MIGRATION, AGE AND GROWTH OF RAINBOW TROUT PARR IN BLACK RIVER, MICHIGAN

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ABSTRACT

MIGRATION, AGE AND GROWTH OF RAINBOW TROUT
PARR IN BLACK RIVER, MICHIGAN

By Thomas M. Stauffer

Juvenile rainbow trout (parr) examined for the study were collected in the Black River, Mackinac County, with an alternating-current electric shocker in 1952 to 1958 and by a weir with a downstream trap in 1951 to 1959. The shocker was employed each autumn in the river upstream from the weir location to sample the age structure and growth of parr before migration. Most of the data used in the study came from a weir that was used to sample the annual downstream migration of parr. The weir was located about 3/4 mile upstream from the mouth of the river and was downstream from rainbow trout spawning areas.

Annulus formation by rainbow trout parr in the Black River occurred between October and April-May. Most parr probably began growing in April or shortly before. The body-scale relationship was best expressed by a linear regression: L (inches) = 0.16 + .0826S (mm x107). The relationship between length (mm) and weight (grams) was a curvilinear regression where $W = .00001384\ L^{3.0426}$.

Growth of rainbow trout parr for the first 3 years of life was about 3 inches per year. During their first growing season, parr of the 1949 to 1951 year classes grew slower than those of the 1956 to 1958 year classes. Within a migratory season, faster growing parr of age I migrated sooner than those that grew slower. As an annual average, parr in the

upper river in the autumn were 68% age 0, 29% age I and 3% age II. Variations in age composition were related to year class strength. Average lengths in inches were 2.9 for age 0, 6.4 for age I and 9.3 for age II. Few parr were of legal size (7.0 inches). As an annual average, parr in the downstream migration were 64% age I, 34% age II and 2% age III. For a given migratory season, age composition varied according to year class strength. Lengths of downstream migrants averaged 4.4 inches (age I), 7.1 inches (age II) and 8.9 inches (age III). Most migration occurred between May 21 and June 30 during hours of darkness or reduced light. Within a migratory season, older parr migrated first. Most migration occurred at water temperatures of 48-58° F.

The number of age-0 fish in the upper river during the autumn was correlated with the number of subsequent downstream migrants.

MIGRATION, AGE AND GROWTH OF RAINBOW TROUT PARR IN BLACK RIVER, MICHIGAN

By

Thomas M. Stauffer

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INTRODUCTION

Young rainbow trout (Salmo gairdneri) inhabit many tributaries of the Great Lakes. At the age of 1 to 3 years, they usually migrate into one of the big lakes where they grow rapidly. After they attain sexual maturity, they return to streams to spawn at an average size of about 5 pounds, and thereby provide an important sport fishery.

Knowledge of the juvenile stage of the rainbow trout's life history is very limited. To expand this knowledge, as well as that on the later stages in the life of this fish, a study was made from 1951 to 1959 on the Black River, a tributary of Lake Michigan. The principal concerns in this thesis are the age, growth and the migration patterns of young rainbow trout (parr) before and during their initial migration into the Great Lakes. Aspects of adult life will be reported at a later date.

The Black River is located in Mackinac County, about 40 miles west of the Straits of Mackinac, in the Upper Peninsula. During the study, it was an excellent rainbow trout stream. It also had heavy spawning runs from Lake Michigan of sea lampreys (Petromyzon marinus), white suckers (Catostomus commersoni), longnose suckers (Catostomus catostomus) and smelt (Osmerus mordax). Moderate to large resident populations of brown trout (Salmo trutta), slimy sculpins (Cottus cognatus) and American brook lampreys (Lampetra lamottei). A small resident population of brook trout (Salvelinus fontinalis) was also present. The middle reaches of the river contained gravel which was utilized for spawning by most of these species. The water was dark brown and generally clear. The average flow 3 miles upstream from the mouth was 33.4 cubic feet per second; the seasonal variation was from 12 to 154 cfs. In the lower 3 miles, two tributaries added about 15 to 20 cfs. The drainage area was 28 square miles. Summer water temperatures seldom exceeded 65° F.

METHODS

Collection of Data

Rainbow trout parr examined for the study were collected with an alternating-current electric shocker and a weir. The locations of the collection sites are shown in Figure 1, dates and numbers of fish collected, in Table 1.

The shocker was employed to sample the age structure of rainbow trout upstream from the weir locations. The following areas were not sampled because populations were judged as low or nil: (1) upstream from the railroad bridge, where the mainstream flows through a swamp and where low gradient makes it unlikely that there was suitable spawning habitat for rainbow trout; (2) the three tributaries above Station 3 where spawning could have occurred but in which reproduction could hardly have been significant because of the small size of the streams (rainbow trout were not found in two collections on Spring Creek); and (3) the upper portions of Peters and O'Neil creeks, which lacked gravel for spawning use. Further, it does not seem likely that any of these areas could have had very many parr that migrated from downstream areas. Northcote's study (1962) of streams with temperatures similar to those of Black River showed there was little upstream movement by rainbow trout of ages 0 and I.

The areas that were judged to contain most of the juvenile population were the mainstream of the river from the 1951 weir site to the railroad and the extreme lower portions of Peters and O'Neil creeks. The mainstream contained many juvenile fish and offered ample spawning habitat for the adult rainbows that entered the Black River. The juveniles in the lower portions of Peters and O'Neil creeks presumably came from the

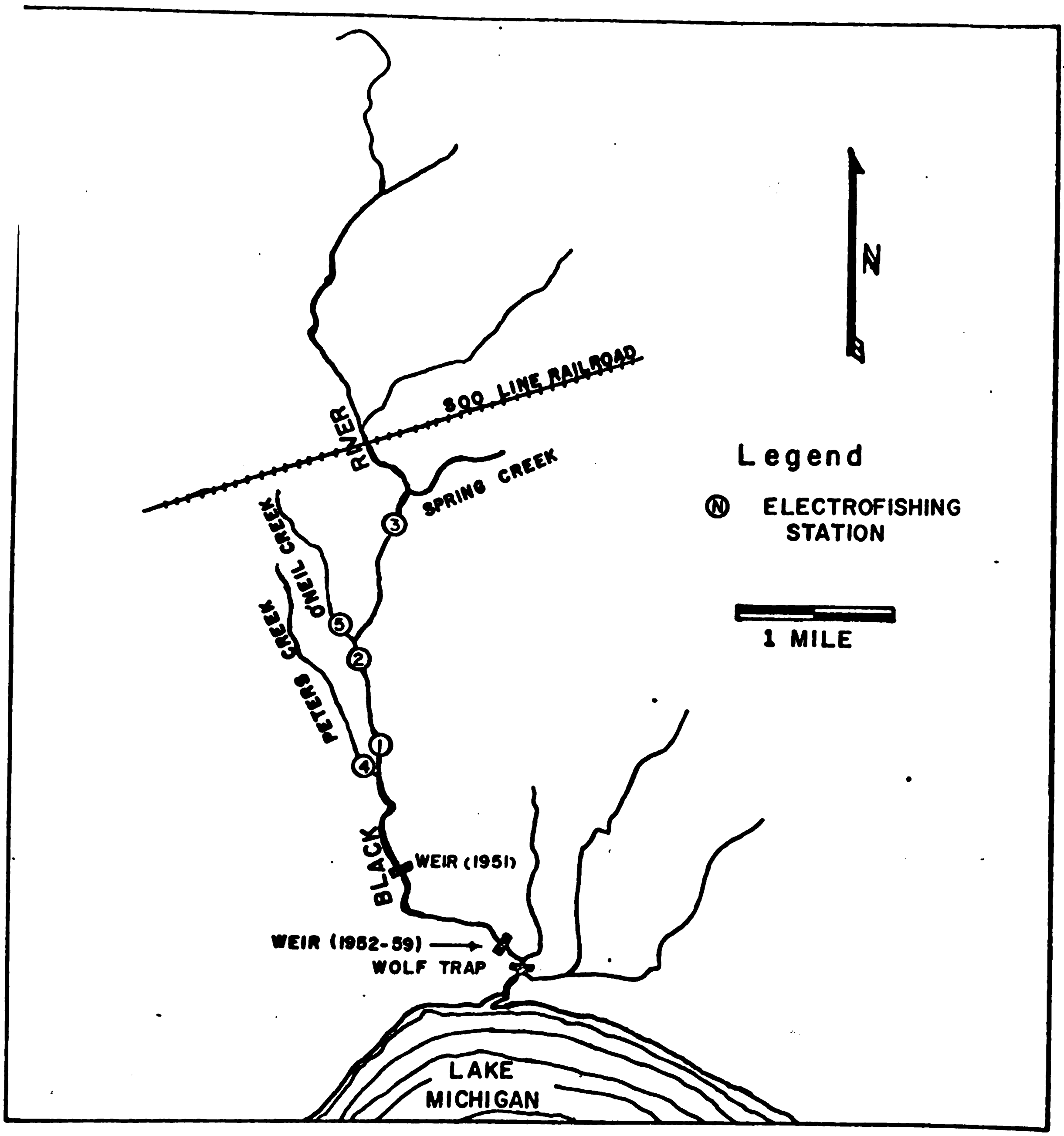

Figure 1.--Black River, Mackinac County, showing collection sites.

TABLE 1

INCLUSIVE DATES OF COLLECTION AND NUMBERS OF RAINBOW TROUT EXAMINED, BLACK RIVER, 1951 TO 1959

Year of collection	Downstream weir trap[a]			A. C. shocker		
	Inclusive collection dates		Number of parr	Inclusive collection dates		Number of parr
	From	To		From	To	
1951	May 8	July 5	454	-	-	...
1952	May 9	July 22	622	September 8	October 17	152
1953	May 4	July 26	2,307	October 2	October 8	114
1954	May 13	July 16	572	October 19	November 6	46
1955	April 27	July 15	664	October 19	October 22	418
1956	May 5	July 13	1,458	October 3	October 11	166
1957	May 1	July 4	716	October 30	November 6	26
1958	April 21	July 18	344	October 14	October 16	149
1959	May 11	July 15	609	-	-	...

[a] Incomplete or no operation during May 14-17, 19-20, July 8-10, 1956; May 26-29, 1957; and April 22-29, 1958.

mainstream. Five stations in the area inhabited by the majority of the juvenile population were sampled in September-November 1952 to 1958 with the alternating-current shocker. Three of the stations were in the mainstream. Stations 1 and 2 had high juvenile densities and Station 3 was in an area of low density. The three stations contained proportionately more rapids and riffle areas than did the juvenile population area as a whole. Hence, larger fish in deeper water may have been undersampled. The remaining two stations were in Peters and O'Neil creeks where the juvenile population was light to medium. About 8 hours were spent collecting each year and 2,300 feet (400-700 feet per station) of stream were sampled. The area sampled at each station was the same every year. Rainbow trout less than 3.5 inches long were measured (total length) and those longer than 3.4 inches were measured, weighed, and scale sampled. All fish were returned alive to the stream.

Most of the data used in this study came from parr caught in the downstream trap of a weir located 4 miles (1951) or 3/4 mile (1952 to 1959) upstream from the mouth of the river. The location of the weir was downstream from rainbow trout spawning areas in the mainstream except in 1951, when about 100 yards of stream suitable for spawning was below the weir. The weir consisted of a hardware cloth fence (½-inch mesh) stretched diagonally across the river on a sheet piling foundation with a downstream trap at the lower end and an upstream trap[1] at the upper end. Usually, the weir was operated from May to July (see Table 1 for exact dates). The traps were visited daily at 8:30 a.m., 5:00 p.m. and 10:30 p.m. Parr caught in the traps were either tagged or fin-clipped to determine

[1] As little upstream migration of parr occurred, it is not discussed in this thesis.

subsequent migration. All were measured and many were also weighed and scale sampled. Parr were then passed over the weir in the direction they were traveling.

Validity of Weir Samples

A Wolf trap (Wolf, 1951), with ½-inch mesh, was installed at a sea lamprey barrier dam (Stauffer, 1964) some 400 yards downstream from the weir. The Wolf trap caught about 17% of the parr migrating downstream when operated during major downstream migrations in 1954 to 1957. It was intended to provide data on speed of downstream migration of fish marked at the weir. However, the trap also caught many rainbow trout (47% of the total catch) that were unmarked.

Since all downstream migrants may not have been caught at the weir, the representativeness of the weir sample was questionable. However, a method of checking its validity was available in the Wolf trap catch. Both unmarked and marked fish were caught by the Wolf trap. I assumed that the catch of unmarked fish in the Wolf trap was representative of the downstream migration and unbiased in respect to length. If the average lengths of these two groups were similar, then the weir catch could be assumed to be representative of the downstream migration. The average lengths of unmarked and marked age-I fish for each year (tabulated below) were tested for differences by Student t tests (Li, 1964).

Year	Average lengths in inches, number of fish in parentheses		t	P
	Unmarked	Marked		
1954	4.37 (62)	4.42 (41)	0.502	>0.50
1955	4.37 (88)	4.65 (152)	4.017	<0.01
1956	4.33 (166)	4.42 (232)	1.538	>0.10
1957	4.63 (25)	4.60 (24)	0.172	>0.80

The _t_ tests revealed no significant differences in lengths of marked and unmarked fish except in 1955 when marked fish were significantly longer. Excluding parr under 3.9 inches (see below), the weir catch seemed to be representative of the total migration except for the small difference in average length during 1955.

In sampling the downstream migration with the weir, escapement of small trout through the ½-inch mesh may have introduced a bias. To determine the length of the fish that might escape, three groups of rainbow trout were confined to the upper end of a hatchery trough by a ½-inch mesh screen. Periodically trout in the lower half of the trough were counted to determine escapement. Rainbow trout 3.9 inches and over were retained, but all trout 3.4 inches or less escaped. In the range of 3.5-3.8 inches, some trout were retained and some were not. Thus, if parr under 3.9 inches migrated downstream at the Black River, at least some would have escaped.

Age and Growth Determination

Scales were taken from an area between the insertion of the dorsal fin and the lateral line. Scales were impressed on clear plastic sheeting with a small roller press. Ages of fish collected from the weir in 1951, 1952, 1958 and 1959 were determined by scale analysis. The anterior scale radii and annuli were measured for subsequent growth determination. From 1953 to 1957, age determinations of fish caught in the weir were made from scale analysis and length-frequency distributions, but scale measurements were not made. Inspection of the 1951 and 1952 length frequencies of parr showed that the modes of the age groups were well defined, but with some overlap. Thus, from 1952 through 1957, parr in the overlapping lengths were scale sampled and the rest were only measured. Parr caught with the shocker that were under 3.5 inches were age 0 as indicated by their distinct length-frequency distribution. Parr over 3.5 inches were aged by scale analysis.

Scales from the 1951 and 1952 downstream run of parr were read by two persons. The 98% agreement in the determinations demonstrated the distinctness of the annuli. The locations of the annuli were usually determined by crowded circuli. The annuli were prominent, and little difficulty was experienced in interpreting the scales. False annuli and other checks were generally absent.

ANNULUS FORMATION

Most annulus formation occurred sometime between the autumn (shocker) collecting and April-May (weir) collecting periods. The small amount of growth beyond the last annulus on parr caught in April or May suggested that in most instances growth began shortly before the fish were caught. A few parr, mostly in ages II and III, had not formed their annulus by early May. Parr with an unformed annulus were not taken after May.

BODY LENGTH-SCALE LENGTH REGRESSION AND BACK-CALCULATION

The body-scale regression was computed from parr in the 1951, 1952, 1958 and 1959 downstream migrations. The fish were mostly of ages I and II and were 3.5 to 9.0 inches long. The relationship was best described by a linear regression ($L = a + bS$) where L is body length in inches, S is anterior scale radius in mm (x107) and a and b are constants. The fish from each year's collections were divided into ½-inch length groups. The average body length and corresponding average scale length of each of these groups (49) were then used to compute the regression of body length on scale length. Each of the 4 years was represented by 12 to 13 groups, each containing at least five fish. The calculated regression, $L = 0.16 + .0826S$, and 95% confidence limits are shown in Figure 2.

Body lengths at various ages were calculated according to "procedure B" as outlined by Whitney and Carlander (1956). This procedure reduces the variations due to deviation of fish length from the "normal" body-scale relationship and differences in size of scales from individual fish. For example, if the observed length of a fish is longer than expected for the size scale observed, then fish length at annulus formation should also be proportionately longer than indicated by annuli measurements. To adjust annuli measurements proportionately to the observed body length, the body length that corresponds to the observed scale length was calculated. The ratio of observed to calculated body length is then multiplied by annuli measurements. This adjusted value is then substituted in the regression formula to obtain back-calculated lengths.

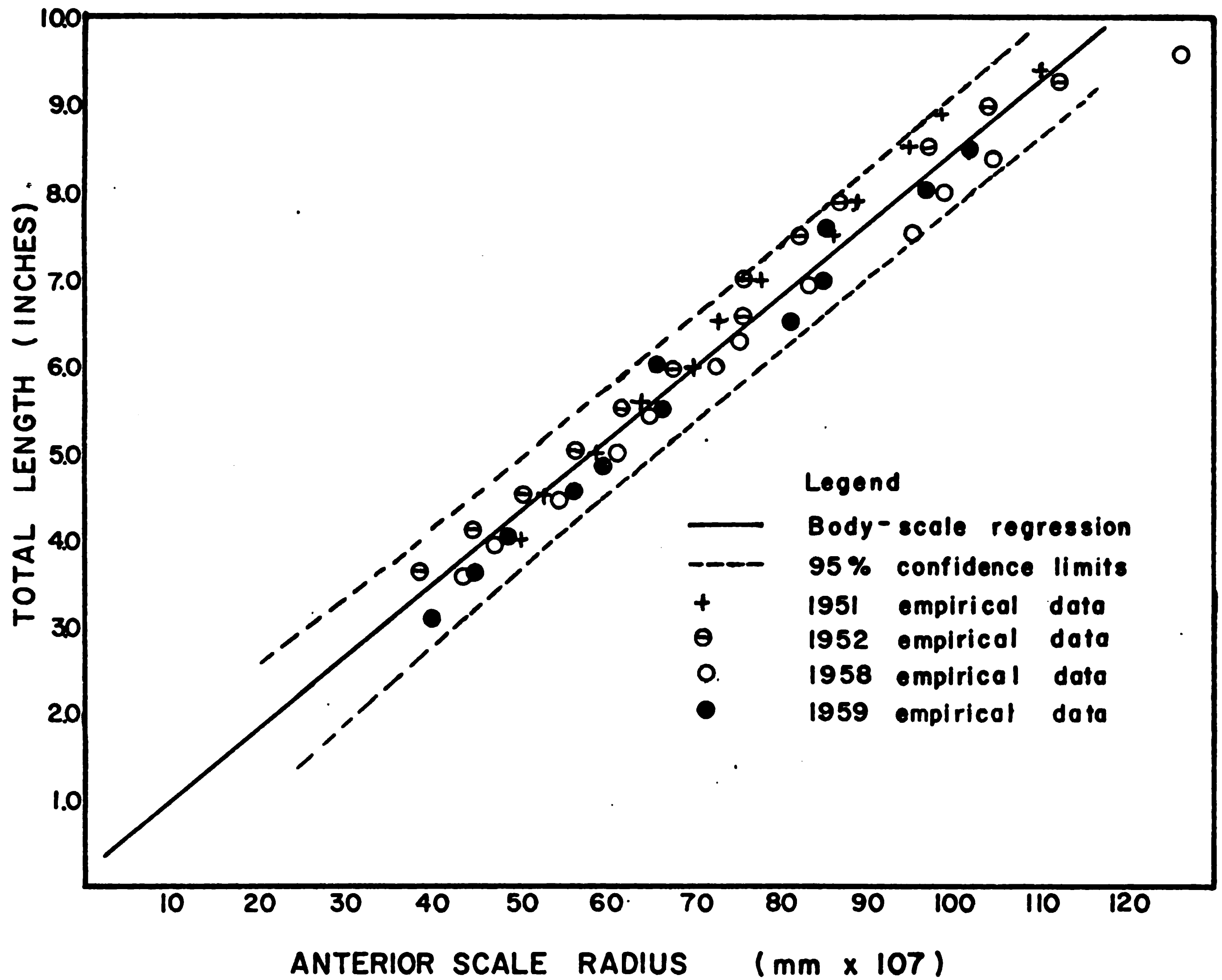

Figure 2. --Body-scale regression of downstream-migrating parr in Black River, Michigan, 1951, 1952, 1958 and 1959.

Validity of the regression and back-calculation was substantiated by the following evidence. First, empirical lengths of parr at the end of their first and second growing seasons were similar to back-calculated lengths from the same year classes caught the following spring and early summer as demonstrated below.

Source of lengths	Age and year class, numbers of fish in parentheses			
	0-I		I-II	
	1957	1958	1956	1957
Empirical (fall)	3.3 (17)	3.0 (129)	6.0 (9)	7.3 (16)
Calculated (following spring)	3.2 (185)	3.1 (564)	6.2 (148)	6.7 (42)

Second, calculated lengths of the age groups (see Table 3) were usually in agreement with empirical lengths of fish caught at the end of the growing season (see Table 4). Finally, other workers found similar lengths (see discussion of growth).

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship was best expressed by the equation for a general parabola, $W = cL^n$ as described by Beckman (1948). To derive the relationship, the weight (grams) of parr between 86 and 224 mm caught in the weir in 1951, 1952, 1958 and 1959 were grouped by 2.5 mm length intervals. Average length and weight of each group was then used to calculate the relationship. Expressed in logarithmic terms, the relationship was $\log W\ (g) = -5.1425 + 3.0426 \log L\ (mm)$. The calculated line $\left[W\ (g) = .00001384\ L\ (mm)^{3.0426}\right]$ and empirical data are given in Figure 3. There was excellent agreement between the calculated line and the empirical data (only alternate groups plotted), demonstrating that the line accurately represented the length-weight relationship.

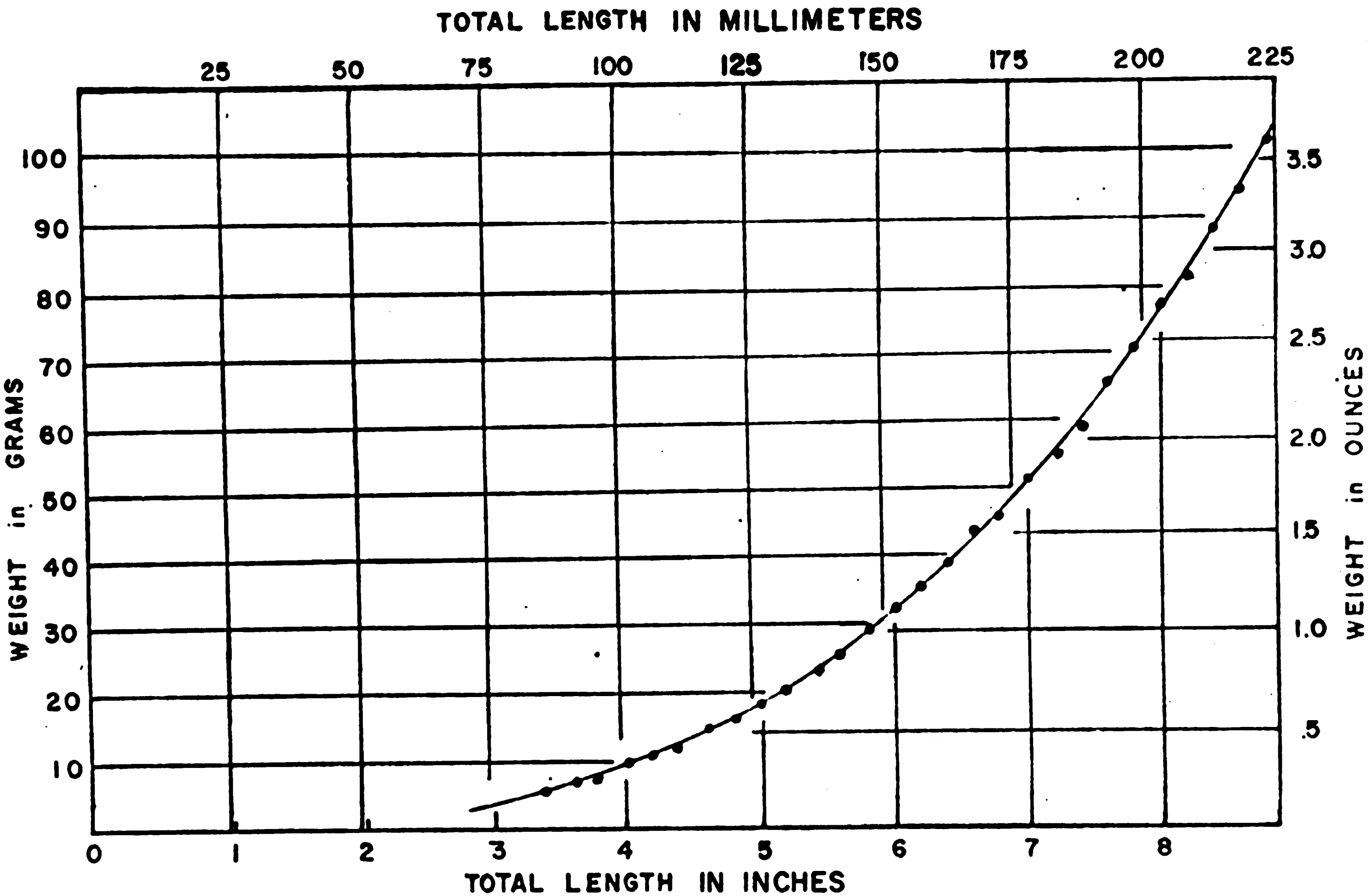

Figure 3.--Length-weight relation of downstream-migrating rainbow trout parr, Black River, Mackinac County, 1951-52, 1958-59. Dots represent empirical data. The line is calculated.

GROWTH RATES

Annual increment in length was determined from empirical data (shocker collections) and back-calculated lengths (1951, 1952, 1958 and 1959 weir catches). Parr, at the end of the first, second and third growing seasons, were available from shocker collections in 1952 to 1958. Mean increments were 2.9, 3.5 and 2.9 inches in successive growing seasons. Mean increments from back-calculated lengths of fish in ages I, II and III were 3.0, 3.5 and 2.9 inches in successive growing seasons (Table 2). Growth increments on the Black River were similar to those found by other investigators. Edward Schultz (personal communication) determined annual increment for rainbow trout from September collections on many Michigan streams. It was assumed that the annual growth was nearly complete. He reported increments of 3.4 inches for the first growing season and 3.5 inches for the second. Shetter and Hazzard (1939) collected young rainbow trout in September on the Little Manistee and Pine rivers, Michigan. Increment during the first growing season was 3.3 inches for both streams and on the Pine River it was 2.6 inches the second season. Rainbow trout parr in Michigan streams grew at a rate of approximately 3 inches per year.

There may have been a difference among years in growth rate of Black River parr. Back-calculated lengths indicated that parr of ages I and II of the year classes 1949 to 1951 (collected in 1951 and 1952) grew slower (Table 2) during their first growing season than did the year classes 1956 to 1958 (collected in 1958 and 1959). Conversely, the average length of age-I parr caught in the weir suggested more rapid growth for year classes 1950 to 1951 than for the 1956 to 1958 year classes (see Table 6). These empirical lengths, however, include an unknown

TABLE 2

BACK-CALCULATED INCREMENT IN LENGTH (INCHES) OF PARR CAUGHT IN THE WEIR, 1951 TO 1952 AND 1958 TO 1959

Age group	Year collected	Increment[a] from age 0 to I	I to II	II to III
I	1951	2.93	....	....
	1952	2.85	....	....
	1958	3.17	....	....
	1959	3.08	....	....
Unweighted average		3.00	....	....
II	1951	2.64	3.22	....
	1952	2.51	3.72	....
	1958	2.79	3.37	....
	1959	2.98	3.68	....
Unweighted average		2.73	3.50	....
III	1951	2.08	2.93	3.07
	1952	2.56	2.95	2.94
	1958	2.28	3.05	3.11
	1959	2.90	2.77	2.51
Unweighted average		2.45	2.92	2.91

[a]Numbers of fish used to compute increment are the same as in Table 3.

amount of growh in the second summer. Hence, there is reason to suspect that the year classes 1949 to 1951 actually did grow slower during the first growing season than did year classes 1956 to 1958.

There were differences in growth rate among age-I fish in respect to time of migration within years. A trend toward decreasing size at annulus I as the migration season progressed was indicated by the calculated lengths at annulus I of age-I parr in 1952, 1958 and 1959 (Table 3). For these years, the average calculated lengths of age-I parr in each time period containing 14 or more fish were subjected to a nonparametric test for trend (Mann, 1945). (The 1951 data were too few to be tested.) Probabilities of a downward trend in average calculated lengths were: .001 (1952), .235 (1958) and .028 (1959). A significant trend occurred in 1952 and 1959. Considered on a yearly basis, the evidence for a downward trend in size at annulus I is conflicting. However, probabilities from the independent sets of data can be combined to give a single probability based on all the observational evidence (see Snedecor, 1956, pp. 216-217). Combination of the three P values gave a chi-square value of 23.8628 (d.f. = 6). The combined data from the 3 years demonstrated that there was a significant downward trend ($P < .001$) in size at annulus I as the migratory season progressed, showing that the faster growing fish migrated earlier.

The average lengths at annuli I and II of age-II parr caught in 1951 were also tested for trend. There was no significant trend in size at either annulus I or II (P .235 and .068, respectively). The data for 1952, 1958 and 1959 were too few to be tested.

TABLE 3

AVERAGE BACK-CALCULATED LENGTHS (INCHES) OF DOWNSTREAM MIGRATING PARR, AGE I TO III, 1951, 1952, 1958 AND 1959

Year and date caught	Age when scale sampled: I		II			III			
	Annulus		Annulus			Annulus			
	I	N[a]	I	II	N[a]	I	II	III	N[a]
1951									
May 1-10	-	0	3.37	6.83	5	2.08	5.23	8.35	6
May 11-20	-	0	3.04	6.85	31	2.11	5.08	8.37	15
May 21-31	-	0	2.71	6.02	90	2.06	4.99	7.73	13
June 1-10	2.98	7	2.53	5.70	62	2.03	4.37	7.70	2
June 11-20	2.98	18	2.51	5.52	70	3.20	6.94	8.66	1
June 21-30	2.89	15	2.56	5.82	82	1.60	4.55	8.44	2
July 1-10	3.00	5	2.62	5.83	29	2.42	4.27	7.54	1
Average and total	2.93	45	2.64	5.86	369	2.08	5.01	8.08	40
1952									
May 11-20	-	0	2.72	6.83	3	2.34	5.21	8.60	3
May 21-31	3.13	49	2.65	6.52	61	2.63	5.62	8.51	14
June 1-10	3.02	82	2.48	6.13	25	2.54	5.46	8.18	2
June 11-20	2.89	148	1.98	5.47	8	-	-	-	0
June 21-30	2.84	111	2.24	4.41	2	-	-	-	0
July 1-10	2.70	65	2.04	5.79	3	-	-	-	0
July 11-20	2.70	45	-	-	0	-	-	-	0
July 21-31	-	0	2.17	5.80	1	-	-	-	0
Average and total	2.85	500	2.51	6.23	103	2.56	5.51	8.45	19

TABLE 3—Continued

Year and date caught	Age when scale sampled: I, Annulus I	I, N[a]	II, Annulus I	II, Annulus II	II, N[a]	III, Annulus I	III, Annulus II	III, Annulus III	III, N[a]
1958									
April 21-30	-	0	3.32	6.99	1	-	-	-	0
May 1-10	-	0	3.19	6.97	10	2.60	5.56	9.35	3
May 11-20	3.46	17	2.88	6.26	75	1.90	4.91	7.93	4
May 21-31	3.13	35	2.80	5.94	16	-	-	-	0
June 1-10	3.23	34	2.59	6.04	19	2.32	4.98	7.78	1
June 11-20	3.08	23	2.67	5.98	8	-	-	-	0
June 21-30	3.19	14	2.52	5.48	3	-	-	-	0
July 1-10	3.14	58	2.47	5.60	16	2.46	5.73	8.30	3
July 11-20	3.49	4	-	-	0	-	-	-	0
Average and total	3.17	185	2.79	6.16	148	2.28	5.33	8.44	11
1959									
May 11-20	3.36	40	3.10	7.17	16	3.22	6.24	7.68	2
May 21-31	3.19	167	2.92	6.34	15	2.28	4.58	9.16	1
June 1-10	3.00	103	-	-	0	-	-	-	0
June 11-20	3.11	75	3.12	7.47	1	-	-	-	0
June 21-30	3.01	119	2.80	6.49	5	-	-	-	0
July 1-10	2.97	56	2.96	6.12	5	-	-	-	0
July 11-20	2.80	4	-	-	0	-	-	-	0
Average and total	3.08	564	2.98	6.66	42	2.90	5.67	8.18	3

[a] Number of parr used to back-calculate average length at the annuli.

PARR IN UPSTREAM AREAS

Age

Parr collected in the spawning areas with an A. C. shocker in the autumns of 1952 to 1958 were of ages 0, I and II (Table 4). In all years of collection except 1953, age-0 parr predominated in number, but there were large fluctuations in age composition. Age-I parr were considered less numerous and predominated only in 1953. Only a few age-II fish were collected. By an unweighted average of the yearly collections, 68% of the parr were age 0, 29% were age I and 3% were age II. A chi-square test (Siegel, 1956) was used to determine if there were differences in the ratios of age-0 and -I parr between mainstream and tributary stations. The numbers of age 0 and I for all years of collection in mainstream and tributary stations were used (in a 2 x 2 contingency table) for the test. There was no significant difference in age composition (d.f. = 1, χ^2 = 0.1333, P $>$0.80). In fact, the proportions of age 0 and I were almost identical. On the other hand, all age-II fish came from mainstream stations; small numbers precluded analysis.

The collections demonstrated that there was considerable variation in year class strength. The 1952 and 1955 year classes outnumbered all the others. They were numerous as age 0 and I parr in the stream (Table 4) and were strongly represented in the downstream migration as age-I fish.

Size

In the autumn, the average lengths of parr at ages 0, I and II were 2.9, 6.4 and 9.3 inches, respectively (Table 4). The average length of age-0 fish was closely similar among year classes 1952 to 1956 and

TABLE 4

NUMBERS AND PERCENTAGES OF AGE 0-II PARR COLLECTED IN SEPTEMBER-NOVEMBER 1952 TO 1958 WITH AN A. C. SHOCKER

(Average lengths in inches in parentheses)

Year of capture	Age						Total
	0		I		II		
	Number	Percentage	Number	Percentage	Number	Percentage	
1952	133 (2.8)	88	19 (6.3)	12	0	0	152
1953	20 (2.8)	17	92 (6.2)	81	2 (8.9)	2	114
1954	36 (2.9)	78	4 (6.4)	9	6 (8.9)	13	46
1955	384 (2.8)	92	31 (6.4)	7	3 (8.9)	1	418
1956	86 (2.8)	52	79 (6.2)	47	1 (9.9)	1	166
1957	17 (3.3)	65	9 (6.0)	35	0	0	26
1958	128 (3.0)	86	16 (7.3)	11	5 (9.8)	3	149
Total numbers and average percentages	804	68	250	29	17	3	1,071

1958, but was greater in the 1957 year class. The same situation applied to age-I fish of these year classes. Fish of the 1957 year class evidently grew faster than those of the other years. The longer length of fish may be associated with the relatively small numbers of the 1967 year class.

A paired *t* test (Li, 1964) was used to determine if there were differences in length (growth) of age-0 fish in mainstream and tributaries. There was no significant difference (d.f. = 5, $t = 0.375$, $P > 0.70$) in average lengths. The average lengths of fish in the samples tested are shown in the table below.

Year	Average lengths in inches, numbers of fish in parentheses			
	Mainstream		Tributaries	
1952	2.3	(44)	3.0	(84)
1954	2.9	(26)	2.9	(9)
1955	2.7	(300)	2.9	(70)
1956	2.8	(60)	2.8	(26)
1957	3.4	(7)	3.2	(10)
1958	3.1	(103)	3.1	(15)

For age-I parr, gross inspection of the data revealed no large difference in average lengths among stations. These data were not tested for significance because of the small number of fish. The small sample of age-II fish precluded even gross analysis.

All age-0 fish were sublegal, 24% of age I were legal size (7.0 inches or longer), and all age-II fish were legal. There was little difference in the percentage (range, 19-26%) of legal-size fish among the stations.

DOWNSTREAM MIGRATION

Age of Parr

Fish in the downstream migration were composed of ages I-III (Table 5). Considered on a yearly basis, age-I trout predominated in 1952 to 1953, 1955 to 1956 and 1959, when they composed 78-95% of the migration. Ages I and II were almost equally represented in 1957 to 1958, and age II predominated (62-81% of the run) in 1951 and 1954. Age III comprised only a small percentage (<1 to 9%) of the run each year. Variation in the age composition of parr in the annual migration seemed related to year class strength which varied considerably. As mentioned before, the catch with the A. C. shocker demonstrated that the 1952 and 1955 year classes were very strong, with a result that age-II fish were strongly represented in the 1954 and 1957 downstream migrations. The 1949 and 1951 year classes also contributed relatively large numbers of age-II migrants (in 1951 and 1953). However, the data were inadequate to determine year class strength.

Considering the downstream migration by year class, most of each class migrated downstream at age I. The ages at migration of the 1952 to 1957 year classes were similar; 63-87% migrated at age I, 12-36% at age II and 1% at age III. The 1950 and 1951 year classes were characterized by unusually low percentages of age-I migrants. The unusually low percentage of age-I migrants from the 1950 year class may be related to the upstream location of the weir in 1951. The 1951 year class may have had unusually good survival to age II, thus contributing a larger number of fish migrating at that age. According to an unweighted average for the year classes 1950 to 1957, 68% of the parr migrated at age I, 31% at age II and 1% at age III. There was no apparent association between age of the migrants and population density.

TABLE 5

NUMBERS AND PERCENTAGES OF AGES I-III PARR CAUGHT MIGRATING DOWNSTREAM, 1951 TO 1959

Year of capture	Age I Number	Age I Percentage	Age II Number	Age II Percentage	Age III Number	Age III Percentage	Total number caught
1951	45	10	369	81	40	9	454
1952	500	80	103	17	19	3	622
1953	1,797	78	499	22	11	<1	2,307
1954	210	37	355	62	7	1	572
1955	531	80	119	18	14	2	664
1956	1,382	95	73	5	3	<1	1,458
1957	359	50	354	50	3	<1	716
1958	185	54	148	43	11	3	344
1959	564	93	42	7	3	<1	609
Average percentage (unweighted)		64		34		2	

Various investigators have determined the age at which parr leave their stream of birth by analyzing growth patterns of scales of adult fish which had returned to the river from lake or sea. Pautzke and Meigs (1941) concluded that 73% of the rainbow trout parr left the stream at the age of 2 years. Briggs (1953) stated: "....most steelhead first spawn at the age of 4 years, after having spent 2 years in the stream and 2 years in salt water." Reynolds[2], in a study of adult rainbow trout that migrated from Lake Michigan into the Platte River, reported that 1% left the stream at the age of 1 year, 96% at 2 years and 3% at 3 years. Greeley (1933), who made the same type of study on the Little Manistee River in Michigan, found that 7.3% of the fish left the stream at the age of 1 year, 82.3% at the age of 2 years, 9.4% in the third year and 1% in the fourth year. These investigators agree that most rainbow trout parr migrate out of the stream at or near the beginning of their third summer.

Shapovalov and Taft (1954) counted downstream migrants with a weir on Waddell Creek, California. The downstream migration consisted of fish of age 0 (40%), I (40%), II (19%) and III (1%). Their data and the Black River data show a considerable number of age-0 and/or age-I migrants which was not revealed by inspection of adult scales (investigators cited in preceding paragraph). Possible reasons for the inconsistency include: (1) a higher mortality of younger fish when they reach the ocean or lake, (2) younger fish are less likely to continue migration into the ocean or lake and (3) fish migrating at age 0 and I were not detected by scale analysis of returning adults.

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2 Reynolds, Dexter B., Jr. 1947. Summary of twenty months investigation on the Platte River and adjacent waters, Benzie County, Michigan, with special reference to the rainbow trout (Salmo gairdnerii irideus). 74 pp. (Typewritten thesis; University of Michigan).

John Hale (personal communication) indicated that migration of age-0 parr occurred in Minnesota streams tributary to Lake Superior. I also observed rainbow trout fry moving from the Little Huron River, Marquette County, into Lake Superior. Such migration likely occurred on the Black River because age-0 fish could easily pass through the ½-inch mesh of the weir.

Size of Parr

The average length of migrating parr from the various year classes ranged from 4.2 to 4.7 inches for age-I fish, from 7.0 to 7.6 inches for age II and from 8.4 to 9.6 inches for age III (Table 6). There was no noticeable association of size with year class strength. The size of fish in the strong year classes of 1952 and 1955 were similar to those in weaker year classes. There did, however, appear to be a trend toward smaller age-I fish among the 1950 to 1958 year classes (Table 6). A nonparametric test for trend (Mann, 1945) showed that the trend was significant ($P < .001$). The reason for the decline in average size of age-I fish is unknown. A trend was not apparent in older fish.

The average lengths of age-I and -II parr caught in the weir increased as the season progressed. The average lengths (unweighted averages of combined yearly collections) of parr during successive 10-day periods in 1951 to 1959 are shown below.

Age	May			June			July	
	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20
I	4.3	4.2	4.0	4.3	4.5	4.6	4.9	5.1
II	7.0	7.2	7.1	7.0	7.2	7.3	7.8	7.8

These data were tested for trend (Mann, 1945). There was a significant upward trend in average lengths ($P < .01$) for both age-I and -II fish. The trends doubtless reflect growth during the migration season.

TABLE 6

AVERAGE EMPIRICAL LENGTHS IN INCHES OF DOWNSTREAM MIGRATING PARR IN THE YEAR CLASSES 1949 TO 1958

Age	Year class										Average
	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	
I	...	4.7	4.7	4.6	4.4	4.4	4.4	4.3	4.4	4.2	4.4
II	7.1	7.4	7.0	7.0	7.2	7.0	7.0	7.0	7.6	...	7.1
III	9.0	8.7	8.6	8.4	9.6	9.0	9.0	8.9	...	...	8.9

Practically all age-I fish were sublegal, about half of age II were legal sized and all age III were legal. Thus, the fish in the migrations are but lightly exploited by anglers in Michigan.

In Waddell Creek, California, Shapovalov and Taft (1954) found that average total lengths [converted from for lengths (Carlander, 1953)] of downstream migrants were 4.2 inches for age I and 7.2 for age II. In the Alsea River, Oregon, downstream migrants averaged 6.0, 6.8 and 7.3 inches at ages I, II and III (Wagner, Wallace and Campbell, 1963). In the Black River, lengths of downstream migrants of these ages were 4.4, 7.1 and 8.9 inches. Fish in the Black River and Waddell Creek were approximately the same lengths. In the Alsea River, the length at age II was similar to that in the other studies, but lengths at ages I and III were not. The cause of the difference is unknown, but may be related to the stocking of rainbow trout in the Alsea River.

Time of Downstream Migration

The downstream migration of parr began in April and extended to the end of July (Table 7). Since few fish were caught at the beginning and end of the collecting operations, it seems valid to assume that the trapping covered practically the entire period of migration. Further, very few parr were taken when the weir was operated in August (1950) and in September-November (1952 to 1955). Most downstream migration occurred from May 21 to June 30. In 8 of the 9 years of study, the percentages of fish that were caught during May 21-June 30, as related to the total catch for the year, were closely similar (77-91%). In 1958, however, the major migration began earlier and lasted longer; only 45% of the migrants were caught during May 21-June 30.

TABLE 7

PERCENTAGES OF PARR MIGRATING DOWNSTREAM
BY TIME PERIODS, 1951 TO 1959

Year of capture	Date of capture										Total number
	April 21-30	May 1-10	May 11-20	May 21-31	June 1-10	June 11-20	June 21-30	July 1-10	July 11-20	July 21-31	
1951	..	2	10	23	16	19	22	8	..	..	454
1952	..	0	1	20	18	25	18	11	7	< 1	622
1953	..	5	3	7	21	32	17	10	5	<1	2,307
1954	..	..	10	23	24	19	16	7	1	..	572
1955	1	1	6	24	28	29	10	1	<1	..	664
1956	..	1	1	13	26	27	16	13	3	..	1,458
1957	..	7	10	24	17	31	8	3	..	..	716
1958	<1	4	28	15	16	9	5	22	1	..	344
1959	..	..	10	30	17	12	20	10	1	..	609

Pautzke and Meigs (1941) reported that the probable peak of downstream migration of immature rainbow trout in Washington occurred in May. In the Alsea River in Oregon, Wagner, Wallace and Campbell (1963) found that most of the downstream migration occurred between mid-April and mid-May. On Waddell Creek, California, Shapovalov and Taft (1954) observed the heaviest downstream migration (69% of the total) from April 1 to July 21, but some downstream migration occurred the year around. In Black River, the period of migration was limited to not more than 4 months.

There were differences among the three age groups in time of migration. Figure 4 gives the average percentages of the annual runs that migrated downstream in different time periods. Periods in which the weir was not operated every year are not included. Although considerable overlap occurred, there was a definite sequence among the age groups for downstream migration. Age-III parr began to migrate first, followed by ages II and I, respectively. Seventy-six percent of age III migration occurred during May, 75% of age II during May 11-June 10 and 70% of age I in June. As on the Black River, older parr in Waddell Creek (Shapovalov and Taft, 1954) migrated first.

The major portion of downstream migration occurred during times of darkness or reduced light (Table 8). Observations indicated that catches examined on night and morning visits to the trap consisted almost entirely of fish which had entered the trap during darkness. Little downstream movement was observed during daylight hours, except under conditions of high and turbid water. There was little seasonal or annual variation in the percentages of fish trapped in the different daily periods.

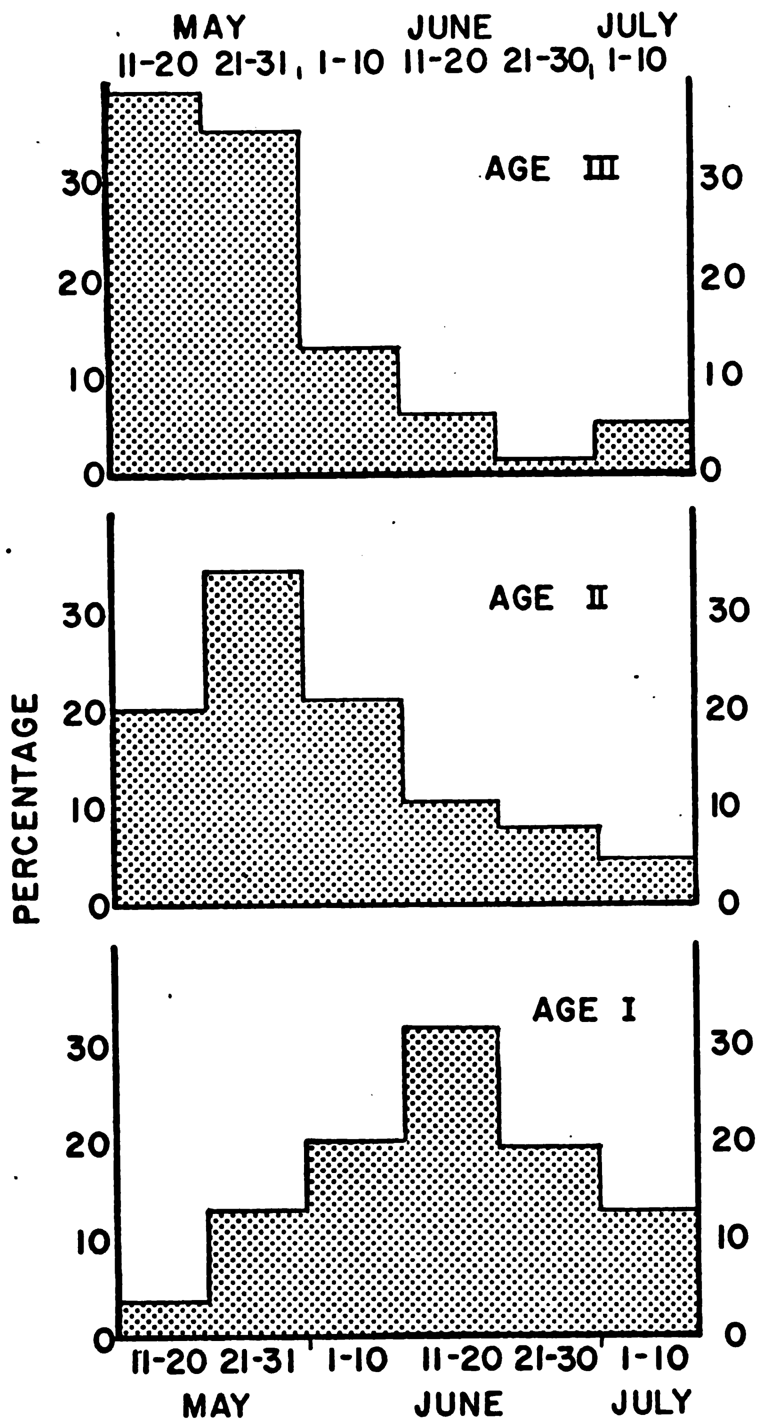

Figure 4. --Average percentages of age-groups I, II and III parr migrating downstream in different time periods, 1951-59.

TABLE 8

PERCENTAGES OF PARR CAUGHT IN THE WEIR DURING
THREE DAILY PERIODS, 1951 TO 1959

Year	Time of capture		
	10:30 p.m.- 8:30 a.m.	8:30 a.m.- 5:00 p.m.	5:00 p.m.- 10:30 p.m.
1951	37	9	54
1952	35	5	60
1953	42	8	50
1954	38	13	49
1955	47	5	48
1956	40	6	54
1957	33	1	66
1958	32	4	64
1959	45	10	45
Unweighted average	39	7	54

The hours of migration on the Black River are in agreement with other studies. Gauley, Anas and Schlotterbeck (1958) studied downstream movements of salmonids at Bonneville Dam on the Columbia River. More juvenile steelheads migrated at night than in daylight hours during 4 of 5 years. On Waddell Creek, Shapovalov and Taft (1954) report "...the bulk of the fish move downstream during the night or at least in the early morning or late evening."

Water Temperature and Downstream Migration

Maximum-minimum water temperatures for the preceding 24 hours were recorded each morning in 1951 and 1952. In 1953, three temperature readings were made daily at visits to the weir. Appreciable migration began when water temperatures approached 50° F. In all 3 years, most of the migration was associated with water temperatures of 48-58° F.

RELATIONSHIP OF UPSTREAM PARR TO DOWNSTREAM MIGRANTS

Ability to predict numbers of downstream migrants by sampling young-of-the-year and age-I fish in the stream would be useful to fish managers to help predict future runs of adults. However, to permit predictions, a reasonably consistant ratio must exist between the numbers of parr in the stream population and the numbers in subsequent migrations. To determine if such a relationship existed in Black River, numbers of parr taken in upstream sampling were compared with numbers of fish of the same year class in subsequent migrations. As the entire population was not sampled, it must be assumed that sampling efficiency in upstream areas and at the weir was approximately constant from year to year. This assumption seemed valid since areas of collection and effort were the same each year. Further, it must be assumed that: (1) over-winter mortality was relatively constant from year to year and (2) mortality was not density-dependent. If these assumptions are valid, then the following positive correlations should be present: (1) numbers of age-0 autumn fish with age-I fish migrating downstream in the following year, (2) numbers of age-0 autumn fish with age-II migrants of that year class and (3) numbers of age-I autumn fish with age-II downstream migrants of the following year.

Spearman rank correlation tests (Siegel, 1956) were used to determine the relationship of the three groups of fish (Table 9). For age-0 autumn fish and age-I fish migrating downstream, there was a significant relationship $\left[P\ (r_s = .857) < .05\right]$. There was also a significant relationship $\left[P\ (r_s = .905) < .05\right]$ between age-0 autumn fish and fish from the same year class migrating downstream at age II. On the other hand, there was

TABLE 9

NUMBERS OF PARR IN THE 1951 TO 1958 YEAR CLASSES CAUGHT IN THE UPPER RIVER AND IN THE WEIR, 1951 TO 1959

Year class	Age: 0-I, Fall catch at age 0 (upper river)	Age: 0-I, Spring-summer catch of age I (weir)	Age: I-II, Fall catch at age I (upper river)	Age: I-II, Spring-summer catch at age II (weir)
1951	.....	.....	19	499
1952	133	1,797	92	355
1953	20	210	4	119
1954	36	531	31	73
1955	384	1,382	79	354
1956	86	359	9	148
1957	17	185	16	42
1958	188	564	.....	.....

no relationship between age-I autumn fish and age-II fish migrated downstream the following year $\left[P\ (r_s = .429) > .10\right]$.

The correlation between numbers of age-0 fish in the autumn with the subsequent numbers of downstream migrants suggests that collections of young-of-the-year in the upper river would be useful in predicting relative sizes of subsequent downstream migrations. A better sampling design in the upper river would probably also show a relationship between age-I fish upstream and numbers migrating downstream as age II the following year provided mortality was constant from year to year and was not density-dependent.

CONCLUSIONS

1. Annulus formation by rainbow trout parr in the Black River occurred between October and April-May. Most parr probably began growing in April or shortly before.

2. The body-scale relationship was best expressed by a linear regression: L (inches) = 0.16 + .0826S (mm x107).

3. The relationship between length (mm) and weight (grams) was a curvilinear regression where $W = .00001384\ L^{3.0426}$.

4. Growth of rainbow trout parr for the first 3 years of life was about 3 inches per year. During their first growing season, parr of the 1949 to 1951 year classes grew slower than those of the 1956 to 1958 year classes. Within a migratory season, faster growing parr of age I migrated sooner than those that grew slower.

5. Parr in the upper river in the autumn were age 0 (68%), I (29%) and II (3%). Variations occurred in age composition; these were related to year class strength. Average lengths in inches were 2.9 for age 0, 6.4 for age I and 9.3 for age II. Few parr were of legal size (7.0 inches).

6. Parr in the downstream migration were of ages I (68%), II (31%) and III (1%). Age composition varied among migratory seasons according to year class strength. Lengths of downstream migrants averaged 4.4 inches (age I), 7.1 inches (age II) and 8.9 inches (age III). Most migration occurred between May 21 and June 30 during hours of darkness or reduced light. Within a migration season, older parr migrated first. Most migration occurred at water temperatures of 48-58° F.

7. The number of age-0 fish in the upper river during the autumn was correlated with the number of subsequent downstream migrants.

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