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AGE, GROWTH, AND DOWNSTREAM MIGRATION OF JUVENILE RAINBOW TROUT IN THE BLACK RIVER, MICHIGAN[1]

By Thomas M. Stauffer

Abstract

Juvenile rainbow trout were examined during 1951-59 while they lived in upstream areas of the Black River and also when on migration to Lake Michigan. Their growth rate in the stream was about 3 inches per year. The body-scale relationship was: L (inches) = 0.16 + .0826S (mm x107). The relationship between length (mm) and weight (g) was: $W = .00001384L^{3.0426}$. On the average, the parr in upper sections of the river in autumn were 68% age 0, 29% age I and 3% age II. Annual variations in age composition were related to year class strength.

For a given migratory season, age composition varied according to year class strength, and the older parr migrated first. On the average, the downstream migration was 64% age-I fish, 34% age II and 2% age III. Lengths of downstream migrants averaged 4.4 inches for age I, 7.1 for age II and 8.9 for age III. Most migration occurred between May 21 and June 30, at night, on subsiding water levels, and at water temperatures of 48-63 F.

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[1] A contribution from Dingell-Johnson Projects F-18-R, F-27-R and F-31-R, Michigan.

Introduction

Young rainbow trout (*Salmo gairdnerii*) 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. The 2 to 12-pound adults provide an important sport fishery when they return to streams to spawn. Knowledge of the habits of juvenile rainbow trout in Great Lakes tributaries has been meager. I studied juvenile rainbow trout in the Black River, a tributary of Lake Michigan, during 1951-59. The age structure and growth of the population in the stream and aspects of the annual migration to the lake were of principle concern.

The Black River is on the north shore of Lake Michigan about 40 miles west of the Straits of Mackinac. During the study, it received heavy spawning runs from Lake Michigan of rainbow trout, sea lampreys (*Petromyzon marinus*), white suckers (*Catostomus commersoni*), longnose suckers (*Catostomus catostomus*), and smelt (*Osmerus mordax*). The river contained moderate to large resident populations of brown trout (*Salmo trutta*), slimy sculpins (*Cottus cognatus*) and American brook lampreys (*Lampetra lamottei*). Rainbow trout spawned on the gravel bottom in the middle reaches of the river. The stream has a drainage area of 28 square miles and, during the time of investigation, the average flow 3 miles upstream from the mouth was 33 cubic feet per second with seasonal variations of 12-154 cfs. Two tributaries added about 15 to 20 cfs in the lower 3 miles. The water was dark brown and generally clear. Summer water temperatures seldom exceeded 65 F.

Methods and materials

Juvenile rainbow trout (parr) in the stream were sampled with an alternating-current electric shocker (Table 1). Sampling was confined to five stations, in areas where rainbow trout were most abundant (Figure 1).

Table 1.--Dates of collection and numbers of rainbow trout examined, Black River, 1951-59

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

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

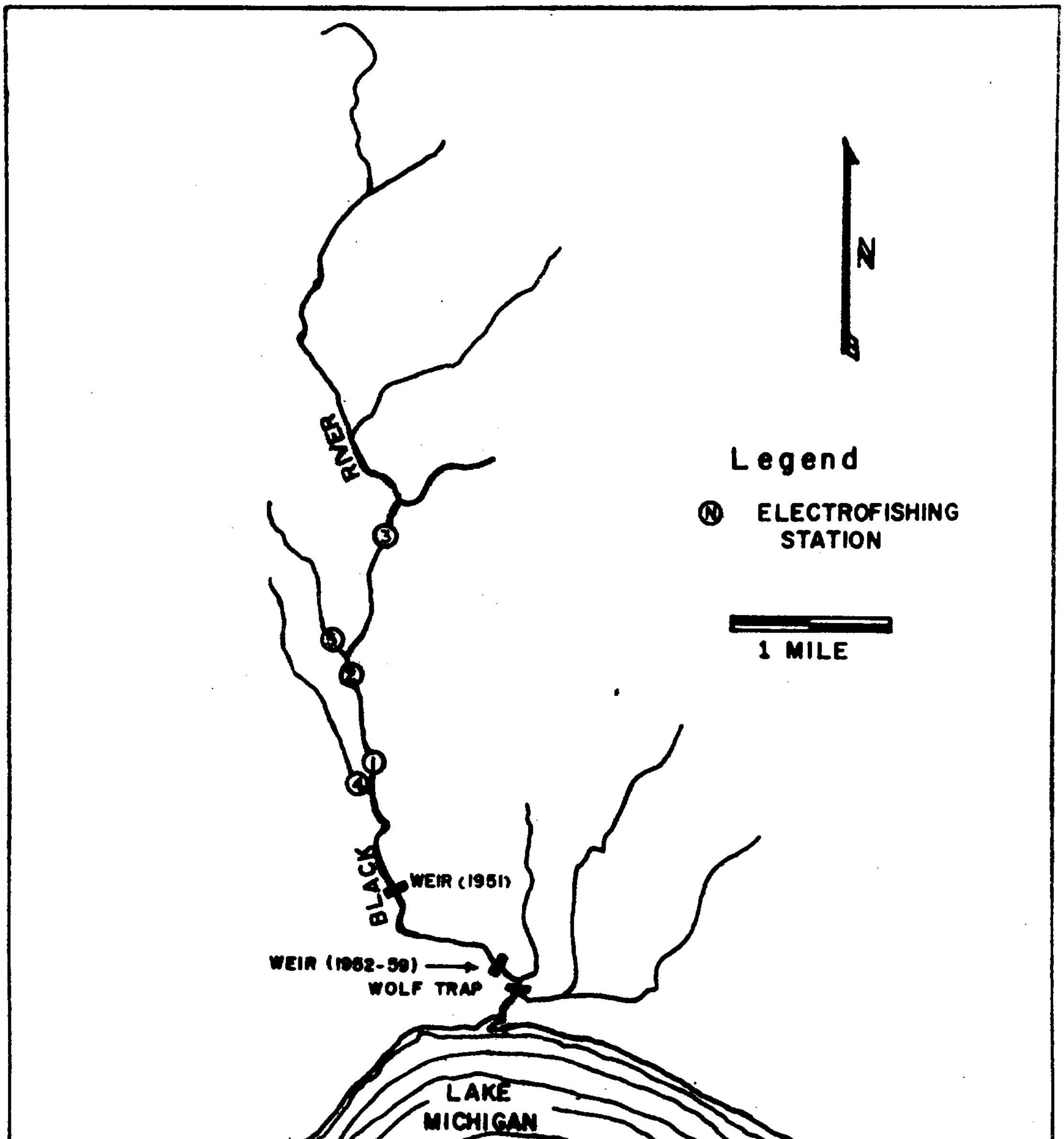

Figure 1.--Black River drainage system and the collecting sites.

Annual collecting effort amounted to 8 hours on 2,300 feet of stream. The areas sampled (400-700 lineal feet of stream per station) were the same every year. Rainbow trout that were 3.5 inches or longer were measured (TL), weighed, and scale sampled, but those smaller than this size were only measured. All fish were returned to the stream alive.

The data used to investigate aspects of downstream migration came from juveniles caught in a weir. In 1951, the weir was located about 3 miles upstream from the mouth of the river, but during 1952-59 it was about 3/4 mile from the mouth (Figure 1). All the rainbow trout spawning areas were above the weir location of 1952-59, but approximately 100 yards of stream suitable for spawning lay below the 1951 location. The weir consisted of a hardware cloth fence of 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[2] at the upper end. The weir was operated from May into July (Table 1) and the traps were visited daily at 0830, 1700 and 2250 hours. Juvenile rainbow trout were either tagged or fin-clipped to determine subsequent migration. All were measured (TL) and many were also weighed and scale sampled. The parr were then passed over the weir in the direction of migration.

Two aspects of weir construction affected the counts of downstream migrants. First, laboratory tests showed that some rainbow trout 3.7 inches and smaller escaped through ½-inch wire mesh but that larger trout were retained. Thus, all age-0 and some smaller age-I migrants could have escaped through the mesh of the weir. I do not know whether age-0 fish were migrating, but there were some small age-I migrants. Secondly, some rainbow trout 3.8 inches and larger escaped through the weir at other points.

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[2] Upstream migration of parr is not discussed because there was so little of it.

Although the escapement of an unknown number of trout less than 3.8 inches introduced an unavoidable bias, the weir catches were representative for the total migration of trout over 3.7 inches long, since their escapement was at random in respect to length and age. A Wolf trap (Wolf, 1951) was operated some 400 yards below the weir in 1954-57, which caught both fish marked at the weir and unmarked fish that escaped through the weir. The average lengths of unmarked and marked age-I rainbow trout caught in the Wolf trap during 4 years of operation ranged from 4.3 to 4.6 inches. In 1954, 1956 and 1957, differences between the measurements of unmarked and marked fish were not significant; only the difference of 0.3 inch in 1955 was significant ($\underline{t}$ = 4.017, d.f. = 238). The average annual ages of juvenile rainbow trout that were caught in the weir and of those that escaped the weir were closely similar. The inconsistent differences varied by not more than 0.3 year.

Scales were taken from an area between the lateral line and the insertion of the dorsal fin. Ages of fish collected from the weir in 1951, 1952, 1958 and 1959 were determined by scale analysis, and the anterior scale radii and annuli were measured for subsequent growth determinations. Age determination of fish caught in the weir from 1953 to 1957 were made from scale analysis and length-frequency distributions. Scale measurements were not made. Parr caught with the shocker that were under 3.5 inches were age 0, as indicated by their distinct length-frequency distribution. Ages of parr over 3.5 inches were determined by scale analysis. In all collections, the annuli were prominent, and little difficulty was experienced in interpreting the scales.

At electrofishing station No. 1 (Figure 1), the U. S. Geological Survey operated a water-stage recorder in 1952-59 and a thermograph in 1952. In 1953-59, I recorded maximum-minimum water temperatures daily during April-July at the weir.

Age and growth

Mean annual increments in length of juvenile rainbow trout were 2.9, 3.5 and 2.9 inches in successive growing seasons as defined by empirical lengths (see Table 4) and 3.0, 3.5 and 2.9 inches as shown by back-calculated lengths (Table 2). The growth increments were similar to those for rainbow trout from other Michigan streams. Edward Schultz (personal communication) determined annual increments of rainbow trout in many Michigan streams from September collections when annual growth was nearly complete. He reported increments of 3.4 inches for the first growing season and 3.5 inches for the second. In September collections, Shetter and Hazzard (1939) found increments in the first growing season of 3.3 inches in the Little Manistee and Pine rivers and 2.6 inches the second season in the Pine River. In summary, rainbow trout parr in Michigan streams grow at a rate of approximately 3 inches per year.

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 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 of five or more fish. The calculated regression, $L = 0.16 + .0826S$, and 95% confidence limits are shown in Figure 2. Body lengths at the various ages were calculated according to "procedure B" as outlined by Whitney and Carlander (1956). Validity of the regression and back-calculation was substantiated by the following evidence. First, emperical lengths of

Table 2.--Average back-calculated lengths (inches) of age I-III parr in the downstream migrations, 1951-52 and 1958-59

Year caught	Age when scale sampled: I, Annulus I	I, Number[1]	II, Annulus I	II, Annulus II	II, Number[1]	III, Annulus I	III, Annulus II	III, Annulus III	III, Number[1]
1951	2.9	45	2.6	5.9	369	2.1	5.0	8.0	40
1952	2.8	500	2.5	6.2	103	2.6	5.5	8.4	19
1958	3.2	185	2.8	6.2	148	2.3	5.3	8.4	11
1959	3.1	564	3.0	6.7	42	2.9	5.7	8.2	3

[1] Number of parr used to back-calculate average lengths at the annuli.

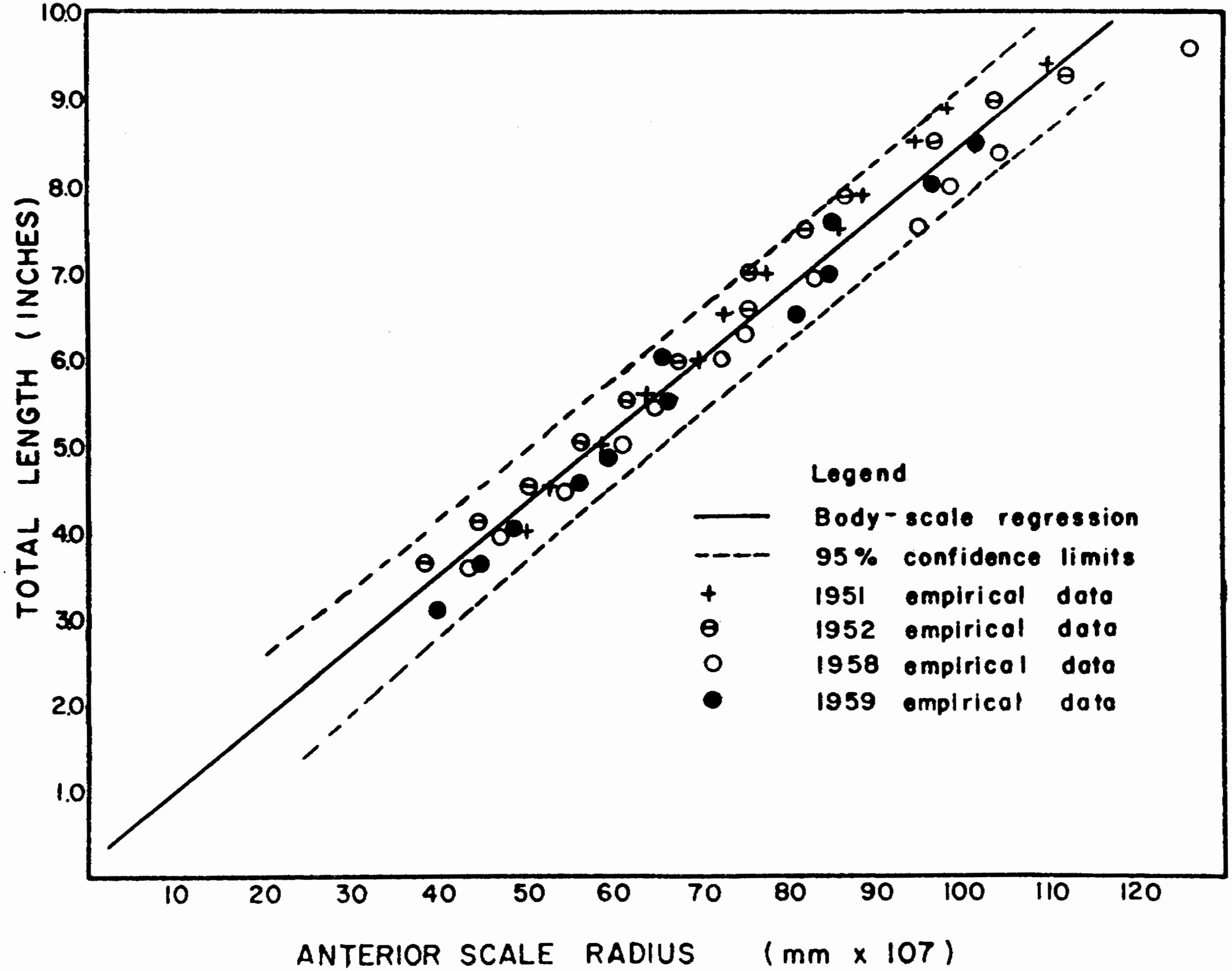

Figure 2.--Body-scale regression of downstream-migrating parr in Black River, 1951-52 and 1958-59

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 (Table 3). Secondly, calculated lengths by age groups (Table 2) were usually in agreement with empirical lengths of fish caught at the end of the growing season (see Table 4). Finally, as mentioned before, other workers found similar lengths.

The length-weight relationship was best expressed by the equation for a general parabola, $W = cL^n$ (Beckman, 1948). To derive the relationship, the weights (g) of parr between 86 mm (3.4 inches) and 224 mm (9.0 inches) caught in the weir in 1951, 1952, 1958 and 1959 were grouped by 2.5 mm (0.1 inch) length intervals. Average length and weight of each group were then used to calculate the relationship. The calculated line $\left[W\ (g) = .00001384\ L\ (mm)^{3.0426}\right]$ and empirical data are shown in Figure 3. There was excellent agreement between the calculated line and the empirical data (alternate groups plotted), demonstrating that the line accurately represented the length-weight relationship.

Parr in upstream areas

Parr in the spawning areas during autumns of 1952 to 1958 were of ages 0, I and II (Table 4). Age-0 parr predominated numerically in all years except 1953. Age-I parr were considerably less numerous and predominated only in 1953. The few age-II fish collected came from mainstream stations. By unweighted averages of the yearly collections, 68% of the parr were age 0, 29% were age I and 3% were age II. 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 age-I parr in the stream (Table 4) and were strongly represented in the downstream migration as age-I fish.

Table 3.--Comparison of empirical and calculated lengths (inches) of parr in the same year class. Number of parr in parentheses

Length derivation	Age and year class							
	0-I				I-II			
	1957		1958		1956		1957	
Emperical (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)

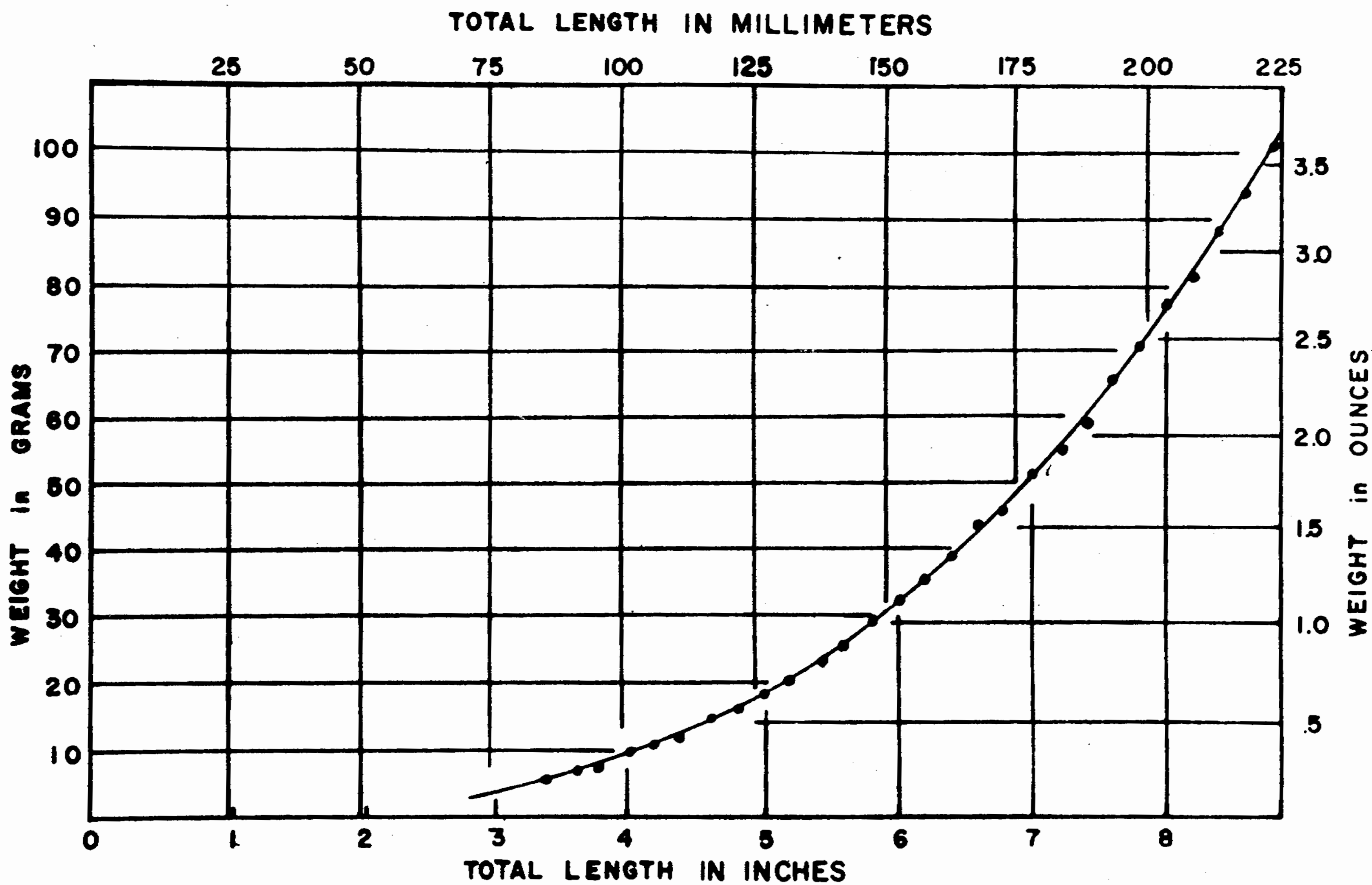

Figure 3.--Length-weight relationship of downstream-migrating rainbow trout parr, Black River, Michigan 1951-52 and 1958-59. Dots represent empirical data. The line is calculated.

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Table 5.--Numbers of downstream-migrating parr caught in the weir, by year class and year of capture

Year of capture	Year class 1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1951	40	369	45	..	..	..	..	..	..	..	..
1952	..	19	103	500	..	..	..	..	..	..	..
1953	..	..	11	499	1,797	..	..	..	..	..	..
1954	..	..	..	7	355	210	..	..	..	..	..
1955	..	..	..	..	14	119	531	..	..	..	..
1956	..	..	..	..	..	3	73	1,382	..	..	..
1957	..	..	..	..	..	..	3	354	359	..	..
1958	..	..	..	..	..	..	..	11	148	185	..
1959	..	..	..	..	..	..	..	..	3	42	564
Total	40	388	159	1,006	2,166	332	607	1,747	510	227	564

Various investigators have determined the age at which juvenile rainbow trout leave the stream of birth by analyzing growth patterns of scales of adult fish that returned to a stream from lake or sea. Pautzke and Meigs (1941) concluded that 73% of the parr in populations they studied 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." From a study of adult rainbow trout that migrated from Lake Michigan into the Platte River, Reynolds (1947) 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 migrated out at the age of 1 year, 82.3% at 2 years, 9.4% in the third year and 1% in the fourth year. These investigators found that most rainbow trout parr migrated out of the natal stream at or near the beginning of their third summer.

Shapovalov and Taft (1954) caught downstream-migrating rainbow trout in a weir on Waddell Creek, California. The migrants were age 0 (40%), I (40%), II (19%) and III (1%). John Hale (personal communication) indicated that that migration of age-0 parr occurred in Minnesota streams tributary to Lake Superior. I also observed rainbow trout fry moving into Lake Superior from a small tributary. These data and those of Black River show considerable numbers of age 0 and I migrants that were not detected by analysis of scales from returning adult fish. Possible reasons for the paucity of young downstream migrants among returning adults include: (1) a high mortality of the younger fish when they reached the ocean or lake, (2) the younger fish did not complete migration out of the stream and (3) fish that had migrated at ages 0 and I were not detected by scale analysis of returning adults.

In the Black River, the average annual length of migrant parr was 4.4 inches (range 4.2-4.7) for age-I fish, 7.1 inches (range 7.0-7.6) for age-II fish and 8.9 inches (range 8.4-9.6) for age-III fish. In Waddell Creek, California, Shapovalov and Taft (1954) found average lengths of rainbow trout migrants to be 4.2 inches for age I and 7.2 for age II. In the Alsea River, Oregon, migrants averaged 6.0, 6.8 and 7.3 inches at ages I, II and III (Wagner, Wallace and Campbell, 1963).

In Black River, there was no noticeable relationship between length and year class strength. The lengths of trout in the strong year classes of 1952 and 1955 were similar to those in weaker year classes. However, for age-I fish, there was a downward trend ($b = -.0583$) in length for the 1950-58 year classes. This trend was significant ($t = 6.34$, d.f. = 7). The reason for the decline in average size of age-I fish is unknown. Such a trend was not apparent in older fish.

Time of migration.--The downstream migration of parr began in April, extended to the end of July, and most of it occurred between May 21 and June 30 (see Figure 5). As few fish were caught at the beginning and end of weir operation, it seems reasonable to assume that the trapping covered virtually 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). The catch of the Wolf trap also showed that nearly all of the downstream run was sampled by the trap at the weir. When the Wolf trap was operated in April-July 1954-57, only 5% of the parr catch was made in April. 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, when the major migration began earlier and lasted longer, only 45% of the migrants were caught during May 21-June 30.

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, most of the downstream migration occurred between mid-April and mid-May (Wagner, Wallace and Campbell, 1963). 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 occurred the year around. In Black River, the period of migration was about 3 months, but the major portion of it lasted about 40 days.

There were differences among the three age groups in time of migration (Figure 4). Age-III parr began to migrate first, followed by ages II and I, respectively. Seventy-six percent of migration by age III 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. As annual averages for 1951-59, 54% (range 45-66) of the parr migrated downstream between the hours of 1700 and 2230, 39% (range 32-47) during 2230-0830, and 7% (range 1-13) during 0830-1700. Observations indicated that catches counted at 1700 and 0830 were practically all 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. The hours of migration on the Black River are in agreement with other studies. Gauley, Anas and Schlotterbeck (1958), who studied downstream movement of salmonids at Bonneville Dam on the Columbia River, found that more juvenile steelheads migrated at night

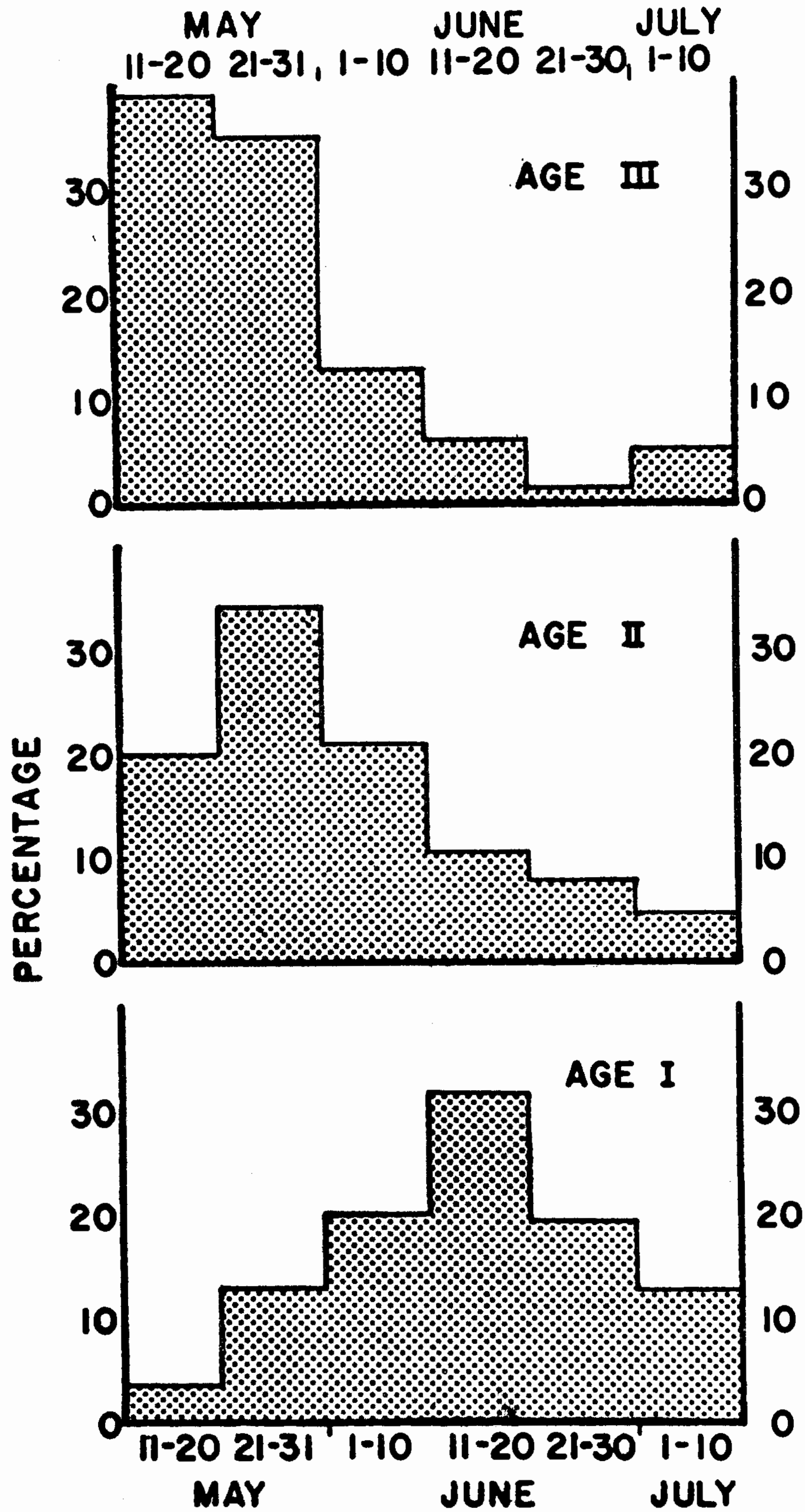

Figure 4.--Average annual percentages of age-groups I, II and III parr migrating downstream in different time periods, 1951-59.

than by day in 4 of 5 years. In 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 volume and temperature.--Downstream migration in the Black River began after the peak of the spring run-off (Figure 5). This happened every year during 1952-59, and usually the peak of migration occurred 1½ to 2 months after the peak of run-off. On the average for 1952-59, parr began to migrate at temperatures from 44 to 50 F; appreciable migration began at 47 to 54 F, and the peak occurred at 48 to 63 F (Figure 5). In Waddell Creek (Shapovalov and Taft, 1954), parr began to migrate downstream about 2 weeks after the peak of run-off, their numbers reaching a maximum 4 months later. Most migration occurred there at water temperatures of 50 to 60 F.

Numerical relationship between the stream and migrant populations

The easiest known way for sampling trout populations in the streams is by electrofishing. Such sampling conceivably could be done for predicting the size of future runs of adult rainbow trout provided good numerical relationships exist between stream-resident juveniles and downstream migrants, and between the latter and adult upstream migrants - all of corresponding year classes. Although it is not possible to demonstrate from this study that all these relationships applied to the Black River, there was good agreement between numbers of parr in the stream and numbers of migrants of the same year classes. A similar relationship may well exist between numbers of young in the stream and numbers of returning adults.

I assumed that sampling efficiency in the Black River was approximately equal from year to year because the collection areas and methods remained the same. The relationships between numbers of various year classes of

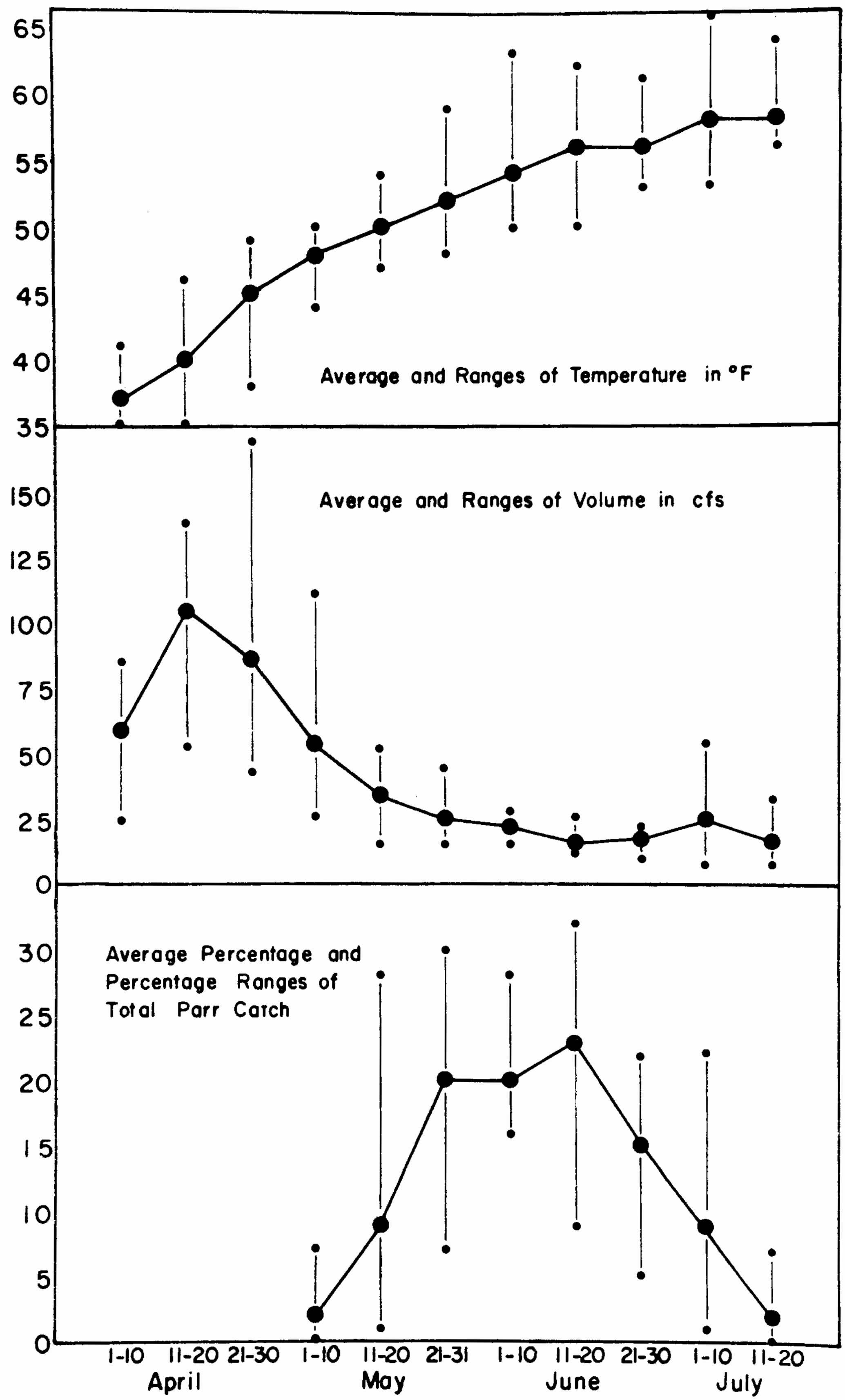

Figure 5.--Water temperatures and volumes of Black River in spring and early summer, and distribution of the migrant parr catch, 1952-59.

parr in the stream (Table 4) and the numbers of them that subsequently migrated (Table 5) are shown in Table 6. Significance of *r* was determined by use of a table of confidence belts for correlation coefficients (Dixon and Massey, 1957). The numbers of age-0 parr sampled in the upper river were fairly well correlated with the numbers of the various year classes that migrated downstream later on. Had a more refined sampling design been used in the upper river, the degree of correlation probably would have been better.

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Table 6.--Relationship between numbers of parr in the stream population and numbers of the same year class that subsequently migrated downstream

Age groups of parr tested for correlation		Inclusive year classes	r
Stream	Weir		
0	I	1952-58	0.638[1]
0	II	1952-57	0.809[1]
0	I + II	1952-57	0.710[1]
I	II	1952-57	0.490

[1] Significant at the 90% level.

Literature cited

Beckman, William C. 1948. The length-weight relationship, factors for conversions between standard and total lengths, and coefficients of condition for seven Michigan fishes. Trans. Amer. Fish. Soc. 75: 237-256.

Briggs, John C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. California Fish and Game, Fish. Bull. 94: 1-62.

Dixon, Wilfrid J. and Frank J. Massey, Jr. 1957. Introduction to statistical analysis. McGraw-Hill Book Company, Inc., New York. 488 pp.

Gauley, Joseph E., Raymond E. Anas and Lewis C. Schlotterbeck. 1958. Downstream movement of salmonids at Bonneville Dam. U. S. Fish and Wildl. Serv., Spec. Sci. Rep. Fish. 236: 1-11.

Greeley, John R. 1933. The growth rate of rainbow trout from Michigan waters. Trans. Amer. Fish. Soc. 63: 361-378.

Li, Jerome C. R. 1964. Statistical inference I. Edwards Brothers, Inc., Ann Arbor, Michigan. 658 pp.

Pautzke, Clarence F., and Robert C. Meigs. 1941. Studies on the life history of the Puget Sound steelhead trout (*Salmo gairdnerii*). Trans. Amer. Fish. Soc. 70: 209-220.

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*). M. S. Thesis, University of Michigan, Ann Arbor, Michigan. 74 pp. (Unpublished)

Siegel, Sidney. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Company, Inc., New York. 312 pp.

Shapovalov, Leo and Alan C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. California Fish and Game, Fish. Bull. 98: 1-375.

Shetter, David S. and A. S. Hazzard. 1939. Species composition by age groups and stability of fish populations in sections of three Michigan trout streams during the summer of 1937. Trans. Amer. Fish. Soc. 68: 281-302.

Wagner, Harry H., Richard L. Wallace and Homer J. Campbell. 1963. The seaward migration and return of hatchery-reared steelhead trout, Salmo gairdneri Richardson, in the Alsea River, Oregon. Trans. Amer. Fish. Soc. 92: 202-210.

Whitney, Richard R. and Kenneth D. Carlander. 1956. Interpretation of body-scale regression for computing body length of fish. Journ. Wildl. Mgt. 20: 21-27.

Wolf, Phillip. 1951. A trap for the capture of fish and other organisms moving downstream. Trans. Amer. Fish. Soc. 80: 41-45.

INSTITUTE FOR FISHERIES RESEARCH

Thomas M. Stauffer

Report approved by G. P. Cooper

Typed by D. S. Greenleaf