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D. S. Shetter

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THE RELATIVE EFFECTIVENESS OF SALMON EGGS AND EARTHWORMS AS BAIT FOR TROUT IN THE STURGEON RIVER, CHEBOYGAN COUNTY

By David S. Shetter

Among various natural baits used to capture rainbow trout in the Sturgeon River drainage (Cheboygan and Otsego counties) in recent years (i.e., prior to 1954), two of the more popular lures have been salmon eggs and earthworms (night-crawler size). Claims that salmon eggs were so effective in capturing trout, especially if egg chumming was employed, that they constituted a threat to the rainbow trout population led the Conservation Commission to ban their use on the Sturgeon River beginning April 20, 1954.

The present study was designed to answer the question of whether salmon eggs are more effective than night crawlers (hereafter referred to simply as worms) as bait in catching trout, and whether chumming increases the catch. The conclusions from this study are that salmon eggs are far more effective than worms as bait, but that chumming with either salmon eggs or worms does not increase the catch.

Methods

Test fishing was carried on at about a dozen different sites on the Sturgeon River and at the so-called "walleye hole" off the mouth of the stream, in Burt Lake. All experimental anglers used 6- or 8-pound test monofilament nylon line

on either a fly rod or a spinning rod. Terminal tackle consisted of No. 8 or No. 10 short-shank gold hooks for egg fishing, and No. 6 long-shank Mustad hooks for worm fishing. One or more split shot were pinched on the line about 14 inches from the hook, with some variation in shot size and distance from the hook, depending on the velocity of the current at the site fished. Much terminal tackle was lost because of the character and amount of cover in and along the stream channel.

A popular brand of salmon eggs was used for egg fishing; worms in lots of 100 to 500 were purchased as needed.

Test fishing was done by paired anglers, who used the two baits and employed chumming during half of their fishing. The choice of bait and chumming for individual anglers on consecutive fishing periods was systematized for precise analysis. Local anglers were consulted as to usual methods of chumming. Chumming was done by throwing about 5 to 30 pieces of the bait into the site to be fished, the objective being to induce the fish to feed.

Test fishing was done during the fall of 1957, and during the spring and summer of 1958. The experimental design of the fishing tests is given in a later section.

All fish caught were measured (total length); most fish larger than 10 inches were scale-sampled for age determination; and except for about 20 hooking mortalities, all fish were released. A high percentage of the fish taken on salmon eggs were hooked rather lightly in the edge of the jaws because of the manner in which this lure was fished.

Field records were kept on 3- by 5-inch cards, one for each hour of angling. Records included the angler's name, date, time, lure used, whether or not chumming was employed, and the species, numbers and lengths of fish caught.

Fishing was conducted on 15 days between October 16 and November 27, 1957; on 9 days between April 30 and May 16, 1958; and on 11 days between July 23 and August 15, 1958, during the summer "run" of rainbow trout.

A total of ten persons, all employees of the Fish Division, took part in the experimental fishing. They were: L. N. Allison, Gaylord R. Alexander, Arnold Hubbell, Donald Peterson, Jack Hammond, Stanley Lievense, Gerald F. Myers, Dana Houseworth, Bud Knight and the author. A majority of these men had prior experience in the use of worms as bait, but little or no prior experience in the use of salmon eggs. Thus any bias due to this factor of experience should have been in the direction of increasing the catch with worms.

In the course of the test fishing, approximately 3,500 worms and 150 jars of salmon eggs were used.

Results of angling

The total catch of trout, by all anglers, during each of the three seasons is given in Table 1. The catches by individual anglers by 1/2-day intervals are given in the Appendix. Fish other than trout (20 white suckers, 1 walleye, 1 creek chub and 1 sculpin) caught during the three fishing periods are not included in the tabulations.

In Table 1 the catch is divided according to lure, method and season, and the numbers of brook and brown trout, regardless of size, are combined. Rainbow trout were classified as "lake-run," or "other," and the observed size ranges are given. A rainbow trout was classified as a lake-run fish if it was larger than 10.0 inches and silvery in color. (The smallest silvery-colored fish taken at the river mouth was 10.0 inches.) Only 4 of the 63 lake-run fish captured were less than 12 inches long. On the other hand, 21 "other" rainbow trout between 10 and 12 inches in total length were captured, and judged as "other" because of the location of capture (near Wolverine) and lack of silvery coloration. The presence of planted, legal-size rainbow trout, some of which exceeded 10.0 inches in total length, negated the possible use of an arbitrary length minimum as a criterion for whether or not a particular fish was a lake-run fish.

Table 1.--Summary of number of trout caught and hours of fishing, by season and method of angling, during test fishing with salmon eggs and worms, Sturgeon River and Burt Lake, 1957-1958

Bait, and fishing method	Species of trout caught[1]	Year and season			
		1957, fall	1958, spring	1958, summer	Total
Eggs only	Rainbow				
	Lake run (10.0"-16.0")	4	0	23	27
	Other (4.0"-11.9")	72	54	73	199
	Brown	4	8	0	12
	Brook	0	1	0	1
	(Hours fished)	81.5	48	64	193.5
Worms only	Rainbow				
	Lake run (14.1"-17.5")	1	0	1	2
	Other (4.0"-11.9")	10	27	15	52
	Brown	5	4	2	11
	Brook	2	3	0	5
	(Hours fished)	81.5	48	64	193.5
Eggs, chummed	Rainbow				
	Lake run (13.0"-23.7")	6	2	17	25
	Other (4.0"-11.9")	23	36	88	147
	Brown	13	20	5	38
	Brook	0	2	0	2
	(Hours fished)	84	48	64	196
Worms, chummed	Rainbow				
	Lake run (11.0"-16.8")	0	3	6	9
	Other (6.0"-9.9")	6	16	23	45
	Brown	3	8	1	12
	Brook	1	3	0	4
	(Hours fished)	83	48	64	195
Total	Rainbow				
	Lake run (10.0"-23.7")	11	5	47	63
	Other (4.0"-11.9")	111	133	199	443
	Brown	25	40	8	73
	Brook	3	9	0	12
	(Hours fished)	330	192	256	778

[1]Length range (inches) of rainbow trout shown in parentheses.

In 330 hours of fishing in the fall of 1957, 122 rainbow, 25 brown and 3 brook trout were caught. Slight deviations from the experimental pattern on three days, caused mainly by loss of tackle by individual anglers, resulted in slightly more hours of chumming (Table 1). In 81.5 to 84 hours of fishing with each lure and type of fishing, the catch of trout of all sizes was as follows:

(1) Salmon eggs only: 76 rainbow, 4 brown.

(2) Worms only: 11 rainbow, 5 brown, 2 brook.

(3) Salmon eggs chummed: 29 rainbow, 13 brown.

(4) Worms chummed: 6 rainbow, 3 brown, 1 brook.

The catch of lake-run rainbow trout was: 4 on eggs only, 1 on worms only, and 6 on salmon eggs chummed, for a total of 11.

During the spring of 1958, a total of 192 hours of angling yielded 138 rainbow, 40 brown, and 9 brook trout. In 48 hours of fishing with each combination of bait and method, the trout catch was as follows:

(1) Salmon eggs only: 54 rainbow, 8 brown, 1 brook.

(2) Worms only: 27 rainbow, 4 brown, 3 brook.

(3) Salmon eggs chummed: 38 rainbow, 20 brown, 2 brook.

(4) Worms chummed: 19 rainbow, 8 brown, 3 brook.

Only five lake-run rainbow trout were caught--two on salmon eggs chummed, three on worms chummed.

During the summer of 1958, a total of 256 hours of fishing took 246 rainbow and 8 brown trout. In 64 hours of fishing with each combination of bait and method, the catch of trout was distributed as follows:

(1) Salmon eggs only: 96 rainbow.

(2) Worms only: 16 rainbow, 2 brown.

(3) Salmon eggs chummed: 105 rainbow, 5 brown.

(4) Worms chummed: 29 rainbow, 1 brown.

Forty-seven lake-run rainbow trout were caught and landed, and an additional 20 were hooked and played long enough for positive identification but were then lost. These lake-run fish were taken by the four combinations of bait and angling method (fish lost, listed in parentheses) as follows: salmon eggs only--23 (7); worms only--1 (2); salmon eggs chummed--17 (10); and worms chummed--6 (1). The fish which were hooked and lost are not included in other tabulations.

A majority of the 11 lake-run rainbow trout taken during the fall of 1957 were caught in the "walleye hole" off the mouth of the Sturgeon River in Burt Lake. Relatively few lake-run fish were observed in any part of the Sturgeon River proper during the 1957 fall fishing. The experimental fishing in the River during early May of 1958 yielded only five lake-run fish. (Warm weather during early March of 1958 apparently brought about an early run of spawning adults, and it is believed that many of these fish had returned to Burt Lake before the opening of the trout season.) The summer fishing of 1958 provided the only large series of lake-run rainbow trout (47) taken in the stream.

Design of the experiment

The experimental design for the test fishing involved two teams of two anglers each. The four anglers always fished during the same time period. One team chummed while the other team did not. The two teams alternated chumming and no chumming on consecutive day or half-day fishing periods; i.e., the team which chummed on a given day fished without chumming on the following day, and vice versa. One angler on each team used eggs while the other used worms; at the end of one hour they reversed baits; at the end of two hours they exchanged fishing sites on the stream for a second two hours of fishing during which they again reversed baits at the end of one hour. Thus, at any one time, each of the four anglers was fishing under a different combination of lure and method; and,

over the span of two consecutive 4-hour test periods, each combination of bait and angling method was used by each angler. The sampling scheme is shown in Table 2.

For trout of all sizes (Table 1), eggs were about 3 times as effective as worms, and chumming was no more effective than not chumming; for lake-run rainbow trout (records given in text, above), eggs were about 5 times as effective as worms, and chumming was only slightly more effective than not chumming. Whether the differences are statistically significant (i.e., reliable) can be determined only by relating the differences to the variation in catch by individual anglers during various periods of test fishing. To allow for possible differences in angler skill and in fishing quality from day to day, the analysis of variance is the most appropriate test. For this analysis the catch per hour was computed for each angler's fishing with one bait during a two-hour period. A logarithmic transformation of the observed catch-per-hour data was used because preliminary analysis of the untransformed data on catch per hour showed a relationship between mean and variance, as well as a number of high interaction terms.

The design, shown in Table 2 as an analysis of variance, was a factorial experiment (Snedecor, 1956) with three factors, each considered a fixed effect. These factors were: bait, angling method, and day (or 1/2-day). The estimate of experimental error is based upon the duplicated measurements made at each trial. The best comparison here, and the one of primary interest, was of bait (eggs versus worms), with each angler fishing each bait at each trial. The effect of chumming was tested on a somewhat different basis, with each angler chumming on alternate trials. Such a comparison might be affected by any interactions of anglers with the various experimental effects.

Table 2.--Experimental design of test fishing on the Sturgeon River, 1957 and 1958, showing distribution of bait and angling method among the anglers

E = eggs only. EC = eggs chummed.

W = worms only. WC = worms chummed.

Period	Angler	Hour of fishing during 1/2 day			
		1st	2nd	3rd	4th
Day 1	A	E	W	E	W
(or 1/2 day)	B	W	E	W	E
	C	EC	WC	EC	WC
	D	WC	EC	WC	EC
Day 2	A	WC	EC	WC	EC
(or 1/2 day)	B	EC	WC	EC	WC
	C	W	E	W	E
	D	E	W	E	W

The pertinent summaries of analysis of variance are shown in Tables 3 and 4 for the following sets of data:

(1) Lake-run rainbow trout, summer, 1958, sorted for individual angling records;

(2) Lake-run rainbow trout, summer, 1958;

(3) All trout, exclusive of lake-run fish, fall, 1957;

(4) All trout, exclusive of lake-run fish, spring, 1958;

(5) All trout, exclusive of lake-run fish, summer, 1958.

The last three analyses were included to provide information on the efficiency of the experimental baits and fishing methods on the smaller fish in the Sturgeon River trout population. The basic data for the above-listed analyses are found in Appendix Tables 1 and 2, and consist of the hours of angling and numbers and species of trout taken by the individual anglers.

To examine the question of whether or not any interaction existed between anglers and the various experimental effects, a separate analysis treating anglers as a fixed effect was made for the data concerning lake-run fish only (Table 3). In this tabulation it was necessary to combine results from an angler and his substitute, where one man was not able to finish a series of trials. The term "time-block" refers to a pair of consecutive fishing trials. This analysis showed no significant interaction of anglers with any factor; in other words, the anglers' behavior was consistent. Furthermore, there is no evidence of difference in effectiveness among the experimental anglers.

Analysis of the angling results

Results from the test fishing have been examined in several ways. The question of greatest importance, the relative effectiveness of salmon eggs as compared to worms as bait for lake-run rainbow trout, could be tested with only one of the sets of data. Only in the summer of 1958 were enough lake-run fish

Table 3.--Summary of analysis of variance to determine if there were significant differences among anglers in fishing for lake-run rainbow trout, summer, 1958, Sturgeon River, Cheboygan County. Data taken from Appendix Table 1. Logarithmic transformation of catch per hour used Log [(Catch/hr x 100) + 1]

Source of variability	Degrees of freedom	Mean square	F value
Total	127	.....	....
Bait	1	11.1392	21.45**
Method	1	0.2450	0.47
Anglers	3	0.3580	0.69
Time blocks	7	0.6352	1.22
Bait x method	1	0.1696	0.33
Bait x angler	3	0.4112	0.79
Bait x time block	7	0.5964	1.15
Method x angler	3	0.1641	0.32
Method x time block	7	0.5228	1.01
Angler x time block	21	0.6346	1.22
Error term	73	0.5193	....

** Indicates a significant difference at the 1 percent level.

Table 4.--Summary of analyses of variance of catch of trout in test fishing, Sturgeon River and Burt Lake, Cheboygan County, Michigan. Logarithmic transformation of catch per hour used--Log [(Catch/hr x 100) + 1]--on data from Appendix Table 1

Source of variability	Lake-run rainbows only, summer, '58		All trout, excluding lake-run rainbows					
			Fall, 1957		Spring, 1958		Summer, 1958	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
Bait	1	11.14**	1	7.00**	1	15.75**	1	30.40**
Method	1	0.24	1	0.94	1	0.00	1	0.00
1/2 days	15	0.56	20	3.04**	11	3.70**	15	3.68**
Bait x method	1	0.17	1	0.00	1	0.00	1	0.08
Bait x 1/2 days	15	0.64	20	0.77	11	1.18*	15	0.92**
Method x 1/2 days	15	0.69	20	0.68	11	0.80	15	0.67
Bait x method x 1/2 days	15	0.37	20	0.44	11	0.36	15	0.26
Error	64	0.51	84	0.47	48	0.56	64	0.37
Total	127	....	167	....	95	....	127	....

* Indicates a significant difference at the 5 percent level.

** Indicates a significant difference at the 1 percent level.

captured to support an analysis of this point (Table 3). Captures of all other trout (excluding lake-run rainbows) were analyzed in a similar way (Table 4). Size and age of fish caught have been examined in lesser detail.

The analyses of the angling results during the summer season on lake-run rainbow trout show a highly significant difference between baits, favoring salmon eggs, with no other significant effects or interactions. Salmon eggs are estimated to be 3.8 times as effective as worms in catching lake-run rainbow trout (Table 5).

The catch of all other trout, excluding lake-run rainbows, agrees in all three seasonal series as to the superiority of salmon eggs over worms (Table 4). During the course of the testing, the differences between baits increased successively in the series. Fishing success increased likewise, while success with worms was highest in the spring trials (Table 4, Fig. 1). Perhaps the skill of the investigators in the use of salmon eggs increased with experience; a seasonal effect also is possible.

The analyses of variance for all trout, excluding lake-run rainbows, shows a highly significant difference among days for all three seasons. Since this means simply that fishing was measurably better on some days (and at some places) as compared to others, the only surprise is that success did not differ significantly from day to day in the catch of lake-run rainbow trout.

The interaction of bait with days was significant in the spring and summer, meaning that the differences between baits operated at different levels of effectiveness on different days. On only one of the 28 half-days did the catch on worms exceed that made on salmon eggs, thus the interaction seems to mean a varying degree of superiority of eggs from day to day, rather than a shift in superiority from one to the other bait.

Summarizing the angling results for lake-run rainbow trout, relatively poor success was recorded during the fall of 1957 and the spring of 1958, apparently because few lake-run fish were in the Sturgeon River at the time. Because of

Table 5.--Mean catch of trout per hour by experimental anglers with eggs and with worms, with and without chumming, in logarithmic units, with equivalent ratio of catch with eggs to catch with worms, for the experimental series

Experimental series	Mean catch in log. units, with standard error (in parentheses)[1]				Equivalent ratio eggs/worms with 95% confidence limits
	Eggs	Worms	Eggs chum	Worms chum	
Lake-run rainbow trout only, summer, 1958	0.716 (±0.126)	0.053	0.731	0.214	3.8 (2.2-7.0)
All other trout					
Fall, 1957	0.827 (±0.106)	0.415	0.673	0.269	2.6 (1.6-4.2)
Spring, 1958	1.572 (±0.152)	0.770	1.578	0.760	6.4 (3.2-13.0)
Summer, 1958	1.606 (±0.108)	0.683	1.645	0.622	9.3 (5.6-15.2)

[1] The standard errors are based upon pooled variance, and are the same for each mean within the same series.

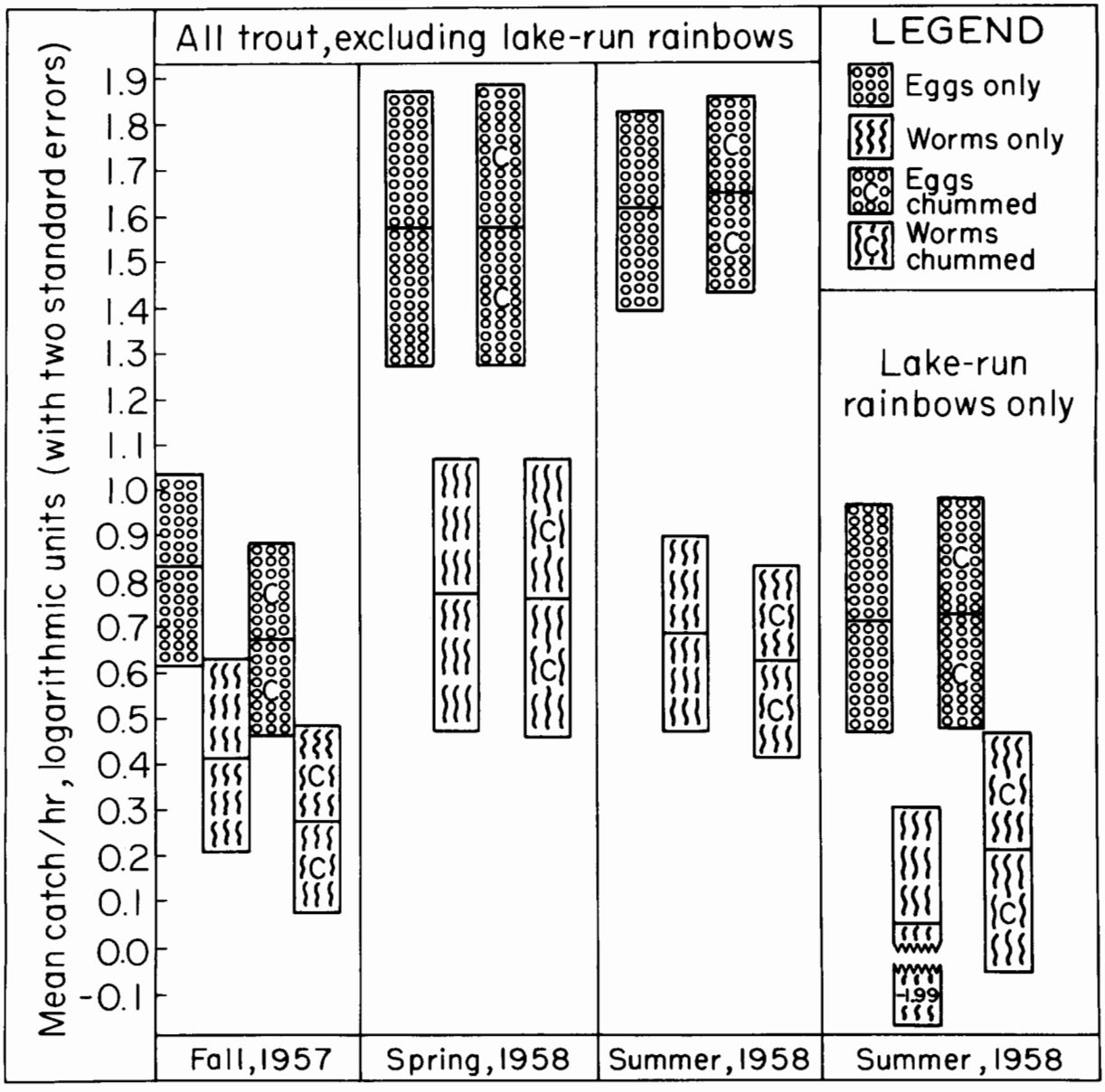

Figure 1.--Mean catch of trout per hour in the Sturgeon River, in logarithmic units (with two standard errors), by various baits and methods.

(Data from Table 5)

the few captures in these seasons, analyses of variance on data pertaining to the lake-run fish was not attempted. The 16 large fish caught during the fall of 1957 and the spring of 1958 were distributed as follows among the different fishing baits and methods: 9 by salmon eggs chummed, 4 by salmon eggs only, 2 by worms chummed, and 1 by worms only. The fishing over the summer run yielded 47 lake-run rainbow trout which provided an adequate set of data for the analysis of variance. This statistical test showed that salmon eggs were 3.8 times as efficient as worms, as bait for lake-run rainbow trout in the Sturgeon River. The analyses of variance showed also that salmon eggs took a significantly larger number of smaller trout than the same amount of fishing with worms. Chumming did not increase the efficiency of the bait for either lake-run or other trout. The period fished (or possibly the stream area) appeared to have some influence on the catch.

Of 84 lake-run rainbow trout hooked in all three series of trials, 63 (75 percent) were brought to hand. Of the 21 fish lost after hooking, most escaped by throwing the hook or tearing off. Less than five broke the terminal tackle.

The size of fish taken by the various baits and angling methods

The numbers, size range in inches, average total length and its standard error, of the trout taken during the three seasons are given in Table 6. Data on the catch with each of the two types of bait are summarized in the last two rows of the table. Rainbow trout caught on salmon eggs had an average total length of 8.6 inches; those taken on worms averaged 9.0 inches. The standard "t" test did not indicate, however, that this difference in average length was significant.

Table 6.--The number, range in total length and average total length in inches, of trout taken during the experimental fishing, Sturgeon River, 1957 and 1958

Method, lure and season	Rainbow trout				Brown trout				Brook trout			
	Number	Range	Average total length	Standard error	Number	Range	Average total length	Standard error	Number	Range	Average total length	Standard error
Eggs only												
Fall	76	4.4-15.0	7.7		4	7.3-8.3	7.7					
Spring	54	5.0-11.4	7.6		8	6.5-14.5	11.2		1	8.8	8.8	
Summer	96	5.7-15.5	9.0									
Total	226	4.4-15.5	8.2	0.16	12	6.5-14.5	9.7	0.86	1	8.8	8.8	0.00
Worms only												
Fall	11	9.5-17.5	9.5		5	6.9-12.5	9.9		2	7.2-12.3	9.8	
Spring	27	5.3-10.5	7.4		4	9.3-14.1	10.4		3	7.8-8.0	7.9	
Summer	16	7.2-14.1	8.8		2	7.5-8.0	7.8					
Total	54	5.3-17.5	8.2	0.29	11	6.9-14.1	9.7	0.66	5	7.2-12.3	8.6	0.93
Eggs chum												
Fall	29	5.6-23.7	10.0		13	6.5-12.8	8.7					
Spring	38	4.5-22.0	8.7		20	7.0-24.0	10.0		2	6.9-7.0	7.0	
Summer	105	5.7-17.0	9.0		5	8.2-11.0	9.7					
Total	172	4.5-23.7	9.1	0.25	38	6.5-24.0	9.6	0.48	2	6.9-7.0	7.0	0.07
Worms chum												
Fall	6	7.1-10.6	8.8		3	7.9-12.3	9.7		1	6.3	6.3	
Spring	19	6.0-20.5	9.4		8	7.0-14.0	9.6		3	6.3-7.8	6.9	
Summer	29	7.2-16.8	10.4		1	11.9	11.9					
Total	54	6.0-20.5	9.9	0.40	12	7.0-14.0	9.8	0.68	4	6.3-7.8	6.8	0.36
All eggs	398	4.4-23.7	8.6	0.14	50	6.5-24.0	9.6	0.41	3	6.9-8.8	7.6	0.62
All worms	108	5.3-20.5	9.0	0.26	23	6.9-14.1	9.8	0.46	9	6.3-12.3	7.9	0.39

The percentage size-frequency distribution of rainbow trout caught on salmon eggs and worms is given in Table 7. These data indicate that about 24 percent of the fish caught on salmon eggs were smaller than 7.0 inches in comparison with about 15 percent of the rainbow trout caught on worms. Chi-square tests were applied to the actual size-frequency records, after arbitrarily dividing the total catch of rainbow trout with each bait into three length categories--4.0-6.9 inches, 7.0-9.9 inches, and 10.0 inches and larger (Table 8). A Chi-square test for heterogeneity of the resulting 4 x 3 table showed highly significant differences to be present (Chi-square equals 15.75, 6 degrees of freedom, $p < 2$ percent), but most of this heterogeneity was identified by testing chumming versus no chumming for fish smaller than 7.0 inches as compared to those 7.0 inches and larger. (Such a 2 x 2 comparison yielded a Chi-square value of 12.64 [p is less than 0.1 percent with one degree of freedom].) Less than half as many fish under 7.0 inches in length were taken with chumming as without chumming, whereas bait or method had no significant effect on the catch of rainbow trout in the other two length groups. A comparison of the over-all effect of salmon eggs against worms revealed no significant difference in size of trout caught.

Age distribution of the trout captured

Scale samples were taken from 242 rainbow trout, 71 brown trout, and 13 brook trout. Several of the larger brown trout and brook trout were caught by personal angling or picked up dead along the stream, but all rainbow trout were caught during the experimental angling described above. The age distribution and the average length of fish of the various age groups is shown in Table 9. Among rainbow trout, age-groups 0 through VII were found; among brown trout (including the extra samples) age-groups I through VIII were noted; among the few brook trout collected, only age-groups I through III were present.

Table 7.--Size-frequency distribution of rainbow trout caught by experimental fishing, Sturgeon River, 1957 and 1958

Bait and angling method, season	Length (inches)													Total
	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-12.9	13.0-13.9	14.0-14.9	15.0-15.9	16 and over	
Eggs only														
Fall	2	9	17	21	12	9	2	...	1	...	2	1	...	76
Spring	1	5	12	16	8	8	2	2	...	...	...	...	...	54
Summer	...	6	15	18	27	7	1	1	1	8	8	3	1	96
Total	3	20	44	55	47	24	5	3	2	8	10	4	1	226
Worms only														
Fall	...	...	1	4	2	...	1	2	...	...	...	...	1	11
Spring	1	5	5	6	4	4	2	...	...	...	...	...	...	27
Summer	...	...	...	2	10	3	...	...	...	...	1	...	...	16
Total	1	5	6	12	16	7	3	2	0	0	1	0	1	54
Eggs chum														
Fall	...	3	7	3	3	5	2	...	...	...	...	...	6	29
Spring	1	1	6	6	10	7	3	2	...	1	...	...	1	38
Summer	...	4	7	29	30	17	1	...	...	4	7	3	3	105
Total	1	8	20	38	43	29	6	2	0	5	7	3	10	172
Worms chum														
Fall	...	...	...	3	...	1	2	...	...	...	...	...	...	6
Spring	...	...	2	1	6	7	...	2	...	...	...	...	1	19
Summer	...	...	2	5	12	4	...	...	...	...	1	2	3	29
Total	...	...	4	9	18	12	2	2	0	0	1	2	4	54
Total														
All eggs	4	28	64	93	90	53	11	5	2	13	17	7	11	398
Percent	1.0	7.0	16.1	23.4	22.6	13.3	2.8	1.3	0.5	3.2	4.3	1.8	2.8	100.0
Total														
All worms	1	5	10	21	34	19	5	4	0	0	2	2	5	108
Percent	0.9	4.6	9.3	19.4	31.5	17.6	4.6	3.7	0	0	1.9	1.9	4.6	100.0

Table 8.--Chi-square analysis of size frequency distribution of rainbow trout caught by experimental fishing, Sturgeon River, 1957 and 1958

Bait and method	Length (inches) Under 7.0	7.0-9.9	10.0 or over	Total
Eggs NC	67	126	33	226
Worms NC	12	35	7	54
Eggs C	29	110	33	172
Worms C	4	39	11	54
Total	112	310	84	506

$$\text{Chi-square } (x^2) = \frac{[(\text{Expected number} - \text{observed number}) - 0.5]^2}{\text{Expected number}}$$

Four angling methods x three size groupings

Bait and method	Under 7.0 inches Obs.	Exp.	x^2	7.0-9.9 inches Obs.	Exp.	x^2	10.0 inches or over Obs.	Exp.	x^2	Total
Eggs NC	67	50.0	5.45	126	138.5	1.04	33	37.5	0.43	226
Worms NC	12	11.9	0.00	35	33.1	0.06	7	9.0	0.25	54
Eggs C	29	38.1	1.94	110	105.4	0.16	33	28.5	0.56	172
Worms C	4	12.0	4.69	39	33.0	0.92	11	9.0	0.25	54
Total	112			310			84			506

$x^2 = 15.75$, 6 d.f., $p < 0.02$

Two baits x 3 size groupings

Bait	Under 7.0 inches Obs.	Exp.	x^2	7.0-9.9 inches Obs.	Exp	x^2	10.0 inches or over Obs.	Exp.	x^2	Total
Eggs	96	88.1	0.62	236	243.8	0.22	66	66.1	0.00	398
Worms	16	23.9	2.29	74	66.2	0.80	18	17.9	0.00	108
Total	112			310			84			506

$x^2 = 3.93$, 2 d.f., $P > 0.1$

Two angling methods x 2 size groupings

Size group	Chum	No chum	Total
Under 7.0"	33	79	112
7.0" or over	193	201	394
Total	226	280	506

$x^2 = 12.64$, 1 d.f., $p < 0.001$

Table 9.--The average length of fish of different age groups taken in experimental fishing in the Sturgeon River, 1957 and 1958

Species	Season	Average total length (inches) of fish in age group									Total samples
		0	I	II	III	IV	V	VI	VII	VIII	
Rainbow trout	Fall	5.9	7.5	9.9	13.8	18.0	23.3	...	...	...	...
		(21)	(29)	(21)	(7)	(3)	(1)	...	...	...	(82)
	Spring	...	5.8	7.4	9.4	11.4	...	20.4	22.0	...	...
		...	(23)	(23)	(39)	(1)	...	(1)	(1)	...	(88)
	Summer	...	8.3	13.4	13.8	13.5	...	...	...	...	...
		...	(21)	(25)	(25)	(1)	...	...	...	...	(72)
Brown trout	Fall	...	7.7	10.6	12.3	...	...	...	27.0[1]	...	...
		...	(11)	(5)	(3)	...	...	...	(1)	...	(20)
	Spring	...	6.5	7.8	10.1	13.0	16.6	...	...	24.0	...
		...	(1)	(13)	(18)	(6)	(2)	...	...	(1)	(41)
	Summer	...	8.3	10.5	13.3	...	18.5	16.2	...	...	...
		...	(2)	(4)	(2)	...	(1)	(1)	...	...	(10)
Brook trout	Fall	...	...	6.8	12.3	...	...	...	...	...	...
		...	...	(2)	(1)	...	...	...	...	...	(3)
	Spring	...	...	7.1	8.4	...	...	...	...	...	...
		...	...	(7)	(2)	...	...	...	...	...	(9)
	Summer	...	8.4	...	...	...	...	...	...	...	...
		...	(1)	...	...	...	...	...	...	...	(1)

[1] Picked up dead, fall, 1957.

The estimated age distribution (Table 10) of the total catch of rainbow trout by experimental fishing was determined by listing the scale samples by inch-groups and age for each season and determining what percentage of the particular inch-group consisted of I's, II's, etc. These percentages were then applied to the catch data of Table 7 for eggs and worms separately.

The data in Table 10 suggest that only in the fall season are any of the faster growing young-of-the-year rainbow trout subjected to hooking, and then mainly when eggs are used as bait. The probable explanation lies in the size of the lure as compared to the length range of this age group.

In the fall and summer fishing, yearlings (age-group I) were most commonly observed among rainbow trout caught with either eggs or worms. In the spring fishing, however, the estimated age distribution of the catch indicated that age-groups II and III were more numerous. The reasons for this variation from the fall and summer age-distribution pattern are not clear at present.

Regardless of the season of fishing, the three youngest age groups contributed approximately 90 percent of the fish hooked.

Relationship of lure restriction to reproduction of rainbow trout in the Sturgeon River

The restriction against the use of salmon eggs has been in effect since April 20, 1954 on the Sturgeon River, and since April 20, 1956 on Burt Lake and the West Branch of the Sturgeon.

No assessment of the effect of the salmon-egg restriction on natural reproduction of rainbow trout in the Sturgeon River is possible. We have no knowledge of the numbers of pre-1954 spawning adults, or of the average annual crop of fingerlings resulting from their spawning. Data from direct-current shocking for the years 1955, 1957 and 1958, furnished by Robert C. Ball of Michigan State University, indicate that natural reproduction had taken place in the West Branch of the Sturgeon River in each of those years.

Table 10.--The estimated age distribution of the total catch of rainbow trout taken by experimental fishing, Sturgeon River, 1957 and 1958

Bait	Season	Estimated numbers of fish in age group								Total
		0	I	II	III	IV	V	VI	VII	
Egg	Fall	32	37	26	6	3	1	...	...	105
	Spring	...	19	36	35	1	...	...	1	92
	Summer	...	121	47	32	1	...	...	...	201
Worm	Fall	2	7	4	4	...	...	...	...	17
	Spring	...	11	13	21	...	...	1	...	46
	Summer	...	24	12	9	...	...	...	...	45
Total	Fall	34	44	30	10	3	1	...	...	122
	Spring	...	30	49	56	1	...	1	1	138
	Summer	...	145	59	41	1	...	...	...	246

A stream survey crew from the Lake and Stream Improvement Section of the Fish Division shocked the main Sturgeon River at 23 sites with alternating-current electrofishing gear during August, 1958. Data from this operation, provided by Roger Wicklund, show that young-of-the-year rainbow trout were collected at 17 of the sampled locations. Native rainbow trout probably were also present at some of the other sites (the efficiency of the gear was rated poor at all shocking stations where young rainbow trout were not captured). Thus the most that can be stated with certainty is that natural reproduction continues in the Sturgeon River drainage at the present time. Whether it is on a higher or lower level than prior to 1954 cannot be answered from the facts at hand.

Twelve of the 47 lake-run rainbow trout caught during the summer of 1958 were recoveries from a planting of 3,000 jaw-tagged fish which had been released off the mouth of the Sturgeon River in Burt Lake on May 23, 1958. The details concerning the individual fish are listed in Table 11. Lengths at tagging were furnished by Martin Hansen. Also taken in the course of fishing during July and August were six jaw-tagged fish from the same planting which were smaller than 10 inches at the time of capture. Partly because of their size and partly because of their coloration, it is inferred that these smaller fish spent very little time in Burt Lake between May 23 and their recapture in July or August, 1958.

The 35 unmarked lake-run rainbow trout caught during the experimental fishing in July and August constituted 74 percent of the catch of larger fish. Their origin could not be determined; probably native and hatchery-reared rainbow trout were included. Burt Lake received 50,000 rainbow trout in 1956, and 37,025 in 1957 (size range in plantings, 4.2 to 10.2 inches), none of which were marked. The presence of young rainbow trout in the Sturgeon River suggests that some of the lake-run fish resulted from natural reproduction.

Table 11.--Recovery data on tagged rainbow trout taken during experimental fishing, July 24-Aug. 13, 1958 from the planting of May 22, 1958, off the mouth of the Sturgeon River, Cheboygan County. Measurements are given in inches.

Tag number	Origin[1]	Length at release	Date recaptured	Length at recapture	Increase	Days free	Location of recapture
31217	Dom.	8.4	7/30/58	11.0	2.6	68	Mouth
31230	Dom.	9.4	7/29/58	14.0	4.6	67	"
32449	W.C.S.	9.7	7/24/58	14.5	4.8	62	"
32226	"	6.6	7/25/58	16.8	10.2	63	"
32025	"	8.1	7/30/58	8.1	0.0	68	"
31529	"	11.1	7/31/58	14.8	3.7	69	6 mi. upstream
31638	"	9.4	7/31/58	14.5	5.1	69	Mouth
31976	"	10.0	7/29/58	15.0	5.0	67	"
31505	"	11.2	7/29/58	14.0	2.8	67	"
32032	"	12.3	8/12/58	16.5	4.2	71	"
31645	"	8.5	8/13/58	13.0	4.5	72	5 mi. upstream
30338	Mich. W.	7.3	7/30/58	10.0	2.7	68	Mouth
30077	"	6.4	7/31/58	7.8	1.4	69	"
29869	"	6.6	7/24/58	8.0	1.4	62	"
29783	"	6.3	7/25/58	7.2	0.9	63	"
30438	"	6.7	7/31/58	8.0	1.3	69	"
29584	"	6.1	7/29/58	6.5	0.4	67	"
29712	"	7.7	8/13/58	13.0	5.3	72	3 mi. upstream

[1] Dom. = Michigan hatchery stock.
W.C.S. = West Coast steelhead stock.
Mich. W. = Michigan wild stock.

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Report approved by G. P. Cooper

Typed by M. S. McClure

Appendix Table 1 (p. 1 of 3)

Hours fished and trout caught by individual anglers, by half-day (4-hour) test periods, according to bait and fishing method, Sturgeon River and Burt Lake, 1957. Anglers are identified by letters as follows:

S - Shetter H - Hubbell L - Lievense Ha - Hammond Ho - Houseworth

A - Allison P - Peterson M - Myers K - Knight Al - Alexander

Under trout caught, R = rainbow trout 10" and more in length, r = rainbow under 10", B = brown trout, S = brook trout.

Date, time	Angler	Bait and method: Eggs only		Bait and method: Worms only		Angler	Bait and method: Eggs chummed		Bait and method: Worms, chummed	
		Hours	Trout caught	Hours	Trout caught		Hours	Trout caught	Hours	Trout caught
Oct. 16, P.M.	S	2	0	2	0	H	2	0	2	0
	A	2	0	2	0	P	2	0	2	0
Oct. 17, A.M.	H	1	0	2	1r, 1B	S	2	0	2	0
	P	2	0	1	0	A	2	0	2	0
Oct. 17, P.M.	H	2	0	1	0	S	2	3r, 2B	2	3r
	P	1	2r	2	0	A	2	0	1	0
Oct. 18, A.M.	S	2.5	0	3	0	H	3	0	3	0
	A	3	0	2.5	0	P	3	0	3	0
Oct. 21, P.M.	H	2	0	2	0	S	2	0	2	0
	P	2	0	2	0	A	2	0	2	0
Oct. 22, A.M.	S	2	0	2	0	H	2	1R	2	0
	A	2	0	2	0	P	2	1R	2	0
Oct. 22, P.M.	S	2	1R	2	0	H	2	0	2	0
	A	2	0	2	0	P	2	0	2	0
Oct. 23, A.M.	H	2	0	2	0	S	2	1R	2	0
	P	2	0	2	1R	A	2	0	2	0
Nov. 6, P.M.	S	2	3r, 1B	2	0	H	2	1r, 1B	2	0
	A	2	0	2	1r, 1B	P	2	1r	2	1B
Nov. 7, A.M.	H	2	0	2	0	S	2	0	2	0
	P	2	0	2	0	A	2	0	2	0
Nov. 7, P.M.	H	2	2R	2	0	S	2	0	2	0
	P	2	0	2	0	A	2	1r	2	0
Nov. 8, A.M.	S	2	6r	2	0	H	2	0	2	0
	M	2	6r	2	0	P	2	3r, 1B	2	0
Nov. 8, P.M.	S	2	2r	2	2r	H	2	0	2	0
	M	2	8r, 1B	2	2r, 2S	P	2	0	2	1S
Nov. 20, P.M.	L	2	2B	2	0	S	2	1r	2	2r
	P	2	1r	2	1r	A	2	4r, 3B	2	0
Nov. 21, A.M.	S	1	0	1	0	L	1	1R	1	0
	A	1	0	1	0	P	1	0	1	0
Nov. 21, P.M.	S	2	0	2	0	L	2	0	2	0
	A	2	1r	2	0	P	2	0	2	0
Nov. 22, A.M.	L	2	5r	2	1r, 1B	S	2	3r	2	1B
	P	2	4r	2	0	A	2	2r	2	0
Nov. 25, P.M.	S	2	1R, 7r	2	2r	H	2	1R	2	0
	A	2	12r	2	0	P	2	1R, 1B	2	0
Nov. 26, A.M.	H	2	0	2	0	S	2	4B	2	0
	P	2	0	2	1B	A	2	2r	2	0
Nov. 26, P.M.	H	2	0	2	0	S	2	0	2	0
	P	2	0	2	0	A	2	0	2	0
Nov. 27, A.M.	S	2	11r	2	1B	H	2	2r	2	1r, 1B
	A	2	4r	2	0	P	2	1B	2	0
Subtotals for anglers	S	21.5	2R, 29r, 1B	22	4r, 1B	S	20	1R, 7r, 6B	20	5r, 1B
	A	18	17r	17.5	1r, 1B	A	20	9r, 3B	19	0
	H	15	2R	15	1r, 1B	H	19	2R, 3r, 1B	19	1r, 1B
	P	19	7r	19	1R, 1r, 1B	P	22	2R, 4r, 3B	22	1B, 1S
	M	4	14r, 1B	4	2r, 2S		0	...	0	...
	L	4	5r, 2B	4	1r, 1B	L	3	1R	3	0

Appendix Table 1 (p. 2 of 3)
(Continued)

Hours fished and trout caught by individual anglers, Spring of 1958

(See previous page for index to anglers and species of trout)

Date, time	Angler	Bait and method: Eggs only		Bait and method: Worms only		Angler	Bait and method: Eggs, chummed		Bait and method: Worms, chummed	
		Hours	Trout caught	Hours	Trout caught		Hours	Trout caught	Hours	Trout caught
Apr. 30, P.M.	S	2	3r	2	0	P	2	2r, 2B	2	0
	A	2	2r	2	1r	Ha	2	6r, 1B	2	0
May 1, A.M.	P	2	1r	2	0	S	2	2B	2	0
	Ha	2	0	2	0	A	2	2r, 2B, 1S	2	0
May 1, P.M.	P	2	1B	2	0	S	2	1r, 1S	2	0
	Ha	2	1r, 1B	2	1B	A	2	1R, 1r, 1B	2	0
May 2, A.M.	S	2	0	2	0	P	2	0	2	1R
	A	2	0	2	0	Ha	2	0	2	0
May 6, P.M.	P	2	0	2	0	S	2	0	2	0
	Ha	2	0	2	0	A	2	0	2	1R
May 7, A.M.	S	2	1r, 1B	2	0	P	2	1B	2	0
	A	2	5r	2	0	Ha	2	1r	2	1R, 1r
May 7, P.M.	S	2	2r	2	0	P	2	1r, 2B	2	1B
	A	2	1B	2	0	Ha	2	3r	2	0
May 8, A.M.	P	2	4r	2	1r	S	2	0	2	0
	Ha	2	10r, 2B	2	3r, 1B	A	2	6r	2	1r, 3B
May 14, P.M.	S	2	1B	2	0	P	2	1B	2	3r, 1B
	Al	2	1r, 1S	2	1r	Ha	2	1r	2	0
May 15, A.M.	P	2	0	2	0	S	2	1B	2	0
	Ha	2	1B	2	0	Al	2	4r, 1B	2	2r, 1B, 3S
May 15, P.M.	P	2	2r	2	1r	S	2	1R	2	1r
	Ha	2	3r	2	2r, 1B	Al	2	6r, 2B, 1S	2	6r, 2B
May 16, A.M.	S	2	7r	2	6r, 1B, 1S	P	2	1r, 2B	2	1r
	Al	2	12r	2	12r, 2S	Ha	2	1r, 1B	2	1r
Subtotals for anglers	S	12	13r, 2B	12	6r, 1B, 1S	S	12	1R, 1r, 4B	12	1r
	A	8	7r, 1B	8	1r	A	8	1R, 9r, 3B, 1S	8	1R, 1r, 3B
	P	12	7r, 1B	12	2r	P	12	4r, 8B	12	1R, 4r, 2B
	Ha	12	14r, 4B	12	5r, 3B	Ha	12	12r, 2B	12	1R, 2r
	Al	4	13r, 1S	4	13r, 2S	Al	4	10r, 3B, 1S	4	8r, 3B, 3S

Appendix Table 1 (p. 3 of 3)
(Concluded)

Hours fished and trout caught by individual anglers, summer of 1958

(See first page of table for index to anglers and species of trout)

Date, time	Angler	Bait and method: Eggs only — Hours	Eggs only — Trout caught	Worms only — Hours	Worms only — Trout caught	Angler	Bait and method: Eggs, chummed — Hours	Eggs, chummed — Trout caught	Worms, chummed — Hours	Worms, chummed — Trout caught
July 23, P.M.	K	2	1r	2	1r, 1B	S	2	7r	2	4r
	Ho	2	1r	2	1r	A	2	10r	2	4r
July 24, A.M.	S	2	0	2	0	K	2	2R	2	1R
	A	2	1R, 3r	2	1r	Ho	2	1R	2	0
July 24, P.M.	K	2	1R	2	0	S	2	2R	2	0
	Ho	2	0	2	0	A	2	1R, 1r	2	0
July 25, A.M.	S	2	0	2	0	K	2	0	2	0
	A	2	2R, 3r	2	0	Ho	2	0	2	1R
July 29, P.M.	S	2	2R, 1r	2	0	K	2	1r	2	2R
	A	2	1r	2	0	P	2	2R, 1r	2	0
July 30, A.M.	K	2	3R, 3r	2	1r	S	2	1R, 2r	2	0
	P	2	1R, 3r	2	1r	A	2	2r, 1B	2	0
July 30, P.M.	S	2	1R, 2r	2	0	K	2	1R, 1r	2	0
	A	2	6R	2	0	P	2	1r	2	0
July 31, A.M.	K	2	2r	2	0	S	2	2R, 1r	2	1R, 1r
	P	2	4r	2	0	A	2	1R, 1r	2	0
July 31, P.M.	S	2	5r	2	0	K	2	1R, 6r	2	1r
	A	2	5r	2	0	P	2	3r, 1B	2	0
Aug. 1, A.M.	K	2	1R, 4r	2	0	S	2	1r	2	0
	P	2	4r	2	0	A	2	1R, 11r	2	1r
Aug. 12, P.M.	S	2	0	2	0	K	2	1r	2	1R
	P	2	0	2	0	Ho	2	0	2	0
Aug. 13, A.M.	K	2	1r	2	0	S	2	1R, 1r, 1B	2	0
	Ho	2	1r	2	1r	P	2	0	2	0
Aug. 13, P.M.	S	2	1R, 1r	2	0	[illegible]	2	1R, 1r	2	0
	P	2	2r	2	0	Ho	2	3r	2	3r
Aug. 14, A.M.	K	2	7r	2	2r	S	2	6r	2	1B
	Ho	2	2R, 1r	2	1R, 1B	P	2	2r	2	1r
Aug. 14, P.M.	S	2	11r	2	3r	K	2	8r, 2B	2	2r
	P	2	4r	2	1r	Ho	2	9r	2	4r
Aug. 15, A.M.	K	2	2R, 1r	2	1r	S	2	3r	2	0
	Ho	2	2r	2	2r	P	2	3r	2	2r
Subtotals for anglers	S	16	4R, 20r	16	3r	S	16	6R, 21r, 1B	16	1R, 5r, 1B
	A	10	9R, 12r	10	1r	A	10	3R, 25r, 1B	10	5r
	K	16	7R, 19r	16	5r, 1B	K	16	5R, 18r, 2B	16	4R, 3r
	P	12	1R, 17r	12	2r	P	12	2R, 10r, 1B	12	3r
	Ho	10	2R, 5r	10	1R, 4r, 1B	Ho	10	1R, 14r	10	1R, 7r

Appendix Table 2 (p. 1 of 3)

Catch of lake-run rainbow trout per hour (converted to logarithms) by individual anglers, baits and time blocks, arranged for an analysis of variance. Each time block covers two consecutive 4-hour fishing periods (see Appendix Table 1). Each value in table represents the catch per hour by one angler during a 2-hour fishing period. Conversion to logarithms by Log [(Catch per hour x 100) + 1]

Time block	Dates	Angler	Bait and method				Sum
			Eggs	Worms	Eggs, chum	Worms, chum	
I	July 23-24	S	0.00	0.00	0.00	0.00	0.00
		A	1.71	0.00	0.00	0.00	1.71
		K	0.00	0.00	2.00	1.71	3.71
		Ho	0.00	0.00	1.71	0.00	1.71
		Sum	1.71	0.00	3.71	1.71	7.13
II	July 24-25	S	0.00	0.00	2.00	0.00	2.00
		A	2.00	0.00	1.71	0.00	3.71
		K	1.71	0.00	0.00	0.00	1.71
		Ho	0.00	0.00	0.00	1.71	1.71
		Sum	3.71	0.00	3.71	1.71	9.13
III	July 29-30	S	2.00	0.00	1.71	0.00	3.71
		A	0.00	0.00	0.00	0.00	0.00
		K	2.18	0.00	0.00	0.00	2.18
		P	1.71	0.00	2.00	0.00	3.71
		Sum	5.89	0.00	3.71	0.00	9.60
IV	July 30-31	S	1.71	0.00	2.00	1.71	5.42
		A	2.48	0.00	1.71	0.00	4.19
		K	0.00	0.00	1.71	0.00	1.71
		P	0.00	0.00	0.00	0.00	0.00
		Sum	4.19	0.00	5.42	1.71	11.32
V	July 31-Aug. 1	S	0.00	0.00	0.00	0.00	0.00
		A	0.00	0.00	1.71	0.00	1.71
		K	1.71	0.00	1.71	0.00	3.42
		P	0.00	0.00	0.00	0.00	0.00
		Sum	1.71	0.00	3.42	0.00	5.13
VI	Aug. 12-13	S	0.00	0.00	1.71	0.00	1.71
		P	0.00	0.00	0.00	0.00	0.00
		K	0.00	0.00	0.00	1.71	1.71
		Ho	0.00	0.00	0.00	0.00	0.00
		Sum	0.00	0.00	1.71	1.71	3.42
VII	Aug. 13-14	S	1.71	0.00	0.00	0.00	1.71
		P	0.00	0.00	0.00	0.00	0.00
		K	0.00	0.00	1.71	0.00	1.71
		Ho	2.00	1.71	0.00	0.00	3.71
		Sum	3.71	1.71	1.71	0.00	7.13
VIII	Aug. 14-15	S	0.00	0.00	0.00	0.00	0.00
		P	0.00	0.00	0.00	0.00	0.00
		K	2.00	0.00	0.00	0.00	2.00
		Ho	0.00	0.00	0.00	0.00	0.00
		Sum	2.00	0.00	0.00	0.00	2.00

In this table N = 128 (8 time blocks, times 4 anglers per block, times 4 catch-per-hour values per angler).

Each of the 128 catch-per-hour values is designated as a value of x.

Sum of x (128 values) = 54.86.

Sum of x^2 (128 values) = 101.3848.

Correction term (CT) for sum of squares within groups = $(54.86)^2/128$ = 23.5127.

Appendix Table 2 (p. 2 of 3)
(Continued)

Summations of logarithms of catch-per-hour data (lake-run rainbow trout) for analysis of variance

d.f. = degrees of freedom

Bait x angler

Cell	Angler	Bait		
		Egg	Worm	Sum
1	S	12.84	1.71	14.55
	A(P)	11.32	0.00	11.32
	K	14.73	3.42	18.15
	P(Ho)	7.42	3.42	10.84
	Sum	46.31	8.55	54.86

Bait x method (chum)

	Method	Bait		
		Egg	Worm	Sum
2	No chum	22.92	1.71	24.63
	Chum	23.39	6.84	30.23
	Sum	46.31	8.55	54.86

Bait x time block

	Bait	Block I	II	III	IV	V	VI	VII	VIII	Sum
3	Egg	5.42	7.42	9.60	9.61	5.13	1.71	5.42	2.00	46.31
	Worm	1.71	1.71	0.00	1.71	0.00	1.71	1.71	0.00	8.55
	Sum	7.13	9.13	9.60	11.32	5.13	3.42	7.13	2.00	54.86

Method (chum) x angler

	Angler	Method		
		No chum	Chum	Sum
4	S	5.42	9.13	14.55
	A(P)	6.19	5.13	11.32
	K	7.60	10.55	18.15
	P(Hp)	5.42	5.42	10.84
	Sum	24.63	30.23	54.86

Method (chum) x time block

	Method	Block I	II	III	IV	V	VI	VII	VIII	Sum
5	No chum	1.71	3.71	5.89	4.19	1.71	0.00	5.42	2.00	24.63
	Chum	5.42	5.42	3.71	7.13	3.42	3.42	1.71	0.00	30.23
	Sum	7.13	9.13	9.60	11.32	5.13	3.42	7.13	2.00	54.86

Angler x time block

	Angler	Block I	II	III	IV	V	VI	VII	VIII	Sum
6	S	0.00	2.00	3.71	5.42	0.00	1.71	1.71	0.00	14.55
	A(P)	1.71	3.71	0.00	4.19	1.71	0.00	0.00	0.00	11.32
	K	3.71	1.71	2.18	1.71	3.42	1.71	1.71	2.00	18.15
	P(Ho)	1.71	1.71	3.71	0.00	0.00	0.00	3.71	0.00	10.84
	Sum	7.13	9.13	9.60	11.32	5.13	3.42	7.13	2.00	54.86

	d.f.	Sum of squares
Total	7	13.4469
Bait	1	11.1392
Angler	3	1.0740
B x A	3	1.2337
Total	3	11.5538
Bait	1	11.1392
Method	1	0.2450
B x M	1	0.1696
Total	15	19.7602
Bait	1	11.1392
Block	7	4.4465
B x B	7	4.1745
Total	7	1.8112
Method	1	0.2450
Angler	3	1.0740
M x A	3	0.4922
Total	15	8.3508
Method	1	0.2450
Block	7	4.4465
M x B	7	3.6593
Total	31	18.8480
Angler	3	1.0740
Block	7	4.4465
A x B	21	13.3275

Appendix Table 2 (p. 3 of 3)
(Concluded)

Formulae for computing sums of squares, and table of analysis of variance

x = each of 128 values for catch per hour (see p. 1 of appendix Table 2)

$CT = (\Sigma x)^2/N = (54.86)^2/128 = 23.5127$

Sum of squares:

For total = $\Sigma x^2 - CT = 101.3848 - 23.5127 = 77.8721$

For anglers = $\Sigma[(\Sigma x_i)^2/N_i] - CT$ (see Cell 1, previous page)

$= \Sigma[(14.55)^2 + (11.32)^2 + (18.15)^2 + (10.84)^2]/32 - 23.5127 = 1.0740$

Each angler fished 32 two-hour periods; hence $N_i = 32$

For bait (see Cell 2) = $\Sigma[(46.31)^2 + (8.55)^2]/64 - 23.5127 = 11.1392$

One bait or the other was used on 64 two-hour periods; hence $N_i = 64$

For method (Cell 2) = $\Sigma[(24.63)^2 + (30.23)^2]/64 - 23.5127 = 0.2450$

For time blocks (Cell 3) = $\Sigma[(7.13)^2 + (9.13)^2 + \text{etc}]/16 - 23.5127 = 4.4465$

Total sums of squares for cells (see Cell 1, bait x angler)

Sum of squares = $\Sigma[(\Sigma x_i)^2/N_i] - CT$

$= \Sigma[(12.84)^2 + (11.32)^2 + (1.71)^2 \ldots \text{etc}]/16 - 23.5127 = 1.2337$

Table of Analysis of Variance

Source	d.f.	Sum of squares	Mean square	F
Total	127	77.8721	.....	....
Bait	1	11.1392	11.1392	21.45**
Method	1	0.2450	0.2450	0.47
Angler	3	1.0740	0.3580	0.69
Block	7	4.4465	0.6352	1.22
Bait x method	1	0.1696	0.1696	0.33
Bait x angler	3	1.2337	0.4112	0.79
Bait x block	7	4.1745	0.5964	1.15
Method x angler	3	0.4922	0.1641	0.32
Method x block	7	3.6593	0.5228	1.01
Angler x block	21	13.3275	0.6346	1.22
Error	73	37.9106	0.5193	....

Mean square = Sum of squares/d.f.

**Indicates a significant difference at the 1 percent level.

Appendix Notes

to supplement Appendix Table 2

This exploratory investigation asks whether there is evidence here of difference among anglers in angling effectiveness, or evidence of an interaction of anglers with some other factor. Such an interaction might arise, say, from some angler having a consistently different result from changing bait than was experienced by other anglers, i.e., perhaps a special skill with one bait. This information is desirable before proceeding to the main analysis where the identity of the paired anglers is lost, the differences between the pairs providing a measure of random sampling error. In the present analysis there is a somewhat parallel loss (confounding) of information of a different kind in the combining of half-days of fishing into time blocks. The present investigation, then, is aside from the main purpose of the study, which was to test for a difference between baits and between methods (chumming and no chumming).

This analysis considers the importance to fishing quality of four factors: bait, method (chumming), angler, and time block of two successive days. The design is that of a replicated (repeated) block, with randomization within the block not complete, in that the anglers were paired. The factors were arranged in a factorial manner, and a factorial analysis of variance is presented here.

In this analysis, all four factors were considered "fixed," i.e., not random samples of some larger population. An assumption of this analysis is that each observed value represents some general true mean value, plus or minus a random measurement error, and plus or minus some value associated with the particular bait, with the particular level of chumming, with the particular angler and with the particular time block, and in addition, further values plus or minus associated with each of the possible interactions. Thus each observed value is considered to be made up of a general mean value with an effect added

for each of the number of possible influences which can be identified here. The purpose of the analysis of variance is to identify and appraise the importance of each of these influences.

The situation may be represented as follows:

$$x = m + e + B + C + A + T + (BxC)+(BxA)+(BxT)+(CxA)+(CxT)+(AxT) + I$$

where:

m = true mean value

e = random error of measurement, involving many unidentified factors

B = effect of the particular bait

C = effect of particular angling method (chumming or no chumming)

A = effect of particular angler

T = effect of particular time block

BxC = effect of the interaction of the particular bait and the particular angling method

BxA, BxT, etc. = other first order interactions

I represents the sum of all higher order interactions (such as Bait x Method x Angler which would measure the consistency among anglers of the Bait x Method interaction).

Such higher order interactions are usually difficult or impossible to interpret satisfactorily. In the present analysis they are combined with the random error of measurement into a pooled error term. Strictly speaking, there is no direct appraisal here of the random error measurement; it is present as a component of the pooled error term.

For convenience of computation this pooled error term is calculated as the residual sum of squares remaining after the four main effects and the seven first order interactions have been subtracted from the total sum of squares. Methods of computation of the various values are illustrated; further directions for calculation may be found in Snedecor (1956).

The analysis of variance allows a test of the importance of each of the sources of variability studied, i.e., here the four main effects of bait, chum, angler and time block and the seven first order interactions among these factors. The test is the so-called "F" test, dividing the mean square associated with the effect being examined, by the appropriate error mean square which here is in each instance the pooled error term. The resulting F ratio is compared with tabulated values to determine statistical significance.

The basic notion in making the F test is that the mean square associated with the effect in question, in an experiment like this one, is made up of two components, the first due to the effect of random errors of measurement and the second due to the effect itself. If the effect in question is non-existent, then the corresponding mean square will approximate that of the error term, being greater or smaller within certain limits, due to chance of sampling. The tabled values of the F ratio state just how much greater than unity the ratio may be, purely by chance of sampling, for different significance levels. If our derived value is larger than the critical ratio, then we may state that statistically significant differences exist, since so large a difference in variances is unlikely purely by chance. If our value is smaller than the critical ratio, however, we do not have evidence for any differences greater than might be attributed to chance variation.

In the present analysis bait was the only effect where the F ratio indicated statistical significance, and this is at the 1 percent level of significance. In particular, there is no evidence of differences among anglers, or of significant interactions of anglers with other factors.