Some environmental influences on egg production in brown trout (Salmo trutta) from Montana streams
by Lawrence L Lockard

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Fish and Wildlife Management
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Abstract:
The relationships between selected parameters of 17 Montana streams and the attainment of sexual maturity and fecundity of their resident female brown trout were studied. Fish from the streams having conductivity and alkalinity levels greater than 100 micromhos/ cm and ppm $CaCO_3$ respectively, were younger at sexual maturity than fish from waters with lower levels. The attainment of earlier sexual maturity in fish from the former streams could not be completely explained on the basis of greater growth rates. Fish from the stream having the highest levels of conductivity had the slowest growth rate but became sexually mature at the youngest age. A positive relationship was found between chemical fertility (conductivities from 70 to 402 micromhos/cm) of streams and the fecundity of their fish. However, in the stream having the highest levels of conductivity, fish were the least fecund. It was concluded the chemical fertility of their streams is generally related to the age at sexual maturity and fecundity of fish except in fish from Bluewater Creek.

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Date June 7, 1974

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LAWRENCE L LOCKARD

A thesis submitted to the Graduate Faculty in partial
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ABSTRACT

The relationships between selected parameters of 17 Montana streams and the attainment of sexual maturity and fecundity of their resident female brown trout were studied. Fish from the streams having conductivity and alkalinity levels greater than 100 micromhos/cm and ppm $CaCO_3$ respectively, were younger at sexual maturity than fish from waters with lower levels. The attainment of earlier sexual maturity in fish from the former streams could not be completely explained on the basis of greater growth rates. Fish from the stream having the highest levels of conductivity had the slowest growth rate but became sexually mature at the youngest age. A positive relationship was found between chemical fertility (conductivities from 70 to 402 micromhos/cm) of streams and the fecundity of their fish. However, in the stream having the highest levels of conductivity, fish were the least fecund. It was concluded the chemical fertility of their streams is generally related to the age at sexual maturity and fecundity of fish except in fish from Bluewater Creek.

INTRODUCTION

The size and age at sexual maturity and the fecundity of female fish appear to be related to features of their environment. In Pennsylvania, brown trout *(Salmo trutta)* from infertile waters had a smaller proportion of mature fish per age class and a smaller weight of eggs than comparable fish from fertile waters (McFadden, Cooper and Anderson 1965). Although taken in the same ocean hauls, chinook salmon *(Oncorhynchus tshawytscha)* from the Sacramento River had twice the egg compliments of those from the Klamath River (McGregor 1922 and 1923). Scott (1962) and Bagenal (1969) demonstrated rainbow trout *(Salmo gairdneri)* and brown trout brought a lower number of eggs to maturity under reduced nutritional levels than fish on higher levels of nutrition.

This study is an attempt to determine the relationships between selected environmental parameters and egg production in brown trout from streams in Montana. Welch (1952), Rawson (1951, 1960), Reimers, Maciolek and Pister (1955), Northcote and Larkin (1956), Moyle (1949, 1956), and Carlander (1955) recognized conductivity and alkalinity as indicators of the fertility of water. In this study associations between conductivity and alkalinity with size and age of fish at maturity were determined. Also the interrelations of conductivity, alkalinity, discharge and standing crop and their relations to fecundity of brown trout in Montana streams were studied. Field collections were made from September 8, to October 23, 1972 and from September 1, to October 19, 1973.

METHODS

A total of 449 female brown trout were collected by electrofishing. Collecting sites were located on streams belonging to the Clark Fork of the Columbia, Yellowstone and Missouri River drainages (Figure 1). These streams had a wide range of physical, chemical, and biotic conditions (Table 1).

At least one fall, winter, and summer measurement of conductivity and alkalinity was made at each collecting site. The field measurements from each stream were averaged with the yearly conductivity and alkalinity averages obtained from Water Resources Data for Montana (U. S. G. S., 1972) when available for a stream. Discharge values were obtained by averaging available yearly values from the above U. S. G. S. records with values measured or estimated by fisheries biologists of the Montana Fish and Game Department. All U. S. G. S. data were obtained from stations near the collecting sites. Eight of the 11 values for standing crops of trout were obtained from Progress Reports of the Montana Fish and Game Department, Fisheries Division. The standing crop estimates for the two collecting sites on Bluewater Creek were obtained by averaging data from Graham (unpublished data) with those of Peters (1971). Standing crop information for Rock Creek is from Gunderson (1966). Discharge was found to be inversely related to standing crop.

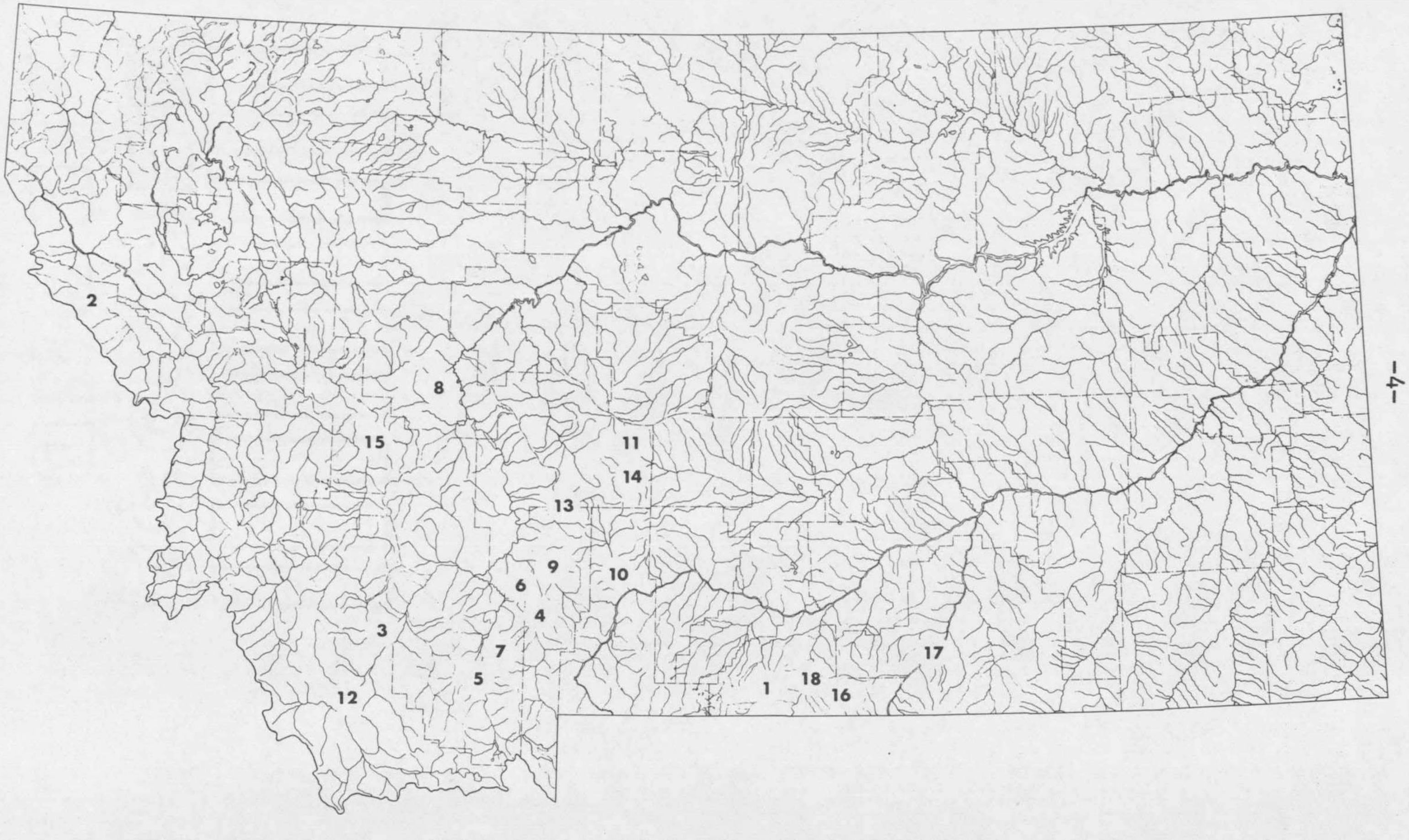

Figure 1. Map showing location of collecting sites.

TABLE 1. SELECTED CHEMICAL, PHYSICAL AND BIOTIC FEATURES OF STREAMS SAMPLED.

Collection Site No.[1]	Location of Site	Conductivity (micromhos/cm)	Alkalinity (ppm $CaCO_3$)	Discharge (C.F.S.)	Standing Crop (lbs. trout/surface acre)
1	Rock Cr.	70	49	169	132
2	St. Regis R.	80	51	555	49
3	Big Hole R.	207	117	1125	36
4	W. Gallatin R.	230	118	791	---
5	Madison R.	249	107	1409	31
6	Baker Cr.	317	154	70	---
7	O'Dell Cr.	348	167	100	101
8	L. Prickley Pear Cr.	358	195	69	226
9	E. Gallatin R.	360	195	400	135
10	Shields R.	402	221	159	---
11	Flagstaff Cr.	405	197	5	---
12	Beaverhead R.	521	193	405	265
13	16 Mile Cr.	522	195	50	336
14	So. F. Musselshell R.	561	243	83	---
15	Little Blackfoot R.	612	188	105	---
16	Bluewater Cr.[2]	798	209	18	122
17	Big Horn R.	805	188	3500	---
18	Bluewater Cr.[3]	1387	214	28	202

[1] See Figure 1.

[2] Section above Bluewater Fish Hatchery.

[3] Section below Bluewater Fish Hatchery.

All fish were collected during September and October of 1972 and 1973 (Table 2). Fish taken were preserved in 10 percent formalin, and later washed in water and stored in 40 percent isopropyl alcohol. Fixation in formalin causes specimens to shrink about 3-4% in length and increase 5-12% in weight (Parker 1963). After preservation, fish were measured, weighed, and scale samples were removed for age determinations. Each fish was classified as mature or immature according to the condition of the eggs in its ovaries. Fish with short, narrow ovaries containing only eggs less than about 1 mm in diameter were classified as immature. Fish having relatively long ovaries with at least some enlarged eggs were classified as mature. However, not all mature fish were used in the fecundity analyses. Mature fish containing eggs in a gradient of sizes were not used because the number of eggs is reduced by resorption throughout the maturation period and regressing eggs could not be distinguished from maturing eggs in these fish. Only fish having distinct recruitment and maturing eggs without intervening size classes of eggs were used in fecundity work. The ovaries from these fish were removed and the number of maturing eggs determined by actual count.

The streams from which collections were made were grouped into classes primarily on the basis of similarities in conductivities following the technique used by McFadden, *et al.* (1965). Streams from which collections 1 and 2 were taken each had less than 100 units

TABLE 2. THE LOCATION, DATE AND NUMBER OF FISH COLLECTED.

Collection Site	1972 Collection Date	1972 Number Fish	1973 Collection Date	1973 Number Fish	Total Fish
1 (Rock Cr.)	Oct. 13	16	Sept. 14	17	33
2 (St. Regis R.)	--	--	Sept. 1	22	22
3 (Big Hole R.)	Oct. 9	17	--	--	17
4 (W. Gallatin R.)	Oct. 18	17	Sept. 25	11	28
5 (Madison R.)	Sept. 21	13	Sept. 20	19	32
6 (Baker Cr.)	Oct. 10	17	Sept. 26	9	26
7 (O'Dell Cr.)	Sept. 22	11	Sept. 21	8	19
8 (L. Prickley Pear Cr.)	Oct. 23	16	Oct. 2	17	33
9 (E. Gallatin R.)	Sept. 18	15	Oct. 4	16	31
10 (Shields R.)	Oct. 6	11	Sept. 24	6	17
11 (Flagstaff Cr.)	Oct. 9	9	--	--	9
12 (Beaverhead R.)	Sept. 26	14	Oct. 17	9	23
13 (16 Mile Cr.)	Sept. 11	13	Oct. 11	14	27
14 (So. F. Musselshell R.)	--	--	Sept. 24	13	13
15 (Little Blackfoot R.)	--	--	Oct. 1	28	28
16 (Bluewater Cr.)[1]	Sept. 8	13	Sept. 12	14	27
17 (Big Horn R.)	--	--	Sept. 15	14	14
18 (Bluewater Cr.)[2]	Sept. 8	13	Sept. 12	37	50

[1] Section above Bluewater Fish Hatchery.

[2] Section below Bluewater Fish Hatchery.

of conductivity and formed Class I. Class II contained streams on which collection sites 3 through 11 were located. These streams had conductivities ranging from 207-405 micromhos/cm at 25° C. Streams of collecting sites 12 through 15 had conductivities of from 521-612 and comprised Class III except for the analysis of size and age at sexual maturity in which Stream 17 was included. The streams of Class II and III were combined into Class IV because their fish had similar relationships to chemical parameters. Class V was made up of Bluewater Creek on which collecting sites 16 and 18 were located. These collecting sites were grouped together primarily because of their high conductivities.

The fish in stream classes were statistically compared by selected procedures and techniques from "Statistical Methods" (Snedecor and Cochran 1971) and "Statistical Methods" (Arkin and Colton 1972). Additional techniques were provided by Dr. R. E. Lund, Mathematics Department, Montana State University.

RESULTS

Size and Age of Sexually Mature Female Brown Trout

Generally the attainment of sexual maturity of fish is dependent on size and age. Inspection of age groups within stream classes indicated an apparent tendency for a higher proportion of the larger females to be sexually mature (Table 3). To test the linearity of this trend regressions were made on fish from age groups in stream classes showing an increase in sexual maturity with increasing length. Z values calculated from these regressions of percents of maturity on fish lengths were compared to tabular Z values (Snedecor and Cochran 1971) to obtain probability values. In age group I, fish from Class V streams showed a significant positive linear relationship between length and sexual maturity ($P = 0.001$). In age group II, a significantly higher proportion of larger fish were sexually mature in Stream Classes I, II, III, and IV with P values of less than 0.05. In age group III+, fish from Stream Classes II and IV had significant positive linear relationships between length and sexual maturity ($P < 0.05$). McFadden, *et al.* (1965) found a tendency within a given year class for a higher percentage of larger than smaller fish to be sexually mature.

The effect of age on the attainment of sexual maturity in fish was determined by comparing the proportions of sexually mature fish

TABLE 3. SIZE AND AGE OF SEXUALLY MATURE FEMALE BROWN TROUT BY STREAM CLASSES.

		Stream Classes									
		I		II		III		IV		V	
Age Group	Length (inches)	#Fish	%Mat.	#Fish	%Mat.	#Fish	%Mat.	#Fish	%Mat.	#Fish	%Mat.
I											
	4.0-4.9	0	--	0	--	0	--	0	--	5	0
	5.0-5.9	0	--	0	--	0	--	0	--	3	33
	6.0-6.9	3	0	0	--	0	--	0	--	16	31
	7.0-7.9	4	0	1	0	0	--	1	0	17	47
	8.0-8.9	1	0	7	0	2	0	9	0	6	100
	9.0-9.9	1	0	6	0	5	0	11	0	0	--
	10.0-10.9	0	--	11	0	10	0	21	0	0	--
	11.0-11.9	0	--	0	--	7	0	7	0	0	--
	12.0-12.9	0	--	0	--	2	0	2	0	0	--
	13.0-13.9	0	--	0	--	2	50	2	50	0	--
	Total	9	0	25	0	28	4	53	2	47	43
II	6.0-6.9	0	--	0	--	0	--	0	--	1	100
	7.0-7.9	0	--	0	--	0	--	0	--	6	67
	8.0-8.9	2	0	1	0	0	--	1	0	6	83
	9.0-9.9	9	33	5	0	2	0	7	0	5	100
	10.0-10.9	6	33	16	13	9	11	25	12	1	100
	11.0-11.9	1	100	29	31	3	0	32	28	1	100
	12.0-12.9	2	100	23	61	9	22	32	50	4	100
	13.0-13.9	1	100	9	67	7	57	16	63	0	--
	14.0-14.9	0	--	19	84	3	100	22	86	0	--
	15.0-15.9	0	--	3	67	5	80	8	75	0	--
	16.0-16.9	0	--	1	100	4	100	5	100	0	--
	17.0-17.9	0	--	1	100	3	100	4	100	0	--
	18.0-18.9	0	--	0	--	2	100	2	100	0	--
	19.0-19.9	0	--	0	--	1	100	1	100	0	--
	Total	21	43	107	48	48	50	155	48	24	88

TABLE 3. Continued.

Age Group	Length (inches)	Stream Classes I		II		III		IV		V	
		#Fish	%Mat.	#Fish	%Mat.	#Fish	%Mat.	#Fish	%Mat.	#Fish	%Mat.
III+											
	8.0-8.9	0	--	0	--	0	--	0	--	1	100
	9.0-9.9	0	--	0	--	0	--	0	--	1	100
	10.0-10.9	3	67	1	0	0	--	1	0	0	--
	11.0-11.9	8	75	3	67	1	100	4	75	2	100
	12.0-12.9	1	100	4	100	2	100	6	100	0	--
	13.0-13.9	5	100	12	92	6	100	18	94	0	--
	14.0-14.9	2	50	13	92	4	75	17	88	1	100
	15.0-15.9	2	100	16	100	9	100	25	100	1	100
	16.0-16.9	2	100	14	93	1	100	15	93	0	--
	17.0-17.9	1	100	8	100	2	100	10	100	0	--
	18.0-18.9	1	100	5	100	3	100	8	100	0	--
	19.0-19.9	0	--	3	100	1	100	4	100	0	--
	20.0-20.9	0	--	1	100	0	--	1	100	0	--
	Total	25	84	80	94	29	97	109	95	6	100
	Grand Total	55	55	212	59	105	51	317	57	77	61

between age groups by a technique of R. E. Lund. The calculated Z value from each comparison was compared to a tabular value in Snedecor and Cochran (1971) to obtain its probability value. Only 2% of age group I fish 8.0-13.9 inches long from Class IV streams were mature, while 34% of comparable fish in age group II were mature. The difference in proportions was significant with a P= 0.001. There were significantly fewer mature 6.0-8.9 inch fish from Class V streams in age group I than in age group II (P= 0.08). The Z value from the above test between age groups I and II for 8.0-13.9 inch fish from Class IV streams and the value from the comparison of 6.0-8.9 inch fish from Class V streams were combined by a method of Snedecor and Cochran (1971). This combined Z value demonstrated a significantly (P= 0.001) higher proportion of age II fish were mature than age I fish. Significantly more of size group 10.0-19.9 inch fish from Class IV streams were mature at age III+ than age II (P= 0.001). This relationship of a higher percent of older females being sexually mature than younger females in the same size group has been reported by McFadden, *et al.* (1965).

Comparisons were made of the proportions of sexually mature female brown trout between stream classifications using a method of Arkin and Colton (1972). No significant difference (0.05 level of significance) was found in the proportion of mature females in Class II and III streams either by age group or grand total so further comparisons by this method were made between the fish of Stream Classes I, IV and V.

There was no significant difference between Class I and IV steams in the proportions of mature females in age group II, however, Class IV streams had a significantly higher proportion of mature females in age group III+ than did Class I streams (P= 0.054). Class V streams had a higher proportion of sexually mature females than both Class I and IV streams in both age group I (P= 0.014 and 0.001, respectively) and age group II (P= 0.001 and 0.001, respectively).

Fisher's randomization test (Bradley, 1968) was used to further test the hypothesis that maturation increases as conductivity increases. The probability of obtaining the increased proportions of mature fish in all age groups with the increasing conductivities in Stream Classes I, II, III, and V (Table 3) is P= 0.00014. If age group I is omitted, the P-value is 0.002, and if in addition Stream Class V is omitted, the P-value is 0.028.

The Class I and IV streams in this study were similar in conductivity and alkalinity to the infertile and fertile streams in the studies of McFadden and Cooper (1962) and McFadden, *et al.* (1965). In the latter study it was found that fish from fertile waters attained maturity at an earlier age than those from infertile waters. This was attributed partially to a greater growth rate of fish in fertile waters; however, they also found that higher proportions of fish of the same size and age were sexually mature in fertile streams.

In the present study, this latter relationship was not observed among fish from Class I and IV streams. Instead, higher proportions of females of a given size and age tended to be mature in the less fertile Class I streams. The differences in age at maturity between fish from Stream Classes I and IV therefore seem closely related to differences in growth rate. The distribution of sizes of specimens of given age groups do indicate faster growth rates in Class IV streams (Table 3). McFadden and Cooper (1962) also reported positive correlations between growth rates of brown trout and environmental fertility.

Class V streams had higher conductivity and alkalinity values than any of the streams studied by McFadden, *et al.* (1965). In the more fertile waters (Class V) fish matured at younger ages than in less fertile waters (Classes I through IV), however, this early maturity in Class V streams was not due to a faster growth rate in fertile waters. That is, the smallest fish in each age group are found in the Class V streams (Table 3). Therefore, some factor other than growth rate or chronological age apparently influenced the size and age at which sexual maturity was reached by fish from the very fertile (chemically) waters of Class V.

Fecundity

Regression analyses for the number of mature eggs in a fish (dependent variable) on fish length and weight (independent variables) were applied to the fish of the individual streams and stream classifications listed in Table 4. Flagstaff Creek and the Big Horn River were omitted from analyses because they lacked a sufficient number of mature fish. T tests for the regressions of numbers of eggs on lengths were statistically significant at the 0.05 level for fish from all streams and stream classifications with most P values being less than 0.01. The T tests for the regressions of number of eggs on weight were also statistically significant at 0.05 level for fish from all streams and stream classifications with only the regressions from the Beaverhead River and South Fork of the Musselshell River having P values greater than 0.01. The regressions of number of eggs on fish weight had R^2 values closer to 1 than the regressions on fish length in 17 of the 21 cases demonstrating they generally better described the variation in numbers of eggs than the regressions on length, although both were significant at the 0.05 level. The R^2 values for regressions of fecundity on fish weight are high because weight is dependent on fecundity.

The regression lines of number of eggs regressed on length and weight of fish in stream classifications are shown in Figures 2 and 3, respectively. The regression lines with steeper slopes show a greater increase in number of eggs per increment of length or weight than lines with lesser slopes. The relationship between the conductivity of individual streams and the fecundity of their fish is illustrated in

TABLE 4. STATISTICS FROM SIMPLE REGRESSIONS OF NUMBER OF EGGS ON LENGTH AND WEIGHT OF FISH.

Stream or	Number of Eggs Regressed on Fish Length				Number of Eggs Regressed on Fish Weight			
Classification	T	df	P	R^2	T	df	P	R^2
Rock Cr.	9.91	17	0.000	0.86	10.84	17	0.000	0.88
St. Regis R.	3.72	11	0.002	0.58	4.34	11	0.001	0.65
Stream Class I	11.41	29	0.000	0.82	10.64	29	0.000	0.80
Big Hole R.	7.15	6	0.000	0.91	9.15	6	0.000	0.94
W. Gallatin R.	5.17	13	0.000	0.69	5.54	13	0.000	0.72
Madison R.	7.19	15	0.000	0.79	8.45	15	0.000	0.84
Baker Cr.	3.08	12	0.005	0.46	4.12	12	0.001	0.61
O'Dell Cr.	4.83	13	0.000	0.66	5.52	13	0.000	0.72
L. Prickley Pear Cr.	5.50	15	0.000	0.68	5.03	15	0.000	0.64
E. Gallatin R.	7.53	18	0.000	0.77	11.50	18	0.000	0.89
Shields R.	5.85	15	0.000	0.71	5.12	15	0.000	0.65
Stream Class II	16.64	114	0.000	0.71	19.80	114	0.000	0.78
Beaverhead R.	1.75	14	0.051	0.19	2.02	14	0.032	0.24
16 Mile Cr.	3.00	14	0.005	0.41	3.95	14	0.001	0.55
So. F. Musselshell R.	2.81	5	0.019	0.66	2.14	5	0.043	0.53
Little Blackfoot R.	3.81	14	0.001	0.53	5.15	14	0.000	0.67
Stream Class III	7.17	50	0.000	0.51	9.10	50	0.000	0.63
Stream Class IV	17.46	165	0.000	0.65	20.95	165	0.000	0.73
Bluewater Cr.[1]	8.54	18	0.000	0.81	26.35	18	0.000	0.98
Bluewater Cr.[2]	6.88	20	0.000	0.71	9.37	20	0.000	0.82
Stream Class V	10.92	39	0.000	0.76	22.72	39	0.000	0.93

[1] Section above Bluewater Fish Hatchery.

[2] Section below Bluewater Fish Hatchery.

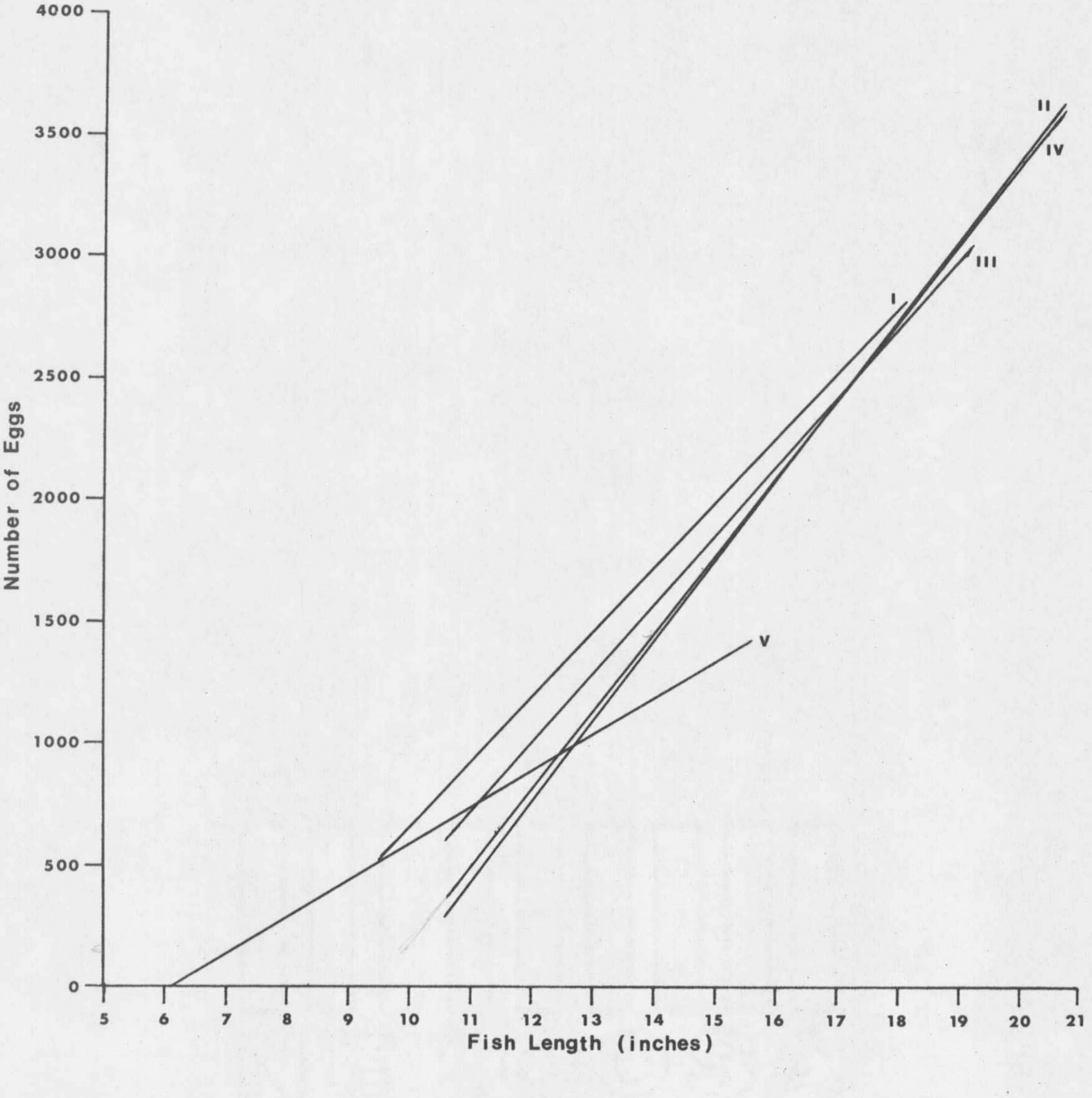

Figure 2. The regression lines of number of eggs on length for fish in stream classifications.

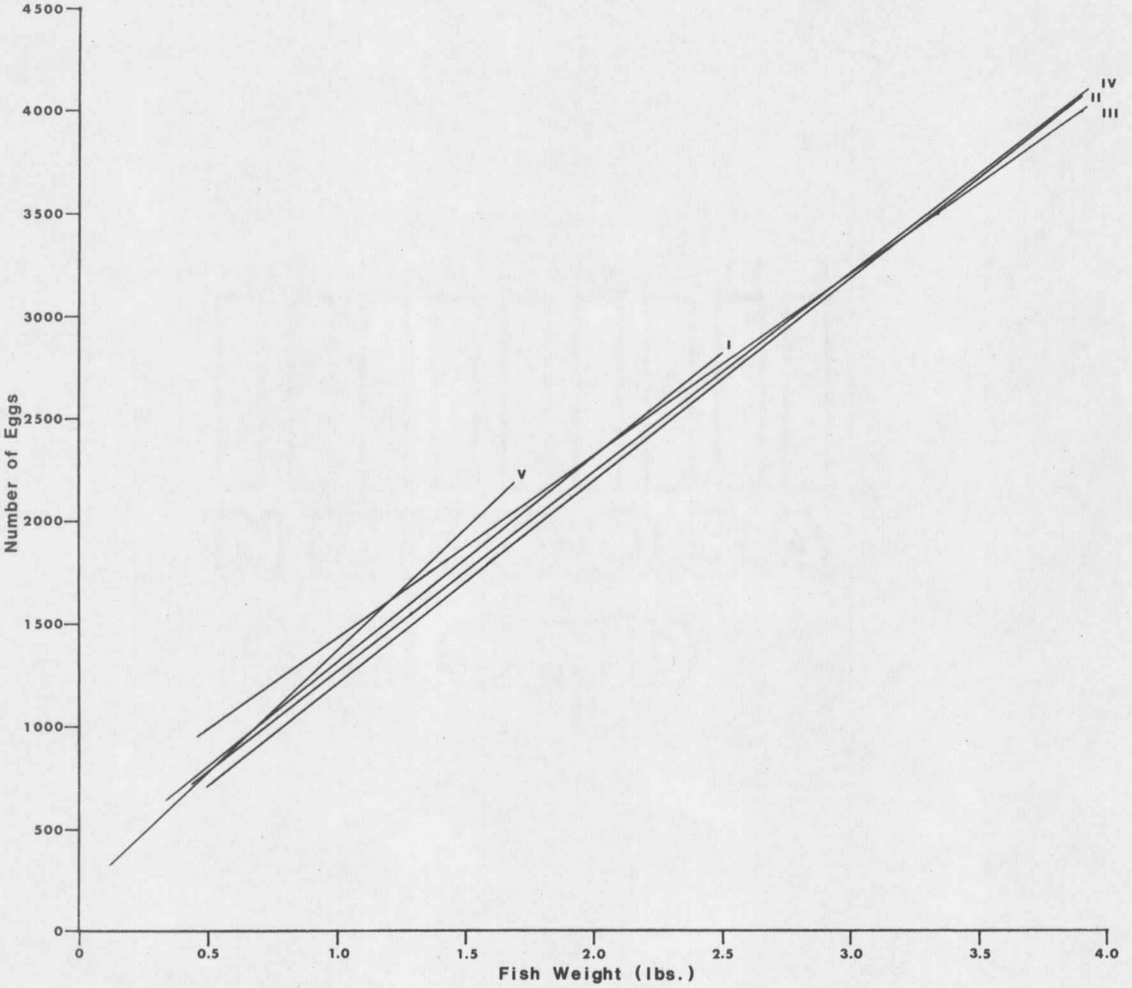

Figure 3. The regression lines of number of eggs on weight for fish in stream classifications.

Figure 4.

Regression coefficients, slopes of the regression lines, were calculated for these regressions on each stream and stream classification (Table 5). The slopes of the stream classification regressions were tested for significant differences by a method of R. E. Lund (Table 6). Six of the 8 comparisons of slopes of regressions on length and 3 of the 8 on weight were significantly different at the 0.05 level of significance.

Fish from Stream Class I were less fecund than fish from Stream Class II (Figures 2 and 4 and Table 5). The difference between these stream classes was statistically significant at the 0.05 level (Table 6). This relationship of increased fecundity with increased conductivity is similar to that found by McFadden *et al.* (1965) in fish from infertile and fertile streams having conductivities and alkalinities similar to those of Class I and II streams in this study.

Fish from Stream Class III appeared to be slightly more fecund than fish from Stream Class I (Figures 2 and 4 and Table 5). This possible relationship of increased fecundity with increased conductivity was not statistically significant at the 0.05 level (Table 6). Stream Class III contained streams with higher levels of conductivity than those reported by McFadden *et al.* (1965).

Fish from Stream Class IV (Stream Classes II and III combined) represent fish from a broad category of chemically fertile streams

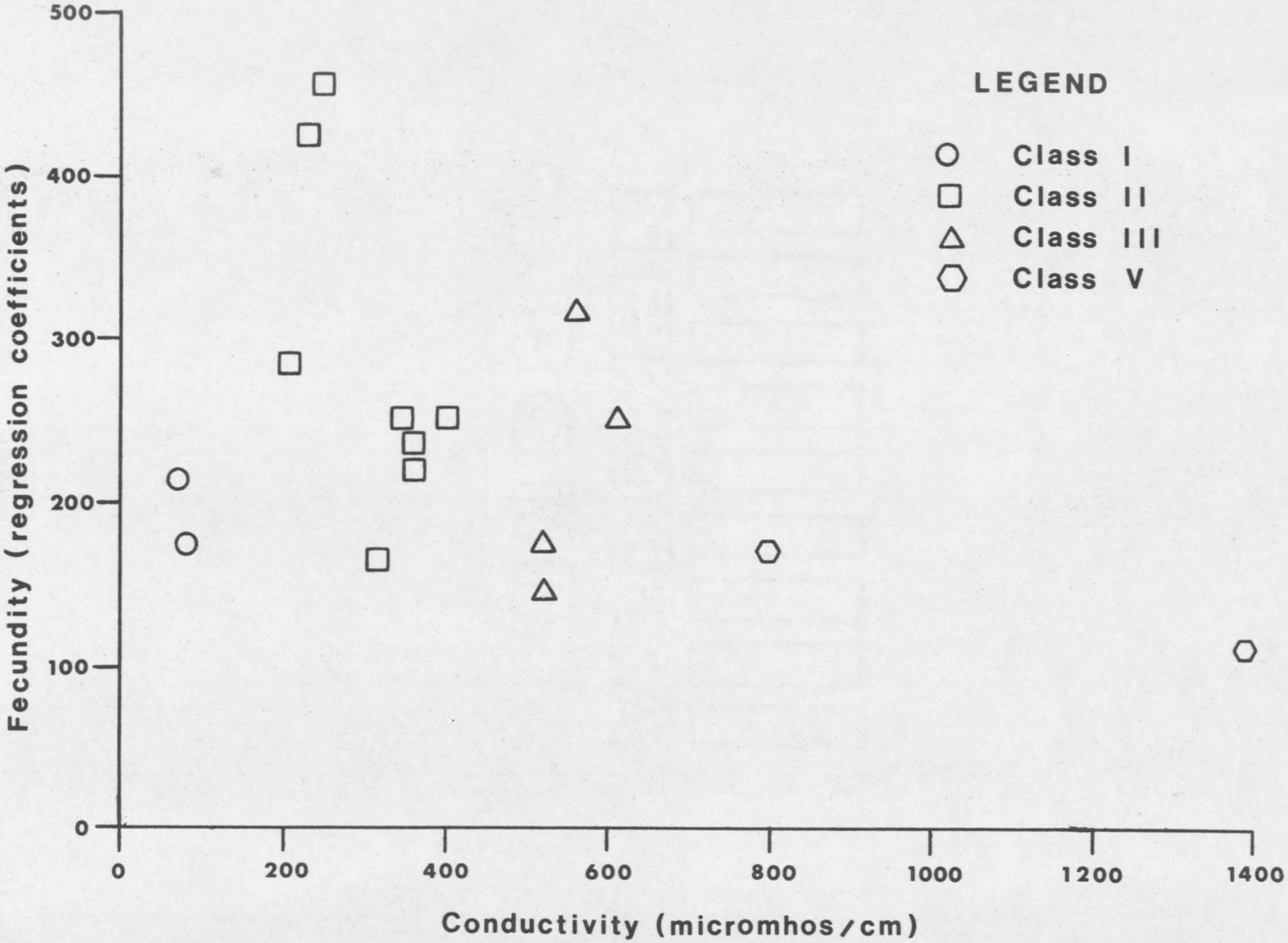

Figure 4. The fecundity (regression coefficient of number of eggs on fish length) of fish versus the conductivity of their streams.

TABLE 5. REGRESSION COEFFICIENTS (SLOPES) OF STREAMS AND STREAM CLASSIFICATIONS.

	Number of Eggs Regressed on Fish Length			Number of Eggs Regressed on Fish Weight		
Stream or Classification	Regression Coefficient	Std Error	N	Regression Coefficient	Std Error	N
Rock Cr.	213	22	18	1100	100	18
St. Regis R.	173	47	12	610	140	12
Stream Class I	254	22	30	1010	95	30
Big Hole R.	284	40	7	860	94	7
W. Gallatin R.	426	83	14	1220	220	14
Madison R.	457	64	16	1100	130	16
Baker Cr.	164	53	13	830	200	13
O'Dell Cr.	248	51	14	950	170	14
L. Prickley Pear Cr.	236	43	16	640	130	16
E. Gallatin R.	218	29	19	770	70	19
Shields R.	252	43	16	800	160	16
Stream Class II	325	20	115	990	50	115
Beaverhead R.	172	98	15	460	230	15
16 Mile Cr.	143	48	15	670	170	15
So. F. Musselshell R.	315	112	6	1400	656	6
Little Blackfoot R.	249	65	15	1210	240	15
Stream Class III	286	39	51	890	98	51
Stream Class IV	318	18	166	970	47	166
Bluewater Cr.[1]	170	20	19	1200	50	19
Bluewater Cr.[2]	113	16	21	1190	130	21
Stream Class V	147	13	40	1180	52	40

[1] Section above Bluewater Fish Hatchery.

[2] Section below Bluewater Fish Hatchery.

TABLE 6. COMPARISONS BETWEEN STREAM CLASSES BY SLOPES OF REGRESSIONS OF NUMBER OF EGGS ON LENGTH AND WEIGHT OF FISH.

Slope Comparison	Number of Eggs Regressed on Fish Length			Number of Eggs Regressed on Fish Weight		
	T	df	P	T	df	P
I vs II	2.42	77	0.018*	0.04	49	0.968
I vs III	0.72	46	0.475	0.88	72	0.382
I vs IV	2.25	73	0.028*	0.38	43	0.706
I vs V	4.18	47	0.000*	1.57	44	0.124
II vs III	0.90	75	0.371	0.91	76	0.366
II vs V	7.61	149	0.000*	2.64	109	0.010*
III vs V	3.39	60	0.001*	2.61	73	0.011*
IV vs V	7.80	174	0.000*	3.00	109	0.003*

*Significant at the 0.05 level.

with conductivities from about 200 to 600 micromhos/cm. In general, these fish were more fecund (P= 0.028) than fish from Class I streams which represent chemically infertile waters. Inspection of Figure 4 suggested there may be a negative linear relationship between conductivity and fecundity of fish from streams within Class IV. This relationship was tested and shown not to be statistically significant (P= 0.11) by regressing fecundity (regression coefficients, Table 5) on conductivity (Table 1) for the 12 streams in Class IV.

Fish from Stream Class V, which had the highest conductivity, had the lowest fecundity. The conductivity values of this stream were about 3 times greater than the highest values reported by McFadden and Cooper (1962). The above results suggest some factor other than conductivity is determining the fecundity of fish in this stream class.

Figure 3 shows the relationship between the number of eggs and weight of fish in each stream class. The number of eggs per increment of fish weight decreased, although not significantly with the increase in conductivity and alkalinity in Stream Classes I and IV (Table 6). The number of eggs per increment of weight increased significantly with increasing conductivity in Classes IV and V. Fish from streams in Class V having the highest conductivity were not significantly more fecund than fish from Class I streams having the lowest conductivity level.

Regressions of number of eggs on weight are not as often used as those of number of eggs on length (Bagenal 1971; Rounsefell 1957; McFadden *et al.* 1965). The weight of fish increase as they advance toward spawning because the weight of their ovaries increase. Since collections of fish in this study were made from different streams, on different dates, their phenological differences made comparisons of the weight-egg regressions between stream classifications useless for analysis of fecundity.

Multiple Regression

Multiple linear regressions were made in an attempt to determine the relative influence of conductivity, alkalinity, discharge and standing crop on the fecundity of fish. For this analysis it was necessary to pick a suitable dependent variable to be regressed on the independent variables of conductivity, alkalinity, discharge and standing crop. The mean number of eggs per fish could not be used as a dependent variable because the mean size of fish from streams differed and larger fish have more eggs than smaller fish. To compare streams, several other dependent variables were chosen to compensate for the size influence of a fish on its number of eggs. These were: (1) number of eggs per inch of fish; (2) number of eggs per pound of fish; (3) number of eggs per inch of a theoretical 15 inch fish obtained from simple regressions of number of eggs on length for each stream; (4) and the mean number of eggs per inch of 13-16 inch fish. The F values obtained from regressing the above mentioned dependent variables on conductivity, alkalinity, discharge and standing crop indicated that none of the multiple regressions were significant at the 0.05 level of significance. These same dependent and independent variables were regressed by stream classifications and F values indicated none were significant.

SUMMARY

An inverse relationship between chemical fertility and age at sexual maturity was found in brown trout from streams of Montana in this study. This same relationship between the chemical fertility of streams, as measured by conductivities and alkalinities, and the age of sexual maturity of brown trout from Pennsylvania has been reported by McFadden *et al.* (1965). They suggested this relationship was due partially to fish in fertile streams having greater growth rates. Growth rate may account for the age at maturity in fish from 16 of the 17 streams in this study, but cannot explain the age at maturity in fish from Bluewater Creek. Bluewater Creek fish attained sexual maturity much earlier than fish from less fertile streams; however, these fish from the chemically most fertile stream had the poorest growth rates of all the fish studied. This shows growth rate was not the determining factor in the attainment of sexual maturity for fish from Bluewater Creek.

McFadden *et al.* (1965) found a positive relationship between the chemical fertility of streams and the fecundity of their fish. A similar relationship was found between chemical fertility and fecundity in fish of this study from Stream Classes I and II, which had conductivities similar to those studied by McFadden *et al.* (1965). However, fish from streams of higher conductivities (Class III) were not significantly more fecund than those from either Class I or II, and fish from Bluewater Creek, chemically the most fertile stream, were the least fecund. Generally the age at sexual maturity of fish from all stream classes and the fecundity of fish from Stream Classes I and II appeared to be related to the chemical fertility of their streams.

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