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FECUNDITY OF COHO SALMON FROM LAKES MICHIGAN AND SUPERIOR [1]

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ABSTRACT

Coho salmon in five spawning runs were examined for egg number, egg size, ovary weight, nonviable eggs and eggs retained. One spawning run in a Lake Michigan tributary (Platte River) in 1969 originated from West Coast eggs while two spawning runs there in 1970 and 1972, and runs in two Lake Superior tributaries (Anna and Huron rivers) in 1970, originated from salmon that had spent their entire life in fresh water.

Numbers and sizes of eggs were significantly correlated with salmon length and weight in all spawning runs except in the Anna River, where egg size and salmon length were not correlated. For salmon from the Platte River, eggs per female averaged 3,096; average egg diameter was 7.2 mm. Weight of ovary of these salmon was about one-fourth the total body weight. Nonviable eggs comprised less than 3% of the total egg number, and egg retention of salmon found dead was about one-third of the total egg complement. There was no important difference in any of the above parameters between salmon originating from West Coast eggs and eggs produced in fresh water. Number and size of eggs from salmon produced in the Great Lakes were similar to that found for West Coast coho salmon.

For salmon in the two Lake Superior tributaries, number of eggs per female averaged 1,973; average diameter was 5.2 mm. Their ovary weight was only about one-eighth of the total body weight, the percentage of nonviable eggs was less than 1%, and one-eighth of the total egg complement was retained by salmon found dead.

Platte River fish differed from Lake Superior fish in that they had both more eggs and larger eggs, a greater percentage of their weight was made up of ovarian tissue, and they appeared to have a higher rate of egg retention.

Eggs of salmon in all five samples appeared normal in every respect, which suggests that coho salmon will become part of the indigenous fauna of the Great Lakes.

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[1] Investigations conducted under Dingell-Johnson Project F-31-R.

Introduction

Massive plantings of yearling coho salmon (Oncorhynchus kisutch) have been made in many tributaries of the Great Lakes since 1966. Survival to maturity has been excellent, and the adults have produced young. Peck (1970) reported that this was the first documented instance of natural reproduction by coho salmon which had spent their entire life in fresh water. At least a few young produced in streams by adults of hatchery origin have survived to maturity and have themselves probably spawned successfully.

The purpose of this report is to describe and compare fecundity and egg retention in five groups of coho salmon that matured in two of the Great Lakes. [2] One group originated from West Coast eggs, whereas the remaining groups originated from eggs of salmon that had spent their entire life in fresh water. Comparison of fecundity parameters should help provide an insight into the very serious problem of higher mortality rates among "freshwater" salmon eggs in hatcheries than of eggs of "saltwater" salmon (Westers, 1972). Information on fecundity should also be generally useful for hatchery production of salmon as well as aid in an understanding of wild coho salmon population dynamics in the Great Lakes region.

The stocks and methods

Origin of salmon.--Salmon were selected for examination from the 1969, 1970 and 1972 spawning runs in the Platte River, a tributary of Lake Michigan. The respective origins of these fish were 300,000 yearling coho planted in the Platte River in 1968; 1,100,000 in 1969; and 400,000 in 1971. Yearlings planted in 1968 were hatched from eyed eggs obtained from the Columbia River, and those planted in 1969 and 1971 came from eggs taken from salmon in the 1967 and 1969 Platte River runs. All of the planted fish were reared in Platte River water. There is a chance that a very few of the salmon examined were from other plants or natural reproduction.

[2] One of the five groups--the Platte River salmon of the 1969 run--was described in Research and Development Report 212, Fecundity of Coho Salmon from Lake Michigan. Stauffer, Thomas M. 1970.

The other two groups were selected from two Lake Superior tributaries. One group came from a large run of adult salmon in the Anna River in 1970. Probably, most of these were from a planting of 226,000 yearlings made at the Anna River in the spring of 1969, but a few feral salmon may have been included. Another group was collected from the Huron River in 1970. These most likely were feral salmon, but strays from hatchery plantings made in the spring of 1969 in other streams could have been present. In the case of each stream, most adults of hatchery origin came from plantings of yearlings that were produced from eggs taken from salmon in the 1967 spawning runs in several Michigan streams. Adult feral salmon were progeny of adult coho originating from Columbia River stock that were planted as yearlings in the Huron River in 1966.

Description of spawning runs.--In Platte River in 1969, the salmon run began on 8 October and extended at least through 10 December (Weaver, 1970). Females in the run averaged 711 mm long.[3] Ovary samples were obtained from 17 green salmon (average length, 677 mm) netted from a raceway at the Platte River egg-taking station on 22 October. Besides these samples, the eggs remaining in 18 salmon found dead in Platte River spawning areas on 18 November were counted.

The 1970 salmon run in Platte River began on 30 September and extended into December (Bullen, 1971). Females in the run averaged 678 mm long.[3] Ovaries were taken from 30 green salmon (average length, 638 mm) netted at the Platte River egg-taking station during 20-30 October from the same raceway that provided the 1969 samples. Dead salmon in Platte River spawning areas were examined for egg retention on the following dates (number examined in parentheses): 29 October (15), 4 November (21), 18 November (15), and 19 November (19).

The 1972 spawning run in the Platte River began in late September, peaked in early October, and continued until mid-November (Frankenberger, 1972). Average length of salmon in the run was about 660 mm. Ovaries were taken from 24 green salmon (average length, 655 mm) netted from the same raceway on 26 October.

[3] Personal communication, Clarence Taube, Fisheries Research Biologist, Michigan Department of Natural Resources.

In the Anna River, adult coho salmon were in the river as early as 11 September 1970, and were spawning as late as 18 November. Females averaged 513 mm long. Green salmon (average length, 515 mm) were obtained with electrofishing gear as follows: 9 on 11 September, 21 on 28 September, and 2 on 1 October. The 11 September and 1 October samples came from spawning areas in the river; 28 September collections were obtained at the mouth of the river. Twenty-eight dead salmon from Anna River spawning areas were sampled for egg retention on 10 November.

The small run of salmon in the Huron River in 1970 began about 17 September and lasted until 9 December or longer. The length of females averaged 491 mm. Sixteen green salmon (average length, 509 mm) were obtained with a trap net from the lower river during 25 September-12 October.

Collection of eggs.--The freshly killed salmon were weighed, measured, and scale sampled and the ovaries were weighed. The ovaries were then preserved in 5% formalin. Dead salmon checked for egg retention were measured, and retained eggs were either counted immediately or preserved for counting later on. All freshly killed salmon were 3-year-old fish. Because salmon found dead were of the same sizes as the others, I assumed that they also were 3 years old.

Egg counts and measurements.--Both viable and nonviable eggs were counted. A device of the kind described by Haskell (1952) was a very helpful aid for this job. Viable eggs had a uniform orange-red color, whereas those believed to have been nonviable when the salmon were killed were off-color. To get average egg diameters, I used a 2% random sample of viable eggs in the preserved ovaries from each fish. I first measured the total volume of the 2% sample by water displacement. Average egg volume was then obtained by dividing total volume by the number of eggs. Average diameter of the eggs from each salmon was obtained by the formula:

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

This method, of course, does not measure variation in egg size within salmon. To get this measure of variation, I weighed each egg in the 2%

random sample from eight randomly selected salmon in each of the test groups and then calculated the diameters of the individual eggs.

Statistical analysis.--Regressions, correlation coefficients (r), and 95% confidence limits were computed for various sets of parameters. Platte River data provide valid regressions for fish within the length range of about 500-800 mm and within the weight range of 1600-5300 g and Anna and Huron river data are valid for fish of around 425-600 mm and 800-2200 g (Table 1). Comparisons can be made for all sizes of salmon between the Platte River groups, and between the groups from the Anna and Huron rivers. However, comparisons among all groups can be made only within the length range of 500-600 mm and within the weight range of 1600-2200 g.

Averages (with 95% confidence limits) were used to compare similar parameters of the groups when these parameters were not strongly (or consistently) correlated with other factors (example: ovary weight-body weight ratio).

Results and discussion

Number of eggs.--There were positive and highly significant regressions for all five groups of salmon between number of eggs and length and weight as shown in Table 2 and Figures 1 and 2. The similarly high values of the correlation coefficients r for both egg number on fish length and fish weight would be expected because the length-weight relationships of the five groups were virtually straight lines (Table 2). The linear nature of the regression of egg number on fish length as determined for Michigan coho salmon is substantiated by the work of Salo and Bayliff (1958) and Drucker (1972) who found a similar relationship for Pacific coho salmon. On the other hand, Shapovalov and Taft (1954) and Allen (1958) describe the egg number-body length relationship as curvilinear. However, inspection of their data suggests that the linear equation would describe this regression nearly as well.

I was unable to find substantiating evidence for the relationship of egg number to salmon weight. However, the existence of such a

Table 1.--Distribution by length (TL) of coho salmon from lakes Michigan and Superior tributaries that were examined to measure fecundity parameters

Length (mm)	River and year				
	Platte			Anna	Huron
	1969	1970	1972	1970	1970
400-449	0	1	0	1	1
450-499	0	0	0	11	6
500-549	1	3	1	15	6
550-599	1	7	3	3	3
600-649	4	4	7	2	0
650-699	3	8	5	0	0
700-749	6	5	7	0	0
750-799	2	2	1	0	0
Total number	17	30	24	32	16

Table 2.--Correlation coefficients (r) for various parameters of Great Lakes coho salmon,[1] 1969, 1970 and 1972

* = significant at 0.05 level; ** = significant at 0.01 level

Correlations	River and year				
	Platte			Anna	Huron
	1969	1970	1972	1970	1970
Egg number-fish length	.797**	.869**	.763**	.716**	.750**
Egg number-fish weight	.802**	.848**	.814**	.771**	.876**
Fish length-fish weight	.984**	.981**	.970**	.912**	.918**
Ovary weight/body weight-fish length	-.333	-.109	.065	.366*	.423
Ovary weight/body weight-egg number	.171	.086	.437*	.724**	.676**
Ovary weight/body weight-egg diameter	-.196	.279	.120	.728**	.695**
Percentage nonviable eggs-fish length	-.202	-.054	.044	.080	.298
Percentage nonviable eggs-egg number	.020	-.223	.141	.172	.324
Percentage nonviable eggs-egg diameter	-.085	.102	.274	-.233	.504*
Percentage egg retention-fish length	.232	.095	----	-.555**	----
Egg diameter-fish length	.900**	.727**	.595**	.300	.738**
Egg diameter-fish weight	.878**	.778**	.622**	.531**	.729**
CV (egg diameter)[2] - fish length	-.536	-.163	.610	.384	.244

[1] Number examined shown in Table 1.

[2] Coefficient of variation of egg diameter for eight randomly selected salmon.

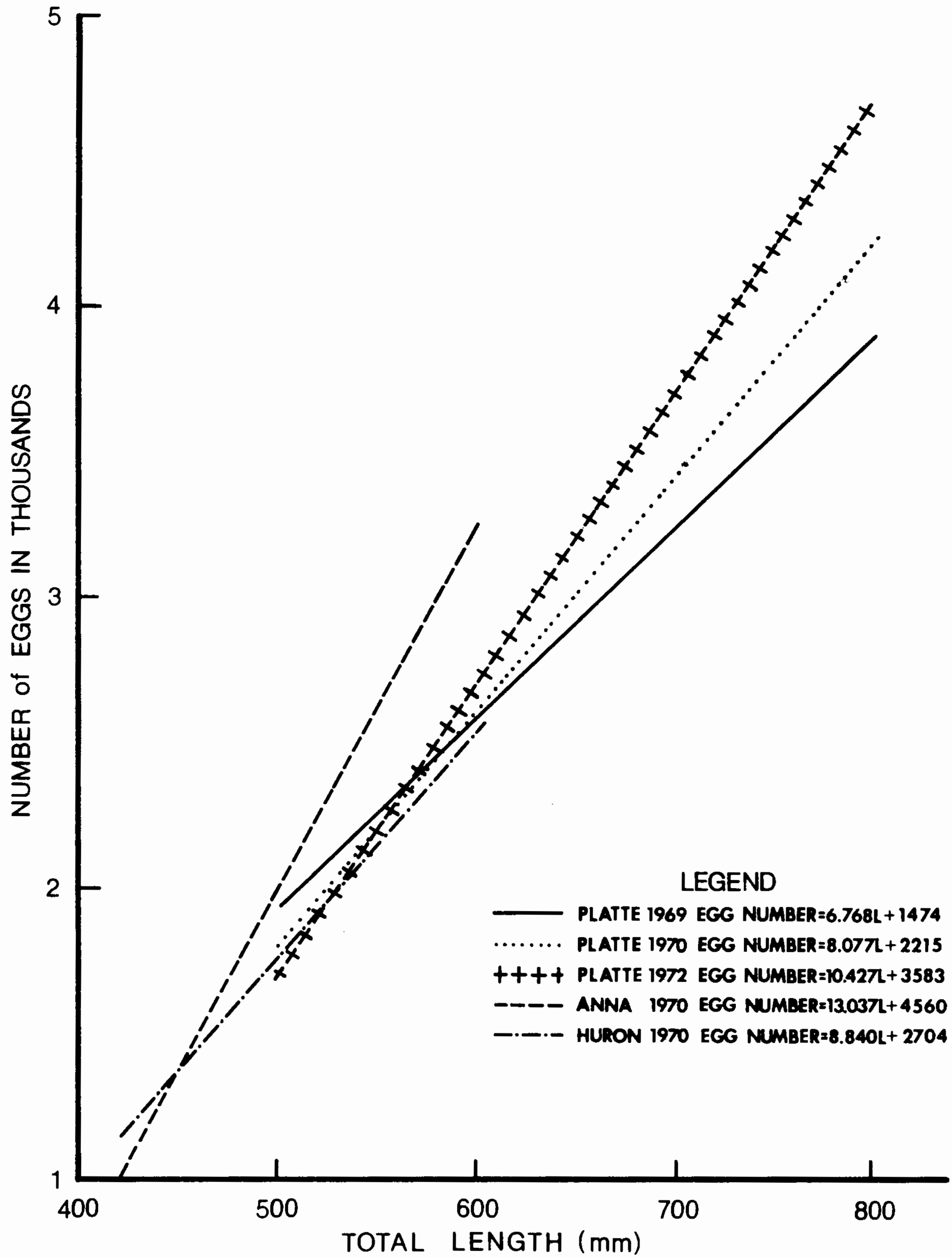

Figure 1.--Relationship of egg number to length of coho salmon from tributaries of lakes Michigan and Superior, 1969, 1970 and 1972.

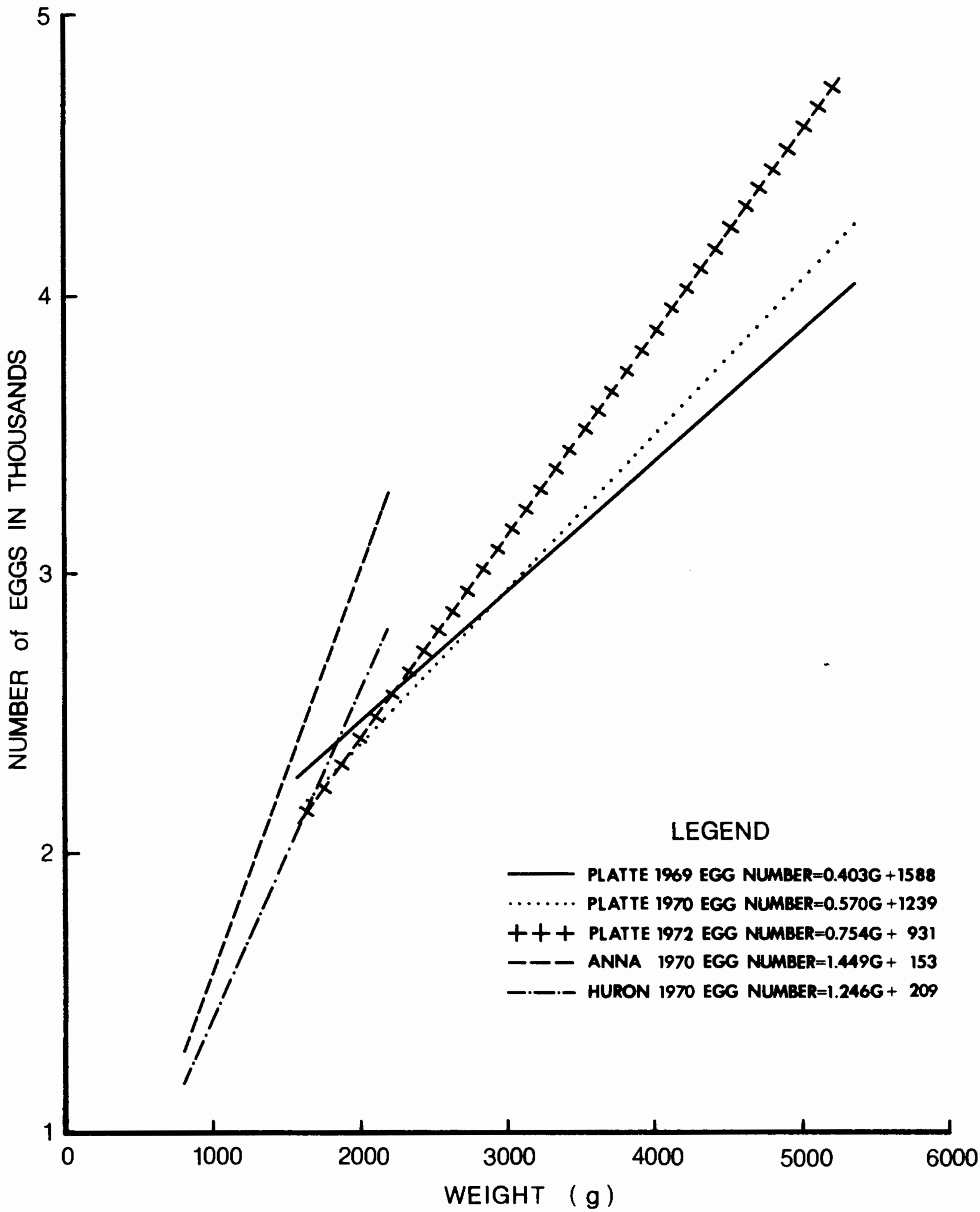

Figure 2.--Relationship of egg number to weight of coho salmon from tributaries of lakes Michigan and Superior, 1969, 1970 and 1972.

relationship seems certain because, for Michigan salmon, the relationships between weight and length are virtually linear ($r > .911$). Further, Bagenal (1969) found a relationship (albeit curvilinear) between egg number and weight in brown trout (Salmo trutta).

Confidence limits (95%) on the 10 regressions of egg number on length or weight showed that there were no differences in number of eggs produced among fish of similar size in the five groups of Michigan salmon, except that the larger salmon from the Anna River had significantly more eggs than did small salmon in the 1969 and 1970 runs in the Platte River. Overall, though, Platte River salmon, because of their greater length and weight, produced an average of 3,096 eggs as compared to 1,973 for Lake Superior fish. Production of larger numbers of eggs by Platte River fish seemed to be an indirect result of an abundant food supply in Lake Michigan as contrasted to low food production in the relatively sterile environment of Lake Superior. This confirms, for coho salmon in the wild, the positive relationship between food supply and egg number noted by Scott (1962) for rainbow trout (Salmo gairdneri) in aquariums and by Bagenal (1969) for brown trout in a hatchery.

In comparison to Pacific salmon of similar sizes (Table 3), Michigan salmon of the 500- and 600-mm size groups were more fecund than Pacific salmon of these groups; fecundity in the 700-mm group was similar in the two areas.

Ovary weight.--The ratio of ovary weight to total body weight was inconsistent in relationships with fish length, egg number, and egg diameter (Table 2). The ovary-body weight ratios of Platte River salmon in 1969 and 1970 were not related to any of these parameters; in 1972 Platte River salmon, the ratio of ovary weight to body weight was correlated only with egg number. For the Anna River, however, this parameter was correlated with fish length, egg number, and egg diameter, as it was for the Huron River fish, excepting fish length.

Because of the inconsistent relationships which could not be interpreted with any degree of reliability, a simple mean was used to compare the different groups of fish. Ovary weight of Platte River fish,

Table 3.--Number and diameter of eggs in coho salmon from various localities

Reference	Area	Avg. TL of salmon (mm)	Avg. egg diameter (mm)	Calculated number of eggs at fish length (mm) 500	600	700
This paper	Lake Michigan					
	1969	677	7.4	1900	2600	3300
	1970	638	7.1	1800	2600	3400
	1972	655	7.1	1600	2700	3700
	Lake Superior[1]	515	5.1	2000	3300	----
	Lake Superior[2]	509	5.4	1700 2	2600	----
Allen, 1968	West Coast	686	7.4	1500	2300	3300
Shapovalov and Taft, 1954	West Coast	---	7.4	----	1600	2600
Salo and Bayliff, 1958[3]	West Coast	---	---	----	1700	2400
Salo and Bayliff, 1958[4]	West Coast	---	---	----	1500	2300
Drucker, 1972	Alaska	793	6.1	----	1800	3300
Smirnov et al., 1968	Kamchatka Peninsula	657	6.8	----	----	----

[1] Anna River.

[2] Huron River.

[3] Year 1937.

[4] Year 1938.

in terms of percentage of total body weight, was almost twice that of Lake Superior salmon (Table 4). The three Platte River groups were similar among themselves, as were the two Lake Superior groups, but comparisons between the Platte River and Lake Superior groups showed significant differences.

One can only speculate as to the causes of these differences. All Platte River fish, regardless of size, probably had enough food (in the form of alewives) to elaborate copious amounts of somatic and ovarian tissue. Lake Superior fish, on the other hand, were probably somewhat restricted by food availability as well as by low water temperatures, with the result that not enough ovarian tissue was developed to fill the abdominal cavity, particularly in the smaller salmon. This suspected relationship between food supply and ovary weight-body weight ratios is not supported, however, by Bagenal's (1969) findings. These show that ovary weight-body weight ratios of starved brown trout were similar to those of fish which were better fed.

Nonviable eggs.--Except for a significant correlation with egg diameter in Huron River salmon, incidence of nonviable eggs was not correlated with fish length, egg number, or egg diameter (Table 2). The cause of the atypical correlation is unknown, but it may be related to the probable wild origin of the Huron River fish.

Because of little or no relationship between incidence of nonviable eggs and fish size, egg number, and diameter, a simple mean with 95% confidence limits was used to compare the five groups of fish. Average percentages of incidence of nonviable eggs in salmon of the five groups was low (Table 4). The only difference among the five groups was that Huron River fish had a significantly lower percentage of nonviable eggs than did the Platte 1972 and Anna River salmon. The lower incidence of nonviable eggs in Huron River salmon cannot be satisfactorily explained, although it may be related to the probable wild origin of these fish.

Egg retention.--The number of eggs retained by Great Lakes salmon found dead was high (Table 4). Although the mean value of egg retention was lower for salmon from the Anna River than for those from Platte River, the

Table 4.--Various parameters of five groups of coho salmon[1] from tributaries of lakes Michigan and Superior, 1969, 1970 and 1972

(95% confidence limits in parentheses)

Salmon group	Average length (mm)	Average weight (g)	Average number of eggs	Ovary weight[2]	Non-viable eggs[3]	Egg retention[4]	Average egg diameter (mm)
Platte, 1969	677 (37)	3535 (564)	3109 (303)	23.7 (1.4)	2.6 (2.5)	34.0 (18.8)	7.4 (0.2)
Platte, 1970	638 (30)	2979 (419)	2938 (282)	26.2 (1.3)	1.3 (1.1)	38.7 (7.6)	7.1 (0.2)
Platte, 1972	655 (25)	3081 (369)	3243 (342)	27.0 (1.3)	0.5 (0.2)	----	7.1 (0.3)
Anna, 1970	515 (14)	1387 (139)	2150 (259)	13.1 (1.4)	0.7 (0.3)	12.1 (8.6)	5.1 (0.2)
Huron, 1970	509 (23)	1274 (193)	1796 (275)	14.2 (1.7)	0.1 (0.1)	----	5.4 (0.2)

[1] See Table 1 for number examined, except for "egg retention" for which 18 were examined from the Platte in 1969, 70 in 1970, and 28 from the Anna River.

[2] Percentage of total fish weight.

[3] Percentage of dead eggs among all eggs.

[4] Percentage of original egg number. Original egg numbers were obtained from egg number-fish length relationships.

difference was only significant for the 1970 Platte River fish. Platte River fish were collected on various dates during the 1970 spawning season; there was no significant difference in percentage of egg retention between early (38.1 ± 10.8) and late (39.4 ± 11.0) arrivals. Also, there was no correlation between length of salmon and egg retention for the two Platte River groups (Table 2). There was, however, a weak negative correlation between egg retention and length of salmon from the Anna River, suggesting that smaller salmon retained more eggs than did larger salmon.

Egg retention was much higher in Michigan salmon than in West Coast coho salmon. Shapovalov and Taft (1954) reported that in West Coast salmon it was very low. Pearson, Conover and Haas (1967) examined 20 dead adult coho salmon in the Willamette River; 18 were completely spent and 2 had not spawned. High egg retention of Michigan salmon may have been due to the high density of spawning stocks in the Platte and Anna rivers. Johnson (1965) reports that high density of sockeye salmon (Oncorhynchus nerka) leads to retention of part of the egg complement. On the other hand, high egg retention of Michigan salmon may be associated with some lack in the freshwater environment.

Egg diameter.--There were positive and significant correlations (Table 2 and Figures 3-4) between mean diameter of eggs and fish length and weight, for four groups of salmon. The Anna River group was an exception because egg diameter in these salmon was not significantly correlated with fish length, although it was with fish weight. Average egg diameters of the three groups of Platte River fish were not significantly different from each other at any length or weight, but were significantly different from Huron River fish at all lengths and weights.

Significant correlation between egg size and fish size has not been demonstrated previously for coho salmon. In fact, Drucker (1972) could find no relationship between egg diameter and coho salmon length. However, Fowler (1972) states, "it is a well established fact that, with an increase in fish size, there is a corresponding increase in both egg number and weight."

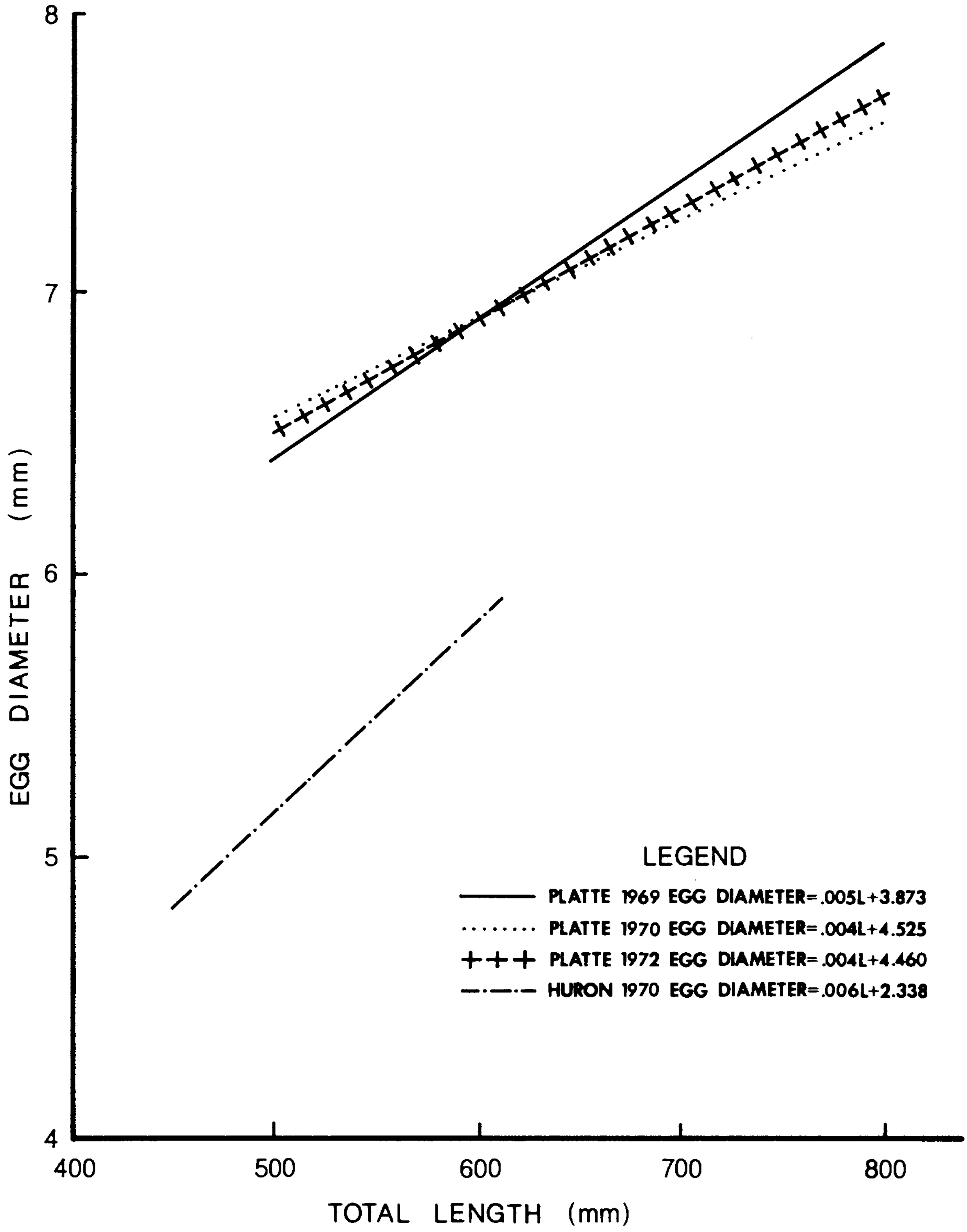

Figure 3.--Relationship of egg diameter to length of coho salmon from tributaries of lakes Michigan and Superior, 1969, 1970 and 1972.

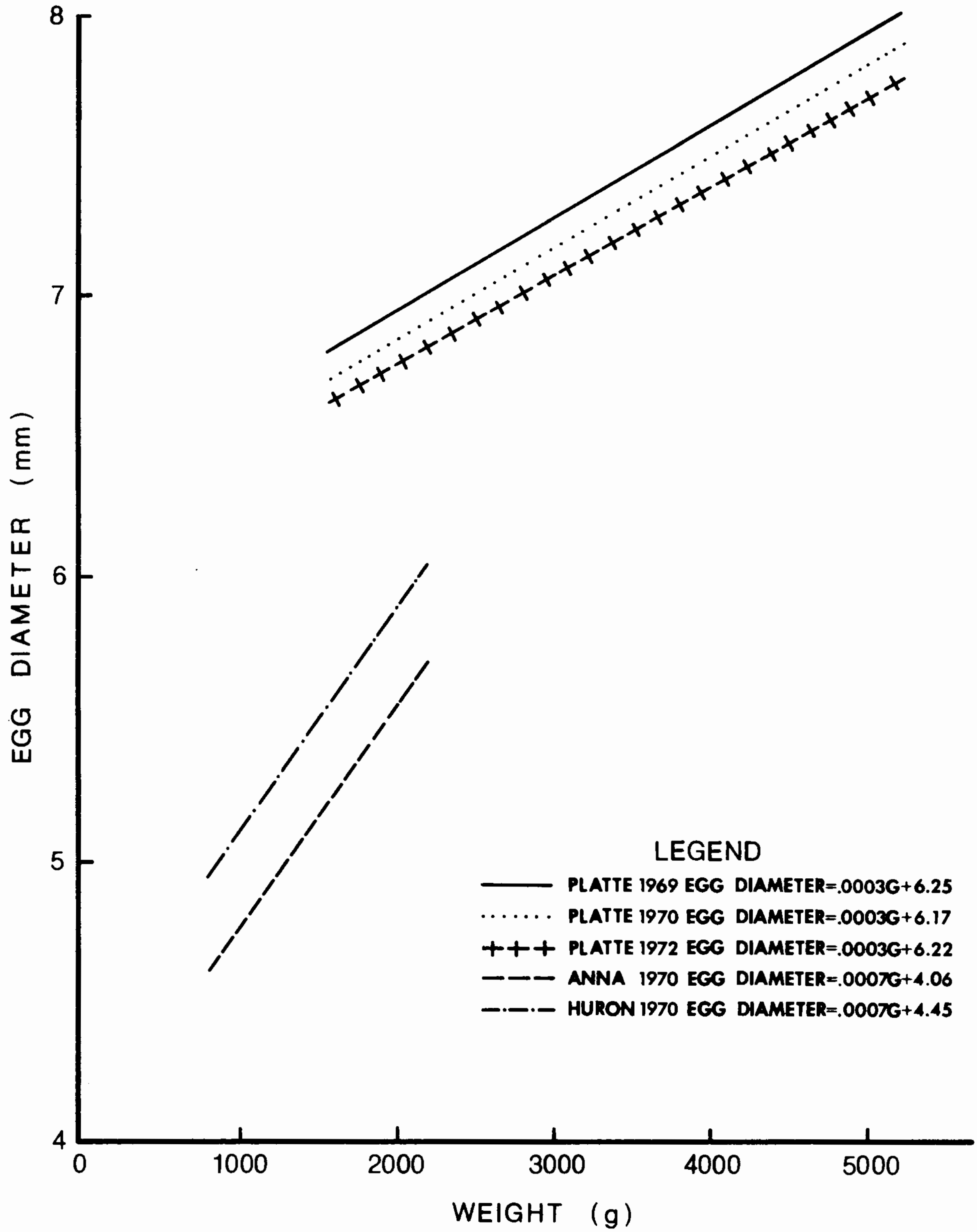

Figure 4.--Relationship of egg diameter to weight of coho salmon from tributaries of lakes Michigan and Superior, 1969, 1970 and 1972.

Overall, Platte River salmon had average diameters of 7.2 mm as compared to 5.2 mm for Lake Superior fish. This difference was significant (Table 4). By volume, Platte River salmon eggs were about three times as large as eggs of Lake Superior fish. Platte River salmon eggs were about the same size as those of Pacific salmon (Table 3).

Variations (coefficient of variation, Steel and Torrie, 1960, p. 20) of egg diameter within individual salmon, and within groups, were small and quite uniform (Table 5). Average coefficients of variation for the five groups were not significantly different. Averages were: 1.6 ± 0.4, Platte 1969; 1.8 ± 0.5, Platte 1970; 1.3 ± 0.5, Platte 1972; 1.6 ± 0.4, Anna; and 1.6 ± 0.3, Huron. Variation in egg size was not associated with fish length because regressions of CV on fish length, for each of the five groups of eight salmon, were not significant (Table 2). Uniformity of egg diameter within coho salmon was in agreement with Brown (1957) who states: "If the spawning period is short, all of the maturing eggs will be of about the same size."

Summary

Fecundity parameters of salmon from Platte River collected in 1970 and 1972, which originated from salmon that had spent their entire life cycle in fresh water, were compared to salmon collected in 1969, which originated from West Coast eggs. The two types were not significantly different in (1) number of eggs produced, (2) percentage of nonviable eggs, (3) egg retention, (4) egg diameter or (5) variation in egg size within salmon. The ratios of ovary weight to total body weight of salmon in 1969 and 1970 were not different, but there was a significant difference between fish in 1969 and 1972. Also, fecundity parameters of the 1970 and 1972 Platte River salmon did not differ much from those that are published for coho salmon from the Pacific Ocean. Egg number and egg diameter were about the same. Egg retention was much higher in the Platte River, perhaps due to the very high density of salmon. Thus, there was little difference in fecundity parameters between freshwater salmon and saltwater salmon. One must look elsewhere for clues to the cause of high mortality of eggs from freshwater salmon.

Table 5.--Average diameter (mm) and coefficient of variation (CV) of eggs from randomly selected coho salmon,[1] 1969, 1970 and 1972

River and year									
Platte 1969		Platte 1970		Platte 1972		Anna 1970		Huron 1970	
$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV
6.8	1.9	6.7	1.5	6.9	0.8	5.1	1.2	5.0	1.3
7.3	1.7	6.5	2.0	6.9	1.3	4.3	1.2	5.7	1.8
7.2	2.1	5.9	2.9	7.3	1.0	5.1	2.1	5.3	1.1
7.8	1.3	7.1	2.2	6.5	1.5	5.5	1.2	5.3	1.6
7.8	1.6	7.0	1.2	7.2	2.0	5.4	2.0	5.8	1.8
7.6	1.0	7.6	1.0	7.0	1.2	5.1	1.6	5.3	1.8
7.7	2.0	7.7	1.5	7.4	1.0	5.2	2.4	5.8	2.2
7.9	1.0	7.6	2.4	7.2	2.0	5.9	1.3	5.8	1.0

[1] Length ranges (mm) were: Platte 1969, 549-782; Platte 1970, 521-737; Platte 1972, 587-734; Anna, 455-561; and Huron, 406-564.

There were only minor differences in fecundity patterns between Anna and Huron river salmon even though their origins probably were different. Anna River fish were reared for 1 year in the hatchery, whereas the Huron River fish were very likely of wild origin.

Platte River fish, which matured in Lake Michigan, differed from Lake Superior fish in these respects: (1) they had more and larger eggs, (2) a greater percentage of their weight was made up of ovarian tissue and (3) their rate of egg retention appeared to be higher.

Various investigators have considered the causes of variations in number and size of fish eggs. Some contend that it is genetically controlled, and others say environmental factors are responsible. A distinctive difference in these parameters between salmon from a very productive environment (Lake Michigan) and salmon from a relatively sterile environment (Lake Superior) indicates that egg number and egg size were determined by environment.

Eggs of Great Lakes salmon appeared normal in every respect. This, coupled with high fecundity and observed natural reproduction (Stauffer, unpublished data), suggests that coho salmon may well become part of the indigenous fauna of the Great Lakes.

Acknowledgments

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