A COMPARISON OF FOUR EASTERN SMALLMOUTH BASS STREAMS[1]

EUGENE W. SURBER
U. S. Bureau of Fisheries, Kearneysville, West Virginia

ABSTRACT

Four smallmouth bass streams in the Potomac River watershed are compared. In the largest stream, the Shenandoah River near Berryville, Virginia, the fingerling bass (*Micropterus dolomieu*) grew to an average length of 4.25 inches during 1936, whereas in the South Branch of the Potomac near Romney, West Virginia, fingerlings attained a length of 2.75 inches by the end of the summer. In the Shenandoah River and probably also in its North Fork, bass grow rapidly and attain the legal size of 10 inches in three years, but in the South Branch of the Potomac and in the Cacapon River from four to six years or more are required for the fish to grow to legal size. The muddy condition of the Shenandoah and North Fork for long periods during the summer affects the success of natural propagation. These streams also have extensive riffle areas over limestone ledges where bass find shelter while feeding. In the South Branch of the Potomac and in the Cacapon River the riffles are short and little shelter is available.

Bottom samples collected in riffles of the four streams failed to show any marked difference in the abundance of organisms. Samples from pools of the South Branch, however, contained approximately twice as much potential bass food as pools of the Shenandoah River. A number of faunal differences in these streams are pointed out. In the clear streams such insect larvae as *Eriocera*, *Atherix*, and *Chauliodes* and the mayfly nymphs of *Isonychia* and *Iron* are more abundant than in the muddy streams where Sphaeriidae, Oligochaeta, larvae of *Elophila* and parnid beetles, and nymphs of *Potamanthus* are more abundant.

The extent of natural propagation in the four rivers was studied quantitatively. The smaller, clearer streams have the most extensive natural propagation. In the small, clear streams, there are many bass but their slow growth indicates serious food competition. In the South Branch of the Potomac the extent of natural propagation is probably about five times greater per mile length of stream than in the Shenandoah River which produces the fastest growing fish of any of the four streams studied.

A seasonal study of the food of fry and fingerling smallmouth bass was made from monthly collections during 1936 in the Shenandoah River and South Branch of the Potomac. The chief items of food were mayfly nymphs of the genus *Baetis* and chironomid larvae. Entomostraca (chiefly *Cyclops*) played a minor role in the food of bass in both streams. In the Shenandoah River, 9.9 per cent of the fry which averaged 10.0 millimeters in length on May 13, 1936, had consumed fish.

The livers of the South Branch fingerling bass contained large numbers of trematode cysts but relatively few were found in the livers of the Shenandoah River bass. There was no evidence that the presence of trematode cysts affected the growth rate, since infested and uninfested fish were very nearly the same size.

Minnow censuses were made on the four rivers. The data given in part, although to a certain extent inaccurate, at least afford some idea of the relative abundance of the more important forage fishes.

These studies indicate that much information of very practical value can be gained by actual field studies of bass streams. In some of these streams it is evident that the stocking of bass is a mistake.

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Introduction

Within a radius of 70 miles from the experimental station at Leetown, West Virginia, are four well-known smallmouth bass streams all of which are in the Potomac River watershed. The largest of these streams, the Shenandoah River (main branch), affords excellent fishing when it is clear, but during July, August, and September it is usually too muddy for fishing. Anglers catch many bass in this stream that weigh over 2 pounds and a relatively large number of bass that weigh from 4 to 5 pounds, but fish over 5 pounds in weight are rare. In the South Branch of the Potomac and in the Cacapon River, the bass taken run small in size, and only a few large individuals weighing 4 pounds or more are taken each year. The proportion of undersized fish is relatively large.

Growth studies show that nearly all bass in the Shenandoah River reach the legal size of 10 inches in three years whereas in the South Branch of the Potomac and in the Cacapon River from four to six years are required. The Shenandoah River drains a relatively rich agricultural section and during heavy showers the plowed clay fields contribute much silt or mud which causes the almost continuous roily condition of the river during the summer. In contrast to the relatively clean bottom and shore line of the Cacapon River and the South Branch of the Potomac, the Shenandoah and its North Fork have deposits of silt and mud over the rocky ledges, banks, piles of shore debris, and tree trunks beyond the water's edge. A greater abundance of willows overhang the banks of the last-named streams. The South Branch of the Potomac and the Cacapon River flow through rather narrow mountain valleys. The South Branch valley contains considerable expanses of flat bottom lands used for agriculture and grazing. The Cacapon valley, on the other hand, is narrow throughout and supports very little agriculture.

The long periods of muddy water, particularly in the lower Shenandoah, affect the success of natural propagation of the bass. The North Fork of this river does not appear to be silted as much as the main river. Even before our bass investigations began, it was observed that bass fry and young of the year were fairly abundant along the shores of the Shenandoah in June and early July, but by October they were much less numerous than in the South Branch of the Potomac. For some unknown reason (which we are attempting to determine) the roily condition of the Shenandoah River causes a sharp and rapid reduction of the population of fry and small fingerlings. Those that survive enjoy less food competition and, therefore, grow more rapidly. Thus the muddy condition of the Shenandoah probably has an indirect beneficial effect on the growth rate of bass in that river. Data collected during 1936 and 1937 indicate that the growth rate of bass is unaffected by long periods of existence in muddy water.

In late September and October, 1935, the Shenandoah River became

so clear that one could see the bottom, even in the deep pools. It was observed during this period that in spite of the previous successful angling there were in reality very few bass present in this river. This condition was in marked contrast to the South Branch of the Potomac where both adult and young bass were seen in relatively large numbers, whenever the water was clear and its temperature above about 60° F. In the Shenandoah River, bass of legal size always occurred in groups, sometimes as large as eleven or more individuals. On one occasion a school of nine bass swam out from beneath a large square boulder, and at another time when a bass was hooked, a school of ten individuals, all large fish, rushed to the boat and attempted to take the lure already set in the jaw of the hooked fish. The occurrence of schools of bass accounts for the variable success of bait fishermen who seek deep holes in the river near rocky riffles where such schools may be expected to occur.

The point which the writer wishes to emphasize is that the Shenandoah River, a large stream, has relatively few bass, but a large proportion of them were of good size. On the other hand, the South Branch and the Cacapon River, relatively small streams, have dense populations of bass in relation to the available food supply but the majority of the fish are relatively small. Actual field studies will determine whether or not our bass streams should be stocked. It is surmised that a large part of the equipment now being used for the propagation of bass in this section of the country might be devoted more profitably to the culture of forage fishes.

The growth rates of fingerling smallmouth bass in the Shenandoah River and the South Branch of the Potomac were compared during 1936 when river conditions permitted good monthly collections through the growing season. In the Shenandoah River, fingerling bass attained an average length of 4.25 inches by September 22, whereas in the South Branch they attained an average length of only 2.75 inches during the same length of time. Not only bass but stonerollers (*Hypentelium nigricans*) and common suckers (*Catostomus commersonnii*) grew more rapidly in the Shenandoah than in the South Branch.

In 1937, when the Cacapon and the North Fork of the Shenandoah River were added to the number of streams under observation, high water prevented really adequate collections in all of the rivers. The data collected showed that fingerling bass in the Shenandoah River were nearly 2.5 inches long by July 30; South Branch bass were about 2.7 inches long by September 13; Cacapon River fingerlings about 2.8 inches in length by September 1; and bass from the North Fork of Shenandoah slightly more than 3.0 inches long by September 16.

Bottom Fauna

The effect of the numerous limestone springs in the Shenandoah valley upon the waters which drain it is shown by chemical analyses

of the water (Table 1). The chemical nature of these waters together with their silt loads affects the kind of organisms found in them as evidenced by the predominating molluscs. In the South Branch and the Cacapon River, many snails of the species *Nitocris carinatus* Bruguiere occur, but comparatively few Sphaeriidae are found although they are very abundant in the riffle areas of the Shenandoah and its North Fork. The large *Lampsilis ovata cohongoronta* Ortmann is found in the South Branch and in the Cacapon River, but it is either absent or very scarce in the Shenandoah River. *Elliptio complanatus* (Dillwyn), a rather large and thick-shelled mollusc, is found in fairly large numbers in all four rivers but is most abundant in the Shenandoah system. Crayfish are most abundant in the South Branch and the Cacapon River.

TABLE 1. A COMPARISON OF CHEMICAL DATA COLLECTED ON FOUR BASS STREAMS

Name of river	Methyl orange alkalinity p.p.m.	Phenolpthalein alkalinity p.p.m.	Free carbon dioxide p.p.m.	pH	Dissolved oxygen p.p.m.	Temperature, degrees F.	Date, 1938
South Branch of Potomac River	30.6	0.00	6.0	7.1	10.2	59.0	April 27
Cacapon River	44.5	0.00	3.7	8.1	9.3	62.0	April 28
Shenandoah River	112.5	Trace	0.0	8.3	10.0	70.0	May 1
North Fork of Shenandoah River	121.9	Trace	0.0	8.3	9.7	69.0	April 30

During 1936, quantitative studies were made of the bottom organisms in riffles of the South Branch of the Potomac and of the Shenandoah River. From this study it was observed that in the South Branch (Figure 1), beginning in May, 1936, the average number of organisms per square foot over a seven-month period was 93.6. The average wet weight with molluscs included was 2.48 grams, and with molluscs excluded, 0.93 grams per square foot. During the same period the averages in the Shenandoah River were 118.8 organisms with wet weights of 3.38 grams (molluscs included) and 1.42 grams (molluscs excluded) per square foot. High water prevented the collection of samples during April, August, and October.

Samples were collected from riffles during the 1937 seasons in the Cacapon River and North Fork of the Shenandoah. In the Cacapon, the average number of bottom organisms per square foot was 147.5 during a five-month period from June to October. The average wet weights of bottom animals were 5.21 grams per square foot with molluscs included and 0.85 gram per square foot with molluscs excluded. Collections in the North Fork of the Shenandoah River were

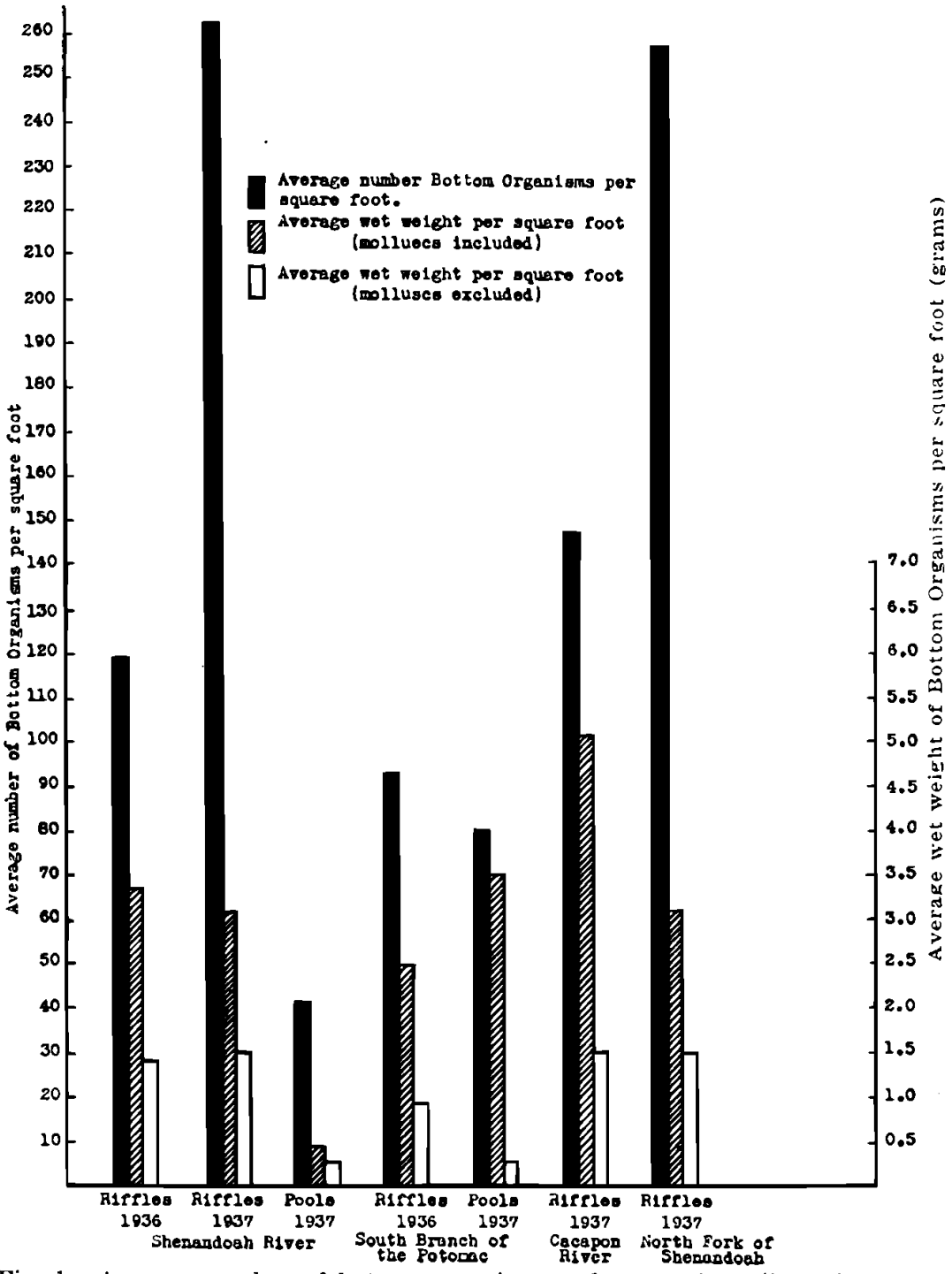

Fig. 1. Average number of bottom organisms and wet weight (inclusive and exclusive of molluscs) in four bass streams.

only made during the months of June, July, and September since high water prevented collecting at other seasons. The average number of organisms per square foot was 257.0. Here the average wet

weights were 3.24 grams per square foot with molluscs included and 1.50 grams with molluscs excluded.

During 1936, the following forms were more abundant in the South Branch of the Potomac than in the Shenandoah River: crayfish, certain snails, mayfly nymphs (*Isonychia* and *Iron*), cranefly larvae (*Eriocera*), snipe fly larvae (*Atherix*), and fish-fly larvae (*Chauliodes*). The following forms were the more important in the Shenandoah River: caddis larvae (*Hydropsyche*), bristle worms (Oligochaeta), mayfly nymphs (*Potamanthus*), hellgrammites (*Corydalus*), aquatic moth larvae (*Elophila*), parnid beetles, and molluscs (Sphaeriidae and *Elliptio*). Mayfly nymphs of the genus *Iron* were not found in the Shenandoah.

The faunal characteristics of the Cacapon River resemble those of the South Branch. *Iron* and *Atherix* were abundant, and in addition an unidentified caddis larva with tiny cases (probably *Brachycentrus*) was found in large numbers attached to the larger stones and boulders in fast water.

During 1937, a comparison was made of the bottom fauna of the Shenandoah River pools in the test section near Berryville, Virginia, with that of the pools of the South Branch in the test section near Romney, West Virginia. In both streams the number and quantity of organisms per square foot in the pools were much less than in the riffles. The South Branch contained about twice as much fish food in the pools as was found in the pools of the Shenandoah River. Oligochaetes and nymphs of the mayfly *Hexagenia* were more abundant in the Shenandoah samples, but *Baetis, Ephemera,* and *Potamanthus* nymphs, *Eriocera* and chironomid larvae were more abundant in pools of the South Branch of the Potomac.

The section under observation in the North Fork of the Shenandoah River is smaller than the section that we are studying in the main river, but the two sections are alike in the possession of extensive riffle areas in which the river flows briskly or falls abruptly over limestone ledges and fragments of limestone and other sedimentary rocks. Both areas are rich in fish food, and the bass live and feed where there is good shelter. In contrast, the South Branch of the Potomac and the Cacapon River have, for the most part, short, gravel and rubble riffles which are relatively inaccessible to the bass. Bass do not feed as much in these areas as in the long pools that separate the short stretches of shallow, swift water.

During floods the grinding action on the bottom of the riffles of the South Branch and the Cacapon River undoubtedly destroys much of the bottom fauna. Actually, the total bottom fauna in the Shenandoah River is quantitatively greater than that in the other streams.

Extent of Natural Propagation of Bass

There is great variation in the abundance of materials suitable for the construction of bass nests in the four streams. The Cacapon and

South Branch abound in suitable areas for nesting. Suitable bottom materials and protected areas are relatively scarce, however, along the banks of the Shenandoah and its North Fork below Strasburg, Virginia.

Ideal conditions were found in 1938 for the observations of the extent of natural propagation of smallmouth bass in these rivers. When the spawning season began all streams were clear and low following a long period of abnormally dry weather. The data (Table 2) collected by George E. Klak and the writer illustrate differences in the extent of natural propagation in these streams.

During 1936 and 1937, no evidence was found of a second or later spawning. In 1938, however, convincing evidence of a second spawning was found in the South Branch and in the Cacapon River. The second spawning occurred a month later than the first, and like it, occurred in both streams simultaneously. The second spawning followed a long period of cool weather and two sudden rises in these rivers caused by heavy showers, which resulted in muddy water. During this interval between the two spawning periods the fry from the first spawning were almost all destroyed. No such catastrophe occurred in these two streams during 1937 or in the South Branch during 1936. The first rise in these rivers took place immediately after the fry had risen from their nests. It therefore appears that high and muddy water in these streams at this time may destroy practically all of the fry. The data on the second spawning appear in the lower half of Table 2. The Shenandoah River was too muddy for detection of further nesting on June 6, but no great difficulty was encountered in the collection of fry from the first spawning. Judging from the variation in the lengths of the fry, a later spawning must have occurred in this river also.

The South Branch of the Potomac River was clear and satisfactory for observations on the extent of natural propagation during 1936 and 1937 when 142 and 205 nests, respectively, were counted in the same section in which 155 nests were observed in 1938. Conditions in the other streams were not satisfactory for observations during 1936 and 1937.

The rather extensive natural propagation (Table 2) is probably adequate for the maintenance of the stocks, except perhaps in the main stream of the Shenandoah. There is grave danger in stocking a stream beyond its capacity to provide sufficient food for the planted fish to grow to legal size. A large number of bass just under the legal size occurs in the South Branch of the Potomac and in the Cacapon where bass spawn annually and produce thousands of fry, many of which are probably consumed by the larger bass. The stocking of these streams with forage fish such as the blunt-nosed minnow, attractive minnow, and mad tom (if this species can be reared artificially) should be undertaken on a large scale. As an alternative the size limit on bass should be temporarily reduced or removed in order to decrease

TABLE 2. DATA ON THE NUMBER AND DIMENSIONS OF BASS NESTS IN FOUR BASS STREAMS, 1938

Item	Cacapon River	Shenandoah River (main stream)	North Fork of Shenandoah River	South Branch of Potomac River
First spawning				
Date of survey	April 28	April 29	April 30	May 2
Water temperatures, degrees F.	67.0	71.0	68.0	69.0
No. of acres in test section	86.4	159.1	109.4	83.3
Average width of river (feet)	150.0	350.0	190.0	250.0
Length of sect. surveyed (mi.)	4.8	3.8	4.8	2.8
Number of nests	[1]105	[2]41	[1]56	[2]155
Number nests per mile	44.2	10.9	23.5	56.4
Number nests per acre	2.4	0.3	1.0	1.9
Number containing eggs	68 [3](64.8)	26 [3](63.4)	8 [3](14.3)	14 [3](9.0)
Number containing fry	2 (1.8)	5 (12.2)	23 (41.1)	95 (61.3)
Number with fry risen	0 (0.0)	0 (0.0)	21 (37.5)	40 (25.8)
Number without eggs or fry	35 (33.3)	10 (24.4)	4 (7.1)	6 (3.9)
Aver. depth of nests (inches)	25.6	22.4	27.0	27.5
Max. depth of nests (inches)	43.5	38.0	37.8	60.5
Min. depth of nests (inches)	6.3	15.0	13.3	6.5
Aver. distance from shore (ft.)	6.8	9.3	8.7	10.0
Second spawning				
Date of survey	June 10	None	None	June 14
Water temperatures, degrees F.	75.0	.....	.....	77.0
Number of nests	[1]63	.....	.....	[1]34
Per cent of first spawning	60.0	.....	.....	43.9
Number containing eggs	8 [3](12.7)	.....	.....	0 [3](0.0)
Number containing fry	7 (11.1)	.....	.....	5 (14.7)
Number with fry risen	40 (63.5)	.....	.....	28 (82.4)
Number without eggs or fry	8 (12.7)	.....	.....	1 (2.9)
Aver. depth of nests (inches)	24.6	.....	.....	18.5
Max. depth of nests (inches)	48.0	.....	.....	32.0
Min. depth of nests (inches)	6.0	.....	.....	8.0
Aver. distance from shore (ft.)	8.7	.....	.....	7.5
Total nests per mile including first and second spawnings	70.7	.....	.....	81.0
Total estimated number fry produced per mile	120,253	18,587 (?)	40,084 (?)	137,855
Estimated number fry per acre	6,611	438 (?)	1,740 (?)	4,551

[1]Right side of stream.

[2]Both sides of stream.

[3]Percentage of total number of nests is given in parenthesis

the obviously too dense populations in the South Branch and in the Cacapon River. Experimentation in large areas of a stream should precede large-scale attempts at population control.

The quantitative study on the extent of natural propagation in bass streams resulted in a fairly good estimation of the magnitude of the bass population of spawning size. (We believe the size at maturity to be at least 8 inches because we have seen no bass under this size attending a nest.) If, for example, 223 bass nests are counted in a 2.75-mile length of river, we may estimate that there are probably 446 bass of a length of 8 inches or larger in that section of river. Random samples of wild fish show that the sexes are nearly equally abundant. The number of bass per mile of river can be used to derive other useful information such as the number of pounds of food which should be produced in that section to enable bass to grow to a certain size.

Studies of the Food of Fry and Fingerling Smallmouth Bass

During the winter and spring of 1937, the stomach contents of 1,076 fingerling bass were examined by Dr. James S. Gutsell and the writer. The samples were collected at monthly intervals between May 13 and October 27, 1937, in the test sections of the South Branch of the Potomac and in the Shenandoah River. Collections were adequate for a study of the changes in the food of growing fingerlings from the time they rose from the nests until about the end of the growing season. Approximately 10 per cent of the Shenandoah River fry averaging 10.0 millimeters in length on May 13 had consumed fish. Many of the fry had not completely absorbed their yolk material. The chief items of food of the fry, however, were mayfly nymphs of the genus *Baetis* and chironomid larvae. Entomostraca (chiefly *Cyclops*) played a minor role in the food of fry in both the Shenandoah and in the South Branch of the Potomac River. In the fry (average length 12.2 millimeters) collected on May 22, 1936, from the South Branch of the Potomac, fish constituted a much less important food item than in the bass fry of the Shenandoah River. Otherwise the principal food items were the same in the two rivers. The mayfly nymphs of *Baetis, Heptagenia,* and *Isonychia* and chironomid larvae were prominent items of food throughout the period of observation. As the bass grew to a larger size, fish became more important in the diet, except in the South Branch of the Potomac where there was a scarcity of forage minnows. Black toad tadpoles were consumed by 10 per cent of Shenandoah River bass (averaging 41.6 millimeters in length) on June 17.

During removal of the stomachs from these fish for food studies, it was noticed that the livers of the South Branch bass fingerlings contained an abundance of trematode cysts. These cysts were more prevalent in the livers of bass from the South Branch than in those of the Shenandoah bass. In the July collection of South Branch fingerlings, 72.8 per cent had infected livers. At the same time only 11.1 per cent

of the Shenandoah River bass had trematode cysts. In the late August and in the October collections 57.8 and 80.2 per cent, respectively, of the South Branch fingerlings were infested with the cysts, while in mid-August and late September 12.8 and 10.5 per cent of the livers of the Shenandoah bass were infested. Livers of the South Branch bass contained, on the average, many more cysts than those of the Shenandoah bass. There is no evidence that the presence of cysts in these fish affected their growth rate, for the average size of infested and uninfested fish was very nearly the same.

Abundance of Forage Fish

During the last two years several fish censuses have been attempted with the primary objective of determining the abundance of forage minnows. It is not practical to attempt an enumeration of forage fish populations in large streams by seining. During the spring of 1938, after some practical experience in the actual counting and weighing of lots of black-head and blunt-nosed minnows, George E. Klak and the writer undertook a careful minnow census on our four streams while they were clear. The results are given in Table 3.

Our general impression was that there are more minnows per unit area of stream in the Shenandoah River where bass reach the legal size of 10 inches in three years than in the other streams. However, our spring census failed to show that the Shenandoah River had more minnows per unit area than, for example, the South Branch of the Potomac River. However, if we calculate the number of forage fish per bass seen or per bass nest counted during the surveys, the greater food supply for bass in the Shenandoah River and its North Fork is very evident.

The most important forage fish for fingerling bass in these rivers are the attractive and rosy-faced minnows, *Notropis amoenus* and *N. rubellus,* and the blunt-nosed minnow *Hyborhynchus notatus.* Other important forage fish are: *Schilbeodes insignis, Lepomis auritus, Notropis hudsonius, Hypentelium nigricans, Catostomus commersonnii,* and *Leucosomus corporalis. N. amoenus* and *N. rubellus* are very active, and the adults are usually found where there is considerable current—where the swift water tapers off into pools below riffles. These minnows are at some distance from the banks where the bass are able to capture them. The blunt-nosed minnow, on the other hand, remains near the shore and in the weed beds of the water willow, *Dianthera americana,* where they are probably more difficult to capture. The mad tom, *Schilbeodes insignis,* is probably also important, particularly in the Shenandoah River where it is a favorite bait for bass. Our census of forage fish unfortunately did not include an estimate of the abundance of this species which is nocturnal in its habits.

There is also a distinct difference in the relative abundance of other species of fish, including rock bass (*Ambloplites rupestris*), sunfish (*Lepomis auritus* and *Apomotis cyanellus*), fallfish (*Leucosomus cor-*

TABLE 3. RESULTS OF MINNOW CENSUS OF FOUR BASS RIVERS, 1938

Item	South Branch of Potomac	Cacapon River	Shenandoah River	North Fork of Shenandoah River
Date of survey	April 26	April 28	April 29	April 30
Length of test section (miles)	2.8	4.8	3.8	4.8
Average width of test section (ft.)	250.0	150.0	350.0	190.0
Area of test section (acres)	83.3	86.4	159.1	104.4
Total number schools of minnows observed	62	78	282	160
Number of schools per mile	22.5	16.4	75.2	33.7
Number of schools per acre	0.7	0.9	1.8	1.5
Estimated number of individuals observed (all schools)	25,198	7,810	24,451	6,284
Estimated number of individuals per mile	9,162	1,644	6,520	1,322
Estimated number of individuals per acre (production)	302.4	90.4	153.7	60.1
Blunt-nosed minnows *(Hyborhynchus notatus)*				
Total number of schools observed	24	18	65	72
Average number of schools per mile	8.7	3.8	17.3	15.2
Average number of schools per acre	0.3	0.2	0.4	0.7
Estimated number of individuals observed	15,978	5,360	12,659	3,128
Estimated number of individuals per mile	5,810	1,128	3,375	658
Estimated number of individuals per acre	191.8	62.0	79.6	29.9
Number of schools of young (length 1 inch) per mile	0.0	0.4	0.5	0.4
Number of schools of intermediates (length 1 to 2 in.) per mi.	5	2.5	10.1	3.4
Number of schools of adults (length 2 to 5 inches) per mile	3.6	0.8	6.7	11.9
Average number of individuals per school (all sizes)	665.8	297.8	143.8	43.4
Average number of individuals in schools of young	0.0	20.0	50.0	25.0
Average number of individuals in schools of intermediates	640.7	380.0	232.5	38.6
Average number of individuals in schools of adults	700.8	190.0	149.0	45.3
Attractive minnows *(Notropis amoenus)* **and/or Rosy-faced minnow** *(N. rubellus)*				
Total number of schools observed	38	60	217	88
Average number of schools per mile	13.8	12.6	57.9	18.5
Average number of schools per acre	0.4	0.7	1.4	0.8
Estimated number of individuals observed	9,220	2,450	11,792	3,156
Estimated number of individuals per mile	3,352	515	3,144	664
Estimated number of individuals per acre	110.6	28.4	74.1	30.2
Number of schools of young (length 1 inch) per mile	7.3	11.4	35.7	11.4
Number of schools of intermediates (length 1 to 2 in.) per mi.	4.4	0.8	15.2	3.4
Number of schools of adults (length 2 to 5 inches) per mile	2.2	0.4	6.9	3.8
Average number of individuals per school (all sizes)	242.6	40.8	65.2	35.9
Average number of individuals in schools of young	70.5	38.7	36.5	18.2
Average number of individuals in schools of intermediates	622.5	70.0	89.1	53.8
Average number of individuals in schools of adults	56.6	40.0	70.0	72.8

poralis), stone rollers (*Hypentelium nigricans*), and carp (*Cyprinus carpio*) in the streams studied. Rock bass and sunfish are very abundant in the Cacapon River, but rock bass are very scarce in the South Branch of the Potomac River, and relatively few occur in the Shenandoah River. Sunfish are numerous in all of these streams, but are least abundant in the Shenandoah. Fallfish and stone rollers are more abundant in the clearer streams, the South Branch of the Potomac, the Cacapon River, and perhaps the North Fork. Carp are most abundant in the Shenandoah.

Of the four streams the Shenandoah River appears to be the best balanced stream with respect to the ratio of the number of forage fish to the number of bass. This balance probably is a result of the curtailment of natural propagation of bass by a lack of good spawning areas and by the severe environmental conditions which reduce the survival rate. Consequently, there are relatively few fish to compete for the available food.

The advice and supervision of Dr. H. S. Davis, In Charge of Aquicultural Investigations, U. S. Bureau of Fisheries, are gratefully acknowledged. Dr. Henry van der Schalie and Mr. Calvin Goodrich of the Museum of Zoology, University of Michigan, identified the molluses referred to in this paper.

Discussion

Acting Chairman Foster: What are the approximate rises in the water level of those streams?

Mr. Surber: There are some tremendous rises in water elevation. In the South Branch of the Potomac in 1936 there was a rise of 18 feet during the flood, and spawning occurred some time later. The flood occurred, I believe, on March 17, and we made our first observations on spawning on May 1 and 2. The flood couldn't have had a great deal of effect on the abundance of bass, because we found almost as many nests that year as we did later.

In the Shenandoah River the rise is even greater. The high-water mark is up near the tree tops—probably 25 or 30 feet from the ground.

Acting Chairman Foster: That has been my experience in Missouri, and I asked the question for the benefit of Mr. Barker, who is very anxious to establish the smallmouth in New Mexico.

Mr. H. B. Woodward: How much silt is carried during the periods of rises?

Mr. Surber: We made no quantitative study of the amount of silt carried, but the amount is tremendous. The South Branch of the Potomac and the Cacapon clear up very quickly, however.

Here is a point I omitted—a very interesting observation made this spring. We found that the results of the first spawning in the Cacapon River and the South Branch of the Potomac were entirely wiped out by floods. We were counting nests when the fry were in them and almost ready to rise, and we are reasonably certain that the majority of those nests produced fry that were later scattered. Then a sudden rise in the river (in fact two rises) occurred and when we came back to collect the fry, which we have never had trouble in doing before, in the South Branch of the Potomac we were able to collect only fifteen fry. We didn't see the fry. They were gone! Approximately 300,000 fry were absolutely wiped out. But the second spawning produced another crop of fry which compensated, to a certain extent, the destruction of the fry which resulted from the first spawning.

In the Cacapon River the same thing happened. In some years there is a flood with very muddy water that may entirely wipe out the hatch of fry.

MR. E. L. WICKLIFF: Are crawfish important in the food of smallmouth bass?

MR. SURBER: We haven't made an intensive study, but I feel certain that crawfish constitute a very important item of the bass food.

ACTING CHAIRMAN FOSTER: Just to clarify your statement, when you refer to the second spawning do you refer to a later spawning of fish which did not spawn earlier in the season?

MR. SURBER: That's right. I think a cool spell interrupted the regular season, because we found no evidence of later spawning during two preceding seasons. This is contrary, I believe, to observations on spawning in artificial ponds, because I know that at our station we have had later spawnings of bass, perhaps on successive rises in temperature, but in these rivers the simultaneity of the spawning has been a marked feature.

MR. A. D. ALDRICH: I would like to ask Mr. Surber if the spotted bass coexists in any of the streams with the smallmouth, or are the streams outside of the range of spotted bass?

MR. SURBER: Our streams are out of their range. The spotted bass is found in southern West Virginia, southwestern Virginia, but not in our section.

MR. H. H. MACKAY: I would like to ask Mr. Surber if he made any observations concerning the percentage of mortality of bass, say 9 and 10 inches long, as compared with bass 12 inches in length. Did you observe the difference in the mortality of eggs laid by 9- and 10-inch bass?

MR. SURBER: We counted the number of fungused eggs in nests but only in rare instances were any numbers of dead eggs found.

MR. MACKAY: One of our investigators has observed that the eggs of the older and larger bass, approximately 12 inches long, are much stronger, and certainly the mortality is much less than that of eggs laid by smaller bass, approximately 9 and 10 inches. Can you verify that observation?

MR. SURBER: No, we have been surprised that we did not find bass of smaller size spawning in these rivers. The bass have been, I think, without exception, over 8½ inches in length, probably over 9 inches. We haven't attempted to study that phase of it yet.

MR. WICKLIFF: Is the second spawning due to the same bass or a different crop of bass?

MR. SURBER: We, of course, would be unable to tell that. Female fish have been actually known to spawn a second time in artificial ponds.

MR. WICKLIFF: Couldn't they be caught and tagged the first time?

MR. SURBER: We rarely catch the female and rarely see the female at the nest. The male, of course, is almost always present. It would be rather difficult, under natural conditions, to catch and tag the females.

MR. T. C. FEARNOW: Mr. Surber's findings make it evident that these streams are receiving naturally a tremendous number of fry every year. I would like to ask him whether or not he has discovered a critical size at which the heavy loss occurs in these fry.

MR. SURBER: There is little doubt but that the heaviest loss occurs within a week after the fry rise from their nests. They disappear even under the best

conditions. In 1936 the South Branch of the Potomac was very clear. The bottom was visible in 15 feet of water, I believe, and the fry, or the bulk of the fry, disappeared within one week after they rose and scattered. We have collected sunfish and rock bass, associates of the bass in these streams, but so far we haven't been able to get any incriminating evidence against either the sunfish or the rock bass, although we find the rock bass eats more fish than do the sunfish. We find very few fish taken as food by the red-bellied sunfish, *Lepomis auritus*, which is the common sunfish in these streams.

DR. H. S. DAVIS: We, as you know, find a comparable loss of the fry in hatchery ponds, and this ordinarily has been ascribed to cannibals. That explanation has never completely satisfied me, and this year I have been trying to make a few observations on the losses of fry at Hackettstown and Leetown. We found that at both places the fry are heavily parasitized even at the time they rise from the nest. Two of the parasites found on fry are undescribed. Fry of the largemouth bass seem to have an entirely different set of parasites than the fry of the smallmouth bass in the same hatchery.

The smallmouth parasites are largely protozoan. In addition, in the largemouth at Hackettstown we found a mixture of sporidia on the gills. Fry brought in from the municipal reservoir (fry hatched from wild fish in the natural water) were fairly loaded with *Ichthyophthirius*. I don't see how the fish could possibly survive the number of parasites on them. That parasite has not been found on the fish hatched either at Hackettstown or at Leetown. I am firmly convinced that a large part of the early loss among the fry is due to parasites.

MR. SURBER: I would like to add that Dr. Davis examined a series of fry from several of our ponds at Leetown. There we found for the first time dead fry scattered over the bottom, no doubt due to parasites.