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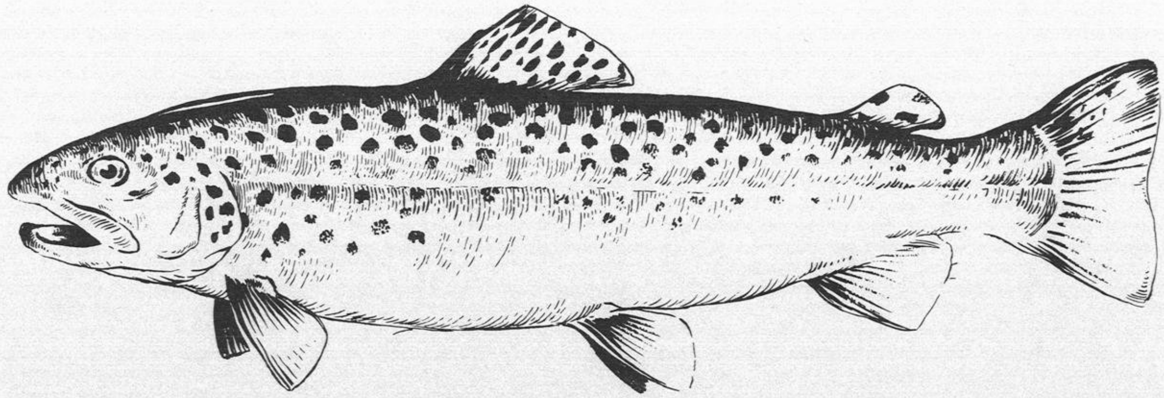
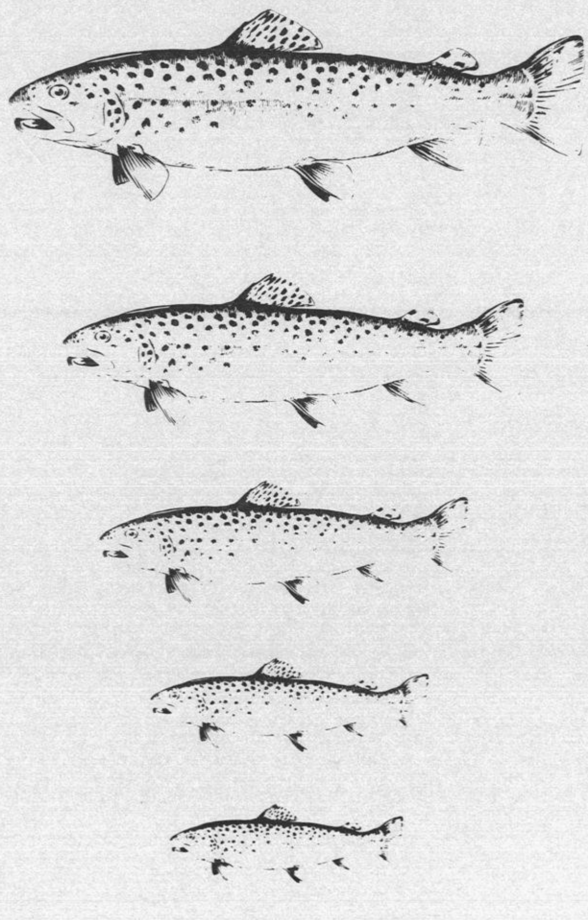


Sexual Maturity and Fecundity of Brown Trout in Central and Northern Wisconsin Streams



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ABSTRACT

A sample of 161 female brown trout *(Salmo trutta)* from 8 central and northern Wisconsin streams were collected between 1966 and 1981 to determine age and size at maturity and length-fecundity relationships. The smallest mature female examined was 7.8 inches. Sexually mature females comprised 4% of the 7.0-7.9 inch size group, 27% of the 8.0-8.9 inch size group, 71% of the 9.0-9.9 inch size group, 92% of fish between 10-12.9 inches, and 100% of fish 13.0 inches and larger. No age I, 70% of age II, 95% of age III, and 100% of age IV and older trout were mature. Within a size group, more old females were sexually mature than young females.

The larger the female, the greater percentage of her body weight was tied up in sexual products. The older the female the greater the percentage of her weight was also tied up in egg production. Ova size increased with the size of the female.

A curvilinear relationship between ova number and total length was found. A log/log transformation produced a straight line relationship. The regression of ova number (Y) on total length (X) for trout from all 8 streams was log Y = 0.065964 + 2.54035 (log X) with an R^2 of 0.82. Average fecundity increased from 229 eggs in 7.0-7.9 inch fish to 2,714 eggs in females 20.0-20.9 inches. Age II fish produced an average of 449 eggs while age V trout produced an average of 2,027. Within an age group fecundity increased progressively with size. Within a size group, fecundity tended to decline with age. In fish of the same size but different age, older females tended to produce fewer but larger eggs.

Maturity and fecundity of Wisconsin brown trout are compared with similar data from New Zealand, Pennsylvania, Michigan, and Montana. Maturity and fecundity of brown trout in Wisconsin were most similar to those aspects of production in brown trout from Michigan streams. Applications of the maturity and fecundity data are discussed relative to determining overharvest, predicting the effects of regulation changes on populations, justifying a possible increase in the minimum size limit on trout streams in southern Wisconsin, and in support of stream habitat improvement.

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by

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INTRODUCTION

This study was conducted to quantify age and size at maturity, and fecundity of wild brown trout *(Salmo trutta)* in central and northern Wisconsin streams. Fecundity data for wild brown trout are scarce in the United States and worldwide, even though relationships between size of spawning stocks and numbers of eggs and young produced are fundamental to an understanding of population dynamics and management of sport fisheries for this species.

Hobbs (1937), Allen (1951), and Hardy (1967) have established a reasonably good set of fecundity data for brown trout in New Zealand. Nichols (1958) documented a length-fecundity relationship for brown trout in Tasmania. A token study by Brown and Kemp (1941) in Montana, a more thorough work by McFadden et al. (1965) in Pennsylvania, and studies by Cooper (1953) and Taube (1976) in Michigan represent the pertinent fecundity data in the United States.

Wild, naturally reproducing brown trout are present in 33% of Wisconsin's 6,200 miles of Class I and Class II streams (Wis. Dep. Nat. Resour. 1980). They also comprise an estimated 28% of the annual angler harvest (Wis. Dep. Nat. Resour. 1979). In the future, brown trout are likely to become an even more important component of the trout resource and trout fishery in Wisconsin because of a slow expansion of their range into native brook trout *(Salvelinus fontinalis)* waters and their ability to withstand fishing pressure and habitat deterioration better than brook trout.

Currently, fishery biologists in Wisconsin routinely use population levels of age 0 fish in the fall or age I in the spring to predict subsequent recruitment to harvestable size (6.0 inches or larger) and to assess the overall well-being of brown trout populations (Thuemler 1976, 1983; Larson 1982). Knowledge of size and age at maturity and potential contributions of each size and age group of brown trout to recruitment processes is particularly relevant to the proper choice of angling regulations that will sustain balanced trout populations for present and future generations to angle. In the past few years, fishing pressure on some brown trout streams in Wisconsin has risen to more than 500 hours/acre and numbers of large fish have declined significantly (Larry Claggett, Wis. Dep. Nat. Resour. Bur. Fish Manage., pers. comm.). As a result, more stringent regulations for brown trout fisheries are going into effect 1 January 1986 on southern Wisconsin streams where fishing pressures are highest. Maturity and fecundity tables developed from this study will better enable fish managers to evaluate and tailor regional angling regulations to the long-term benefit of both anglers and the trout populations.

THE STUDY STREAMS

Wild brown trout were collected from 8 streams: 4 in central Wisconsin, 1 in northeast Wisconsin, and 3 in northwest Wisconsin (Fig. 1). In central Wisconsin, the South Branch of Wedde Creek originates in southwestern Waushara County and flows 4.9 miles before merging with the North Branch to form Wedde Creek. Four miles north, the Mecan River originates from Mecan Spring and flows 31 miles before emptying into the Fox River in Marquette County. Radley Creek begins in southwestern Portage County and flows 11 miles before joining the Crystal River in southwestern Waupaca County near the town of Rural. Emmons Creek originates from Fountain Lake roughly 3 miles north of Radley Creek and flows 6 miles before entering the 724-acre Chain O'Lakes in Waupaca County.

All of the South Branch of Wedde Creek, Radley and Emmons creeks and the upper 6.6 miles of the Mecan River are Class I trout water.* All 4 streams were once native brook trout streams but now support primarily wild brown trout. The Mecan River also contains a small but self-sustaining population of rainbow trout *(Salmo gairdneri)*. Substrates in the 4 streams consist primarily of fine sand with gravel riffles occurring frequently in Emmons Creek and the Mecan River and occasionally in Radley Creek and the South Branch of Wedde Creek. Aquatic vegetation ranges from sparse in Emmons Creek, Radley Creek, and the Mecan River to moderately abundant in the South Branch of Wedde Creek. Primary species are watercress *(Nasturtium officinale)* and water buttercup *(Ranunculus* sp.).

The North Branch of Beaver Creek, hereafter referred to as Beaver Creek, originates in northeastern Wisconsin in south central Marinette County. Beaver Creek flows 8.7 miles, merges with the South Branch of Beaver Creek, and empties into the Peshtigo River 3.0 miles downstream. The upper 6.3 miles of Beaver Creek is Class I trout water and contains both brown trout and brook trout. Brown trout are more numerous in the lower two-thirds of the stream. Substrates are sand and silt with gravel suitable for brown trout reproduction being scarce. Aquatic vegetation is common and consists predominantly of tape grass *(Vallisneria americana)* and water buttercup.

In northwestern Wisconsin, Eighteen Mile Creek originates in Diamond Lake in the Chequamegon National Forest in south central Bayfield County. Eighteen Mile Creek is all Class I trout water and flows 13.4 miles before entering Long Lake Branch, a tributary of the White River. Brown trout and brook trout are both present, with brown trout being more abundant in the lower two-thirds of the stream. Gravel and cobble substrates are common but aquatic vegetation is scarce.

McKenzie and Parker creeks are also located in northwestern Wisconsin in Polk and St. Croix counties, respectively (Fig. 1). McKenzie Creek begins at McKenzie Lake in northeastern Polk County and flows north about 7 miles to join the South Fork of the Clam River at the upper end of Clam Falls Flowage. Parker Creek originates in south central St. Croix County and flows 2.4 miles before emptying into the Kinnickinnic River. The middle 4.6 miles of McKenzie Creek and the lower 0.4 mile of Parker Creek are Class I water. Brown trout and brook trout are present in both streams but brown trout are far more abundant. Aquatic vegetation is scarce in McKenzie Creek and common in Parker Creek, especially water buttercup.

Gravel substrates are moderately abundant in the lower reach of Parker Creek and in certain reaches of McKenzie Creek. Sand, silt, and clay are the most common substrates in both streams with some cobble and boulder areas present in McKenzie Creek.

Aquatic invertebrates provide the primary food source for trout in all 8 streams. Forage fish are not abundant in any of the streams but are more common in McKenzie and Parker creeks. Other physical and chemical characteristics of the 8 streams are presented in Table 1. Additional information about the streams may be found in Avery (1983), Avery and Hunt (1981), Lowry (1971), and Hunt (1982, 1983).

* Class I streams have high quality trout water with enough natural reproduction to sustain populations of wild trout at or near carrying capacity. Stocking of hatchery trout is not required (Wis. Dep. Nat. Resour. 1980).

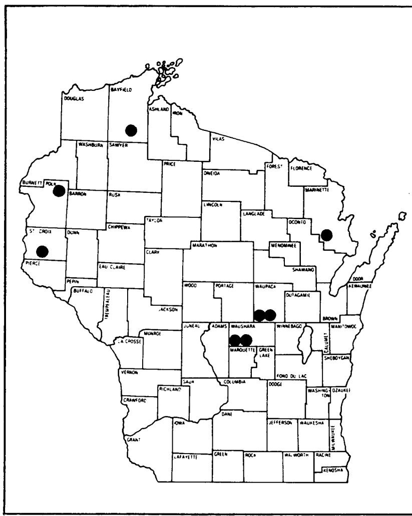

FIGURE 1. *Location of trout streams sampled for brown trout fecundity studies.*

TABLE 1. *Physical and chemical characteristics of eight Wisconsin trout streams from which female brown trout were removed to determine fecundity.*

Parameter	Mecan River	So. Br. Wedde Creek	Radley Creek	Emmons Creek	Parker Creek	Beaver Creek	McKenzie Creek	Eighteen Mile Creek
pH	7.6-8.0	7.6-7.9	7.5-8.0	7.9-8.2	7.6	7.8-8.0	7.3-8.5	7.6
Conductivity	330-356	276-319	288-339	320-355	337	291-416	220-280	140-196
Alkalinity	160-170	131-147	135-157	161-186	162	114-171	89-150	54-70
Average width	21.5	12.3	16.7	18.9	17.0	15.2	20.0	22.0
Average depth	0.9	1.1	1.2	1.1	0.7	1.0	—	0.8
Average discharge	21.6	8.8	17.0	21.8	8.5	14.9	15-20	21.0
Gradient	< 15	< 15	< 15	< 15	12.0	7.3	—	35.0

METHODS

Collections of wild brown trout were carried out as an adjunct to sampling brown trout populations that were being investigated as part of other research projects within the Cold Water Research Unit. Consequently, trout collected for eventual use in this fecundity investigation were taken over a period of several years. The sample from McKenzie Creek was obtained on 12 October 1966. Trout from Emmons and Radley creeks and from the South Branch of Wedde Creek and Mecan River were collected on 24-25 October 1978. Brown trout were taken from Eighteen Mile Creek and Beaver Creek during 1-10 October 1980. Brown trout from Parker Creek were collected on 17 September 1981.

All trout were collected using a stream electrofishing boat equipped with a 220-volt DC generator, 1 negative electrode, and 2-3 positive electrodes. Brown trout to be sacrificed were selected based upon their size and when possible their external appearance as females. Ovaries were excised after the fish were anesthetized, measured to the nearest 0.1 inch (total length), weighed to the nearest gram, and examined for fin clips. Scale samples of brown trout from Eighteen Mile, Beaver, and Parker creeks were taken to facilitate aging. The age of trout from McKenzie, Emmons, Radley, and the South Branch Wedde creeks and the Mecan River were determined from known-aged fish fin-clipped during previous studies (Lowry 1971, Avery and Hunt 1981). Ovaries from most specimens were removed in the field, weighed to the nearest gram, labeled, and preserved in 10-15% formalin. Some trout were taken to the laboratory and placed in a refrigerator overnight. Ovaries from these fish were removed and processed the following morning.

Preserved ovaries from individual streams were left in formalin from 2 to 16 months before egg counts were made. Egg counts from all ovaries from each stream were made within 2 to 4 days of each other. Just prior to counting the eggs, ovaries from individual fish were rinsed in water and placed in a white enamel dissecting tray along with a small amount of water. All ova were then separated from connecting tissue and counted. Average egg diameter was determined from a random sample of 30 ova from each fish.

RESULTS AND DISCUSSION

The size, age, fecundity, and characteristics of ova from brown trout collected from all 8 trout streams are summarized in Appendix I. A total of 255 females were collected, with a range of 21 to 60 fish taken from each stream. A total of 167 females were mature, with a range of 14 to 38 mature fish from each stream. Six mature females were at least partially spawned out thus reducing the usable sample size of mature fish to 161 for use in determining fecundity.

Ages of 122 mature females were determined. A range of 5 to 31 fish were aged from individual streams. Ages of the remaining mature trout could not be determined because of regenerated scales and because scale samples were not taken from some fish which lacked a known-aged fin clip.

Sexual Maturity

Sexual maturity of female brown trout is dependent upon the size and age of the individual fish and possibly upon genetic factors. Fish size is directly or indirectly related to all environmental factors affecting growth and survival.

No sexually mature females were found in the 6.0-6.9 inch size group (Table 2). Fish in this size range were collected from only 2 of the 8 streams but in none of the 8 streams did trout of this size show any phenotypic indications of being mature. The smallest mature female examined was a 7.8 inch fish collected from Eighteen Mile Creek. This was the only mature fish found in the sample of 24 trout comprising the 7.0-7.9 inch size group. Maturity increased with size until at 13.0-13.9 inches all females were sexually mature.

Within a size group, more old females were sexually mature than young females. For example, of trout 8.0-8.9 inches long, 35% of the age II but none of the age I females were mature (Table 3). In the range of 9.0-9.9 inches, a substantially higher percentage of the age III trout were mature than age II, and no age I were mature. This relationship was also observed by McFadden et al. (1965) for brown trout from Pennsylvania.

Size of brown trout at maturity in Wisconsin is similar to that observed for brown trout from the Platte River, Michigan (Table 4). The most divergence occurs in the 10.0-10.9 inch and 11.0-11.9 inch size groups. Incidence of maturity among Platte River females in these size groups was 78% and 83%, respectively, compared to 93% for similar sized fish in Wisconsin. Cooper (1953) found only 5% of females in the 8.0-9.9 inch size range were mature from the Manistee and AuSable rivers in Michigan. Incidence of maturity was 27% in females of this size in Wisconsin streams. Cooper also reported 80% of females in the 10.0-13.9 inch size group were mature and this compares with an incidence of maturity of 93% in similar sized females in Wisconsin streams. Essentially all trout larger than 14.0 inches were mature in both Michigan and Wisconsin.

Generally, female brown trout do not mature until their third fall of life at age II (Mills 1971, Heacox 1974). In this study, 95% of age III and all age IV and older females were sexually mature (Table 5).

Although most trout in the individual Wisconsin streams matured at age II, females in Eighteen Mile Creek were an exception. Only 13% of the age II females from this stream were mature (Append. I). Eighteen Mile Creek was the least fertile, has the highest gradient, and the shortest growing sea-

TABLE 2. *Size at maturity of female brown trout.*

Inch Group	No. in Sample	Percent Mature
6.0-6.9	11 (2)*	0
7.0-7.9	24 (6)	4
8.0-8.9	48 (8)	27
9.0-9.9	42 (8)	71
10.0-10.9	41 (8)	93
11.0-11.9	30 (7)	93
12.0-12.9	20 (7)	90
13.0-13.9	11 (6)	100
14.0-14.9	11 (5)	100
15.0+	17 (5)	100

*Number of streams sampled in parentheses.

TABLE 3. *Percent sexual maturity in female brown trout by size and age.*

Length (inches)	Age Groups I	II	III	IV	V
6.0-6.9	0 (8)*				
7.0-7.9	0 (19)	50 (2)			
8.0-8.9	0 (16)	35 (23)			
9.0-9.9	0 (4)	68 (25)	100 (9)	100 (1)	
10.0-10.9	0 (1)	88 (16)	100 (15)	100 (2)	
11.0-11.9		88 (8)	100 (8)	100 (3)	
12.0-12.9		100 (3)	67 (6)	100 (3)	
13.0+		100 (1)	100 (6)	100 (12)	100 (8)

*Sample size in parentheses.

TABLE 4. *Percent maturity of brown trout by size group.*

Inch Group	Percent Mature WI	MI*
6.0-6.9	0	0
7.0-7.9	4	8
8.0-8.9	27	35
9.0-9.9	71	64
10.0-10.9	93	78
11.0-11.9	93	83
12.0-12.9	90	92
13.0+	100	100

*Platte River, MI (Taube 1976).

TABLE 5. *Age at maturity of female brown trout.*

Age Group	No. in Sample	Percent Mature
I	47	0
II	79	70
III	44	95
IV	21	100
V	8	100

TABLE 6. *Average percent body weight of ova in brown trout from 4 central Wisconsin streams collected 24-25 October 1978.*

Inch Group	No. Sampled	Avg. Percent Body Weight of Ova
8.0-8.9	11	10.1
9.0-9.9	19	12.6
10.0-10.9	18	13.7
11.0-11.9	15	14.2
12.0-12.9	9	16.7
13.0-13.9	2	14.5
14.0-14.9	3	16.7
Total	77	

son of the 8 streams studied. If these data were not included in the overall average, 85% of the age II fish would have been mature rather than the 70% figure shown in Table 5.

Within age group II, the age when females first begin to mature, there was a strong tendency for a higher percentage of the larger trout to be mature (Table 3). Similar trends could not be detected in the older age groups because nearly all fish were mature. McFadden et al. (1965) also noted that within an age group a higher percentage of larger trout were mature.

Age at maturity among Wisconsin brown trout was similar to females from the Platte River in Michigan. The biggest discrepancy was a 16% maturity in age I females in the Platte River (Taube 1976) vs. no mature yearlings in Wisconsin streams. Approximately 77% of age II, 88% of age III, and all age IV were mature from the Platte River; corresponding values for females from Wisconsin streams were 70%, 95%, and 100%, respectively. Allen (1951) found a surprising 91% of age I trout were mature in Horikiwi Stream in New Zealand while 95% of age II and 100% of age III and older trout were mature.

McFadden et al. (1965) found approximately 14% of age I females between 8.0 inches and 10.9 inches were mature in fertile Pennsylvania streams, but that none smaller than 8.0 inches were mature. In infertile streams, he found a small number of age II females in the 6.0-6.9 inch size group were mature. Taube (1976) found 16% of age I females from the Platte River in Michigan were mature and these fish averaged 8.0 inches. In Horokiwi Stream in New Zealand, 91% of the age I trout were mature (Allen 1951). Average size of these yearlings, however, ranged from 11.3 inches to 15.4 inches depending upon the reach of stream in which they were found. No mature age I females were found in the central and northern Wisconsin streams sampled in the present study even though 47 fish of that age ranging from 6.0 inches to 10.2 inches were examined, including 19 fish 8.0 inches and larger. The smallest mature female found in the 8 Wisconsin streams was a 7.8 inch age II individual from Eighteen Mile Creek. Reproduction, i.e., recruitment, in central and northern Wisconsin streams is therefore not only dependent upon age II and older trout but also upon fish approximately 8.0 inches or more in length in the fall.

Percent Body Weight of Ovaries

The percent body weight of the reproductive products varies with the stage of the reproductive cycle of the trout. A subsample of 77 trout collected from 4 central Wisconsin streams on 24-25 October 1978 minimized the bias caused by differing stages of the reproductive cycle. Based upon this subsample, the larger the female the greater percentage of her body weight was tied up in sexual products (Table 6). This relationship was also evident for trout collected from all 8 Wisconsin streams, even though collecting dates in the fall differed by as much as 5 1/2 weeks (Append. II). In both instances, the relationship broke down in the larger size ranges when the sample size did not exceed 4 fish per inch group.

Ovaries comprised from 5.7% of the body weight of an 11.3 inch fish from Parker Creek to 21.7% of the body weight of a 15.2 inch fish from Eighteen

Mile Creek (Append. I). They comprised an average of 12.9% of the body weight of all females from 8.0 to 13.9 inches. Although sample sizes were small in the larger size groups, ovaries comprised an average of 16.8% of the body weight of trout 14.0 to 20.9 inches.

The older the female the greater percentage of her weight was also tied up in egg production. Total weight of ova in ages II, III, IV, and V trout averaged 12.9%, 13.2%, 15.6%, and 18.4%, respectively, of the total body weight.

TABLE 7. *Fecundity statistics for 8 brown trout populations. The regression of number of eggs (Y) on total length (X).*

Stream	Linear Regression Equation	F Value	Correlation Coefficient
McKenzie Creek	log Y = 0.4477 + 2.1894	log X 41.03*	.87
Beaver Creek	log Y = 0.1801 + 2.5720	log X 145.77*	.96
Eighteen Mile Creek	log Y = 0.2757 + 2.3748	log X 572.53*	.97
Radley Creek	log Y = 0.3094 + 2.2531	log X 99.01*	.86
Emmons Creek	log Y = -0.3801 + 2.9526	log X 37.12*	.86
So. Br. Wedde Creek	log Y = 0.3361 + 2.9875	log X 118.24*	.94
Mecan River	log Y = 0.8665 + 3.4189	log X 99.35*	.96
Parker Creek	log Y = 1.0361 + 1.5566	log X 19.18*	.75
All streams	log Y = 0.0660 + 2.5404	log X 734.16*	.91

* Significant at 0.05% level.

Ova Size

Average egg diameter ranged from 3.4 mm in an 8.2-inch trout from Emmons creek and an 8.8-inch trout from Beaver creek to 5.6 mm in a 19.7-inch trout from Eighteen Mile Creek (Append. I). In general, larger females produced larger eggs in all 8 streams. Hardy (1967) and Taube (1976) observed similar relationships in brown trout from New Zealand and Michigan. Comparisons of egg size between streams were not made because eggs from all streams were neither preserved in the same concentrations of formalin nor preserved for the same lengths of time before being measured. Within individual streams average diameter of ova was larger for an older-aged fish than for a younger-aged fish of the same size (Append. I). Bagenal (1969*b*) found more progeny survived from large eggs than from small eggs.

Fecundity

Length and fecundity data from each stream were plotted and a curvilinear relationship of the type $F = aL^b$ was found where F = fecundity, L = total length, and a and b are a constant and exponent that can be determined from the data. Other studies have documented a similar relationship (Bagenal 1969*a*, 1973; Hardy 1967).

Logarithmic transformation of length and fecundity data expressed the best straight line relationship and provided easier analysis of the data following standard regression and analysis of variance and covariance methods. Regression equations describing the fecundity of trout are presented in Table 7. In each case, an analysis of variance indicated the relationship between $\log_{10}$ length to $\log_{10}$ egg number was significant at the 0.05 level.

An analysis of covariance was made to see if a single regression line could statistically fit the data from all 8 populations. Analyses were made using all trout, trout from 8.0-13.9 inches, and trout from 9.0-12.9 inches. The single slope hypothesis was rejected ($P<0.05$) in all instances.

A comparison between slopes of the individual regression lines using their 95% confidence intervals indicated that the differences being observed in the single regression analysis above were most likely due to trout from either Parker Creek or the Mecan River. Excluding the data from either stream did not help, however. Analyses of covariance for the 7 other streams still showed statistically significant differences between slopes ($P<0.05$).

An alternative hypothesis that streams in a similar geographical area might show statistically similar length-fecundity relationships was tested also using analysis of covariance techniques. The 8 streams were divided into 2 groups of 4 streams each: Emmons Creek, Radley Creek, South Branch of Wedde Creek, and the Mecan River representing central Wisconsin streams; and Beaver Creek, Eighteen Mile Creek, McKenzie Creek, and Parker Creek representing northern Wisconsin streams. The length-fecundity relationship in neither of the above groupings could be statistically described by a single regression line. The single slope hypothesis for the 4 northern streams was rejected at $P<0.05$. A $P = 0.08$ for the 4 central streams showed a somewhat better fit. However, a highly significant ($P<0.01$) difference between intercepts negated the acceptance of a single regression line.

Although the above analyses indicate a significant statistical difference in length-fecundity relationships between streams, these differences are probably not significant from the practical or biological standpoint of trout management in Wisconsin. A coefficient of determination (R^2) of 0.82 for the regression expressing the length-fecundity relationship of trout from all 8 streams indicates that 82% of the variation in fecundity of all trout can be explained or accounted for. The regression and the 95% confidence interval is graphed in Figure 2 along with the log/log plot of observed ova numbers and total lengths of females from all 8 streams.

The pooled average fecundity of brown trout from the 8 streams increased progressively with both the size and age of the fish. Fecundity increased from an average of 229 eggs in 7.0-7.9 inch trout to 2,714 eggs in trout 20.0-20.9 inches (Table 8). Age II females, i.e., first-time spawners, produced an average of 449 eggs, while age V fish produced an average of 2,027 (Table 9).

Within an age group, fecundity increased progressively with size suggesting that faster growing individuals are more fecund (Table 10). Within a size group, fecundity tended to decline with age indicating that faster growing younger fish are more fecund than their older counterparts of the same size.

Fecundity of brown trout from the Madison River, Montana is generally greater than the fecundity of similar size trout in Michigan, New Zealand, and Wisconsin (Fig. 3). The data from Montana (Brown and Kemp 1941) is based on a sample of only 37 fish and there was no correlation between size or age of females and the number of eggs present. Because of the small sample size and the fact that most other studies (Hardy 1967, Taube 1976, Bagenal 1969*a*, Allen 1951) have shown a high correlation between either fish size or age of females and fecundity, the Montana data are probably not representative of length-fecundity relationships for brown trout in that state. Horton (1961) found no relationship between the size of female and the number of eggs produced in a

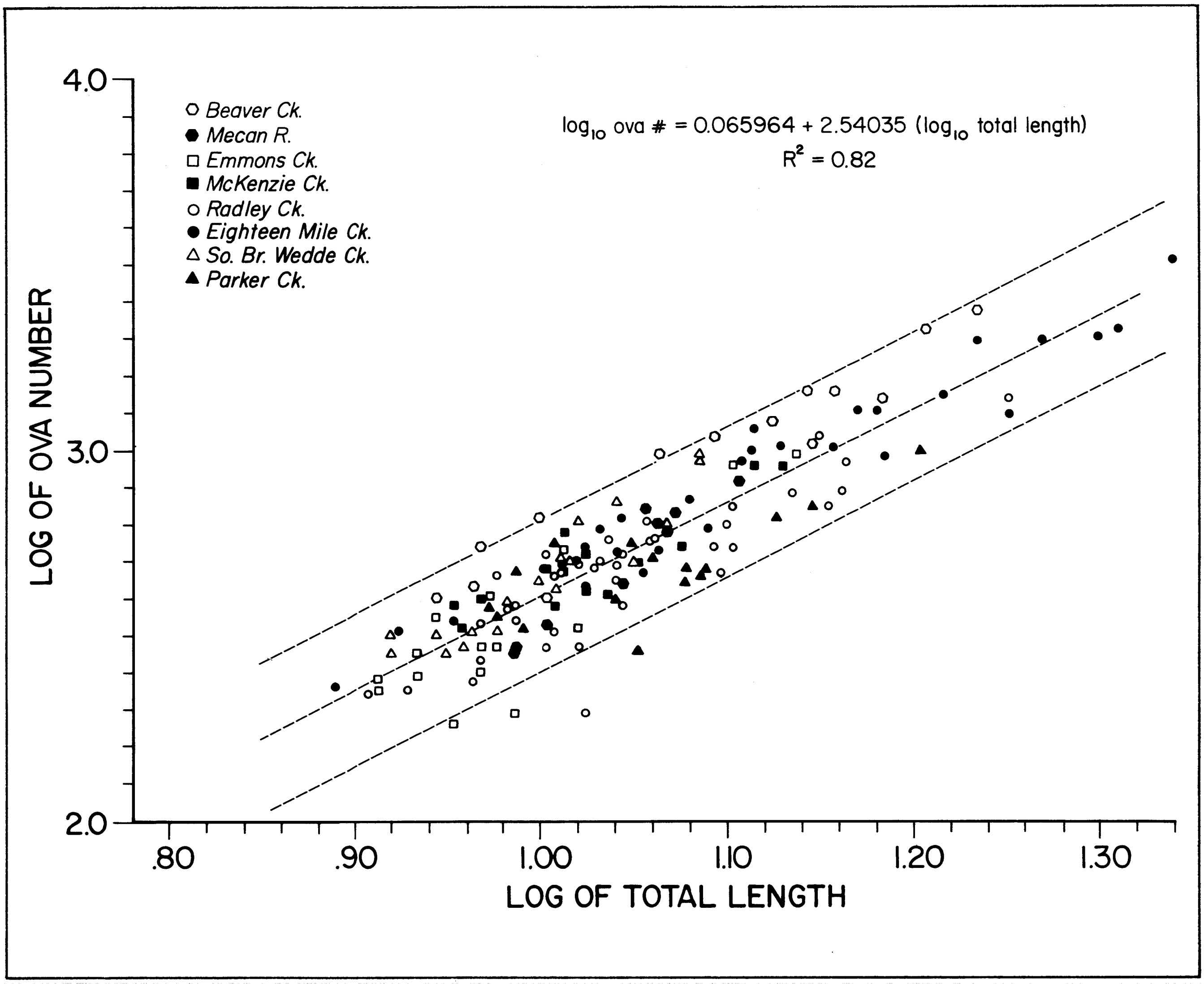

FIGURE 2. *Log/log plot of ova numbers vs. total length of brown trout plus overall regression line with 95% C.I.*

TABLE 8. *Average fecundity of brown trout by inch group.*

Inch Group	No. Sampled	Average No. Eggs	Standard Deviation
7.0-7.9	1	229	—
8.0-8.9	13	285	55
9.0-9.9	29	342	81
10.0-10.9	37	472	103
11.0-11.9	27	561	131
12.0-12.9	17	692	216
13.0-13.9	11	944	256
14.0-14.9	10	1,017	249
15.0-15.9	4	1,231	195
16.0-16.9	3	1,518	576
17.0-17.9	4	1,753	538
18.0-18.9	1	2,050	—
19.0-19.9	2	2,041	20
20.0-20.9	2	2,714	800
Total	161		

TABLE 9. *Average fecundity of brown trout by age group.*

Age Group	No. Sampled	Average No. Eggs	Standard Deviation
II	54	449	209
III	40	544	354
IV	20	901	511
V	8	2,027	605
Total	122		

stream in England but it was not clear whether the number of eggs per female was obtained by direct count or by excavation of trout redds, a process subject to many sampling errors.

Fecundity of brown trout in New Zealand is significantly greater than the fecundity of brown trout in Wisconsin until a size of 14.0-16.0 inches is attained (Fig. 3). Thereafter, Wisconsin fish produce more eggs. Females from the Manistee and AuSable rivers in Michigan are more fecund than trout from Wisconsin or New Zealand over the entire size range. Females from the Platte River, Michigan produce fewer eggs for their size than brown trout from Wisconsin but differences are not significant over the size range measured.

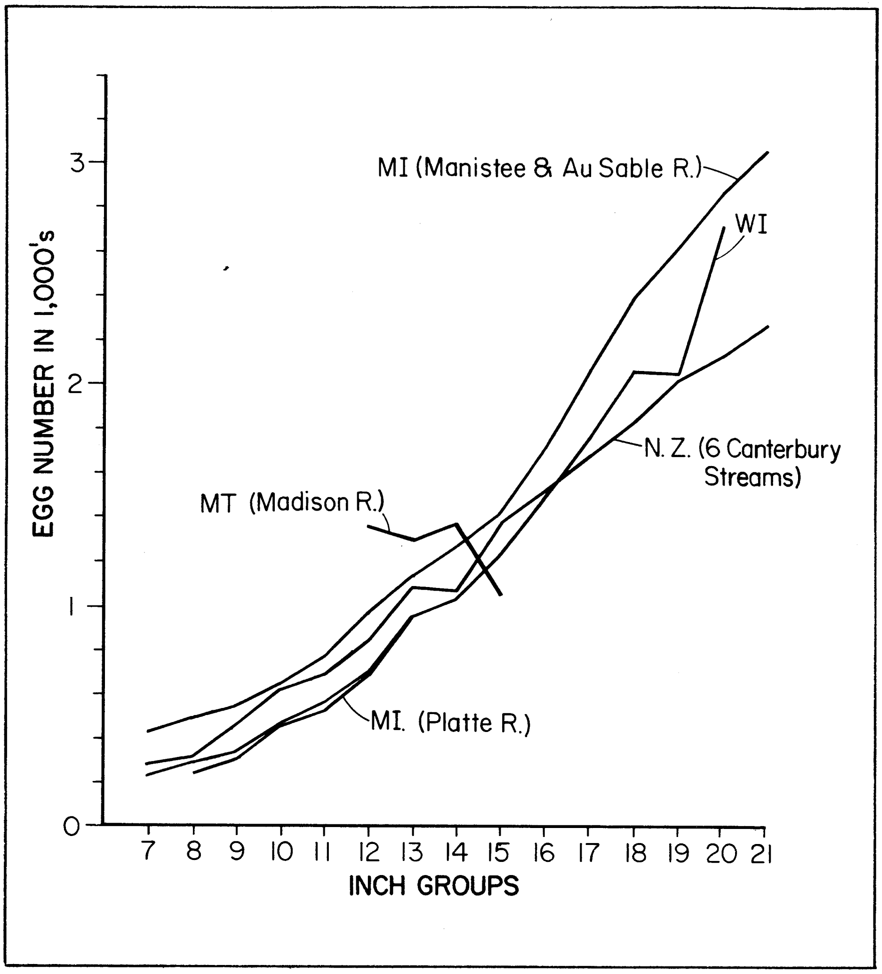

FIGURE 3. *Average brown trout fecundity per inch group.*

TABLE 10. *Average fecundity of brown trout by size and age.*

Inch Group	Age Groups II	III	IV	V
7.0-7.9	229*(1)**			
8.0-8.9	285 (12)			
9.0-9.9	376 (17)	300 (9)	196 (1)	
10.0-10.9	505 (14)	439 (14)	392 (2)	
11.0-11.9	562 (6)	545 (8)	465 (3)	
12.0-12.9	852 (3)	542 (3)	696 (3)	
13.0-13.9	1,202 (1)	786 (2)	1,122 (4)	
14.0-14.9		1,072 (3)	1,154 (3)	
15.0-15.9			1,166 (2)	
16.0-16.9			1,698 (2)	1,416 (1)
17.0-17.9		2,138 (1)		1,622 (2)
18.0-18.9				2,050 (1)
19.0-19.9				2,041 (2)
20.0-20.9				2,714 (2)

* Average number of eggs.

** Sample size in parentheses.

MANAGEMENT IMPLICATIONS

Information presented in this report on size and age at maturity and on fecundity of wild brown trout makes it possible for fish managers in Wisconsin to better assess the health of brown trout populations once the standing stocks have been determined. Using a male:female ratio of 1:1 (McFadden et al. 1962, Libosvarski 1967), the potential egg production of a population may now be determined. Symptoms of overharvest and subsequent dependence of a population on a single age group (first time spawners) for recruitment can now be recognized with greater certainty also.

The length-fecundity relationship documented in this report improves the capability of predicting how present regulations or new ones could affect natural recruitment in Wisconsin streams. For example, the fecundity of one 14.0 inch female is roughly equivalent to that of two 10.0 inch females, while one 18.0 inch fish produces the same number of eggs as two 14.0 inch trout. Angling regulations like slot size limits, designed to reduce harvest of large trout at the expense of harvesting a greater number of medium-sized fish, might therefore be an equitable tradeoff from the standpoint of improving or maintaining adequate recruitment and improving the quality of the fishery in the process.

Over the last few years support from fish managers and trout anglers in southern Wisconsin to increase the minimum size limit from 6.0 inches to 9.0 inches and reduce the daily bag from 5 to 3 fish has resulted in regulatory changes to that effect beginning 1 January 1986. These regulatory changes were made to improve the average size and number of large brown trout available to anglers. Information in this study strengthens the justification for these regulatory changes since they should allow greater numbers of trout to reach the size and age necessary to spawn at least once.

Habitat improvement in Wisconsin trout streams is usually expensive but absolutely necessary to combat stream degradation caused by beaver and poor land management practices. Such projects consume a great deal of the fish manager's time and budget but such projects have proven to be successful in increasing survival and abundance of larger trout (Hauber, pers. comm., Hunt 1978, Hunt, in press). The results of this study further substantiate the value of increasing abundance of larger trout through implementation of such habitat improvement projects. Both the existing fishery and future fishing are benefitted through the process of enhanced reproductive potential. This can be illustrated using data from a habitat improvement project on the West Branch of the White River (Hunt 1978). Brown trout over 10.0 inches increased from 40 per mile before installation of habitat improvement devices to a 3-year average of 251 following habitat improvement. Using a 1:1 ratio of males to females, a 93% maturity of females over 10.0 inches, and an average fecundity of 820 eggs for fish 10.0-15.9 inches, potential egg production should have increased from 15,580 to 95,120. This is more than a 6-fold increase and an increase in the population of legal sized trout would be expected in the stream as a whole if not within the particular study area in the future.

Additional maturity and fecundity data should continue to be collected from streams throughout Wisconsin to refine and improve the length-fecundity relationship of brown trout statewide and regionally.

SUMMARY

1. A curvilinear relationship between number of ova and total length was determined from 161 mature brown trout from 8 Wisconsin streams. The best straight line relationship was a log/log plot. The regression, $\log_{10}$ egg number = 0.065964 + 2.54035 ($\log_{10}$ fish length), explained 82% of the variation in fecundity of all trout.
2. Female trout did not mature until age II and at a size of nearly 8.0 inches.
3. Faster growing fish matured sooner than their slower growing counterparts.
4. Fecundity increased with both size and age of females. Average fecundity ranged from 229 eggs in 7.0-7.9 inch fish to 2,714 eggs in 20.0-20.9 inch trout. Fecundity increased from an average of 449 eggs in age II females to 2,027 eggs in age V fish.
5. The larger the female, the higher the percentage body weight was tied up in egg production. Larger females also produced larger eggs. In fish of the same size but different age, older females produced fewer but larger eggs.
6. Average fecundity of Wisconsin brown trout was similar to the average fecundity of trout from the Platte River in Michigan but was generally less than the average fecundity of fish from New Zealand, the Manistee and AuSable rivers in Michigan, and the Madison River in Montana.

APPENDIXES

APPENDIX I. Size, age, and fecundity data on female brown trout collected in the fall from 8 Wisconsin trout streams.

McKenzie Creek 12 Oct 1966

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
8.3	104	—	X		—	—	—
8.5	88	I	X		—	—	—
9.0	136	II		X	383	18	4.0
9.1	135	II		X	330	18	4.2
9.3	154	II		X	395	21	4.2
10.1	170	II		X	478	24	4.1
10.2	200	II		X	384	23	4.2
10.3	174	II		X	464	22	4.1
10.3	218	II		X	605	34	4.2
10.6	215	II		X	526	32	4.3
10.6	231	II		X	531	31	4.2
10.6	228	III		X	420	31	4.4
10.8	207	II	X		—	—	—
10.9	213	II		X[a]	411	27	4.5
11.2	212	—	X		—	—	—
11.3	247	II		X	499	25	4.2
11.4	214	II	X		—	—	—
11.9	294	—		X	549	47	4.7
13.0	358	—		X	909	64	4.5
13.5	463	III		X	904	66	4.6
14.7	502	IV		X[b]	—	—	—

[a] Ovary loose.
[b] Partially spawned out.

Emmons Creek 24 Oct 1978

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
6.6	48	I	X		—	—	—
6.7	50	I	X		—	—	—
6.8	50	—	X		—	—	—
6.8	55	I	X		—	—	—
6.8	48	I	X		—	—	—
7.1	54	I	X		—	—	—
7.7	62	I	X		—	—	—
7.8	66	I	X		—	—	—
8.1	80	I	X		—	—	—
8.2	88	II	X	X	224	7	3.4
8.2	90	II		X	238	10	3.8
8.5	82	I	X		—	—	—
8.6	92	II		X	243	10	3.8
8.6	98	—		X	285	10	3.7
8.8	105	II		X	354	7	3.5
8.9	106	—	X		—	—	—
9.0	118	III		X	184	14	4.7
9.3	116	III		X	249	16	4.3
9.3	135	III		X	297	21	4.7
9.4	128	II		X	421	21	4.2
9.5	124	—		X[b]	—	—	—
9.5	140	III		X	292	20	4.6
9.7	122	IV		X	196	13	4.5
10.3	190	—		X	531	39	4.9
10.5	186	IV		X	334	24	4.8
12.7	282	—		X	913	54	4.3
13.7	378	—		X	981	44	4.0

Radley Creek 24 Oct 1978

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
6.0	35	I	X		—	—	—
6.3	34	—	X		—	—	—
6.4	44	I	X		—	—	—
6.6	44	I	X		—	—	—
6.7	48	I	X		—	—	—
6.8	48	—	X		—	—	—
7.0	50	—	X		—	—	—
7.1	57	I	X		—	—	—
7.1	60	I	X		—	—	—
7.5	60	—	X		—	—	—
7.6	66	I	X		—	—	—
7.6	65	I	X		—	—	—
7.9	82	I	X		—	—	—
7.9	70	—	X		—	—	—
8.0	70	—	X		—	—	—
8.1	83	I	X		—	—	—
8.1	85	II		X	219	7	3.7
8.3	100	II	X		—	—	—
8.5	110	II		X	225	9	3.9
8.5	88	II	X		—	—	—
8.6	84	II	X		—	—	—
8.6	76	I	X		—	—	—
8.7	104	I	X		—	—	—
9.2	128	III		X	232	15	4.7
9.3	125	II		X	270	17	4.4
9.3	140	—		X	342	14	4.0
9.4	146	II		X	460	19	4.0
9.6	144	III		X	372	21	4.4
9.7	172	III		X	378	21	4.4
9.7	155	III		X	348	18	4.3
10.1	146	II	X		—	—	—
10.1	178	—		X	526	26	5.5
10.1	143	III		X	292	17	4.5
10.2	160	—		X	456	21	4.2
10.2	178	IV		X	325	20	4.7
10.5	186	—		X	494	21	4.0
10.5	188	III		X	298	24	5.1
10.6	186	III		X[a]	194	11	4.6
10.7	202	—		X	476	24	4.3
10.8	202	—		X	518	28	4.3
10.9	215	—		X	574	27	4.1
11.0	190	—		X	446	21	4.1
11.0	200	—		X	495	29	4.5
11.1	216	III		X	525	31	4.6
11.1	236	IV		X	381	34	5.3
11.4	232	—		X	639	35	4.5
11.5	248	III		X	581	40	4.7
11.5	244	III		X	575	44	4.8
12.4	268	—		X	545	41	4.9
12.5	282	—		X	465	42	5.0
12.6	298	—		X	626	44	4.9
12.7	304	IV		X	550	47	5.0
12.7	312	—		X	701	58	5.0
13.2	355	—		X[a]	470	46	5.4
13.7	416	—		X	766	72	5.0
14.1	430	—		X	1,094	86	4.9
14.3	420	—		X	701	64	5.1
14.5	460	—		X	769	69	4.9
14.6	500	—		X[a]	927	87	5.3
17.6	870	—		X[a]	1,371	118	5.2

So. Br. Wedde Creek 25 Oct 1978

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
7.4	60	I	X		—	—	—
7.4	56	I	X		—	—	—
7.6	60	I	X		—	—	—
7.8	66	I	X		—	—	—
8.2	76	I	X		—	—	—
8.3	—	—	X		—	—	—
8.3	92	II		X	316	13	3.9
8.3	94	II		X	285	11	3.8
8.4	76	I	X		—	—	—
8.8	110	II		X	317	14	3.9
8.8	94	I	X		—	—	—
8.9	106	II		X	284	10	3.5
8.9	104	—	X		—	—	—
9.1	120	II		X	293	15	4.1
9.2	114	II		X	326	16	4.0
9.3	106	II	X		—	—	—
9.4	132	I	X		—	—	—
9.5	140	II		X	327	16	4.0
9.6	144	II		X	391	22	4.3
10.0	154	II		X	442	17	3.8
10.2	170	III		X	424	31	4.6
10.3	172	III		X	510	30	4.6
10.4	180	II		X	503	23	4.0
10.5	182	II		X	652	30	3.8
11.0	200	—		X	717	32	3.9
11.2	206	III		X	504	30	4.4
11.7	248	—		X	636	44	4.4
11.8	252	—		X	635	38	4.4
12.2	286	II		X	970	47	4.1
12.2	292	—		X	928	52	4.2

Mecan River 25 Oct 1978

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
8.0	76	—	X		—	—	—
8.2	82	I	X		—	—	—
8.2	86	I	X		—	—	—
8.4	98	—	X		—	—	—
8.5	96	II	X		—	—	—
8.5	86	I	X		—	—	—
9.1	116	I	X				
9.3	124	I	X				
9.7	136	—		X	282	13	4.0
9.7	148	II		X	297	12	4.0
9.9	142	—	X		—	—	—
10.1	164	II		X	341	16	4.1
10.6	176	III		X	548	26	4.2
10.8	192	III		X[b]	34	2	4.2
11.1	204	II		X	435	20	4.2
11.4	270	III		X	689	37	4.6
11.4	222	II		X[b]	186	8	4.2
11.6	250	—		X	633	32	4.1
11.7	260	—		X	605	25	4.1
11.8	276	—		X[a]	676	33	4.3
12.8	372	—		X	830	66	6.0
12.9	304	III		X[b]	227	14	4.7
15.1	566	—		X[a]	1,291	95	4.9

Eighteen Mile Creek 1 Oct 1980

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
7.8	73	II	X		—	—	—
7.8	79	II		X	229	6	3.5
8.0	80	II	X		—	—	—
8.2	90	II	X		—	—	—
8.4	94	II		X	322	6	—
8.5	99	II	X		—	—	—
8.6	92	II	X		—	—	—
8.7	106	II	X		—	—	—
8.8	96	II	X		—	—	—
9.0	106	II	X		—	—	—
9.0	116	III		X	348	14	3.9
9.2	120	II	X		—	—	—
9.2	126	II	X		—	—	—
9.4	130	II	X		—	—	—
9.8	160	II	X		—	—	—
9.9	150	II	X		—	—	—
10.1	178	III		X	477	27	4.3
10.3	184	III		X	490	29	4.5
10.5	196	III		X	504	22	3.8
10.6	190	III		X	423	22	4.2
10.6	172	III		X	548	26	4.0
10.8	214	III		X	622	33	4.5
11.0	210	IV		X	543	36	4.5
11.1	214	III		X	661	32	4.2
11.4	242	IV		X	472	32	4.5
11.6	260	III		X	536	36	4.6
12.0	294	III		X	736	40	4.3
12.3	294	IV		X	610	38	4.4
12.8	296	IV		X	928	52	4.6
13.4	412	IV		X	1,027	74	4.8
13.7	386	IV		X	1,008	60	4.4
13.8	420	IV		X	1,022	74	4.7
14.0	428	IV		X	1,168	80	4.7
14.4	490	IV		X	1,030	76	4.6
14.8	560	IV		X	1,263	100	4.7
15.2	580	—		X	1,303	126	5.0
15.3	508	IV		X	946	84	4.9
16.5	654	V		X	1,416	122	5.0
17.2	850	V		X	1,991	182	5.1
17.6	960	V		X	1,252	154	5.4
18.5	920	V		X	2,050	178	4.9
19.6	1,044	V		X	2,055	186	5.1
19.7	1,235	V		X	2,027	238	5.6
20.4	1,375	V		X	2,148	214	5.3
20.7	1,500	V		X	3,279	281	5.0

Parker Creek 17 Sep 1981

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
7.0	54	I	X		—	—	—
7.8	72	I	X		—	—	—
7.8	78	I	X		—	—	—
8.0	86	I	X		—	—	—
8.1	90	I	X		—	—	—
9.4	138	II		X	368	12	3.7
9.5	162	II		X	356	14	3.9
9.7	156	II		X	468	20	4.0
9.8	166	II		X	334	16	14.1
10.2	172	II		X	565	20	3.9
10.7	232	II		X	503	26	4.2
11.0	224	II		X	398	24	4.4
11.2	220	II		X	561	19	4.0
11.3	212	III		X	286	12	3.9
11.5	244	II		X	507	24	4.4
12.0	302	III		X	436	26	4.6
12.0	275	II		X	478	24	4.1
12.2	268	III		X	455	28	4.6
12.3	286	—		X	483	29	4.5
13.4	410	III		X	668	39	4.6
14.0	424	III		X	700	40	4.4
16.0	662	IV		X	999	80	5.0

Beaver Creek 10 Oct 1980

Total Length (inches)	Weight (g)	Age	Immature	Mature	No. Ova	Weight Ova (g)	Avg. Diameter Ova (mm)
7.1	52	I	X		—	—	—
7.4	60	I	X		—	—	—
7.5	60	I	X		—	—	—
7.5	62	I	X		—	—	—
8.1	81	II	X		—	—	—
8.1	70	I	X		—	—	—
8.8	105	II		X	396	9	3.4
8.8	64	I	X		—	—	—
8.9	105	II	X		—	—	—
9.2	124	II		X	430	13	3.6
9.3	136	II		X	555	16	3.5
9.5	120	II	X		—	—	—
10.0	175	II		X	668	21	3.7
10.1	150	III		X	397	13	3.9
10.2	163	I	X		—	—	—
11.6	252	II		X	970	30	3.7
12.4	304	II		X	1,107	40	3.6
12.7	390	III	X		—	—	—
12.8	326	III	X		—	—	—
13.3	378	II		X	1,202	34	3.5
13.9	440	IV		X	1,431	87	4.3
14.0	450	III		X	1,055	54	4.4
14.4	534	III		X	1,461	102	4.5
15.2	652	IV		X	1,385	114	4.8
16.1	868	IV		X	2,397	144	4.4
17.2	886	III		X	2,138	127	4.4
20.4	1,375	—		X[b]	—	—	—

APPENDIX II. Average percent body weight of ova in brown trout collected in 8 Wisconsin streams, September-October 1978.

Inch Group	No. Sampled	Avg. Percent Body Weight of Ova
7.0-7.9	1	7.6
8.0-8.9	13	9.7
9.0-9.9	29	12.2
10.0-10.9	27	13.2
11.0-11.9	37	13.2
12.0-12.9	17	14.5
13.0-13.9	11	14.5
14.0-14.9	10	16.0
15.0-15.9	4	18.1
16.0-16.9	3	15.1
17.0-17.9	4	16.8
18.0-18.9	1	19.3
19.0-19.9	2	18.6
20.0-20.9	2	17.2
Total	161	

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