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SEXUAL MATURITY AND FECUNDITY IN BROWN TROUT OF THE PLATTE RIVER [1]

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ABSTRACT

Sexual maturity in brown trout of the Platte River begins in males when they are between 177 and 202 mm (7 and 8 inches) in length, and in females essentially when they are between 202 and 228 mm (8 and 9 inches). At these sizes, incidence of maturity in the two sexes was the same, 35%. At age I, 32% of the males and 16% of the females were mature. Incidence was virtually 100% in males when they reached 253 mm (10 inches) or age III, and 100% in females at 304 mm (12 inches) or age IV.

In the length range of 202-354 mm (8-14 inches), the average number of eggs produced per female trout by inch group ranged from 241 to 936. The largest number found among 89 fish (202-472 mm or 8.0-18.6 inches) was 2,419. Although fecundity varied widely between individuals of similar size and identical age, it was as a whole positively correlated with both size and age. The formulas for regression of egg number on length are: N = 7.3 (total length, mm) -1498.8 and N = 186.1 (total length, inches)-1,498.8. The formula for egg number by age is: N = 353.3 (age group)-155.7.

Size of eggs also varied considerably between individual fish, but like fecundity, it was correlated with size and age of females; that is, the larger and older females produced the larger eggs. Average diameter of eggs from brown trout collected in September ranged from 3.2 to 4.8 mm.

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[1] Contribution from Dingell-Johnson Project F-31-R, Michigan.

Introduction

The size at which fish attain sexual maturity and the number of eggs they produce are important considerations in the management of sport and commercial species. These aspects of fish life history may be significant factors also in survival of a species in a highly competitive situation, but the implications of this relationship are not so apparent as are those of the relationship to management.

While investigating competition between coho salmon (Oncorhynchus kisutch), brown trout (Salmo trutta) and rainbow trout (Salmo gairdneri) in the Platte River, Benzie County, I (assisted by other persons) recorded fecundity and onset of sexual maturity in the brown trout. These records are reported here.

Materials and methods

We examined 118 male and 158 female brown trout from Platte River to obtain information on sexual maturity and fecundity. These fish were collected in the fall, from 1969 through 1972. Most of them (203) were collected in 4.83 km (3 miles) of experimental water, and the remainder were obtained at three locations 1.61-6.44 km (1-4 miles) downstream.

For the egg counts, whole fish or the ovaries alone were preserved in 10% formalin. Eggs were counted 2 to 4 months after collection, following immersion in water about 3 days to remove excess formalin. Use of an egg counter similar to the one described by Haskell (1952) speeded counting.

Egg size, expressed in diameter, was obtained from volume data. The total volume of eggs from each fish was determined by water displacement. Dividing this value by the number of eggs gave the

average volume of a single egg.[2] The average diameter was calculated by the formula for finding the diameter of a sphere when the volume is known:

$$D = \sqrt[3]{6 \text{ vol.}/\pi}$$

Brown trout that had lived in Lake Michigan were differentiated from those that had lived only in the river by the distinctly different growth pattern of the scales, which resulted from much faster growth in the lake. The lake-run trout could often be recognized also by their paler color, although their hues darkened with continued residence in the stream.

Lengths of fish recorded in this report are total lengths, given both in millimeters and inches.

Sexual maturity

In the Platte River, and as reported for other populations, male brown trout attain sexual maturity at a smaller size and at an earlier age than females. Although maturity in both sexes first appeared in fish of the 177-201 mm (7-inch) size group, it essentially commenced in the 202-227 mm (8-inch) group among females. To the length of 329 mm (13 inches), females usually lagged one inch group behind males in respect to the proportion that were mature (Table 1). From the standpoint of age, incidence of maturity in females was about half of what it was in males by the end of the second summer of life. By the end of the third summer (age II), it was virtually equal (Table 2).

Nearly all males are mature when they have reached 253 mm (10 inches). Exceptions among 42 males of this size and larger were 2 immature fish in the 253-278 mm (10-inch) group, and 1 in the 279-303 mm

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[2] It is fairly certain that the preservative had altered the volume to some degree, as indicated by these two recent tests: (1) Eggs of five freshly killed brown trout that Gaylord Alexander placed in 10% formalin increased in volume about 7% on the average (range, 5-8%) over a period of 11 days. Following 14 additional days in the same solution and 3 days in water, the volumes of the complements had decreased, but still averaged 3% larger than before preservation. (2) I remeasured the eggs of five brown trout that 23-25 months previously had been measured for this study of fecundity. Three complements were unchanged, but the volumes of the other two had shrunk 3 and 8%.

(11-inch) group. Nearly all females are mature when they are 304 mm (12 inches) long. Of 46 females that were at least this size, only 2 did not contain eggs. Both were age III; their lengths were 307 mm (12.1 inches) and 373 mm (14.7 inches). It has been observed that individual females of various species of fish may be barren some years after they have attained maturity (Alm, 1959; Bagenal, 1967). This may have been the situation with these two trout, and it seems especially likely in the case of the larger one. Alm (1959) reported an instance in which approximately 17% of a group of brown trout that had spawned previously failed to produce eggs.

Fecundity

Fecundity was determined from complete egg complements of 89 brown trout that had lived in the river system all their life. The smallest of these females (193 mm or 7.6 inches, age I) contained the fewest eggs (107), and the second largest (462 mm or 18.2 inches, age IV) contained the largest number (2,419). In trout 202-355 mm (8-14 inches) long, the greater increases in number appeared in the 253-278 mm (10-inch) and 329-354 mm (13-inch) groups, amounting to 53 and 52%, respectively (Table 3). By age, the greatest increase (80%) occurred with the transition from age III to age IV (Table 4). The counts were highly variable between individual fish in all size and age groups. The extent to which egg production may vary, even between fish of nearly identical sizes, is illustrated by the following data from five females:

Length		Age	Number	Mean egg	Collection
mm	Inches	group	of eggs	diameter (mm)	date
345	13.6	II	1,255	3.9	9/7/72
348	13.7	IV	704	4.5	9/27/72
350	13.8	II	881	4.6	9/29/70
350	13.8	III	584	4.1	9/29/71
353	13.9	III	1,231	4.7	9/18/72

Despite its broad divergence among individual fish, as illustrated above, mean egg number progressively increased with length of females, and also with age, in the size range of 193-472 mm (7.6-18.6 inches) covered in this study. Tests demonstrated that the apparent increases of egg number with increase in size and age of females are statistically significant. The correlations with length ($r = 0.97$) and with age ($r = 0.98$) are significant at levels of 99.9 and 99.5%, respectively. Both relationships are linear. The formulas for regression of egg number (N) on length and age are:

$$N = 7.3 \text{ (total length, mm)} - 1498.8$$

$$N = 186.1 \text{ (total length, inches)} - 1498.8$$

$$N = 353.3 \text{ (age group)} - 155.7$$

Other studies (Allen, 1951; Hardy, 1967; Nicholls, 1958; Bagenal, 1969a) have also shown a relationship between fish length and egg number in brown trout; Allen found this relationship to be linear, whereas the other investigators found it to be curvilinear. McFadden, Cooper, and Andersen (1965) found a direct relationship between egg weight and fish weight.

The foregoing information on fecundity concerns brown trout that had been in the river all their life. Also examined were five females collected in the river that had spent from one to two growing seasons in Lake Michigan. The latter contained from 1 1/2 to 5 times more eggs (see tabulation below) than the larger of the females (355-472 mm or 14-18.6 inches) that had lived only in the river (Table 3).

Length		Age	Number	Mean egg	Collection
mm	inches	group	of eggs	diameter (mm)	date
495	19.5	II	4,895	4.3	10/20/70
507	20.0	II	3,526	5.1	9/27/72
541	21.3	III	4,118	5.1	10/28/71
553	21.8	II	4,882	5.4	11/5/70
614	24.2	III	4,148	5.3	10/28/71

Size of eggs

Measurements were obtained on eggs from fish collected during 7-30 September. Stuart (1953) noted that eggs of brown trout in Scotland have nearly attained their ultimate dimensions by September. It could not be determined whether progress of development was similar in Platte River, because insufficient samples were collected after September. In Platte River, brown trout spawn from the latter part of October into November. Average egg diameter among 70 "river" females ranged from 3.2 to 4.8 mm. The eggs borne by four of the five migrant females from Lake Michigan were larger than the largest in the "river" fish; three of the four migrant fish were captured about a month later than the "river" trout, but all five were larger also (see tabulation on page 5). Hence, it cannot be determined whether the larger size of their eggs was due more to the later time of collection or to the larger size of the fish.

Size of eggs in Platte River brown trout differed appreciably between individual fish of the same size or age. However, egg size was linearly correlated ($r = 0.81$) with length of females, and also with age ($r = 0.92$). Both correlations were significant at the 95% level. These relationships are indicated in Tables 3 and 4. A linear relationship between egg size and fish length in brown trout was observed in other studies (Hardy, 1967; McFadden et al., 1965).

Discussion and conclusions

The tendency of male brown trout in the Platte River to attain sexual maturity at smaller size and younger age than females is a common characteristic of brown trout and of other salmonids (McFadden, Cooper, and Andersen, 1965; Alm, 1959; Carlander, 1969). Information on size at maturity in brown trout of Michigan has been published on only one other population. In the Manistee River (Cooper, 1953), 80% of the females from 253 to 355 mm (10 to 14 inches) were mature, as were 100%

of those larger; incidence of maturity among Platte River females of these size groups was 85 and 96%, respectively, quite similar to that given for the Manistee River. In the range of 202-253 mm (8-10 inches), however, only about 5% of the Manistee River females were mature, as compared to 48% of those from the Platte River. Presumably better growth at early age resulted in fewer trout from the Manistee River being mature at this size.[3]

Information on fecundity in brown trout is surprisingly scarce. I combined fecundity data from various parts of the world (Carlander, 1969) into one group, and then made comparisons with data from Platte River. Among females 177-253 mm (7-10 inches) and 253-329 mm (10-13 inches) in length, the mean number of eggs per fish in the conglomerate grouping exceeded the corresponding mean for Platte River fish by 42% and 20%, respectively; however, the two means for the length interval of 329-380 mm (13-15 inches) were virtually the same--that for Platte River being less than 1% larger. Age III brown trout from the Madison River, Montana, that Brown and Kamp (1942) examined, bore on the average 80% more eggs than did the substantially smaller age III females from the Platte River. On the other hand, age IV females from the Madison River were somewhat smaller than age IV females from the Platte River, and contained 20% fewer eggs. Compared with average egg numbers computed from samples collected on various Michigan streams (Cooper, 1953), brown trout from the Platte River of the 25.4-mm (1-inch) groups from 202 through 354 mm (8 through 13 inches) produced 20-100% fewer eggs, but those 355-472 mm (14-18.6 inches) together produced 5% more.

Besides broad differences between waters, possibly fecundity in brown trout can vary significantly from year to year in a given body of water. Bagenal (1973) has recorded such variation in several species of fish other than salmonids.

Apparently little is known in regard to significance of egg size variation within specific populations. Brown trout in streams of low fertility generally produced eggs that were smaller than those produced

[3] Personal communication from Edwin L. Cooper.

by brown trout in streams of higher fertility (McFadden et al., 1965). However, experiments that Bagenal (1969a) conducted gave apparently different results on egg size; in these tests the better fed brown trout produced the smaller eggs (as determined by dry weight), as well as the greater number. In the summary of the report on his experiments, Bagenal contended that egg size ought to be determined on the basis of either dry weight or chemical composition, rather than by wet weight, as the latter "may only be a reflection of the time of spawning." Should his contention be valid, then volumetric and dimensional measurements of fresh or preserved eggs are of questionable significance also. This matter of procedure apparently deserves further investigation.

In another experiment, Bagenal (1969b) found that survival rate of brown trout fry was significantly higher for fry hatched from large eggs than those from small eggs.

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Table 1. --Sexual maturity among Platte River brown trout in relation to length [1]

Length group		Male		Female	
mm	Inches	Number examined	Percent mature	Number examined	Percent mature
152-176	6.0- 6.9	12	0	6	0
177-201	7.0- 7.9	17	35	12	8
202-227	8.0- 8.9	22	68	26	35
228-252	9.0- 9.9	25	68	22	64
253-278	10.0-10.9	20	90	23	78
279-303	11.0-11.9	14	93	23	83
304-328	12.0-12.9	2	100	13	92
329-354	13.0-13.9	0	...	9	100
355-633	14.0-24.9	6	100	24	96
Total		118	...	158	...

[1] Fish collected from 31 August to 5 November 1969-1972.

Table 2. --Sexual maturity among Platte River brown trout in relation to age [1]

Age group	Length			Number examined	Percent mature
	Mean (mm)	Standard deviation (mm)	Mean (inches)		
Males					
I	190	25.4	7.5	31	32
II	241	25.4	9.5	48	79
III	310	50.8	12.2	15	93
IV	485	....	19.1	1	100
Total	...	....	....	95	...
Females					
I	202	25.4	8.0	25	16
II	264	35.6	10.4	56	77
III	305	50.8	12.0	34	88
IV	409	66.0	16.1	12	100
Total	...	....	....	127	...

[1] Fish collected from 31 August to 5 November 1969-1972.

Table 3.--Number and size of eggs in Platte River brown trout in relation to size of females

Length group		Number of fish [1]	Number of eggs	
mm	Inches		Range	Mean [3]
202-227	8.0- 8.9	8	171- 317	241 ± 42
228-252	9.0- 9.9	14	205- 409	295 ± 39
253-278	10.0-10.9	18	291- 640	452 ± 58
279-303	11.0-11.9	18	325- 754	522 ± 66
304-328	12.0-12.9	11	413-1,073	681 ± 126
329-354	13.0-13.9	8	584-1,255	936 ± 238
355-472	14.0-18.6	12	980-2,419	1,737 ± 267
Total		89		

Length group		Number of fish [2]	Number of eggs per cubic centimeter		Mean [3] egg diameter (mm)
mm	Inches		Range	Mean	
202-227	8.0- 8.9	7	25-57	37	3.7 ± 0.3
228-252	9.0- 9.9	14	23-41	34	3.8 ± 0.1
253-278	10.0-10.9	12	22-34	26	4.2 ± 0.1
279-303	11.0-11.9	15	21-32	25	4.2 ± 0.1
304-328	12.0-12.9	7	19-28	22	4.4 ± 0.2
329-354	13.0-13.9	6	19-32	24	4.3 ± 0.3
355-472	14.0-18.6	9	17-33	23	4.3 ± 0.3
Total		70			

[1] Collected from 31 August to 5 November 1969-1972.

[2] Collected 7-30 September 1969-1972.

[3] With 95% confidence limits.

Table 4.--Number and size of eggs in Platte River brown trout in relation to age of females

Age group	Number of fish [1]	Number of eggs	
		Range	Mean [3]
I	4	107- 404	279 ± 207
II	41	190-1,255	493 ± 79
III	26	171-2,406	766 ± 216
IV	10	459-2,419	1,382 ± 477
V	1	...	1,601 ± ...
Total	82		

Age group	Number of fish [2]	Number of eggs per cubic centimeter		Mean [3] egg diameter (mm)
		Range	Mean	
I	3	25-43	35	3.8 ± 0.9
II	32	19-41	28	4.1 ± 0.1
III	20	17-57	27	4.1 ± 0.2
IV	9	19-33	24	4.3 ± 0.2
V	1	...	21	4.5 ± ...
Total	65			

[1] Collected from 31 August to 5 November 1969-1972.

[2] Collected 7-30 September 1969-1972.

[3] With 95% confidence limits.

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