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FACTORS INFLUENCING REPRODUCTION OF BROWN TROUT ABOVE AND BELOW A FLOOD WATER DETENTION DAM ON TROUT CREEK, WISCONSIN

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ABSTRACT

This study was initiated to determine the influence of a flood water detention dam upon the spawning environment and survival of brown trout eggs in Trout Creek, Wisconsin. Trout redds were counted above and below the detention dam during the fall of 1975, 1976, and 1977. Substrate composition, intragravel temperatures, and intragravel dissolved oxygen (D.O.) were monitored in selected redds above and below the dam. Embryo development and survival were determined in each stream reach by excavating trout redds throughout the respective egg incubation periods. Stream temperature and discharge in each stream reach were also monitored.

Brown trout spawning generally occurred from late October to mid-December and began 1 to 2 weeks earlier below the detention dam than above it. Each year, more than twice as many redds were constructed above the dam than below it. A higher incidence of superimposition and "false" redds occurred below the dam and was attributed to a lack of suitable spawning areas. The composition of redd materials above and below the dam was not significantly different. Sedimentation of trout redds during the respective egg incubation periods could not be demonstrated. Embryo survival to hatching was positively correlated to stream temperatures and to a lesser extent, to intragravel D.O. concentrations above 6 ppm. Stream temperatures and intragravel D.O. concentrations within redds were higher above the dam and resulted in significantly better overall survival to hatching than below the dam. An absence of heavy run-off and flooding during the 3 winters precluded any effect of the detention dam upon embryo survival, but the data provide a basis for future comparisons when winter flooding does occur.

Department of Natural Resources • Madison, Wisconsin

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INTRODUCTION

Since the completion of a flood water detention dam (built by the SCS under PL 566 funding) on Trout Creek (Iowa County) in 1964, spawning conditions for wild brown trout (Salmo trutta) appear to have been drastically altered. A 300-yd section of stream above the dam was a major spawning area prior to dam construction, but the number of trout redds (nests) present in this reach since construction has declined markedly. The number of redds found below the dam appears to have declined, too.

The reduction in trout redds in both stream sections is believed to be due to the detention dam and its effects upon streamflow and sedimentation processes. During periods of heavy rainfall and/or rapid snowmelt, runoff waters are impounded by the dam and inundate 1/4 to 1/3 mile of stream. The streambed has become heavily silted within the area of intermittent impoundment and some gravel spawning areas have been buried. When impoundment occurs during late fall or winter, brown trout eggs which have been deposited in the affected area are probably suffocated due to the reduction in stream current and deposition of fine sediments over the streambed.

The stream reach below the detention dam is subjected to prolonged periods of sedimentation following each major storm event. Silt-laden water is discharged from the impoundment for up to several weeks as the "catch basin" drains and the streamflow above the dam cuts through silt layers deposited in the stream channel during impoundment. Burial of some gravel areas and excessive siltation of remaining areas are believed responsible for the decline in trout redds here, too. The present study was initiated to determine the influence of impounded, silt-laden water upon the spawning environment and embryo survival of wild brown trout above and below the dam during the fall and winter months. Studies were conducted during three reproductive seasons, 1975-76, 1976-77, and 1977-78. Work conducted and results obtained during each season will be discussed separately. A final summary and conclusion section will follow discussion of the individual years of study. This study is one phase of a cooperative venture with the Wisconsin Department of Natural Resources, Soil Conservation Service, U.S. Geological Survey, and University of Wisconsin-Madison to assess the total effects of the flood control structure upon the biological and physical components of Trout Creek.[1]

DESCRIPTION OF THE STUDY AREA

Trout Creek is located in northeastern Iowa County in south central Wisconsin (Fig. 1). The stream flows northwesterly from the Village of Barneveld to its junction with Mill Creek, roughly 8.0 miles downstream. Base discharge is 7.7 cfs (3,465 gal/min), average width is 7.2 ft; gradient is 55 ft/mile, and the total drainage area is 18.5 sq miles (Piening and Threinen 1968). Although the entire stream below Birch Lake is classified as trout water, natural reproduction occurs primarily in the 3.4-mile reach between Arndt Spring and the second intersection of the stream with County Trunk Highway T. This reach is Class I[2] trout water and constitutes the study area. A flood water detention dam (Public Law 566, Structure 8) bisects the study area. The dam impounds water only when stream discharge exceeds the capacity of a 36-in. outlet culvert. This usually occurs several times a year due to heavy rains or rapid snowmelt in the coulee-type[3] watershed.

FALL AND WINTER, 1975-76

PROCEDURES

Numbered metal fenceposts designating 300-yd stations were present on Trout Creek when this study began in October 1975. On 29 October and 13 November, the stream was surveyed on foot from station 9 to station 30 to determine the number and distribution of trout redds (Fig. 1). Five redds below and 5 redds above the dam were selected for substrate analyses and monitoring of intragravel concentrations of dissolved oxygen (D.O.).

One substrate sample was collected from each redd on 14 November, 8 January, and 12 February. Initial samples were to determine substrate composition immediately following egg deposition. Successive samples were taken to characterize substrate composition late during the egg development period and again near the time of fry emergence from in-stream gravels. A substrate sampler similar to that described by McNeil and Ahnell (1964) was used. Samples were dried and sifted through 7 standard soil sieves with mesh ranging from 0.106 mm to 8.0 mm. Each fraction of the sample was weighed and converted to a percentage of the particle size distribution.

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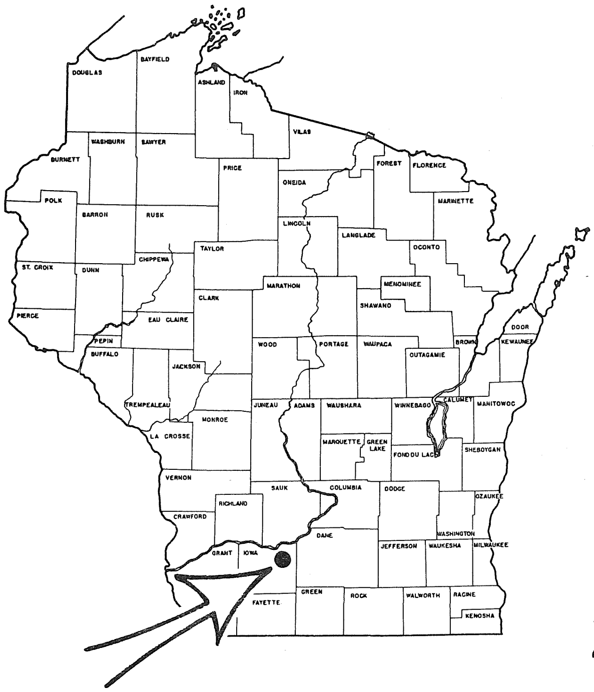
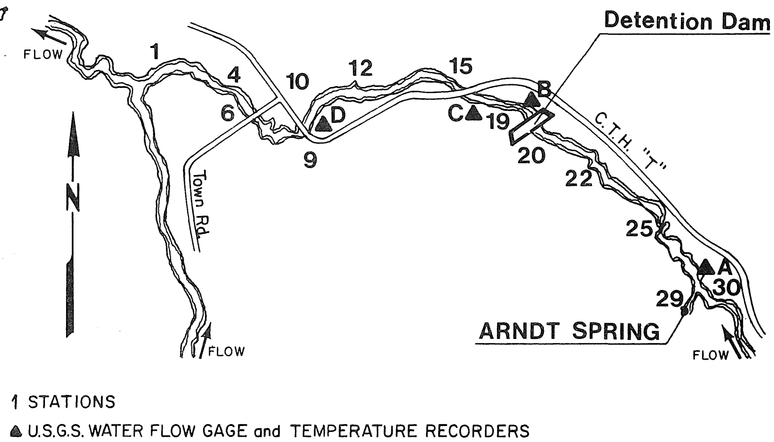
1 In addition to the investigation reported here other phases of the Trout Creek study funded by the Soil Conservation Service include: (1) "The effects of silting on a stream trout population and evaluation of siltation damage controls," O. M. Brynildson-principal investigator, Wisconsin Department of Natural Resources, Water Resources Section; (2) "The effects of a flood-control structure on sedimentation, stream channel morphology, and streamflow in Trout Creek," R. S. Grant - principal investigator, U.S. Geological Survey; and (3) "The effects of a Soil Conservation Service impoundment and other perturbations on arthropods in Trout Creek," W. L. Hilsenhoff - principal investigator, University of Wisconsin-Madison.

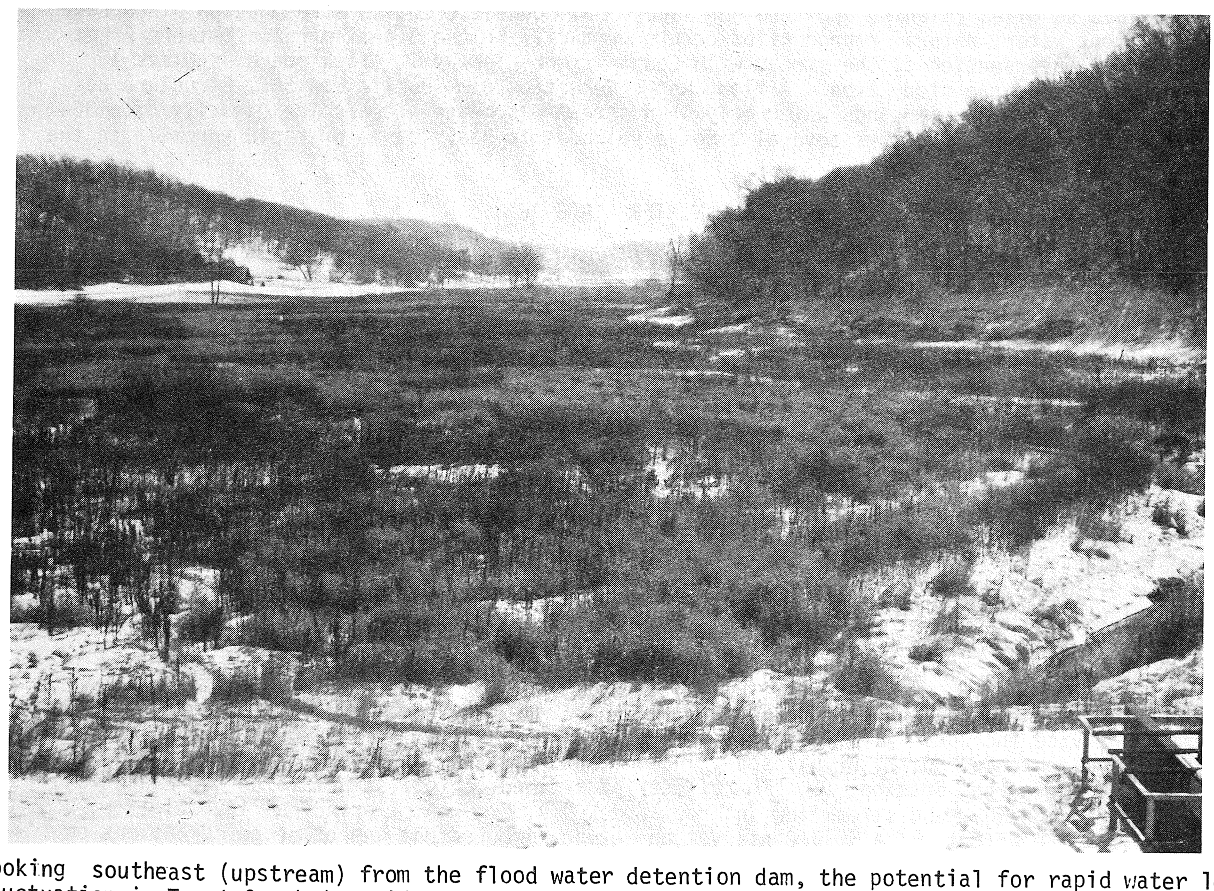
2 Class I - High grade trout waters with good year-round stream temperatures and sufficient natural reproduction to fill the available habitat. Little or no stocking of hatchery trout is necessary.

3 Coulee - "A steep walled, trenchlike valley."

FIGURE 1. Location and study zone of Trout Creek, Iowa County, showing relative positions of 300-m stations.







Looking southeast (upstream) from the flood water detention dam, the potential for rapid water level fluctuation in Trout Creek is evident from the steep terrain.

Biweekly monitoring of intragravel concentrations of dissolved oxygen was conducted on the 10 study redds beginning on 14 November and ending on 13 February 1976. Procedures used were similar to those described by McNeil (1962). Plastic standpipes, 34 in. long, having an inside diameter of 0.75 in., and having 30 1/16-in. holes drilled in the bottom 3.0 in., were driven into the substrate. Holes in the bottom 3.0 inches of each standpipe were enlarged to 1/8 in. following the second sampling run to permit better exchange of intragravel water. Usually 2 or 3 standpipes were driven into each redd on a line perpendicular to stream flow. A fencepost was installed adjacent to each redd and the distance to each standpipe was recorded to enable similar placement of standpipes on successive sampling dates. Standpipes were positioned 6.0 in. apart and driven 6-7 in. into the substrates. Sand, gravel, and turbid water were evacuated orally using a piece of 1/2-in. flexible plastic tubing. Water samples were collected the following day and standpipes were removed until the next sampling period. Stream water samples were collected during each sampling period at stations 10 and 21. Harper's (1953) semi-micro modification of the Winkler method was used to analyze water samples for D.O. content. Samples were "fixed" at the stream site and titrated later in the laboratory.

In conjunction with substrate analyses and D.O. determinations, intragravel water temperatures and stream temperatures were measured at the 10 study redds as well as 7 others on 13 February. A soil probe equipped with a YSI thermistor was used to measure intragravel temperatures at 6.0-in. intervals across each redd. Measurements were taken approximately 2.0 in. below the substrate-water interface. Corresponding stream temperatures were taken with a hand thermometer.

Stream temperatures were recorded continuously from 14 November to 5 February using Ryan submersible thermographs installed at stations 10 and 21. Stream depth and current velocity over the 10 redds were measured on 14 November using a pigmy Gurley meter.

On 22 December, 2 redds below the dam and 7 redds above the dam were partially excavated to determine embryo survival and stage of development. Seventeen redds, including the 10 routinely sampled for D.O., were excavated on 13 February to determine embryo survival to the "fry" stage.

FINDINGS

Enumeration of Trout Redds

From 8 to 9 redds below the dam and from 31 to 37 redds above the dam were located during the October and November stream surveys (Appendix Table 1). On 13 November 1975, Southern District Fish Manager Cliff Brynildson conducted an independent redd survey and identified 10 redds below the dam and 64 redds above the dam. The discrepancy in redd counts was not surprising due to the subjective nature of deciding what is and what is not a completed trout redd. No redds were found in the first 300-yd station above the dam in any of the three surveys.

Stream Temperatures

Within the study area, most accrual of groundwater occurs in stations 30 and 29 in the vicinity of and including Arndt Spring (Fig. 1). Some accrual occurs between stations 28 and 21 but below the dam, in stations 19 through 10, very little emergence of groundwater is evident. Mean weekly water temperatures at station 21 were 1-4^{o}F warmer than corresponding temperatures downstream in station 10 throughout the winter (Table 1).

TABLE 1. Mean weekly stream temperatures (in ^{o}F) in station 10, below the dam, and in station 21 above the dam.

Week of	Station 10	Station 21
9 November 1975	41.1	42.8
16	44.3	45.4
23	36.6	38.0
30	38.1	38.8
7 December	39.1	40.6
14	37.5	41.6
21	38.3	40.3
28	38.6	40.4
4 January 1976	33.2	38.9
11	35.7	
18	36.5	
25	37.2	
1 February	35.4	

TABLE 2. Current velocities and water depths over selected redds and mean percentage by weight of redd substrates, 1975-76.

Station and Month	Redd No.	Current Velocity Over Redd (ft/sec)	Water Depth Over Redd (ft)	Percentage by Weight Retained by Sieve at Different Sieve Openings (mm) 2.0	1.0	0.25	0.016
Below Dam							
10	W-1						
November		1.37	0.50	92.7	2.4	4.2	0.7
January				69.2	3.4	22.6	4.8
February				81.2	2.9	14.2	1.5
13	W-4						
November		1.70	--				
January				73.3	3.4	21.1	2.1
February				70.8	3.4	22.9	2.5
15	M-1						
November		1.23	0.50	67.3	2.4	26.6	8.8
January				73.9	2.7	19.3	4.2
February				68.5	2.6	21.8	6.8
18	M-3						
November		2.50	0.55	65.0	3.6	25.3	6.2
January				74.5	3.5	20.1	2.0
February				69.8	3.6	20.8	5.8
19	W-6						
November		2.48	0.45	74.2	2.0	18.7	5.0
January				72.1	2.2	16.2	9.4
February				81.8	1.6	12.2	6.0
Above Dam							
21	W-7						
November		2.10	0.45	86.0	3.0	8.8	2.2
January				89.3	1.4	6.8	2.6
February				85.0	2.4	11.0	1.8
24	M-5						
November		1.65	1.20	79.3	1.6	14.1	5.0
January				70.4	4.0	17.9	7.8
February				71.7	2.2	19.1	7.1
	W-13						
November		1.48	1.50	40.4	2.5	43.3	13.7
January				80.8	2.1	12.6	4.3
February				70.5	2.7	20.4	6.3
26	W-17						
November		2.50	--	81.7	2.9	13.3	2.0
January				73.1	2.4	18.2	6.4
February				72.1	3.1	20.8	4.1
27	W-22						
November		2.50	--	86.0	3.0	8.8	2.2
January				78.2	2.2	12.4	7.3
February				62.6	2.6	30.4	4.3

Substrate Composition, Water Depth, and Current Velocity

Fine materials in trout redds reduce their permeability. Low permeability, in turn, inhibits both the influx of fresh oxygenated water to buried eggs and the removal of metabolic wastes. Changes in the percentage composition of fine particles ($\leq$1 mm diameter) in trout redds were inconsistent during the egg incubation period (Table 2). The percentage of fine particles increased in 5 redds, decreased in 3 redds and showed no trend in the 2 remaining redds. There were no marked differences in the percentages of fine materials in redds above and below the dam. Streamflows were stable throughout the winter so these data do not reflect possible changes in substrate composition resulting from high winter runoff. There was no detectable relationship between current velocity and/or water depth over the redds and substrate composition.

TABLE 3. Concentrations of dissolved oxygen (ppm) in intragravel water, 1975-76.*

Station	Redd No.	Sampling Dates 11 Dec.	 23 Dec.	 22 Jan.	 13 Feb.	Mean	Variance
Below Dam							
10	W-1	0.3 0.6 1.0	3.2 9.7	7.2 8.4		4.34	15.9
13	W-4	6.6 7.3	5.1 8.2	9.9 9.6	7.2 9.2	7.88	2.76
15	M-1	4.5 2.6	6.1 4.2	9.2 5.1	2.3 4.7	4.84	4.75
18	M-3	7.1 7.7	4.8 6.4	3.8	2.4	5.66	4.00
19	W-6	8.5 8.9	7.3 10.3	7.8	3.4 3.8	7.16	6.66
Above Dam							
21	W-7	7.0 6.1	5.8	9.6 10.6	7.2 7.9	7.64	6.97
24	M-5	3.4 5.2 6.4	6.3 1.2	8.0	3.7	4.86	5.26
	W-13		5.0 4.0	7.8 6.3	7.5 6.4	6.16	2.12
26	W-17	1.3 7.3 5.6	6.7 4.1	5.8 4.4	6.8 1.7	4.87	4.69
27	W-22	6.1 6.6	5.8 4.7	9.9 9.1	5.1 7.6	6.84	3.46

* Concentrations below 5.0 ppm are underlined.

Intragravel Dissolved Oxygen

Intragravel concentrations of dissolved oxygen (D.O.) varied considerably within and between trout redds during the sampling period* (Table 3). Based upon studies of other scientists on the effects of D.O. upon egg survival of salmon species (Alderdice et al. 1958; Coble 1961; Silver et al. 1963), 5.0 ppm (mg/l) D.O. was selected as a "ball-park" figure above which reasonable survival of trout embryos could be expected in Trout Creek. D.O. concentrations were below 5 ppm in 13 of 36 samples (36%) taken below the dam and in 9 of 37 samples (24%) taken above the dam. Mean D.O. concentrations were below 5 ppm in 2 of the 5 redds sampled both below and above the dam. There appeared to be little difference in intragravel D.O.'s in trout redds above vs. below the dam.

*D.O.'s in the November sampling periods were disregarded because 1/16-in. holes in the standpipes appeared to impede water movement or exchange.

Egg Development and Survival

Neither of 2 redds excavated below the dam on 22 December contained eggs. Two of 7 redds excavated above the dam were also empty. The other 5 redds contained "eyed" eggs and one contained a few live sac fry. Survival in these redds was 0%, 14.2%, 20.8%, 90.4%, and 92.8% with an average of 43.6%.

Three of 17 redds excavated on 13 February were empty, i.e. "false" redds. In 3 of 5 redds below the dam and in 5 of 9 redds above the dam, live sac fry were present (Table 4). Thus, hatching of sac fry was evident in 57% of the 14 redds containing eggs.

Survival of embryos ranged from 7.9% to 17.4% with an average of 12.9% in 4 redds below the dam (Table 4). In the fifth redd (W-4 in station 13), groundwater emergence was detected and embryo survival was 86.7%*. Sac fry had hatched from 81% of the eggs in this redd. Above the dam, embryo survival averaged 52.9% and ranged from 0% to 93.2%. Fry showing little evidence of their yolk sac were present in one redd above the dam indicating that some may already have emerged from instream gravels. In general, survival to the sac fry stage was roughly 4 times greater above the dam than below it.

Survival vs. Abiotic Factors

Embryo survival was not well correlated with substrate composition of redds, current velocities over individual redds, or intragravel D.O. (Table 5). Mean percentage by weight of substrate materials smaller than 1.0 mm was 23.1% for the 5 redds with the lowest survival and 24.9% for the 5 redds with the highest survival. Mean percentage of material smaller than 0.25 mm was 5.4% for the 5 redds with the lowest survival and 3.8% for the 5 redds with the highest survival. None of the differences between percentages of fine materials were statistically significant ($P = 0.05$). Mean current velocity was 2.05 ft/sec over both the 5 redds with the poorest survival and the 5 redds with the best survival. Survival was, thus, independent of current velocities within the range of values observed. Mean intragravel D.O. ranged from 4.84 to 7.88 ppm in the 10 redds and also showed no relationship to embryo survival.

There was a strong positive trend between embryo survival and warmer water temperatures. Stream temperatures and thus egg incubation temperatures were warmer above the dam (Fig. 3) and 4 of the 5 redds with the highest embryo survival were located there (Table 5). The fifth redd (W-4) and one in which survival was the highest, was located below the dam but was influenced by upwelling groundwater in the mid-40's (^{o}F).

DISCUSSION

Extensive beds of watercress (Nasturtium sp.) covered large portions of riffles above the dam in Trout Creek when trout spawning activities began in November. These beds of watercress constricted and often braided the streamflow into narrow channels with high current velocities. Trout redds were often found in these channels. When the beds of watercress began to die off in December and January, current velocities and water depths over many redds declined as streamflow became less restricted. Silt beds formerly anchored by the watercress were eroded away even though streamflows remained stable. Declines in water depth and stream velocity over redds and deposition of fine sediments in streambed gravels are known to have negative effects upon the interchange of intragravel water and supply of D.O. to incubating eggs. Thus, natural vegetation changes in Trout Creek may have had some detrimental effects upon embryo survival at least above the dam.

Trout eggs in Trout Creek were always found in gravel substrates above sand, silt, and clay deposits. Substrates collected, however, probably did not reflect the environment of the developing eggs because of: (1) observed variability in the depth of gravel substrates within and between redds (2-12 in.), (2) the uniform depth to which substrate samples were collected, and (3) deliberate avoidance of the "egg pocket" in each redd in order not to affect egg survival.

Absence of a strong positive relationship between intragravel D.O. and egg survival may have been due to the locations of standpipes in redds. Eggs tended to be deposited in oval shaped pockets (maximum dimensions 18 by 8 in.) linearly oriented with the current. Best placement of standpipes would have been on the vertical axis of each redd rather than on the horizontal axis. Also, changes in streambed morphometry and other visual cues made similar placement of standpipes on successive sampling dates difficult when the distance from the standpipes to only one permanent reference point was known.

The 1975-76 study period on Trout Creek was in many respects a period of trial and error. Several facts did emerge, however:

1. The detention dam had no negative effects upon the reproductive success of brown trout from the time of egg deposition to fry emergence because streamflows were stable throughout the incubation period. The data provide a basis for future comparisons when streamflows are more erratic.

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*Intragravel temperature was 48.2^{o}F or 7.4^{o}F warmer than the stream temperature. The temperature gradient never differed more than 1.8^{o}F (1^{o}C) in all other redds checked.

2. Survival of trout eggs was more closely related to stream temperature than to intragravel D.O. and substrate composition.

3. Recruitment through natural reproduction below the dam was undoubtedly minor in 1976 due to the low number of redds observed and low survival of deposited eggs.

TABLE 4. Numbers of live and dead embryos found in trout redds, 12 February 1976.

Station	Redd No.	Dead Embryos		Live Embryos		Survival
		Eggs	Sac Fry	Eggs	Sac Fry	(%)
Below Dam						
10	W-1	169		25	2	13.7
13	W-4	8	4	9	69	86.7
15	M-1	93		8		7.9
18	M-3	241		51		17.4
19	W-6	76			11	12.6
Above Dam						
21	W-7	164		35	22	25.8
25	W-15	63				0
24	M-5	130				0
24	W-13		3		7	70.0
26	W-17	117		152		56.5
27	W-22	105	4	173	9	62.5
28	W-23	2	1		41	93.2
28	W-25	16	1	49	12	78.2
29	W-27	8		68		89.5

TABLE 5. Survival of trout embryos on 12 February 1976 in relation to composition of redd substrates, current velocities over redds, and mean intragravel dissolved oxygen determined on four dates from 11 December 1975 to 12 February 1976.

Station	Redd No.	Survival (%)	% by Weight of Redd Substrates on 12 Feb. 1976		Current Velocity Over Redds on 14 Nov. 1975 (ft/sec)	D.O. (ppm)	
			<1.0 mm	<0.25 mm		Mean	Variance
24[a]	M-5	0	26.2	7.1	1.65	4.86	5.26
15	M-1	7.9	28.6	6.8	2.23	4.84	4.75
19	W-6	12.6	18.2	6.0	2.48	7.16	6.66
10	W-1	13.7	15.7	1.5	1.37	4.34	15.90
18	M-3	17.4	26.6	5.8	2.50	5.66	4.00
21[a]	W-7	25.8	12.8	1.8	2.08	7.64	6.97
26[a]	W-17	56.5	24.9	4.1	2.50	4.87	4.69
27[a]	W-22	62.5	34.7	4.3	2.50	6.84	3.46
24[a]	W-13	70.0	26.7	6.3	1.48	6.16	2.12
13	W-4	86.7	25.4	2.5	1.70	7.88	2.76

[a] Above detention dam.

FALL AND WINTER, 1976-77

PROCEDURES

In order to quantify the period of major spawning activity in Trout Creek and improve the accuracy of the total redd counts, bimonthly redd surveys were conducted from 27 October 1976 through 12 February 1977. Station 9 was surveyed twice and subsequently eliminated due to the absence of gravel substrates and lack of any evidence of spawning activity. Each identified redd was marked with a numbered wooden stake driven into the nearest stream bank. The date observed, position of the redd relative to the stake, and a ranking relative to size--i.e. small, medium, large--and form--i.e. poor, fair, good--were recorded.

Between 9 and 13 November, 6 redds below and 6 redds above the dam were selected for bimonthly monitoring of intragravel concentration of dissolved oxygen. On each sampling date, 2 or 3 standpipes were installed on the longitudinal or Y axis of each redd with the upstream standpipe (No. 1) installed 0.5 ft behind the deepest point of the depression made by the spawning female. To assure similar positioning of standpipes in successive sampling periods, the distance from the No. 1 standpipe to two stakes driven into the nearest bank was recorded. These stakes were separated by 8-10 ft and paralleled the stream. Additional standpipes were installed at 1-ft intervals directly behind the No. 1 standpipe. Procedures used to determine intragravel D.O. were similar to those used in fall and winter of 1975-76.

Stream depth and current velocity were measured at the position of the No. 1 standpipe in the 12 redds on 9 November 1976 and 9 February 1977. Intragravel water temperatures were measured in each redd on 22 December across a transect 1 ft behind the No. 1 standpipe. Measurements were taken at 1-ft intervals, 2-4 in. below the substrate water interface.

Stream water temperatures were recorded continuously throughout the spawning and egg incubation period at U.S.G.S. gauging stations A, C, and D located in stations 10, 17, and 29, respectively (Fig. 1).

On 22 December, 1 redd above the dam and 1 redd below the dam were partially excavated to determine embryo survival and stage of development. Two redds above the dam and 3 redds below the dam were partially excavated on 28 January 1977. Three redds routinely sampled for D.O.'s. were excavated on 29 January. On 9 February, the remaining 9 redds routinely sampled for intragravel D.O.'s were excavated. Further excavations of 3 redds above the dam and 4 redds below the dam were made on 2 March following heavy rains and spring flooding in late February.

FINDINGS

Enumeration of Trout Redds

A total of 36 redds below the dam and 44 redds above the dam were found during the spawning period (Appendix Table 2). No redds were present in station 20, the first 300 yd above the dam.

Spawning activities began 1-2 wk earlier below the dam but the main spawning period lasted 2 months (27 October through 22 December) both above and below the dam (Fig. 2). The latest redds were constructed at the upper extremities of both reaches of stream.

Bimonthly redd counts permitted a higher degree of accuracy in distinguishing between "trial" redds and "completed" redds than if less frequent counts had been made. Numerous redds were difficult to distinguish after only 2-3 wk. Also, in many instances where superimposition[1] occurred and where redds were constructed in close proximity to one another, redd counts would have been negatively biased had they not been counted and marked bimonthly.

Stream Temperatures

Mean weekly stream temperatures from early November through mid-February were much warmer above the dam nearer the main sources of groundwater (Fig. 3). Mean weekly temperatures at station 29 ranged from 41°F to 44°F. Corresponding temperatures at stations 17 and 10, 2.0 and 3.2 miles downstream, ranged from 32°F to 40°F with temperatures usually 1-3°F warmer at station 17. During a 3-wk period in January, 1977, mean weekly temperatures at station 10 dropped to between 32.3°F and 33.3°F. The stream froze over and 1-3 in. of anchor ice covered the streambed as far upstream as station 12.

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[1] Construction of 1 redd on top of another by different female trout.

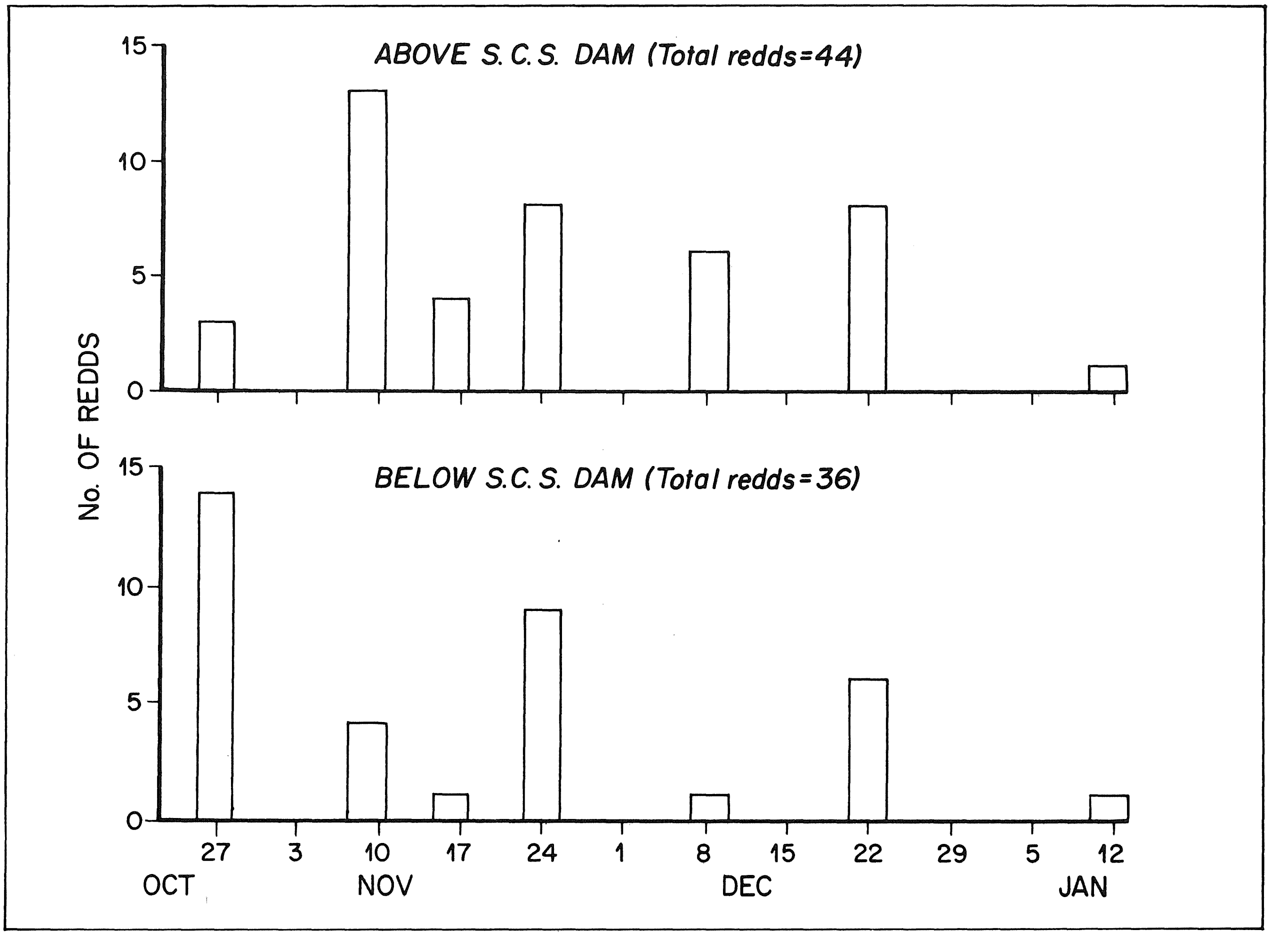


FIGURE 2. Chronology of redd construction by brown trout in Trout Creek, fall and winter, 1976-77.

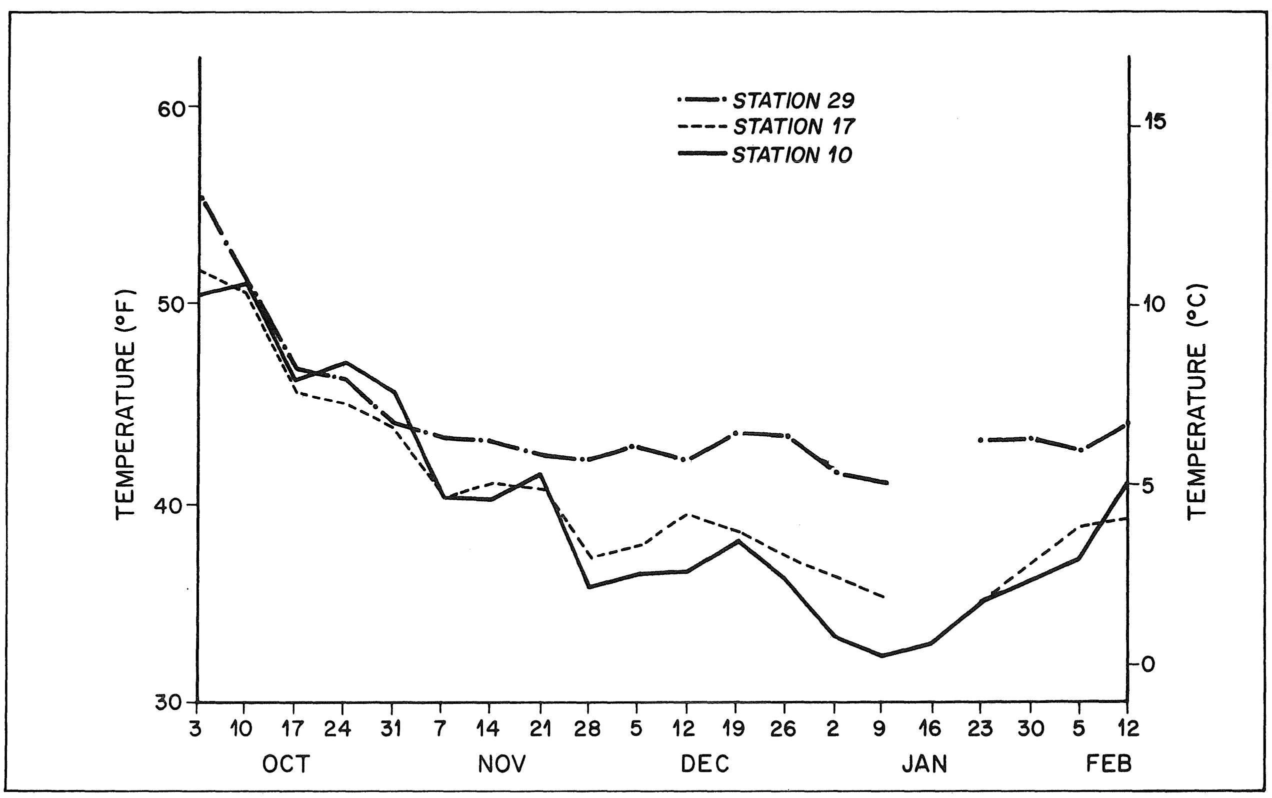
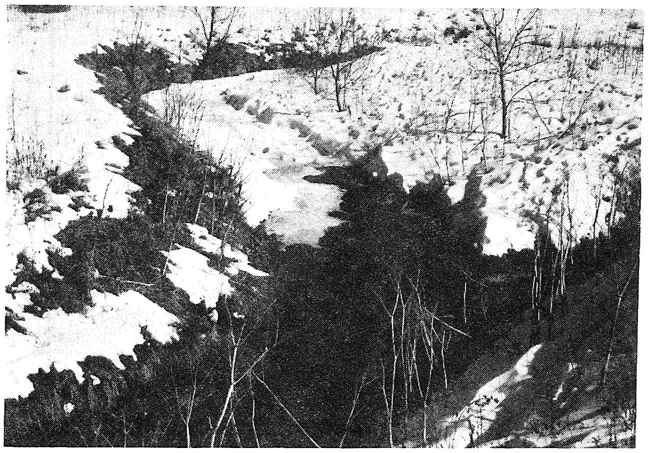


FIGURE 3. Mean weekly water temperatures during the spawning and egg incubation periods for brown trout in Trout Creek, fall and winter, 1976-77.



The warming influence of groundwater is readily observed in Trou Creek in the upper reaches of the study zone near Arndt Spring.

Water Depth, Current Velocity, and Intragravel Temperatures

In general, both depth and velocity of water over redds in Trout Creek declined during the egg incubation period (Table 6). In 6 of 9 redds monitored, declines in stream depth ranged from 0.05 to 0.3 ft. Increases in stream depth ranged from 0.05 to 0.1 ft over 3 redds. Declines in stream velocity ranged from 0.37 ft/sec to 1.0 ft/sec over 6 of the 9 redds. Velocity was stable over 1 redd and increased 0.05 ft/sec and 0.14 ft/sec over the other two.

Declines in stream depth and current velocity over redds were more apparent above the dam (Table 6). Water depths declined over 3 of the 4 redds monitored while stream velocity declined over all 4 redds. This is consistent with the prevalence of more aquatic vegetation, primarily watercress, above the dam. This vegetation tended to constrict the stream channel during late summer and fall as it did in 1975. Winter die-off in December and January allowed the stream to flatten out and slow down. Stream discharge remained stable throughout the entire period.

TABLE 6. Stream depths and current velocities over brown trout redds during the egg incubation period, 1976-77.

Redd No.	Date	Depth (ft)	Velocity (ft/sec)
Above Dam			
25	11-9-76	.55	1.52
	2-9-77	.35	0.52
7	11-24-76	.85	1.61
	2-9-77	.55	1.24
58	11-9-76	.60	2.17
	2-9-77	.70	1.17
31	11-9-76	.90	1.71
	2-9-77	.75	0.84
Below Dam			
39	11-9-76	.60	2.17
	2-9-77	.50	2.22
40	11-24-76	.50	1.41
	2-9-77	.55	1.55
56 U	11-9-76	.60	1.78
	2-9-77	.50	.82
56 L	11-24-76	.40	1.49
	2-9-77	.50	1.35
34	11-24-76	.50	1.58
	2-9-77	.45	1.58

TABLE 7. Intragravel dissolved oxygen concentrations in brown trout redds above and below the detention dam on Trout Creek, Iowa County, 1976-77.

Station	Redd No.	Standpipe No.	Sampling Dates 9 Nov.	23 Nov	8 Dec.	22 Dec.	12 Jan.	26 Jan.	8 Feb.	Mean D.O. (ppm)
Above Dam										
28	25	1	6.4	7.7	8.5	8.6	6.0	8.1	6.8	
		2	7.9	7.7	8.6	9.2	7.7	4.3	9.3	7.99
		3	9.1	7.8	9.8	10.0	5.9	9.6	8.9	
27	7	1		8.5	9.6	10.0	5.8	6.4	4.5	7.63
		2		8.1	7.6	9.9	7.0	5.1	9.1	
25	58	1	7.6	9.2	4.4	5.9		7.1	7.1	7.62
		2	8.9	8.8	8.4	8.8	7.7	6.6	8.5	
22	31	1	7.4	7.9	9.3	10.1	6.9	4.9	7.7	8.06
		2	5.2	7.4	8.7	10.4	9.8	7.1	10.0	
22	44	1		3.8	5.9	5.2	4.6	4.2	*	
		2		6.4	4.3	5.1	5.0	4.1	*	4.81
		3		3.8	5.2	4.4	4.6	5.5	*	
21	45	1	7.4	7.2	6.2	7.9	4.8	8.5	*	
		2	7.8	7.9	9.2	8.1	7.5	2.0	*	7.28
		3	5.9	8.3	7.8	9.5	7.2	7.9	*	
Below Dam										
19	39	1	8.3	8.5	7.3	5.9	10.5	3.2	6.3	6.36
		2	6.1	4.2	6.9	6.1	6.0	4.1	5.7	
15	40	1		9.1	10.1	7.8	2.7	3.6	9.4	5.98
		2		6.7	8.9	8.7	0.0	1.1	3.6	
13	56 L	1		17.4	8.9	7.7	10.8	6.2	7.0	9.75
		2		11.1	10.9	8.2	14.0	6.8	8.0	
13	56 U	1	7.1	1.5	12.6	3.5	SI	0.7	3.3	5.18
		2	8.0	4.4	6.4	7.2	SI	4.4	3.1	
10	34	1	9.4	10.4	6.5	10.3	F^1	3.4	9.1	5.55
		2	10.3	6.1	4.7	0.8	F^1	4.2	1.5	
10	36	1	9.5	1.7	7.0	0.2	F^1	0.9	*	
		2	9.0	11.0	10.4	9.1	F^1	0.9	*	5.52
		3		10.9	9.1	6.7	F^1	0.4	*	

* Redds excavated 29-1-77.
SI = Shelf ice over redd.
F^1 = Stream frozen over; anchor ice present; assumed ⩽0.5 ppm D.O.

Groundwater emergence was indicated in 1 of the 12 study redds when examined on 22 December. Temperature of intragravel water in redd 44 above the dam was 5.9°F warmer than stream temperatures (Appendix Table 3). The temperature difference in all other redds was less than 1.1°F.

Intragravel Dissolved Oxygen

In spite of several sources of potential error occurring occasionally in the sampling technique and/or laboratory procedures, two generalities emerged from the bimonthly determinations of intragravel D.O.:*

1. On a given sampling date, intragravel D.O. concentrations were more consistent within individual redds above the dam than below the dam, varying less than 3 ppm (mg/l) in all but 3 instances (Table 7). Below the dam, intragravel D.O. within a redd varied by more than 3 ppm (mg/l) as many as 14 times or in 39% of the redd samples.

2. Intragravel D.O. concentrations were higher in redds above the dam. D.O.'s fell below 5 ppm during more than 1 sampling period in only 2 of the 6 redds above the dam. Below the dam, D.O.'s fell below 5 ppm at more than 1 sampling period in 5 of the 6 redds.

Egg Development and Survival

Egg survivals in 1 redd excavated above and 1 redd excavated below the dam on 22 December were 97% and 99%, respectively. Both redds were located on the first redd survey on 27 October but only a few eggs in each redd had developed to the "eyed" stage. Two different size groups of eggs in the redd above the dam indicated deposition from at least two different females, i.e. superimposition. Pigmentation in the two size groups was also different.

On 28 January 1977, partial excavation of a redd above the dam found 2 live sac fry and 6 "eyed" eggs. Excavation of a second redd found a 95% survival of eggs and blood vessels were evident in some of the embryos. Two "swim-up" fry were also seen swimming near the bank in station 25 indicating that some fry emergence had already occurred above the dam. Below the dam, 1 of 3 redds excavated was empty. Survival in the one redd was 91% and all eggs had developed to the "eyed" stage. The third redd had been previously excavated on 22 December. Eggs found on 28 January were alive but showed very little development since the initial excavation.

On 29 January, 3 redds routinely sampled for intragravel D.O. were excavated, i.e. redds 45 and 44 above the dam and redd 36 below the dam (Table 8). Survival was nil in redd 36. Eggs ranged from opaque white to black and had evidently been dead for some time. Above the dam, survival was 66% in redd 44 and 97% in redd 45. Sac fry were found in both redds. Superimposition was indicated in both redds by the presence of embryos in a wide variety of developmental stages ranging from "eyed" eggs to sac fry. Some sac fry in redd 44 were very large and showed little evidence of a yolk sac. Groundwater emergence was indicated in this redd and emergence of some sac fry had undoubtedly already occurred. Survival was, therefore, higher than the 66% indicated.

The remaining 9 redds, 4 above and 5 below the dam, were excavated on 9 February. One redd below the dam failed to contain any eggs (Table 8). Survival in the other 8 redds ranged from 0% to 100%. Below the dam, live eggs were present in only 2 redds, 56 L and 40. Embryos were well developed in both redds and a lack of sac fry indicated that emergence had probably not yet occurred. Survival was 80% and 91%, respectively. It is significant to note that 60-65% of all redds found below the dam were located in close proximity to redds 56 L and 40, in stations 13 and 15, respectively (Appendix Table 2). Above the dam, survival ranged from 91% to 100% in 3 of the 4 redds excavated. Sac fry and developing embryos were found in redds 31, 58, and 7 but only dead eggs were present in redd 25. Eggs in redd 25 were either opaque white or black and had been dead for some time.

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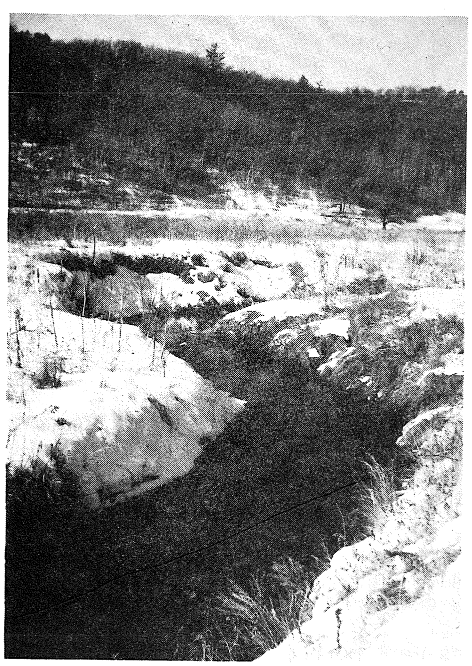
*Most potential sources of error were inherent in the sampling technique when working in subfreezing temperatures and near freezing water temperatures, i.e., water freezing in standpipes, suction tubes, vials, etc.



During the winter, Trout Creek remains relatively ice free in the upper half of the study zone (left photo), while anchor ice, shelf ice and complete freezing over often occurs in the lower half of the study zone (right photo).

Further excavations of 3 redds above the dam and 4 redds below the dam were made on 2 March following heavy rains and spring flooding which occurred in late February. Live eggs were found in all but 1 redd below the dam and it contained a single dead sac fry. Above the dam, live sac fry were present in 2 redds but only dead eggs in a third redd. Fry emergence had probably already occurred from the latter redd. Apparently, the flood waters in late February had no adverse affect upon the survival of eggs and fry still remaining in streambed gravels.

There was no evidence of "false" redds above the dam; thus all 44 redds counted probably contained trout eggs. A 33% incidence of "false" redds was observed below the dam, lowering the number of productive redds from the 36 observed to 24.

Survival vs. Abiotic Factors

Embryo survival was not correlated with either change in water depth or stream velocity over the trout redds (Table 9). Good survival was positively correlated with mean D.O. concentrations equal to or greater than approximately 6.0 ppm. Several inconsistencies are apparent in redds 44, 25, 34, 36, and 39 and must be explained, however.

Substrates in redd 44 were shallow (3-6 in.) and overlying soft clay. Groundwater emergence was evident and trout eggs were buried only 3 to 4 in. below the substrate surface. Standpipes used to sample D.O. were driven 6-8 in. into the substrate and were thus into the clay layer. The slow rate of water exchange in the clay layer would explain the low D.O.'s in the water sampled at this depth and, thus, the low mean D.O. of 4.81 ppm. D.O.'s within the egg pocket were undoubtedly higher, accounting for the embryo survival in excess of 66% (Table 9).

Redd 25 was initially in a channel formed between the streambank and a dense bed of watercress. Winter die-off of the watercress dropped the water level and exposed the back half of the redd. Fragments of watercress then collected on the front half of the redd. Freezing temperatures and poor exchange of intragravel water were thus responsible for the total egg mortality observed even though mean D.O. was 7.99 ppm (Table 9).

Anchor ice below station 12 sealed the streambed from water exchange during most of January and intragravel water samples were, therefore, not collected at redds 34 and 36. D.O.'s can be assumed near zero during this period and explains the total egg mortality in both redds in spite of mean D.O.'s of 5.55 and 5.52, respectively (Table 9).

Embryonic development was well advanced in the dead eggs found in redd 39. Substrates were severely compacted in this redd, lending credence to low permeability and perhaps inadequate D.O. supplies even though mean D.O. exceeded 6 ppm (Table 9). Oxygen demand of developing embryos increases greatly as hatching approaches.

DISCUSSION

In the fall of 1976, the number of brown trout redds above and below the detention dam on Trout Creek was adequate to produce a good year class in 1977. Survival from egg to emergence of sac fry was generally good (above 90%) above the dam and most, if not all, fry had emerged before the spring thaw and high water in late February. Below the dam, survival to the advanced embryo stage was either nil or good (above 80%) depending upon location of the redd. Most redds were found in 1 of 4 riffle areas located in stations 10, 13, 15, and 19. Near-freezing water temperatures in January 1977 destroyed eggs in redds below station 12 due to the formation of 1 to 3 in. of anchor ice on the stream bottom. Survival to the advanced embryo stage was good in stations 13 and 15 where the majority of redds were located. These eggs had been in the streambed for up to 4 months, however, and were not hatched by 2 March. Development was obviously retarded by cold water temperatures and whether or not emergence of sac fry finally occurred was not determined. Silver et al. (1963) found that prolonged residence of salmon embryos in streambed gravels resulted in smaller, weaker fry subject to higher mortalities. So even if fry did emerge, high survival appears unlikely. Redds in station 19 contained the only sac fry found below the dam and these sac fry were dead. Water temperatures were warmer here but substrates were extremely compacted and may have prevented the sac fry from emerging.

Redds in which good survival appeared most likely below the dam were those in riffle areas where gravel substrates covered the entire width of the stream, i.e. in stations 13 and 15. Greater stability of intragravel conditions would naturally occur in these riffles rather than in redds constructed in isolated pockets of gravel subject to shifting sand and silt deposits.

TABLE 8. Embryo survival in trout redds above and below the detention dam in Trout Creek, Iowa County, 1977.

Redd No.	Date Sampled	Survival (%)
Above Dam		
25	2-9-77	0
7	2-9-77	98
58	2-9-77	91
31	2-9-77	100
44	1-29-77	66+
45	1-29-77	97
Below Dam		
39	2-9-77	0*
40	2-9-77	91
56 U	2-9-77	No Eggs
56 L	2-9-77	80
34	2-9-77	0
36	1-29-77	0

*Dead, well-developed embryos found.

TABLE 9. Egg survival vs. changes in stream depth, water velocity and intragravel dissolved oxygen, 1976-77.

Redd No.	Survival (%)	Chg in Depth (ft)	Chg in Velocity (ft/sec)	Mean D.O. (ppm)
Above Dam				
31	100	-.15	-.87	8.06
7	98	-.30	-.37	7.63
45	97			7.28
58	91	+.10	-1.0	7.62
44	66+			4.81
25	0	-.20	-1.0	7.99
Below Dam				
40	91	+.05	+.14	5.98
56 L	80	+.10	-.14	9.75
39	0	-.10	+.05	6.36
34	0	-.05	0.0	5.55
36	0			5.52
56 U	No Eggs	-.10	-.96	5.18

Multiple redds, i.e. superimposition, were common in Trout Creek and were often indicated by large "cleanings" such as this one.

Superimposition of redds results in lower production of trout due to premature excavation of embryos and to burial of others under excessive amounts of substrate. Superimposition may be an important factor limiting embryo survival, particularly below the dam where gravel substrates appear more limited and superimposition, more prevalent.

Hatching and emergence of fry had already occurred above the dam when high water and impoundment behind the dam occurred in late February. The dam, therefore, had no influence upon reproductive success upstream. Below the dam, emergence of fry had not occurred by early March. Whether or not the impoundment of flood waters had an effect upon egg survival here was not determined. Cold stream temperatures rather than siltation or superimposition appeared to be the major factor limiting reproductive success.

FALL AND WINTER 1977-78

PROCEDURES

The study was continued for another fall-winter period for the purpose of defining the spawning period, acquiring another total redd count, and determining relative egg survival above and below the detention dam. Redd counts were made bimonthly between 19 October and 27 December. Procedures for marking and recording were identical to those used in 1976-77.

From 4 to 7 redds, both above and below the detention dam, were partially excavated on 1 and 9 February and 2 March 1978 to determine embryo survival and stage of development.

FINDINGS

Enumeration of Trout Redds

A total of 50 redds below the dam and 118 redds above the dam were located (Appendix Tables 4 and 5). Spawning activity had already started in Trout Creek when the first redd count was made in late October (Fig. 4). Major spawning activity below the dam occurred from 12 October through 6 December. Above the dam it began 2 weeks later and extended from 25 October through 20 December.

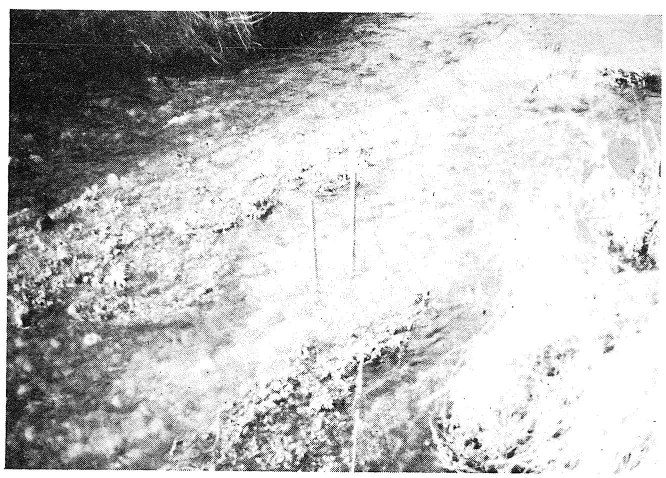
Egg Development and Survival

Eggs and/or sac fry were present in 5 redds above the dam and 4 redds below the dam sampled on 1 February (Table 10). Only 2 eggs were found in 1 of the 5 redds sampled above the dam and it was, therefore, considered a "false" redd. Egg survival ranged from 0% to 100% in the 4 other redds sampled both above and below the dam. Live sac fry were present in 2 of the 4 redds above the dam while all eggs present were dead. These redds, 24 and 26, were located within 0.25 mile of Arndt Spring where embryo development is more rapid due to warmer stream temperatures. Live eggs were present in 3 of the redds sampled below the dam but no sac fry were present. Superimposition was indicated in redd 16 by two different sizes of eggs each at a different stage of development. Embryo development was generally not as far along in the redds below the dam.

On 9 February, 2 of 6 redds sampled above the dam and 4 of 7 redds sampled below the dam were "false" redds. Live sac fry were present in redd 10 B above the dam; live embryos were well developed in the other redds. Live fry and dead eggs were present in 2 of the 3 good redds below the dam. Only dead eggs were present in the third redd. The yolk sac was completely absorbed on a few fry below the dam; thus it is possible that some emergence had already occurred.

A final 11 redds were sampled on 2 March (Table 10). Two of 6 redds sampled above the dam and 2 of 5 redds sampled below the dam were "false" redds. Sac fry were present in 1 of the 4 good redds above the dam and in 1 of the 3 good redds below the dam. In general, however, embryo development was further along in redds above the dam.

Throughout the entire incubation period, apparent survival of brown trout eggs averaged 46% above the dam and 52% below the dam. Based on a 29% incidence of "false" redds above the dam, the total number of productive redds was 84 rather than the 118 marked. This is still a 91% increase over the number of redds counted in the fall of 1976. Also, if a 31% incidence of "false" redds is assumed below the dam, then the total number of productive redds was 34 rather than 50. This represents a 42% increase in the number of productive redds estimated in the fall, 1976.



Trout redds above the detention dam are often constructed within channels created by aquatic vegetation (note standpipes installed for sampling intragravel water).

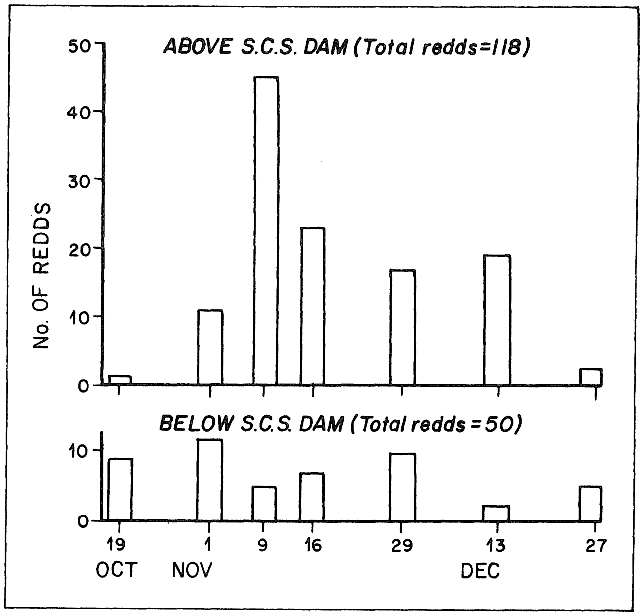


FIGURE 4. Chronology of redd construction by brown trout in Trout Creek, fall and winter, 1977-78.

TABLE 10. Embryo survival in trout redds excavated above and below the detention dam in Trout Creek, Iowa County, 1977.

Station	Redd No.	Date Observed	Date Sampled	Survival (%)
Above Dam				
22	1	11-01-77	02-01-78	0
22	4	11-01-77	02-01-78	*
22	5A	11-09-77	02-01-78	100
28	24	11-09-77	02-01-78	6
28	26	11-09-77	02-01-78	29
22	4B	11-29-77	02-09-78	25
22	12	11-09-77	02-09-78	*
24	81	11-29-77	02-09-78	*
28	87	11-29-77	02-09-78	36
30	88	11-29-77	02-09-78	93
25	10B	11-09-77	02-09-78	88
29	89	12-13-77	03-02-78	71
23	35	11-16-77	03-02-78	No eggs*
24	91	12-13-77	03-02-78	80
25	84	11-29-77	03-02-78	0
26	92	12-13-77	03-02-78	17
28	93	12-13-77	03-02-78	*
Below Dam				
13	4	10-19-77	02-01-78	88
15	7	10-19-77	02-01-78	0
16	8	10-19-77	02-01-78	100
10	16	11-09-77	02-01-78	48
13	11	11-01-77	02-09-78	No eggs*
13	12	11-01-77	02-09-78	No eggs*
13	5B	11-01-77	02-09-78	No eggs*
13	5C	11-01-77	02-09-78	0
15	61	11-01-77	02-09-78	35
14	13	11-01-77	02-09-78	78
18	25	11-16-78	02-09-78	No eggs*
10	20	11-16-77	03-02-78	19
13	26	11-29-77	03-02-78	No eggs*
13	23	11-16-77	03-02-78	91
17	27	11-29-78	03-02-78	11
18	30	12-13-77	03-02-78	*

*"False" redds containing ≤8 eggs or fry.

DISCUSSION

Based upon the various developmental stages of eggs and sac fry observed in the excavated redds, hatching and emergence of brown trout fry probably occurred from February through March 1978. There were no rapid thaws or warm rains during the egg incubation period, therefore, no flooding. Water was not impounded behind the detention dam; thus, the dam had no effect upon the reproductive success of wild brown trout.

SUMMARY AND CONCLUSIONS

Spawning activities of brown trout in Trout Creek begin in late October and extend into January. Peak activity occurs during November and remains significant through mid-December.

During the two years when total redd counts were made, 44 and 118 redds were located above the dam. The corresponding incidence of "false" redds was 0% and 29%. Below the dam, 36 and 50 redds were present during the two years when total redd counts were made. The observed incidence of "false" redds was 33% and 31%, respectively.

Sedimentation of brown trout redds during the egg incubation period could not be demonstrated using the conventional substrate sampling techniques employed in this study. Variability in the depth of instream gravels and in the depth at which trout eggs were deposited, in conjunction with standardized D.O. and substrate sampling, i.e., taken at constant depths, made intra-redd comparisons of substrate composition, D.O.'s, and egg survival meaningless.

The single most important factor affecting egg survival and fry emergence in Trout Creek was the stream temperature regime. Stream temperatures became progressively colder downstream and egg survival became poorer. An important secondary factor affecting survival was intragravel D.O. concentrations. For the stream as a whole, better survival of trout eggs was in redds having the highest mean D.O. concentrations. Significant differences in intragravel D.O. were not apparent in redds above the dam vs. below the dam.

Water velocity and depth over trout redds declined more above the detention dam than below it during the egg incubation period. Aquatic vegetation, primarily watercress, was far more abundant above the dam and by late summer restricted and often braided the stream channel. Normal winter die-off of watercress occurred in December and January and this decreased water depth and current velocities. No direct effect upon egg survival in trout redds was determined, however, except in one redd which was left partially exposed to freezing air temperatures and in which egg survival was nil.

"False" redds, superimposition, variability in the number of eggs deposited per redd, and variability in egg survival between redds make redd counts an unreliable index to reproductive potential in trout streams. Repetitive total redd counts in a specified area can indicate a change in substrate quality if sufficient spawners are present and the number of redds increase or decrease significantly. During this study, the absence of brown trout redds in the 300 yd of stream above the detention dam was due to the absence of exposed gravels. Prior to dam construction, gravel was common in this stream reach and trout used the area extensively for spawning purposes. Intermittent impoundment of water behind the dam and subsequent sedimentation of fine materials which occurred has destroyed this area for spawning purposes. However, arguments as to whether this loss has affected year class strength of wild brown trout in Trout Creek cannot be substantiated by this study. The detention dam was not found to have any significant affect upon natural reproduction of brown trout, at least from egg deposition to fry emergence, during the 3 yr of this study. This was due primarily to the absence of high water and stream impoundment until after the majority of fry had emerged from the streambed.

It should be mentioned that with the initiation of this study by the DNR, the Soil Conservation Service improved their maintenance of the drain culvert through the detention dam. Prior to this study, debris often partially plugged the culvert and was responsible for extended periods of stream impoundment following major storm events. The extended impoundment subjected the stream reach below the dam to abnormally long periods of sedimentation due to the release of turbid water from the impoundment. Speaking qualitatively, proper maintenance of the drain culvert has resulted in shorter retention of impounded water and in some improvement of the streambed above the dam. I recommend that greater emphasis be placed on prompt maintenance of such drain culverts on trout streams so that they function as designed, particularly during the spawning and incubation periods for trout.

LITERATURE CITED

Alderdice, D. F., W. P. Wickett, and J. P. Brett
1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. J. Fish. Res. Board Can. 15:229-249.

Coble, D.
1961. Influence of water exchange and dissolved oxygen in redds on survival of steelhead trout embryos. Trans. Am. Fish. Soc. 90(4):469-474.

Harper, E. L.
1953. Semimicro determination of dissolved oxygen. Anal. Chem. 25:187-188.

McNeil, W. J.
1962. Variation in the dissolved oxygen content of intragravel water in four spawning streams of southeastern Alaska. U.S. Fish & Wildl. Serv. Spec. Sci. Rep. Fish. No. 402. 15 pp.

McNeil, W. J. and W. H. Ahnell
1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish & Wildl. Serv. Spec. Sci. Rep. Fish. No. 469. 15 pp.

Piening, R. and C. W. Threinen
1968. Surface water resources of Iowa County. Wis. Dep. Nat. Resour. 106 pp.

Silver, S. J., C. E. Warren, and P. Doudoroff
1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Trans. Am. Fish. Soc. 92(4):327-343.

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APPENDIX TABLE 1. Distribution of brown trout redds in Trout Creek located during stream surveys on 29 October and 13 November 1975.

Station No.	No. Redds
Below Dam	
10	2 redds; 1 sampled
13	2 redds; 1 sampled
15	2 redds; 1 sampled
17	1 redd; questionable
18	1 redd; sampled
19	1 redd; sampled
Above Dam	
21	3 redds; 2 questionable, 1 sampled
22	4 redds
23	3 redds; 1 questionable
24	3 redds; 2 sampled
25	4 redds; 2 questionable
26	3 redds; 1 sampled
27	5 redds; 1 questionable, 1 sampled
28	4 redds
29	4 redds
30	4 redds

APPENDIX TABLE 2. Total redd count on Trout Creek above and below the detention dam, fall, 1976.

Station No.	Redd No.	Rating of Form			Rating of Size		
		Good	Fair	Poor	Large	Medium	Small
Below Dam							
10	(36)	X			X		
	No Stake	X			X		
	(34)	X				X	
12	49		X				X
13	*46		X				X
	59	X			X		
	22		X			X	
	53		X		X		
	*(56)L	X			X		
	*(56)U		X		X		
	27	X			X		
	47			X			X
	No Stake		X			X	
14	35		X				X
	60 L		X				X
15	60 U	X			X		
	54			X			X
	*(40)	X			X		
	38	X			X		
	*No Stake	X			X		
	No Stake	X			X		
	No Stake			X			X
	61	X					X
	No Stake		X				X
18	37			X			X
19	*(39)		X		X		
	No Stake		X		X		
	No Stake	X			X		
	No Stake		X		X		
Above Dam							
21	50		X			X	
	32		X				
	(45)	X			X		X
	No Stake		X				
	48		X				
	63		X			X	
	No Stake		X			X	
22	No Stake		X			X	
	*(44)	X			X		
	64		X		X		
	41						
	33		X		X		
	57	X			X		
	(31)	X			X		
24	43		X			X	
	65			X		X	
	66		X		X		
25	42	X			X		
	26			X		X	
	67		X				X
	68		X				X
	*(58)	X			X		
26	70			X			X
	17		X			X	
	* 3	X				X	
	No Stake		X			X	
27	(7)	X			X		
	* 21		X			X	
	Metal Rod	X				X	
28	(25)	X			X		
	71			X			X
	No Stake	?				?	

APPENDIX TABLE 2. continued.

Station No.	Redd No.	Rating of Form			Rating of Size		
		Good	Fair	Poor	Large	Medium	Small
29	**Metal Rod**		X				X
	Metal Rod	X			X		
	No Stake		X			X	
	No Stake		X			X	
	No Stake		X			X	
30	No Stake		X				X
	*No Stake	X			X		

* - Superimposition occurred and indicates multiple redd.

( ) - Redds selected for intragravel D.O. sampling.

APPENDIX TABLE 3. Stream and intragravel temperatures recorded at each of 12 brown trout redds selected for study in Trout Creek, 22 December 1976.

Redd No.	Stream Temp. (^{o}F)	Maximum Intragravel Temp. (^{o}F)
Above Dam		
25	44.2	44.6
7	44.1	44.1
58	43.3	43.5
31	42.4	42.8
44	42.8	48.7
45	42.1	42.1
Below Dam		
39	41.4	41.4
40	39.7	39.7
56 U	40.1	41.0
56 L	40.1	41.5
34	35.6	36.7
36	36.0	36.0

APPENDIX TABLE 4. Total redd count on Trout Creek above the detention dam, fall, 1977.

		Rating of Form			Rating of Size			Total
Station No.	Redd No.	Good	Fair	Poor	Large	Medium	Small	Redds
21	2	X			?			3
	3	X				X		
	No stake							
22	(1*)	X			X			11-13
	(4)	X			X			
	(5A)	X			X			
	5B							
	(12)		X				X	
	13A		X		X			
	13B		X		X			
	14		X			X		
	33			X			X	
	(4B)	X			X			
	5C		X			X		
	(89)						X	
23	6	X				X		9
	36							
	15A		X			X		
	15B			X	X			
	15C		X			X		
	15D		X			X		
	34C		X			X		
	(35)		X		X			
	80		X		X			
24	7*	X			X			13-19
	7C			X		X		
	37A		X			X		
	37B		X			X		
	16	X				X		
	17A		X			X		
	17B			X		X		
	18			X			X	
	38		X				X	
	39			X			X	
	40*		X			X		
	No stake			X		X		
	(81)		X				X	
	82			X		X		
	90			X			X	
	No stake		X			X		
	(91)		X				X	
25	8*	X			X			14-17
	9		X			X		
	10A			X			X	
	19		X				X	
	(10B)	X				X		
	No stake	X					X	
	No stake			X	X			
	41		X			X		
	19B		X				X	
	42	X				X		
	43			X	X			
	83			X	X			
	(84)	X				X		
	41B		X			X		
	No stake	X					X	
26	20A		X		X			8-10
	20B		X			X		
	44			X		X		
	20C		X			X		
	45A	X				X		
	45B			X		X		
	45C		X				X	
	20D	X				X		
	20E		X				X	
	(92)		X			X		

*Superimposition occurred and indicates multiple redd.
( ) Redds sampled.

APPENDIX TABLE 4. Continued.

Station No.	Redd No.	Rating of Form			Rating of Size			Total Redds
		Good	Fair	Poor	Large	Medium	Small	
27	11							9-12
	21	X			X			
	22*		X		X			
	23*		X		X			
	46A			X	X			
	46B		X				X	
	22C	X				X		
	22D	X				X		
	85		X		X			
	46C	X					X	
28	No stake*		X			X		7-11
	(24)		X			X		
	25A			X		X		
	25B		X			X		
	(26)	X				X		
	86			X		X		
	(87A)			X		X		
	87B		X		X			
	(93)	X				X		
	No stake			X				
29	(27A)		X			X		11-13
	27B			X		X		
	27C	X				X		
	28*		X			X		
	29A	X					X	
	29B	X					X	
	29C		X				X	
	30A						X	
	30B						X	
	27D	X				X		
	47		X			X		
	No stake	X			X			
	No stake		X			X		
	47B		X				X	
30	31A	X				X		7-9
	31B	X				X		
	31C*							
	32		X				X	
	(88)			X		X		
	94A		X			X		
	94B			X			X	
	94C		X				X	

*Superimposition occurred and indicated multiple redd.
( ). Redds sampled.

APPENDIX TABLE 5. Total redd count on Trout Creek below the detention dam, fall, 1977.

Station No.	Redd No.	Rating of Form			Rating of Size			Total Redds
		Good	Fair	Poor	Large	Medium	Small	
10	1	X			X			3
	(16)		X			X		
	(20)	X			X			
13	2A	X				X		22-23
	2B*		X			X		
	9							
	10		X			X		
	3	X			X			
	(4)	X			X			
	(11)	X			X			
	5A	X					X	
	(12)		X		X			
	(5B)	X			X			
	(5C)	X			X			
	No stake	X			X			
	17		X			X		
	21		X			X		
	22		X				X	
	(23)		X			X		
	No stake			X			X	
	No stake	X				X		
	No stake		X			X		
	(26)		X			X		
	No stake		X			X		
	31		X				X	
14	(13)			X		X		2
	No stake		X				X	
15	6*		X		X			9-11
	(7)		X		X			
	14		X			X		
	15		X			X		
	(61)		X			X		
	19		X			X		
	18*		X				X	
	24		X			X		
	No stake			X		X		
16	(8)		X		X			2
	No stake		X			X		
17	(27)	X			X			1
18	(25)		X			X		8
	28	X			X			
	29		X			X		
	No stake		X			X		
	(30)		X			X		
	No stake		X		X			
	No stake		X			X		
	No stake		X				X	

*Superimposition occurred and indicates multiple redd.
( ) Redds sampled.