time.

It is certain that the scenic streams and their wild trout populations will increase in importance in years to come. First of all, they are situated within 100 miles of Washington, D.C., and other large metropolitan areas. Many attractive trails provide access for fishermen and hikers. Secondly, the condition of the watersheds has improved greatly since the park was established. Most of the poor, mountain-side farms and cutover areas which contributed to silting, pollution, and warming of the streams have reverted to forest. Thus, the potential for a greater fishery resource is improving.

COLLECTION OF DATA

The research plan included a survey of each of the 46 streams. Because of limitations on the time and manpower which could be devoted to this park, the surveys had to be accomplished over a period of several years. The plan also called for intensive observations on 6 of the larger or more important streams, and quantitative data on their fish were collected each autumn from 1954 through 1957. Supplementary surveys were made on the same waters during other seasons of the year from 1953 through 1959.

A large amount of rather diffuse data was obtained in the surveys. Most of the findings were furnished to the National Park Service in periodic and annual reports. Only selected data are presented in this paper to illustrate important features of the streams and the fish populations.

Trout and other fishes were collected in measured areas of streams with cresol compound (Wilkins, 1955), or with electrofishing gear (Petty, 1955; Lennon and Parker, 1957 and 1958). A 230-volt, AC, alternate-polarity electrode system, used in conjunction with blocks of cattle salt, was the means employed most successfully to obtain reliable estimates of the numbers and pounds of trout per acre of stream. These were the first enumerations of the fish populations in the park because efficient collecting tools were not available to the previous investigators.

THE STATUS OF TROUT POPULATIONS PRIOR TO 1952

We assume that the brook trout were close to maximum abundance in 1950 and 1951. A review of the surveys by King (1936), Taylor (1941), Chamberlain (1951), Henderson (1950), and the reports by park rangers in 1951 and 1952 show the development of the trout fishery.

Many of the streams had been abused prior to the establishment of the park. King began his observations on them a few years after they came under park protection, and during a period of drought as well. He wrote, for example, that Madison Run was not a trout stream, but 5 years later Taylor rated it as good. Chamberlain classed it as exceptionally rich in trout food organisms, and park rangers considered it good trout water in 1950. We observed a fine spawning population in 1952.

Brokenback Run was rated as a possible trout stream by King, as fair by Taylor, but it became one of the seven most heavily fished streams by 1950. Big Run, a large and important stream, appeared to King to be better suited to smallmouth bass than brook trout. Taylor

Table 1:- The fishes of Shenandoah National Park.

Family and species	Distribution	Abundance
SALMONIDAE		
1. Rainbow trout	limited	rare
2. Brook trout	wide	abundant
CYPRINIDAE		
3. Eastern redbelly dace	"	"
4. Rosy dace	"	common
5. River chub	limited	rare
6. Common shiner	"	"
7. Blacknose dace	wide	abundant
8. Longnose dace	"	"
9. Creek chub	limited	rare
CATOSTOMIDAE		
10. White sucker	wide	"
11. Northern hog sucker	"	common
12. Golden redhorse	limited	rare
13. Torrent sucker	"	abundant
ICTALURIDAE		
14. Margined madtom	"	rare
ANGUILLIDAE		
15. American eel	"	"
CENTRARCHIDAE		
16. Rock bass	"	"
17. Redbreast sunfish	"	"
18. Smallmouth bass	"	"
PERCIDAE		
19. Fantail darter	wide	abundant
20. Johnny darter	"	"
COTTIDAE		
21. Mottled sculpin	"	"

considered it as fair trout water; Henderson found trout up to 12 inches long plentiful in 1950; and Chamberlain called the bottom fauna rich. We observed numerous trout up to 14 inches long in 1952.

A few of the large streams, such as the Rapidan, Hazel, Hughes, and Staunton rivers, were listed as good trout waters by King or Taylor and as excellent by Henderson or park rangers about 10 years later. On the other hand, several streams remained relatively poor for trout through the years.

The improvements in the trout populations were the result, in large degree, of the continuous and various efforts of the National Park Service. Before 1950, the larger and more accessible streams were stocked annually with fingerling and legal size brook trout. The North Fork of Moorman River was also stocked with rainbow trout. Fishing seasons were only slightly more than 2 months long; a 7-inch minimum size restriction was imposed; and the use of natural bait was prohibited. Furthermore, the streams were well protected, and the erosion of roads and hillsides into the streams was reduced.

These efforts, in addition to favorable weather and water conditions, contributed to an overabundance of small trout by 1950-1951. Henderson reported that many of the trout were only 2 or 3 inches long at the end of their second summer, and that many sexually mature fish were only 4 or 5 inches long. Fishermen complained to park rangers about the abundance of large-headed, sublegal trout. This situation was a large part of the reason that the National Park Service requested the Fish and Wildlife Service to perform a survey of the fishery. Before the survey could be started, however, the trout population began to decline.

DECLINE OF TROUT POPULATIONS

Drought

A series of severe droughts began in Shenandoah in the autumn of 1951 and continued into 1955. They were related to the widespread drought conditions which affected central and southwest States from 1952 to 1955 (Larimore, Childers, and Heckrotte, 1959). The dry periods in the park in 1951 and 1952 occurred during the fall months. In 1953, the drought persisted from August until late fall, whereas in 1954 it lasted from June to October. Less damaging conditions occurred during the summer and fall of 1955. The record of rainfall for the July-October period each year from 1945 through 1959 illustrates the succession of droughts (table 2).

Water levels:-- Stream flows were quickly and strikingly affected by the droughts. Many riffle areas, especially in the headwaters, were dry during the autumns of 1951 and 1952. The longer drought in 1953 caused most of the streams to become largely dry between their sources and the park boundary. Shrunken pools were widely isolated. Temperature and pH readings in adjacent but isolated pools disclosed that the flow of ground water between them was small. The temperatures differed up to 3° F. between pools and pH ranged from 6.0 to 7.0.

Increases in acidity were greatest in the fall and they were believed to be due to heavy accumulations of fallen leaves in the water. Kendall and Dence (1927) reported a similar situation which adversely affected trout of certain New York streams. The concentrations of dissolved oxygen and carbon dioxide remained within favorable limits for fish, however, because the low temperatures prevented rapid decomposition of the leaves.

The most critical effects of drought on water levels were observed in 1954. Beginning in June, stream flows decreased rapidly. The conditions on Big Run were considered typical of those on many of the streams. The normal flow of 5,400 gallons per minute at a station located midway between the source of the stream and the park boundary was reduced in July to 14 gallons per minute and in August to 10 gallons per minute. It was estimated that 75 percent of the length of the stream was dry by late August. In fact, the entire headwater section which previously contained numerous trout was completely dry.

The majority of the streams during the summer flowed at less than 0.2 cfs. The larger Rapidan River and Hughes River had only 5.5 and 2.0 cfs respectively in mid-August, representing only small fractions of normal flows.

Table 2:-- Record of rainfall in inches for July-October periods in years 1945-1959.

Year	Rainfall exclusive of severe flash floods					Flash floods	Grand Total
	July	August	September	October	Totals		
1945	6.6	3.1	7.6	0.6	17.9	....	17.9
1946	5.4	2.2	4.0	3.6	15.2	....	15.2
1947	4.7	3.8	4.9	2.4	15.8	....	15.8
1948	5.3	3.8	4.7	5.9	19.7	....	19.7
1949	6.6	7.0	2.1	3.4	19.1	....	19.1
1950	4.5	4.1	3.9	2.3	14.8	....	14.8
1951	2.8	3.0	0.5	0.7	7.0	....	7.0
1952	1.9	5.0	4.5	1.4	12.8	....	12.8
1953	3.6	3.3	3.5	2.0	12.4	....	12.4
1954	2.2	2.8	1.6	1.9	8.5	9.0 1/	17.5
1955	0.9	6.0	1.1	2.5	10.5	13.5 2/	24.0
1956	8.6	3.8	5.4	4.9	22.7	....	22.7
1957	1.4	0.7	4.5	4.8	11.4	....	11.4
1958	5.0	6.4	1.3	2.1	14.8	....	14.8
1959	3.3	3.1	4.6	5.5	16.5	....	16.5
Averages	4.2	3.9	3.6	2.9	14.6		

1/ Hurricane Hazel, October 15, 1954: 9.0 inches of rainfall

2/ Hurricane Connie, August 12, 1955: 4.6 inches of rainfall
Hurricane Dianne, August 18, 1955: 8.8 inches of rainfall

There is no question that large numbers of fish perished in the drying pools and riffles because escape was impossible. We had occasion to sample brook trout and other species in isolated pools which suddenly dried within a day or two later. As the levels of the pools receded and the amount of cover was reduced, the larger trout attempted to move downstream. Their attempts to cross drying or dry riffle areas were observed in several instances. Between periods of rest, the trapped fish charged the downstream edge of their isolated pool seeking an avenue of escape. The attempts were more than probes since the fish often threw themselves out of the water temporarily. It may be significant that the larger trout, 10 or more inches long, were quick to disappear from the streams when sections began to dry up.

Water temperatures:-- The droughts in the autumns of 1951, 1952, and 1953 were not complicated by unfavorable water temperatures. During the summer drought in 1954, however, temperatures as high as 82° F. were measured in the isolated pools. The high temperatures persisted for days at a time, and the trout were in distress. Adult trout rested upright on the stream bottom, and made no attempt to support themselves on pectoral fins. They showed no movement except a rapid rate of respiration. Counts of 136 gill movements per minute were made on 10-inch trout lying in 76° water. Embody (1921) observed that brook trout in stream water at 83.3° exhibited great distress and a refusal to eat, but survived.

The trout also showed no fear. One could wade into the pools and touch them. No mortalities, however, could be charged directly to the high temperatures. Rather, the warm water may have contributed to an increase of losses by predation.

Predation:-- The drying of the streams caused the fish to congregate in isolated pools. As the levels of these pools receded, much of the usual cover became unavailable, and the fish were exposed to easy predation. Furthermore, the high temperatures of water in July and August 1954 made the trout almost helpless and subject to easy capture. During autumn, accumulations of fallen leaves served as temporary cover and the fish hid in them.

Common watersnakes (Natrix sipedon) killed many trout. This species is abundant in the park, and in fact, many local fishermen shun the streams in summer because of their dislike for the numerous "moccasins". As many as five large watersnakes were observed prowling at once in one shrunken pool. Three individuals were killing trout simultaneously in another small pool. One of the snakes, 31.4 inches long, killed and swallowed a 7.9-inch brook trout. Another slightly smaller snake killed a 7-inch trout. The third snake released its still living prey and escaped.

Following the random observations on predation, selected isolated pools were checked daily. The watersnakes continued to wipe out a large proportion of the adult trout which were trapped there. The pools generally contained greater numbers of blacknose and longnose dace, common shiners, suckers, sculpins, and darters than trout. It was surprising, therefore, to find that the snakes took the adult trout in marked preference to the other species. The trout may have been more susceptible to capture than the other fish because of their lethargy in the warm water. Also, the trout were larger than the other species, with the occasional exception of hog suckers and white suckers. Their size may have been a factor in attracting the predators since Lagler and Salyer (1947) reported finding brown trout up to 8.5 inches long in the stomachs of watersnakes.

American eels occur commonly in several streams, particularly on the east side of the park. On the possibility that they prey on trout, dozens of specimens from 14 to 33 inches long were captured and opened. Most of the stomach contents consisted of crayfish. One eel, 24 inches long, had eaten an 8-inch trout.

There was no evidence that other predators were as damaging as watersnakes to trout during the summer drought. Herons were observed rarely, but kingfishers were more abundant than usual along the streams. We concur with Larimore, Childers, and Heckrotte (1959) that predators can and do remove large numbers of fish from shallow pools during periods of discontinuous flow.

Trout spawning:-- The autumn droughts in 1951, 1952, and 1953 seriously affected spawning. Brook trout in the park spawn during the last week of October and the first week of November. In the years mentioned, many of the riffle areas were dry or were completely choked with fallen leaves. The trout in isolated pools made many redds, most of which were incomplete. Those redds at the sides of pools were often left dry by shrinking water levels. The survival of ova in some redds may have been jeopardized by the reduced exchange of ground water. Furthermore, our collections demonstrated that the distribution of sexes in the isolated pools was very unequal. Thus, recruitment during the three successive years was small.

Floods

As so often happens, severe flash floods interrupted the droughts. Furthermore, they damaged the declining trout populations. Following a dry winter, 4.5 inches of rain caused flash floods to sweep the streams on March 1, 1954. The long, summer drought the same year was broken on October 15 by the disastrous Hurricane Hazel which dumped 9 inches of rain on the park headquarters area. Some watersheds received up to 17 inches of rain in that storm. Hurricanes Connie and Dianne added to the flood damages in August 1955 with 4.6 and 8.8 inches of rain respectively.

Scouring:-- The steep watersheds proved to be highly susceptible to damage by flash floods. The stream beds were badly scoured, and the numerous fords on access roads and trails were washed out. It was impossible to conduct immediate surveys of damages to the streams and fish until the National Park Service repaired the impassable roads.

The scouring during the March 1954 flood was so impressive that we planned to measure some of the effects of future floods. Boulders of various sizes in and along the stream beds were to be marked with paint and their locations plotted on a stream map. Tentative selections which included very large boulders were made on Big Run. Before the plan was implemented, the flood attending Hurricane Hazel swept the stream, and the selected boulders could not be found. Indeed, the mile-long section of stream which had contained the boulders as well as abundant rubble and gravel was scoured to clean bedrock.

Damage to aquatic life:-- It is known that floods and scouring cause losses to fish and to fish food organisms. Quite by accident, flood pools were discovered in the woods at some distance from the streams following the March 1954 flood. Sac-fry brook trout, blacknose dace, and mayfly nymphs were observed in them. The pools soon dried and the fish and nymphs were lost.

It appeared that the flash floods are more damaging to fish and invertebrates when they follow periods of drought. Then, the fish are concentrated in pools, and their physical condition may be poor. Their ability to withstand floods is thus reduced. The presumption is based on the fact that water levels and fish were in better condition in August 1955 when hurricanes Connie and Dianne struck, and the damages to the fish were less.

Population estimates

No quantitative estimates of trout populations were made in 1952 and 1953. Young-of-the-year brook trout were extremely scarce in seven streams which were examined in the spring of 1953. The fishing, on the other hand, during the May 1 - July 10 season that year was fair. Voluntary creel census records from 13 streams showed catch rates which ranged from 0.4 to 1.0 trout per hour, and the trout averaged slightly more than 8 inches in length. It was noted, however, that trout over 10 inches long were less numerous than in 1952.

The trout were obviously in critical condition in the spring of 1954 following the fall drought and the March flood. Many appeared emaciated. Estimates were made of the populations in seven streams, based on collections obtained with cresol. Only 11 trout over 7 inches long were collected in 1,500 yards of formerly excellent trout waters. The estimates ranged from 1.7 pounds of trout per acre in Big Run to 7.7 pounds in Piney Run. Moreover, few young-of-the-year and yearling trout were found. As a result, the National Park Service closed all streams in the park to fishing for the year.

The trout populations were estimated again in the fall of 1954, shortly after the flood caused by Hurricane Hazel. The summer drought and the flood caused demonstrable losses. There were only 16 trout per acre in Big Run in contrast with 44 per acre in the preceeding March. There were losses also among the smallmouth bass and forage fishes in the lower section of Big Run. Trout were scarcer in Jeremys Run and the North Fork Moorman River than in Big Run, but they were somewhat more numerous in Piney Run and Rapidan River.

The validity of the estimates of the trout population in 1954 is, however, subject to question. Both the spring and fall surveys immediately followed flash floods which had terminated periods of low water. Although the sampling was extensive, it could not be justified as representative of streams which recently had been largely dry. Furthermore, the sampling gear and procedures for soft water streams were undergoing testing and improvement. We concluded that the estimates for this year were probably low.

THE RECOVERY OF TROUT POPULATIONS

The small numbers of surviving brook trout spawned successfully in November 1954. This marked the beginning of the recovery of the populations. Water levels remained favorable after the hurricane flood, and it was the first time since 1950 that spawning conditions were good.

Park streams remained closed to fishing in 1955 to afford some protection to the few adult trout in the event of another prolonged drought. Fortunately, conditions were less severe than in the preceding year.

Stocking

An attempt was made in 1955 to accelerate the recovery of trout populations in 13 of the 46 streams by stocking fingerling brook trout of the Appalachian strain. The experiment was prompted by the good results obtained in stocking the same strain in flood-damaged streams in Great Smoky Mountains National Park and in Tennessee streams in 1954. A total of 22,089 fingerlings which averaged 2.7 inches long was stocked in June. Most of them were fin-clipped to permit future identification.

The fingerlings appeared to thrive until hurricanes Connie and Dianne brought flash floods in August. Thereafter, only a few were found. The survival in Big Run through the summer was 0.7 percent of the 5,500 fish stocked. In contrast, wild young-of-the-year brook trout survived the floods relatively well, despite their smaller size. The stocking was a failure, and none has been attempted since.

Population estimates

1955:-- The populations of brook trout in most of the streams improved greatly in 1955 as a result of better water levels which permitted spawning and good survival. Piney Run, one of the good streams in the park, is an example (table 3). There were 115 trout or 8.5 pounds per acre in the fall of 1954. A year later the estimate included 418 trout or 34.5 pounds per acre.

Whereas most of the increase was due to young-of-the-year fish, there was significant improvement in the condition and growth of the older fish. Reflecting the amelioration of food and water supplies, the coefficient of condition ($R = \frac{W \times 10}{L^3}$; Cooper and Benson, 1951) of 7- to 11-inch trout increased from 1.41 in 1954 to 1.62 in 1955. The latter compares favorably with Cooper's and Benson's mean coefficient of 1.65 (range: 1.40-2.11) for a group of 100 wild brook trout collected in the Pigeon River, Michigan, in 1949. The lengths of trout captured in Piney Run in 1954 ranged from 2.9 to 10.4 inches. In 1955, the fish ranged from 2.4 to 11.4 inches long, and 25.7 percent of them were over 7 inches long.

Good reproduction occurred in most of the streams during early November. Many redds with 8- to 12-inch trout over them were located. Fertilized ova in excellent condition were found in selected redds then, and again in January 1956.

Table 3:-- Estimates of the numbers and pounds of brook trout per acre.

Stream	1955 Trout per acre		1956 Trout per acre		1957 Trout per acre		1959 Trout per acre	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
Big Run	615	25.5	449	10.6	281	12.3	265	18.7
Burgess River	...	...	...	...	...	...	506	20.1
Conway River	...	...	...	...	...	...	516	19.0
Hawksbill Creek, Little	...	...	...	...	...	...	1,190	34.4
Hogcamp Branch	2,679	165.0	2,125	50.8	1,782	64.7	2,200	85.3
Moorman River, N.F.	65	29.6	98	3.3	45	4.5	96	5.6
Piney Run	418	34.5	1,489	43.3	750	25.9	605	27.3
Pocosin Hollow Run, L.F.	...	...	...	...	...	...	924	28.1
Ragged Run	...	...	...	...	...	...	1,744	56.3
Rapidan River	368	19.3	525	16.2	375	14.2	582	17.4
Rose River	...	...	...	...	...	...	383	14.5
White Oak Canyon Run	...	...	...	...	...	...	1,653	55.6

Some of the trout in Big Run demonstrated a preference for spawning in the newly dug gravel which the National Park Service used to rebuild the fords washed out by hurricanes Connie and Dianne during the summer. The preference was most obvious in sections of the stream where the natural bottom material is mostly a shalt-type shale type gravel.

1956:--On the basis of the successful reproduction in 1954 and 1955 and the improved survival and growth of trout, the park was reopened to fishing on May 1. The fishing season was lengthened to conform with the State of Virginia season. The regulations included a 9-inch minimum size, a daily possession limit of 8 fish, and a requirement that only artificial lures be used. As expected, anglers quickly removed most of the trout over 9 inches long.

Despite some low water levels in the spring, the year was favorable for the continued improvement of trout populations. The hatch of brook trout was good, and advanced fry collected in Big Run and Piney Run in late April ranged from 1.0 to 1.4 inches long. It was noteworthy that a successful hatch occurred in North Fork Moorman River for the first time in several years. Furthermore, rainbow trout spawned successfully in Moorman River for the first time.

The large and attractive North Fork of Moorman River is perhaps the most marginal of the park trout streams. It is easily accessible, however, and it receives heavy pressure from fishermen who reside in the Charlottesville, Virginia, area. It was stocked repeatedly with rainbow trout in the late 1940's on the assumption that this species would do better than native brook trout in the relatively warm water. It appears, however, that the rainbows moved downstream into the Charlottesville Municipal Reservoir, a short distance out of the park, and became established there. None was seen in the North Fork during the severe drought years. Some large specimens were observed in the spring of 1955, but no evidence of spawning could be found. Rainbows up to 20 inches long moved upstream again in the spring of 1956, and some successful reproduction took place. An estimate made in November included 77 young-of-the-year per acre which ranged from 2.3 to 4.7 inches long.

Hogcamp Branch, a remote tributary of the Rose River, contained a contrasting abundance of trout. It was one of the very few streams in the park which escaped the damaging effects of the droughts and floods. Furthermore, it had a good population of brook trout before the fishing seasons were closed for two years. There were 2,679 trout or 165 pounds per acre in the fall of 1955. They ranged from 2.4 to 10.4 inches long, and 15 percent were over 7 inches long (table 4). This was, by far, the largest population which has been found in the park.

Hogcamp also provided an example of the impact of heavy fishing pressure on a small stream. The stream was fished hard in 1956, and the larger fish were removed. Most of the 2,125 trout found per acre in the fall were young-of-the-year and yearlings, and the weight of trout per acre had dropped to 50.8 pounds. Less than 3 percent of the fish were over 7 inches long, despite the fact that the minimum legal size was 9 inches.

The population estimates for 1956 in table 3 are misleading in one respect. We attempted as far as possible to base the estimates on collections which were made at the same survey stations year after year. Supplemental surveys in the fall of 1956 disclosed that brook trout were again present in the extensive areas of mainstream, headwaters, and tributaries which had been dry in 1954 and barren in 1955. Thus, we concluded that the populations had improved greatly in numbers and distribution even though the estimates do not demonstrate the fact. Big Run, for example, shows a decline in 1956, part of which is attributable to fishing. There was, however, a large movement of trout into the barren headwaters and tributaries which reduced the numbers and pounds of trout in the mainstream.

1957:-- The over-winter survival and growth of trout was checked in several streams in April. The survival of fingerling brook trout was good, but their growth since the previous November was small. The survival and growth of fingerling rainbow trout was very good in the

Table 4:-- Length-frequency distribution of fall-caught, brook trout per acre

Stream and year	Length group of trout (inches) 1-1.9	2-2.9	3-3.9	4-4.9	5-5.9	6-6.9	7-7.9	8-8.9	9-9.9	10-10.9	11-11.9	12-12.9	13-13.9	Totals
Big Run														
1955	...	99	381	34	11	29	20	13	13	9	3	3	...	615
1956	1	200	150	15	41	17	14	10	1	...	...	...	...	449
1957	...	21	104	38	56	38	15	9	2	...	...	...	...	281
1959	...	28	66	29	40	37	40	18	5	2	...	...	...	265
Hogcamp Branch														
1955	...	359	359	269	778	509	150	225	...	30	...	...	...	2,679
1956	15	644	853	195	223	135	60	...	...	...	...	...	...	2,125
1957	...	135	300	929	314	45	60	...	...	...	...	...	...	1,782
1959	...	479	434	568	329	299	76	15	...	...	...	...	...	2,200
Moorman River, N.F.														
1955	...	...	...	...	5	...	5	...	22	...	11	11	11	65
1956	...	4	54	29	4	...	3	4	...	...	...	...	...	98
1957	...	...	5	...	5	16	16	3	...	...	...	...	...	45
1959	...	16	36	4	9	16	13	2	...	...	...	...	...	96
Piney Run														
1955	...	30	230	28	6	15	37	18	27	18	9	...	...	418
1956	8	367	675	160	101	93	37	40	8	...	...	...	...	1,489
1957	...	147	282	100	135	60	12	7	...	7	...	...	...	750
1959	...	112	133	102	130	71	54	3	...	...	...	...	...	605
Rapidan River														
1955	...	30	128	97	52	25	9	12	11	4	...	...	...	368
1956	...	106	225	78	39	43	28	6	...	...	...	...	...	525
1957	...	22	90	145	61	31	24	2	...	...	...	...	...	375
1959	...	162	99	165	105	38	13	...	...	...	...	...	...	582

North Fork Moorman River. They averaged 3.5 inches long on November 29, 1956, and 5.5 inches on April 12, 1957.

The eastern seaboard region from Virginia northward experienced another drought during the summer and early fall (table 2). Streams in the park once again became very low or intermittent, and water temperatures were high.

The surveys made in December demonstrated that the numbers of trout had decreased (table 3). On the other hand, the weight of trout per acre had increased in some streams and decreased in others. An examination of the length-frequency distribution of trout disclosed that there were far fewer young-of-the-year trout than in 1956 (table 4). The smaller numbers were the result of poor survival conditions in the summer and the fewer spawners in the fall of 1956. As mentioned previously, the larger adult trout responsible for the abundant reproduction in 1955 were cropped during the 1956 fishing season.

1958:-- Estimates of the fish populations were made only in the spring, and the surveys included 22 streams which were not studied previously. We sought to determine whether the trout had recovered from the disastrous droughts and floods. One or more survey sites were located on each stream. Where only one site was possible, it was located on the lowermost section or most accessible section. We assumed that if trout were found at these sites, they would be present in equal or greater numbers upstream or in the more inaccessible sections.

The numbers of brook trout in 16 of the 22 streams ranged from a few to 851 fish per acre. Young-of-the-year trout, 0.9 to 1.5 inches long, were observed in most of them. Although no trout were seen or collected in 6 streams, it would be unsafe to conclude that they do not exist in the upper waters.

1959:--Sixteen new streams were included in the surveys. Three were barren of trout, and the estimates for the others ranged from16 to 1,744 trout per acre. The populations were relatively good in the 5 streams which had been surveyed in previous years. The data indicate that of the larger and more heavily fished streams, Big Run, Piney Run, and Rapidan River are better producers of trout than the North Fork Moorman River.

Growth of trout

The growth of brook trout was relatively rapid during the period of population recovery. Henderson (1950) listed the ages of brook trout which he collected in Shenandoah streams in the fall of 1950. The trout were abundant at that time, and their growth was slower than that of trout we collected in 1956-57. For example, among the trout sampled in Big Run, age II fish ranged from 4.0 to 7.9 inches long in 1950 and from 6.0 to 10.9 inches long in 1956-57. Age III fish ranged from 5.0 to 9.9 inches in 1950 and from 8.0 to 12.9 inches in 1956-57.

In general, the growth of brook trout was more rapid in the warmer streams. Thus, trout in the North Fork Moorman River and Big Run grow slightly faster than in Piney Run. Rainbow trout also grew well in the North Fork. The 1956 year class averaged 3.5 inches in November of that year and 7.8 inches long in December 1957.

Furthermore, two-year-old brook trout in park streams in April 1957 ranged from 6.0 to 12.9 inches long whereas 35 wild trout of the same age from a productive New Hampshire stream in July 1957 ranged from 6.0 to 9.9 inches. Most of the Shenandoah fish were in the 9.0-9.9-inch group and most of the New Hampshire fish were 7.0-7.9 inches.

Among 86 legal size, brook trout (9.0-12.9 inches long) which were captured by anglers or during surveys on Big Run and Piney Run in 1956 and 1957, 23 trout were beginning their third summer; 57 their fourth summer; and 6 their fifth summer. No 5-year-old fish were taken by us at any time.

THE SPORT FISHERY

Season and regulations

Upon the reopening of fishing in 1956, the season was lengthened to correspond to that of the State of Virginia. It now opens in early April on the same date as the State, and it closes on the same date as the State, or on October 15, whichever is the earlier.

A Virginia license is required in the park and, until recently, the high cost of a non-resident permit deterred many tourists from enjoying the fishing. Now a short-term permit is available to non-residents at a lower cost. Only artificial lures are permitted; the daily bag limit is 8 trout; and the minimum legal size is 9 inches.

A 9-inch minimum size was adopted as a compromise between recommendations for fishing-for-fun-only and the renewal of the previous 7-inch limit. It was applied primarily to protect the spawning potential, especially during the recovery years. It also serves to improve the sporting aspects of trout fishing, as demonstrated on the North Branch of the Au Sable River in Michigan (Cooper, 1951). Although the higher size restriction cuts down the yield of trout to fishermen, such yield is, and must continue to be, of secondary importance in Shenandoah.

The trout resources and the sport fishery can be preserved best by applying a fishing-for-fun-only program on the streams such as has been tested on selected streams in Great Smoky Mountains National Park (Lennon and Parker, 1960). The program would be especially appropriate in Shenandoah, and a start in this direction was made in 1961. Under terms of an agreement between the park and the State of Virginia, the headwaters and tributaries of the Rapidan and Staunton rivers were opened to fishing-for-fun (Sheridan, 1961). All trout captured must be returned to the water immediately. Although only months old, the program has been called a success from the standpoint of angler participation and fishing quality (Birchfield, 1961 and Yeager, 1961).

Creel census

The streams in the park are not subject to the fishing pressures which are typical of northern trout waters. In general, the pressure is relatively heavy during the first several days of the season. Thereafter, the drop is so sharp that one must search for fishermen. For example, there were 38 fishermen on the 5-mile long Big Run on May 1 and 2, 1956, when the park was reopened to fishing. On Memorial Day, there were only 7 anglers on the stream. On opening day in 1957, 28 fishermen were counted on the stream. On the same day, park rangers counted only 191 fishermen on 17 streams. Within a few days after the openings, fishermen were also scarce on the State-managed trout waters beyond the park boundary.

It appears that the average fisherman in the Blue Ridge region fishes for trout several times immediately after the season opens and then devotes his efforts to the abundant warm water fisheries in larger waters. Only the relatively few avid trout fishermen frequent the mountain streams throughout the season.

Limit catches of 8 trout are rare. We checked anglers during their fishing who had up to 6 legal trout. Most of the fishermen expressed approval of the 9-inch minimum size and satisfaction with the quality of fishing. They stressed that fewer 9- to 14-inch wild trout in the creel were preferable to several more 7-inch wild trout.

Management aspects

Wild brook trout occur in at least 37 of the 46 streams. No trout were found at the sites surveyed on 9 streams, but we cannot conclude that they are barren of trout. The exotic rainbow trout is established in the North Fork Moorman River, but the population is small. Smallmouth bass and redbreast sunfish are found in the lower courses of a few streams, but in such small numbers that they are of no importance in the sport fishery. Thus, management should be directed almost exclusively to the brook trout.

The outstanding factor which influences the trout populations and the sport fishery is the

weather. Under favorable conditions, most of the streams have excellent capacities for supporting and producing trout. Brook trout up to 14 inches long and rainbow trout over 20 inches long are reported by anglers. On the wet side of the weather cycle, park personnel can expect complaints from fishermen that the streams are becoming over-populated with small, large-headed trout. It must be remembered then that the abundance is temporary, and the populations will be reduced again by the droughts and flash floods which occur during the dry years of the weather cycle. Significant fluctuations in populations will occur also in some streams as a result of short droughts or local floods. Thus, dependent upon the weather, the sport fishery of the park is marginal.

Demands will be made to stock hatchery-reared trout during periods when the wild populations are small. It was apparent, however, in the present study that the drought and flood conditions which decimated the wild fish would be equally or more inimical to stocked trout. It was apparent also that small numbers of survivors can quickly repopulate the streams as soon as water conditions permit.

SUMMARY

The populations of native brook trout in streams of Shenandoah National Park increased from relative scarcity in the late 1930's to abundance in 1950. The National Park Service requested a survey by the Fish and Wildlife Service to answer, in part, the complaints of fishermen that there were too many small, large-headed trout.

The fishery situation in the park changed radically at the time the survey was undertaken. A series of severe droughts, beginning in 1951 and continuing into 1955, curtailed reproduction and caused large losses of trout and other species. Up to 75 percent of the lengths of some streams were dry in the summer of 1954. The drying stream beds, the high temperatures of water in isolated pools, and predation by watersnakes contributed to the heavy mortality.

Two unusually severe flash floods in 1954 damaged stream beds and caused further losses of fish. The floods appeared to be especially damaging when they occurred as interruptions in a drought.

The park was closed to fishing in 1954 and 1955 to protect the small remnants of the trout populations.

There was no evidence that any species had been eliminated during the drought years.

Recovery of the fish populations was rapid despite the small numbers of adult fish, once water conditions improved enough to permit reproduction and good survival. One of the better streams which was surveyed annually contained 8.5 pounds of brook trout per acre in 1954, 34.5 pounds in 1955, and 43.3 pounds in 1956. Within the two years, the trout and other species also distributed themselves throughout long sections of mainstreams and headwaters which were dry in 1954. Among the non-game species, fantail darters made a particularly quick recovery in numbers and distribution.

An attempt to augment the recovery of brook trout by stocking Appalachian-strain fingerlings in 1955 appeared unsuccessful.

The growth of trout was relatively rapid during the period of population recovery. Two-year-old trout in one of the principal streams in 1950 ranged from 4 to 8 inches long; fish of the same age in 1956 and 1957 ranged from 6 to 11 inches. Age III fish in 1950 were 5 to 10 inches long, but those of the same age in 1956 and 1957 were 8 to 13 inches.

The park was reopened to fishing in 1956. The season and subsequent seasons were set to conform more closely with those of the State of Virginia. Legal-size trout (9 inches) are cropped closely, but populations have remained good as a result of favorable water conditions. Two streams were placed under fishing-for-fun-only regulations in 1961.

The welfare of trout populations in the park is dependent to an unusual extent on the weather cycle. The numbers of trout will vary from abundant in wet years to scarce in drought

years. The short, steep streams are particularly vulnerable to drying during droughts and to severe scouring during flash floods. These factors influence the sport fishery much more strongly than fishing regulations or fishing pressures. Thus, from a long-range point of view, the streams are considered marginal for trout, and they must be managed as such.

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