AN EVALUATION OF YELLOWSTONE CUTTHROAT TROUT PRODUCTION IN THREE TRIBUTARIES OF THE YELLOWSTONE RIVER, MONTANA

by

Patrick Arthur Byorth

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 1990

APPROVAL

of a thesis submitted by

Patrick Arthur Byorth

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Date	Chairperson, Graduate Committee

Approved for the Major Department

Date	Head, Major Department

Approved for the College of Graduate Studies

Date	Graduate Dean

STATEMENT OF PERMISSION TO USE

VITA

Patrick Arthur Byorth was born on February 22, 1964 to John Patrick and Ann Marie Acher Byorth in San Francisco, California. From the age of six months, he was raised in Billings, Montana with his six brothers and sisters and was graduated from Billings Central High School in May, 1982. In August, 1982 he was enrolled in Carroll College, Helena, Montana and earned a Bachelor of Arts in Biology in May, 1986. He began to pursue a Master of Science degree in Fish and Wildlife Management in June 1987 with the Montana Cooperative Fishery Research Unit at Montana State University.

ACKNOWLEDGEMENTS

I sincerely appreciate the assistance of the following people throughout this study. Dr. William Gould directed the study, provided field assistance, and critically reviewed the manuscript. Drs. Calvin Kaya, Robert Moore, and Robert Eng also reviewed the manuscript. Mr. Chris Clancy, Montana Department of Fish, Wildlife, and Parks, suggested the study and offered valuable advice. Harold Whitney, Montana Department of Fish, Wildlife, and Parks, and the Gardiner office of the Gallatin National Forest provided lodging. Mr. and Mrs. Peter Schmidt, Mr. and Mrs. Robert Roller, and Mr. Randy Wuertz graciously granted access to the streams across their properties. The Montana Department of Fish, Wildlife, and Parks funded the research through the Montana Cooperative Fishery Research Unit. The staff of the Bozeman Fish Technology Center provided access to their tools and shop facilities.

I thank the faculty and staff of the Biology Department of Montana State University for assistance throughout my stay there. My most sincere thanks go to my friends and family for their friendship, support, assistance in the field, and especially their willingness to share in the pleasure of experiencing God's creation.

TABLE OF CONTENTS

	Page
LIST OF TABLES	vii
LIST OF FIGURES	ix
ABSTRACT	xii
INTRODUCTION	1
DESCRIPTION OF STUDY AREA	4
METHODS	8
Discharge and Water Quality	8
Spawning Censuses	9
Cutthroat Trout Redds	10
Cutthroat Trout Fry	12
RESULTS	15
Cedar Creek	15
Discharge and Water Temperatures	15
Spawning Censuses	16
Cutthroat Trout Redds	22
Cutthroat Trout Fry	25
Tom Miner Creek	29
Discharge and Water Temperatures	29
Spawning Censuses	32
Cutthroat Trout Redds	33
Cutthroat Trout Fry	37
Big Creek	41
Discharge and Water Temperatures	41
Spawning Censuses	42
Cutthroat Trout Redds	42
DISCUSSION	47
Cedar Creek	47
Tom Miner Creek	49
Big Creek	51
LITERATURE CITED	54

LIST OF TABLES

Table Page

1. Mean (standard deviation) dissolved oxygen, alkalinity, specific conductance, and pH of the study streams, 1987-1989.......................... 4

2. Substrate size classification modified from the Wentworth classification in Welch (1948)...............12

3. Discharge and percentage of instream flow diverted for irrigation from Cedar Creek, Montana, 1989..................16

4. Sex ratio of spawning cutthroat trout in Cedar Creek, Montana, 1988 and 1989................................19

5. The mean (standard deviation) total lengths and weights of cutthroat trout spawning in Cedar Creek, Montana, 1988 and 1989.......................22

6. Number and percentage of cutthroat trout redds constructed in relation to percentage availability of habitat classes in Cedar Creek, Montana, 1988 and 1989.......................24

7. Mean (standard deviation) of selected characteristics in a sample of cutthroat trout redds from Cedar Creek, Montana, 1988 and 1989................25

8. Summary of cutthroat trout fry production parameters in Cedar Creek, Montana, 1988 and 1989................27

9. Habitat parameters of 40 newly emerged cutthroat trout fry in Cedar Creek, Montana, 1989...............................28

LIST OF TABLES (continued)

Table Page

10. The mean (standard deviation) total lengths and weights of cutthroat trout spawning in Tom Miner Creek, Montana, 1988 and 1989........................33

11. Means (standard deviation) of selected characteristics in a sample of cutthroat trout redds from Tom Miner Creek, Montana, 1988 and 1989..........36

12. Summary of cutthroat trout fry production parameters in Tom Miner Creek, Montana, 1988 and 1989................38

13. Habitat parameters of locations used by newly emerged cutthroat trout fry in Tom Miner Creek, Montana, 1989........39

14. Means (standard deviation) of selected characteristics in a sample of cutthroat trout redds from Big Creek, Montana, 1988 and 1989......................45

LIST OF FIGURES

Figure Page

1. Map showing the location of the study streams in the upper Yellowstone Valley, Montana.................. 6

2. Daily discharge in Cedar Creek, Montana, 1988 and 1989.......................16

3. Water temperatures in Cedar Creek, Montana, 1988 and 1989................17

4. Numbers of cutthroat trout spawners trapped in Cedar Creek, Montana, 1988, and spawners electrofished in a 185 m section in 1989.......................18

5. Length-frequency distribution of spawning cutthroat trout captured in Cedar Creek, Montana, 1988 and 1989.......................19

6. Number of cutthroat trout captured at different water temperatures in Cedar Creek, Montana, 1988................................21

7. Number of cutthroat trout captured at time-of-day in Cedar Creek, Montana, 1988..................21

8. Longitudinal distribution of cutthroat trout redds in Cedar Creek, Montana, 1988 and 1989................23

9. Percentage of cutthroat trout redds dewatered at discharge rates measured in Cedar Creek, Montana, 1988 and 1989......................26

LIST OF FIGURES (continued)

Figure | Page

10. Number of cutthroat trout fry captured in 5 and 13 emergence traps in Cedar Creek, Montana, 1988 and 1989, respectively....26

11. Number of emigrating cutthroat trout fry captured in Cedar Creek, Montana, 1988....29

12. Daily discharge in Tom Miner Creek, Montana, 1988 and 1989....30

13. Water temperatures in Tom Miner Creek, Montana, 1988 and 1989....31

14. Length-frequency distribution of spawning cutthroat trout captured in Tom Miner Creek, Montana, 1988 and 1989....32

15. Longitudinal distribution of cutthroat trout redds in Tom Miner Creek, Montana, 1988 and 1989....35

16. Percentage of cutthroat trout redds dewatered at discharge rates measured in Tom Miner Creek, Montana, 1988 and 1989....36

17. Number of cutthroat trout fry captured in 5 and 10 emergence traps in Tom Miner Creek, Montana, 1988 and 1989, respectively....37

18. Numbers of emigrating cutthroat trout fry trapped in Tom Miner Creek, Montana, 1988....40

19. Daily discharge in Big Creek, Montana, 1988 and 1989....41

LIST OF FIGURES (continued)

Figure Page

20. Water temperatures in Big Creek, Montana, 1988 and 1989................43

21. Longitudinal distribution of cutthroat trout redds in Big Creek, Montana, 1988 and 1989................44

22. Percentage of cutthroat trout redds dewatered at discharge rates measured in Big Creek, Montana, 1988 and 1989.......................46

ABSTRACT

The range and abundance of Yellowstone cutthroat trout (*Oncorhynchus clarki bouveri*) has decreased due to competition and hybridization with introduced species, susceptibility to harvest, and the loss of spawning sites, especially due to irrigation withdrawals. Fry production, the effects of dewatering on fry production, and instream flows suitable for fry production were evaluated in three tributaries of the Yellowstone River during 1988, a drought year, and 1989, a year of normal precipitation. Cedar Creek produced the greatest number of cutthroat trout fry (2,000 and 14,000 in 1988 and 1989, respectively), although 13-20% of the potential fry production was lost due to dewatering of redds. A minimum instream flow of 0.035 m^3/s would have prevented this loss. Tom Miner Creek was the second most productive spawning tributary, producing an estimated 700 and 3,400 fry in 1988 and 1989, respectively. Fifteen to 50% of production was lost due to dewatering of redds caused by natural fluctuations in streamflow, not by irrigation withdrawals. High sediment loads also may have limited fry production in this stream. Big Creek produced the fewest fry because irrigation withdrawals caused severe dewatering in the lower 1600 km. A discharge of 0.320 m^3/s would have protected redds and should restore cutthroat trout fry production in Big Creek.

INTRODUCTION

The Yellowstone cutthroat trout (*Oncorhynchus clarki bouveri*) was once found in abundance within the Yellowstone River basin from the headwaters in Yellowstone National Park east to the Tongue River basin (Hadley 1984). Presently, the distribution of native fluvial Yellowstone cutthroat trout is restricted to the Yellowstone River and its tributaries from its headwaters downstream to the mouth of the Boulder River near Big Timber, Montana (Clancy 1988). Hadley (1984) reported that pure strain Yellowstone cutthroat trout exist in only 8% of their original range. In response to this decline in range, the Montana Department of Fish, Wildlife, and Parks classified it as a "species of special concern" (Holton 1980).

The reduction in the Yellowstone cutthroat's range has been accompanied by a reduction in abundance within its range. The number of pure strain Yellowstone cutthroat in the upper Yellowstone River has been reduced by hybridization with introduced rainbow trout (O. *mykiss*) (Berg 1975). Leary et al. (1989) found introgression by rainbow trout to occur in 30-40% of Yellowstone cutthroat populations in the upper Yellowstone drainage. The number of cutthroat trout has been reduced through competition with non-native rainbow trout and brown trout (*Salmo trutta*), and by exploitation (Berg 1975, Hadley 1984). The upper Yellowstone River supports a popular cold-water fishery (Berg 1975, Javorsky 1984), and Yellowstone cutthroat trout are vulnerable to anglers, susceptible to overharvest (Griffith 1972, Hadley 1984, Varley and Gresswell 1988), and are now managed under special regulations in portions of the Yellowstone River (Clancy 1987, Clancy 1988).

Perhaps the most important factor in the decline of cutthroat trout in the Yellowstone River is reduced recruitment due to dewatering of spawning tributaries for agricultural irrigation (Berg 1975, Hadley 1984, Clancy 1988). Diversion of stream flows for irrigation begins during runoff and continues through early fall. Cutthroat trout spawn, eggs incubate, and fry emerge and rear during this same period. Berg (1975) reported that 94 km of tributary streams were either completely dry or severely dewatered during the peak of irrigation in 1974, while 55 km of tributaries were dry or severely dewatered in 1975. Only seven tributaries of the Yellowstone River currently support successful spawning runs (Clancy 1988).

The 1989 Montana Legislature authorized a 5-year study period to allow the Montana Department of Fish, Wildlife, and Parks to pursue the lease of water rights to maintain instream flows to protect aquatic resources. This study was initiated to evaluate fry production and effects of dewatering on production of Yellowstone cutthroat trout in three tributaries of the Yellowstone River: Cedar, Tom Miner, and Big creeks.

Specific objectives of the study were:

1. To determine potential fry production in each stream.
2. To establish a record of redd numbers and locations for future monitoring.
3. To evaluate effects of decreased water levels on fry production in each stream.
4. To recommend instream flows that would maximize recruitment.

Field research for the study was conducted from August through October 1987 and from June through September 1988 and 1989.

DESCRIPTION OF STUDY AREA

The study streams are located in Park County, in south-central Montana, and are tributaries of the upper Yellowstone River. Primary land-uses in the area are cattle and hay production and recreation.

The study streams have gravel-cobble beds and perennial flows. Pertinent water quality parameters are presented in Table 1.

Table 1. Mean (standard deviation) dissolved oxygen, alkalinity, specific conductance, and pH of the study streams, 1987-1989.

	Stream		
Parameter	Cedar Creek	Tom Miner Creek	Big Creek
DO[ab] (mg O_2/l)	8.2(0.8)	8.7(0.8)	8.8(1.2)
Alkalinity (mg $CaCO_3$/l)	378.6(264.4)[b]	267.7(292.8)[e]	46.1(5.4)[d]
Conductivity (µmhos/cm)	139.2(41.6)[c]	158.3(24.6)[b]	81.0(13.2)[c]
pH	7.6(0.6)[c]	7.6(0.4)[b]	7.2(0.4)[c]

[a] Dissolved oxygen
[b] n=6
[c] n=5
[d] n=3
[e] n=7

Cedar Creek arises in the Absaroka Mountains, has an 8% average gradient and enters the Yellowstone River 17.7 km north of Gardiner, Montana (Figure 1). It is the smallest study stream with an approximate mean annual discharge of 0.1 m^3/s and an average stream width of 4 m. The study section included the lower 823 m of the stream. Immediately upstream from the study section is a series of irrigation diversions which remove the majority of stream flow between June and October, and provide barriers to spawning cutthroat trout.

A pair of adjacent culverts were installed in Cedar Creek 175 m from its mouth during construction of U.S. Highway 89. These culverts acted as a barrier to spawning cutthroat until a ladder-like structure was installed in the base of the north culvert (Belford 1986).

Cedar Creek is regarded as a high quality cutthroat trout spawning stream (Clancy 1988). Small populations of cutthroat trout, brook trout (Salvelinus fontinalis), rainbow trout, mountain whitefish (Prosopium williamsoni), and mottled sculpin (Cottus bairdi) reside in the stream. Cottonwood (Populus spp.) and woods rose (Rosa woodsii) are the predominant riparian plants on Cedar Creek.

Tom Miner Creek drains Tom Miner Basin in the Gallatin Mountains, has a 7% average gradient, and enters the Yellowstone River 27.2 km north of Gardiner, Montana. Mean annual discharge was 1.1 m^3/s and average stream width was

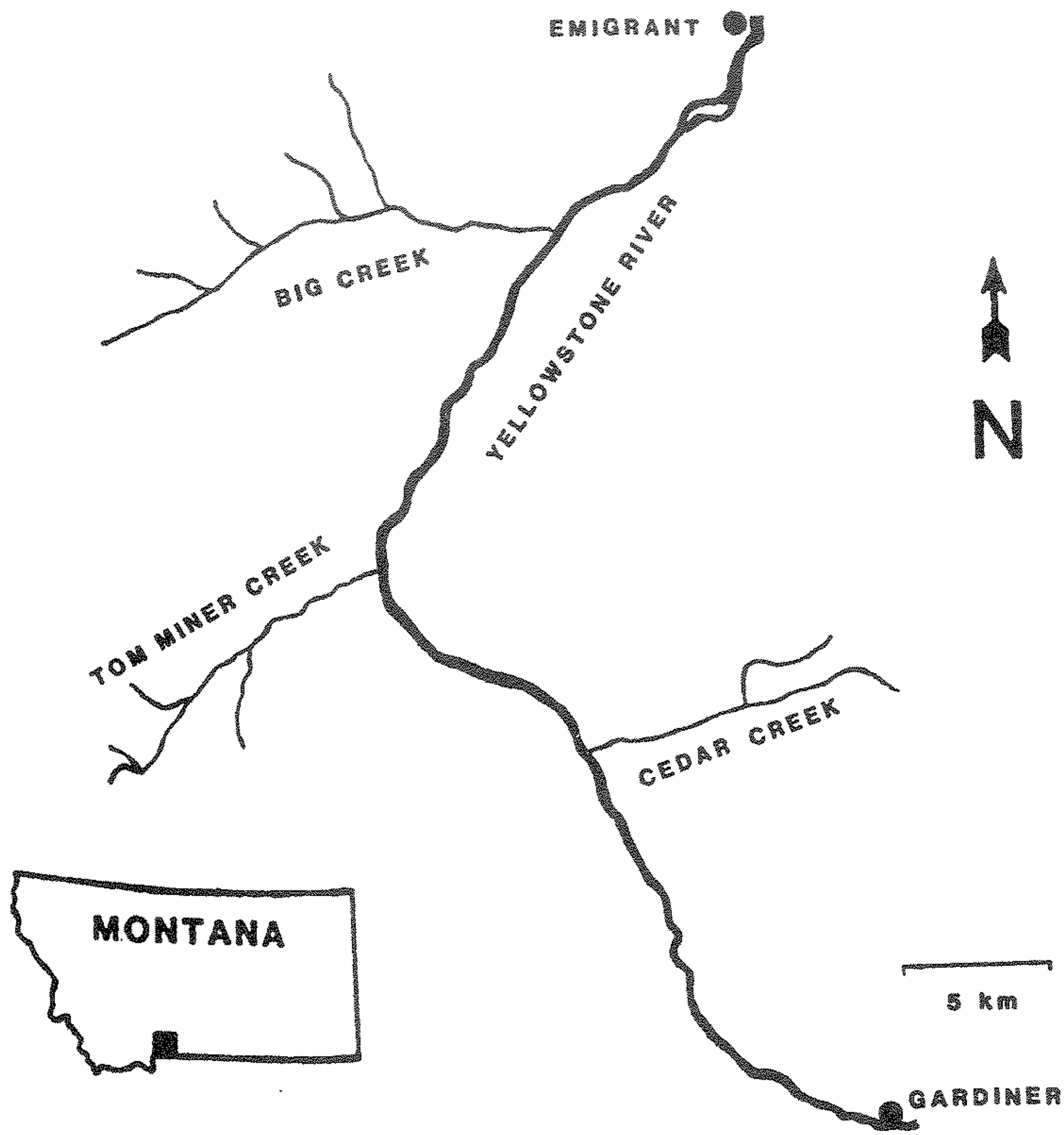

Figure 1. Map showing the location of study streams in the upper Yellowstone Valley, Montana.

7 m. The study section consisted of the lower 850 m of the stream. One small irrigation headgate lies within the study area, but it did not cause significant dewatering during the study period. A series of landslides (slumps), located approximately 3 km from the mouth of Tom Miner

Creek, contribute sediment to the stream resulting in high turbidity and sediment deposition, especially during spring runoff (Mohrmann et al. 1988).

Tom Miner Creek is regarded as a high quality spawning stream for cutthroat trout (Clancy 1988). Resident fish species include cutthroat trout, rainbow trout, brown trout, brook trout, mountain whitefish, mottled sculpin, and longnose dace (Rhinichthys cataractae). The riparian zone of Tom Miner Creek is predominantly composed of cottonwood, woods rose, alder (Alnus spp.), and red osier dogwood (Cornus stolonifera).

Big Creek is the largest of the study streams with an approximate annual discharge of 2 m^3/s and averages 7 m wide. Big Creek flows out of the Gallatin Range, has a 3% average gradient, and enters the Yellowstone River 34 km north of Gardiner, Montana. The study section extended 2.5 km upstream from its mouth. Irrigation diversions, located 1.6 km, 2.5 km and 2.7 km from the mouth, divert summer flows and leave the lower 1.6 km dry in most years.

In spite of severe dewatering, Big Creek sustains a small annual spawning run of cutthroat trout, although fry production is minimal. Fish species in Big Creek include cutthroat trout, rainbow trout, rainbow-cutthroat hybrid, brown trout, brook trout, mountain whitefish, and mottled sculpin. Riparian vegetation is dominated by cottonwood, willow (Salix spp.), and woods rose.

METHODS

Discharge and Water Quality

Water chemistry parameters were periodically measured in each stream for descriptive purposes. Dissolved oxygen and alkalinity were measured with a Hach DR-EL2 field kit. Alkalinity levels were verified with Gran titrations performed in the laboratory. Specific conductance was determined with a model RB3 Solu-Bridge portable meter. A VWR Scientific model 55 digital-mini pH meter was used to determine the pH of study streams.

Taylor thermometers were used to provide daily maximum and minimum water temperatures for each stream during the field seasons. Mean daily fluctuation (MDF) was calculated as the average difference between the daily maximum and minimum temperature.

Discharge was monitored daily in each study stream during the field seasons. Staff gauges were installed and transects established at points 67, 670, and 300 m upstream from the mouths of Cedar, Tom Miner, and Big creeks, respectively. Discharge was measured at each transect with a Gurley AA current meter. Transects were divided into partial sections such that no section would contain more than 10% of the total width (USGS 1977). Staff gauge levels were recorded each time discharge was measured and a rating curve was constructed for each stream.

Spawning Censuses

Spawning runs of cutthroat trout were censused to determine their timing and to characterize each run. The 1988 spawning run was censused using upstream and downstream traps. The traps consisted of a poultry wire lead (25.4 mm diameter mesh) attached to a 0.91 x 0.61 x 0.61 m holding trap positioned at each end of the lead. Traps were installed 5, 600, and 300 m upstream from the mouths of Cedar, Tom Miner, and Big Creeks, respectively. In the latter two streams, trap placement at the mouth was precluded by high spring flows. Traps were checked at least twice daily. Cutthroat trout caught in traps were anesthetized, weighed, measured (total length (TL)), marked with a fin clip, and their sex and spawning condition determined. After processing, fish were released upstream from the traps.

In 1989, spawning runs in Cedar and Tom Miner Creeks were censused periodically by electrofishing with a Coffelt backpack, or bank electrofishing unit. The section electrofished in Cedar Creek extended from the mouth 185 m upstream. The section electrofished in Tom Miner Creek began 550 m from the mouth and extended 120 m upstream.

Cutthroat trout were processed in the same manner described above. The 1989 spawning run in Big Creek was not sampled.

Cutthroat Trout Redds

In both field seasons cutthroat trout redds were located by periodically walking the length of each study section. The presence of eggs within indistinct redds was confirmed by disturbing its tailspill while holding a hand net in the current below to collect eggs freed from the substrate. Each redd was marked with a stone painted fluorescent orange bearing an individual number. Marked stones were placed at the downstream end of the tailspill of redds to identify new redds superimposed upon originally marked redds. During the final surveys, a measuring tape was used to determine the distance of redds from the mouth of the stream.

General spawning habitat was classified into three categories modified from Bisson et al. (1981). Riffle/runs were shallow (10-50 cm) stretches with moderate velocity (20-50 cm/s) and moderate turbulence. Pools, including plunge pools, were deep (>50 cm), with low velocity (<20 cm/s), and were at least as long as the stream was wide. Cascades were high gradient, high velocity (>50 cm/s) reaches with turbulent current flowing over alternating steps creating a series of small waterfalls and pools shorter than stream width. The length of each category within study sections was measured with a 50 m tape.

Water depth and velocity at a sample of redds were measured at the upstream margin of the tailspill with a Gurley AA current meter or a Gurley pygmy current meter. Water velocity was measured 20 mm above the substrate.

In mid-August, 1989, substrate samples were collected from 11 redds in Cedar Creek and 10 redds in Tom Miner and Big Creeks. A metal cylinder 15.5 cm in diameter and open at one end was driven 5-15 cm into the substrate at the upper margin of the tailspill. A garden trowel was inserted under the cylinder mouth to allow a plastic lid to be placed across the opening to minimize the loss of fine sediments. The cylinder was inverted and contents were placed in polyethylene bags marked with the stream name and redd number. Each sample was air dried and sorted through a series of U.S. Standard sieves. Each sample was hand shaken for 30 s through 63.5 and 19.05 mm sieves. The remainder of each sample was sorted through 12.7, 9.53, 4.75, 2.0, 0.84, 0.42, 0.21, 0.140, and 0.075 mm sieves mounted on a Tyler Ro-Tap sieve shaker operated for 2 min. Fractions were weighed to the nearest 0.1 g and the percentage of total sample weight was recorded. Substrate materials were classified according to a modification of the Wentworth classification (Table 2) presented in Welch (1948).

As discharge decreased, redds in each stream were periodically surveyed. During each survey, the number of dewatered redds at the current discharge was recorded. The lowest discharge which protected 100% of redds was considered the optimal minimum instream flow.

Table 2. Substrate size classification modified from the Wentworth classification in Welch (1948).

Substrate class	Particle size range (mm)
Cobble	63.5-256
Gravel	2.0-63.5
Fines	
Sand	0.074-2.0
Silt	<0.074

Cutthroat Trout Fry

A sample of redds was fitted with emergence traps to determine the timing of fry emergence and production of fry per redd. The design for emergence traps was modified from Fraley et al. (1986). Traps were constructed in two sizes. Traps measuring 61 cm x 61 cm were placed on five, six, and one redd in Cedar, Tom Miner, and Big Creeks, respectively. In 1989, traps measuring 30 cm x 30 cm were fitted to 17 redds in Cedar Creek. In Tom Miner Creek, seven redds were fitted with small traps and six with large traps.

Emergence traps were checked every other day for emergent fry. Fry in the traps were transferred into a hand net, counted, a sample was measured (TL), and they were released in the vicinity of the trap.

Fry rearing habitat was measured in Cedar Creek and Tom Miner Creek in 1989. Fry were observed by slowly walking upstream, pausing frequently. The point at which a fry was observed to be holding its position was considered its focal point. Water depth and velocity were measured at the focal point with a Gurley pygmy current meter mounted on a wading rod. Velocity was measured at 0.6 of water depth above the substrate. Habitat parameters were measured according to methods modified from Sando (1981). The percentage of substrate size classes within a radius of 50 cm centered at the focal point was visually estimated by using the classification system listed in Table 2. The surface areas of organic debris and rock large enough to provide cover were measured separately within the radius using a ruler.

Fry traps were installed at the mouths of Cedar and Tom Miner Creeks in 1988 and 1989 to capture emigrating fry. A modified Wolf trap (Wolf 1950), consisting of a triangular plywood flume with 8 cm walls which diverted the stream flow into a holding box, was placed in Cedar Creek on July 28, 1988. A similar apparatus modified for higher flows was installed on August 5, 1989. A fry trap was installed at the mouth of Tom Miner Creek on July 28, 1988. The trap consisted of a holding box placed in mid-channel and connected to a v-shaped lead constructed with 1.6 mm mesh nylon netting. A similar apparatus was placed in Tom Miner Creek on August 7, 1989, but higher flows in 1989 necessitated installing two adjacent traps with separate leads.

In 1988 traps were operated continuously and checked every other day until September 1, and thereafter checked twice per week until traps were removed on September 26. In 1989, traps were operated twice weekly from sunset to sunrise until September 1. According to Smith (1944), cutthroat trout fry tend to emigrate at night. Fry caught in the traps were processed as stated for emergent fry.

Statistical tests were performed using MSUSTAT (Lund 1988) and programs by Daniel Gustafson (Biology Department, Montana State University). A level of significance of p=0.05 was used for all tests.

RESULTS

Cedar Creek

Discharge and Water Temperatures

The discharge patterns in Cedar Creek differed between 1988, a drought year, and 1989 (Figure 2). Peak runoff was 0.384 m^3 lower, and occurred 1 week earlier in 1988 than in 1989. However, in 1989 runoff peaked twice, in mid-May, prior to the field season, and in June (USDA 1989). Base flow in 1988 was 0.005 m^3 higher and was reached 6 days earlier than in 1989. However, 1989 discharge fluctuated from the low of 0.014 to 0.025 m^3/s until August 15, when it increased to 0.036 m^3/s and remained through the rest of the study period.

Discharge was measured above and below irrigation diversions in 1989. The lowest flows in the study section occurred in mid- to late July when over 95% instream flow had been diverted for irrigation (Table 3).

Temperature patterns in Cedar Creek were similar between 1988 and 1989, although temperature increased at a slower rate in 1989 (Figure 3). Temperatures reached their maximum when discharge was lowest. MDF were 7.0 and 6.6 °C in 1988 and 1989, respectively.

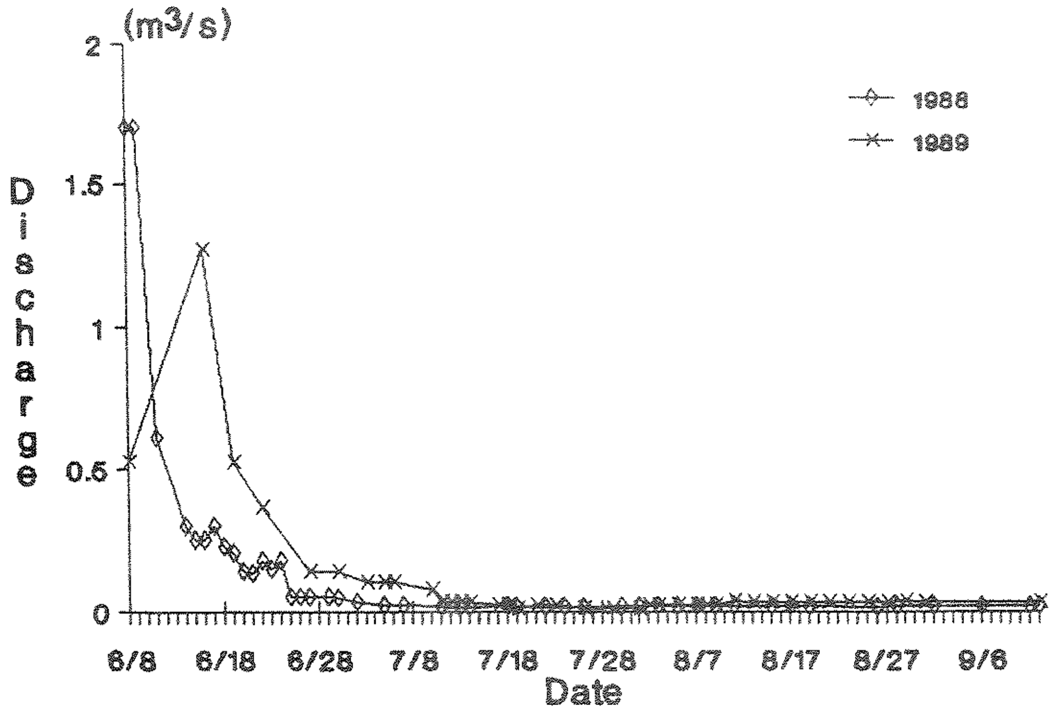

Figure 2. Daily discharge in Cedar Creek, Montana, 1988 and 1989.

Table 3. Discharge and percentage of instream flow diverted for irrigation from Cedar Creek, Montana, 1989.

	Discharge (m^3/s)		
Date	Above diversions	Below diversions	Withdrawn (%)
July 6	0.742	0.104	86.0
July 19	0.361	0.014	96.2
July 26	0.449	0.014	97.0
August 8	0.287	0.025	91.3

Spawning Censuses

Spawning cutthroat trout began to migrate into Cedar Creek in early June in 1988 and 1989 (Figure 4). A total

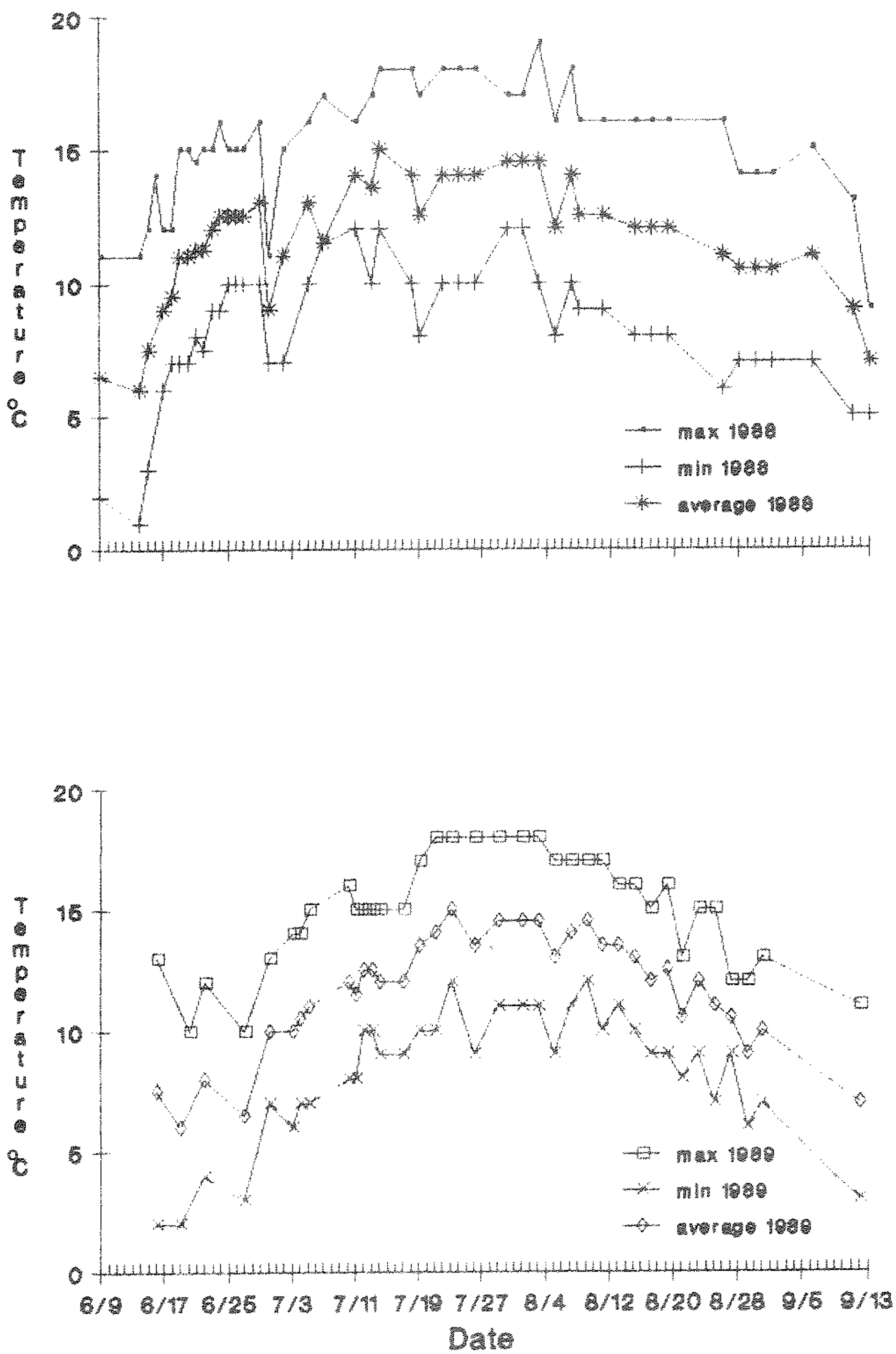

Figure 3. Water temperatures in Cedar Creek, Montana, 1988 and 1989.

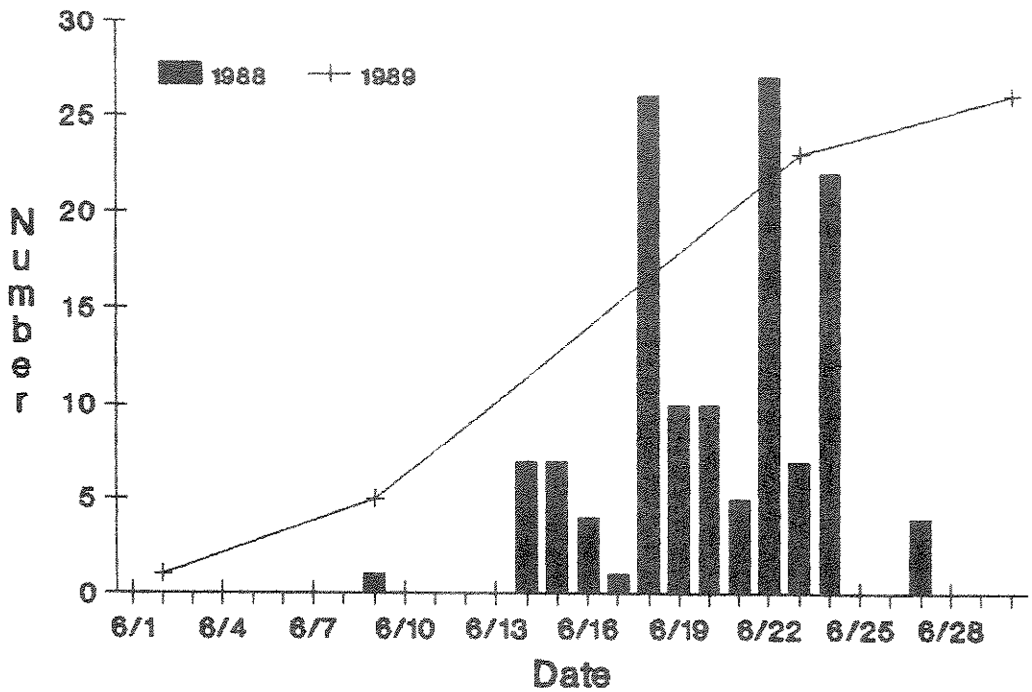

Figure 4. Numbers of cutthroat trout spawners trapped in Cedar Creek, Montana, 1988, and spawners electrofished in a 185 m section in 1989.

of 144 spawners were trapped in 1988, 80% between June 18 and 24. Fifty-seven spawners were captured by electrofishing in 1989. In 1988, cutthroat between 320-396 mm were predominant in the census, but spawners less than 320 mm increased in proportion in 1989 (Figure 5). In 1988, only cutthroat trout were captured, but during the 1989 census 10 rainbow trout were captured in Cedar Creek and four were in spawning condition.

In 1988, the male to female ratio steadily decreased until June 22 when it stabilized near 1:1, near the peak of immigration (Table 4). Berg (1975) indicated that during the peak of spawning in Cedar Creek the male:female ratio approached 1:1. In 1989, the final census on June 30

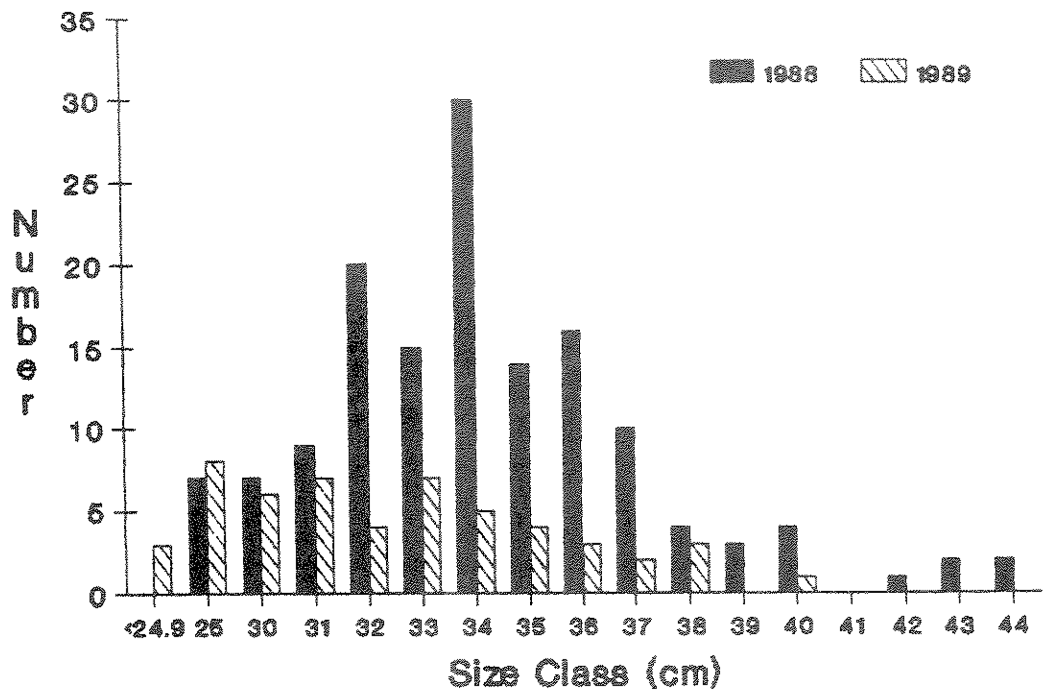

Figure 5. Length-frequency distribution of spawning cutthroat trout captured in Cedar Creek, Montana, 1988 and 1989.

Table 4. Sex ratio of spawning cutthroat trout in Cedar Creek, Montana, 1988 and 1989.

	Sex Ratio (M/F)			
Date	1988*	(N)	1989	(N)
June 9	1/0	1	3.0	3
June 14	7.0	8		
June 15	2.75	15		
June 16	2.60	18		
June 17	2.16	19		
June 18	1.81	45		
June 19	1.50	55		
June 20	1.37	64		
June 21	1.52	68		
June 22	1.16	93		
June 23	1.18	96	5.67	20
June 24	1.10	116		
June 27	1.14	120		
June 30			2.10	24

* Cumulative sex ratio

resulted in a 2:1 sex ratio suggesting that peak of immigration had not yet occurred and was at least 1 week later than in 1988.

Spawning migration was correlated with water temperature in Cedar Creek. In 1988, 77% of all spawners were trapped at water temperatures of 12-14 °C (Figure 6). This range of temperatures was usually reached between 1400-1800, the same period in which 79% of spawners were captured (Figure 7).

The net effect of the 1988 drought was to alter the timing of the normal spawning cycle by accelerating runoff and subsequently, the rate at which temperatures increased. The preferred range of temperatures and hence the peak of spawning, incubation and emergence, was reached 1-2 weeks earlier in 1988 than in 1989.

The average length and weight of male cutthroat trout (Table 5) spawning in Cedar Creek decreased significantly from 1988 to 1989 (t_l=2.601, p=0.011, and t_w=2.701, p=0.008). The decrease in male spawner size appeared to have been due to an increase in the proportion of males less than 300 mm in total length. In 1988, only 9.4% of male cutthroat trout captured were in this size range, while in 1989, 25% were less than 300 mm in length. Female spawner length and weight did not change significantly between years (t_l=0.84, p=0.403, and t_w=1.153, p=0.25).

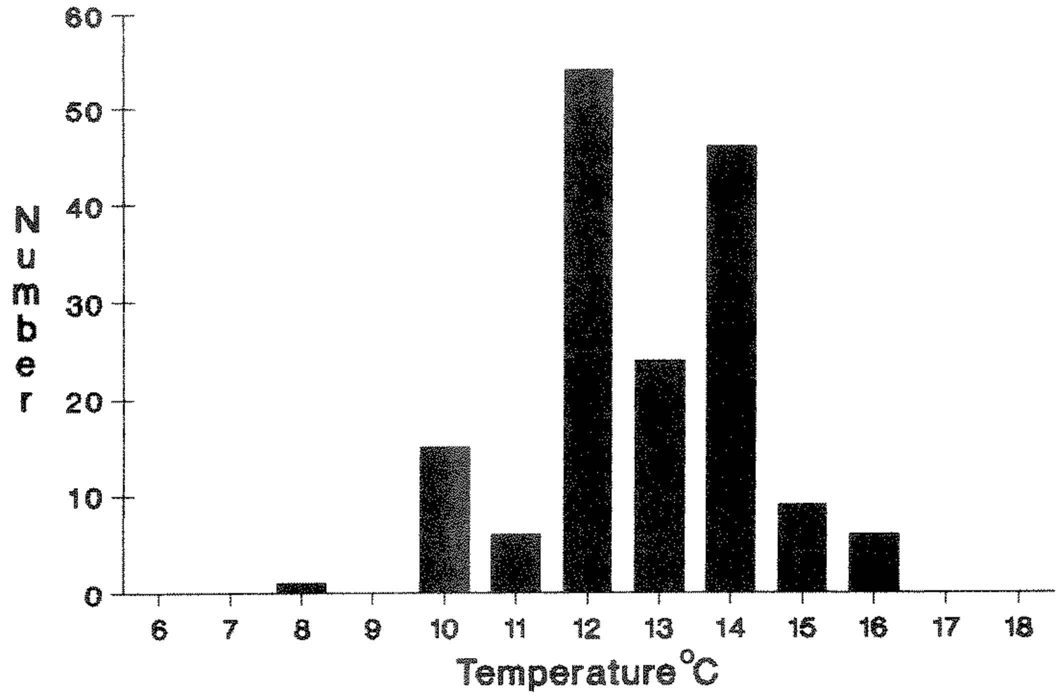

Figure 6. Number of cutthroat trout captured at different water temperatures in Cedar Creek, Montana, 1988.

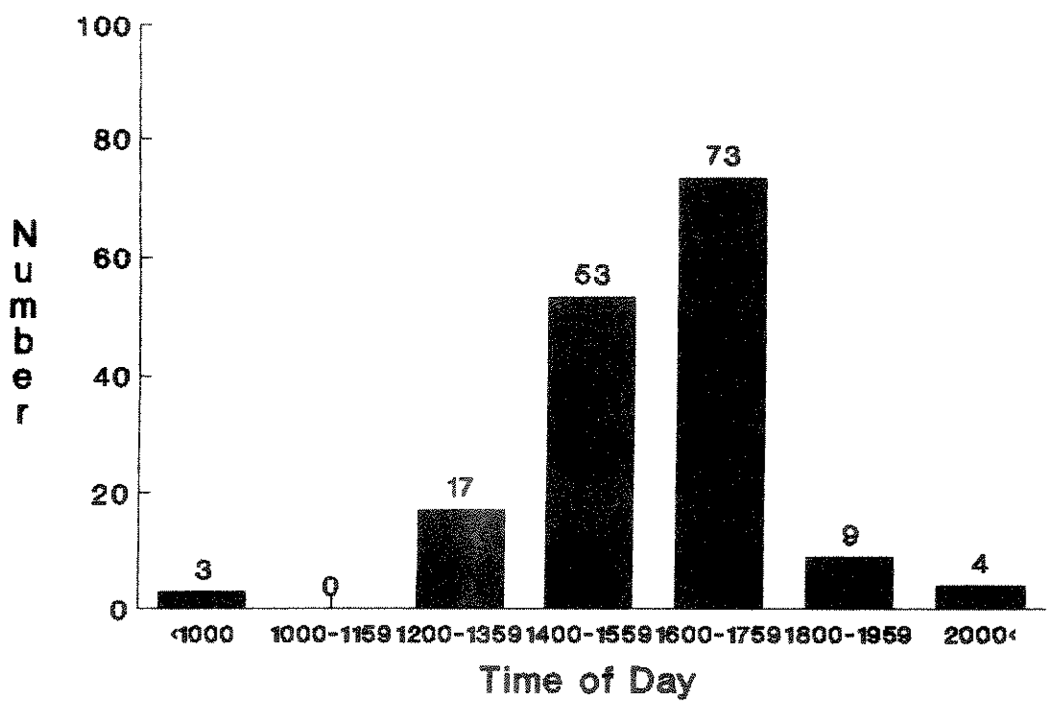

Figure 7. Number of cutthroat trout captured at time-of-day in Cedar Creek, Montana, 1988.

Table 5. Mean (standard deviation) total lengths and weights of cutthroat trout spawning in Cedar Creek, Montana, 1988 and 1989.

	Males		Females	
	1988	1989	1988	1989
Number caught	62	33	61	16
Mean (SD)				
length (mm)	343(35)*	322(39)*	352(26)	346(21)
weight (g)	436(141)*	326(139)*	481(136)	409(82)

* Indicates significant difference

<u>Cutthroat Trout Redds</u>

Seventy-two cutthroat trout redds were found in Cedar Creek between June 16 and July 5, 1988. Sixty percent of those redds were constructed during the last 2 weeks of June. In 1989, 138 redds were found between June 22 and July 13. During this year, 91% of redds were constructed during the first 2 weeks of July. The distribution of redds in Cedar Creek was similar between years (Figure 8).

Cutthroat trout constructed redds in Cedar Creek in three major habitat types: cascades, riffle/runs, and pools. However, redds were not distributed in direct proportion to availability of these habitat types (Table 6). Riffle/runs were used in greater proportion than available, while cascades were used less than available. Pools were used in nearly equal proportion to

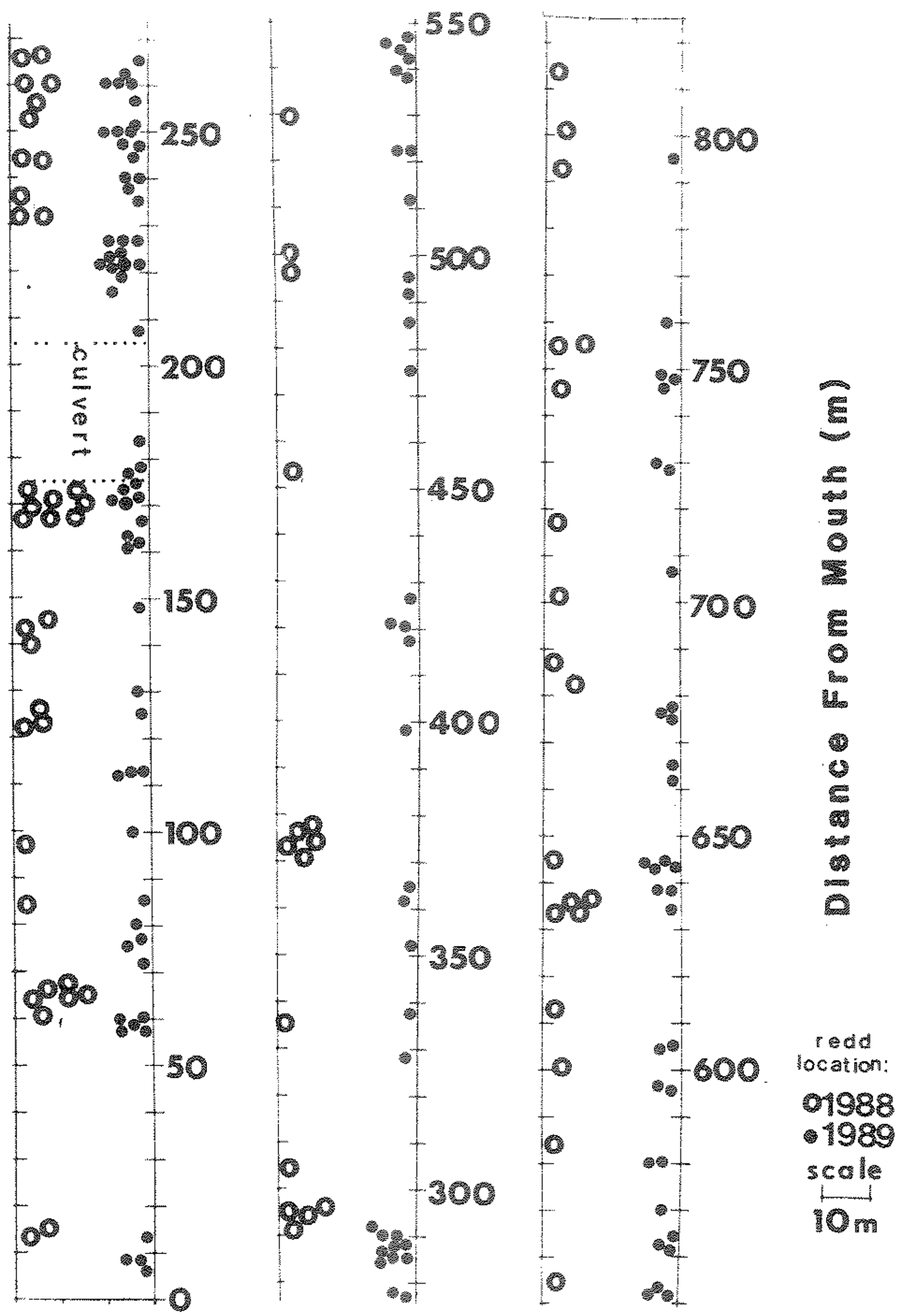

Figure 8. Longitudinal distribution of cutthroat trout redds in Cedar Creek, Montana, 1988 and 1989.

availability. In both years cutthroat trout appeared to select spawning areas by habitat type (chi-square=8.413, p=0.038 in 1988, and chi-square=44.98, p=0.00, in 1989).

In 1989, the improved (north) culvert under U.S. Highway 89 was also used as a spawning site.

Table 6. Number and percentage of cutthroat trout redds constructed in relation to percentage availability of habitat classes in Cedar Creek, Montana, 1988 and 1989.

Habitat class	%(Number) redds		% Habitat
	1988	1989	
Cascade	47(32)	37(48)	58
Riffle/run	28(19)	28(49)	17
Pool	25(16)	22(24)	22
Culvert	0(0)	3(4)	2

Average depth, velocity, and substrate composition for a sample of redds are presented in Table 7. Mean depth did not differ between 1988 and 1989 (t=-0.282, p=0.779). Redds were observed at depths 6.1-18.3 cm, and 6.1-21.3 cm in 1988 and 1989, respectively. Eighty-six and 75% of redds sampled in 1988 and 1989, respectively, were built at depths 9.1-15.2 cm. Mean current velocity at redds did not differ significantly between 1988 and 1989 (t=0.316, p=0.753). Velocities of 0.111-0.680 m/s, and 0.000-0.680 m/s were observed in 1988 and 1989, respectively. However, 64 and 72% of the redds in 1988 and 1989, respectively, were constructed at velocities of 0.160-0.277 m/s.

Gravel dominated the weight of the substrate materials in redds (Table 7). It comprised 46.1-97.5% of the sample weight, while cobbles were 0-50.8%, and fines were 1.8-13%.

Table 7. Mean (standard deviation) of selected characteristics in a sample of cutthroat trout redds from Cedar Creek, Montana, 1988 and 1989.

Parameter	1988	N	1989	N
Depth (cm)	11.6(3.10)	44	11.8(3.70)	53
Velocity (m/s)	0.263(0.12)	44	0.256(0.096)	53
Substrate				
% weight cobble			16.5(20.3)	11
% weight gravel			73.8(19.6)	11
% weight fines			7.0(4.1)	11

Fifteen (21%) and 18 (13%) of the redds in Cedar Creek became dewatered as discharge declined in 1988 and 1989, respectively (Figure 9). A minimum flow of 0.035 m^3/s would have been sufficient to prevent redds from becoming dewatered in both years.

Cutthroat Trout Fry

Emergence of cutthroat trout fry in Cedar Creek began in late July and was complete by mid-August 1988 (Figure 10). In 1989, emergence began 1 week later and continued approximately 2 weeks later than in 1988. The greatest peak in emergence occurred just after discharge increased in mid-August. Of five redds fitted with emergence traps in 1988, one produced no fry, and four produced a total of 182 fry (Table 8). Nine of 13 traps captured 1,535 emergent fry in 1989. Non-producing redds may represent redds excavated by cutthroat trout, but not implanted with fertilized eggs (Smith 1941, Chapman 1988).

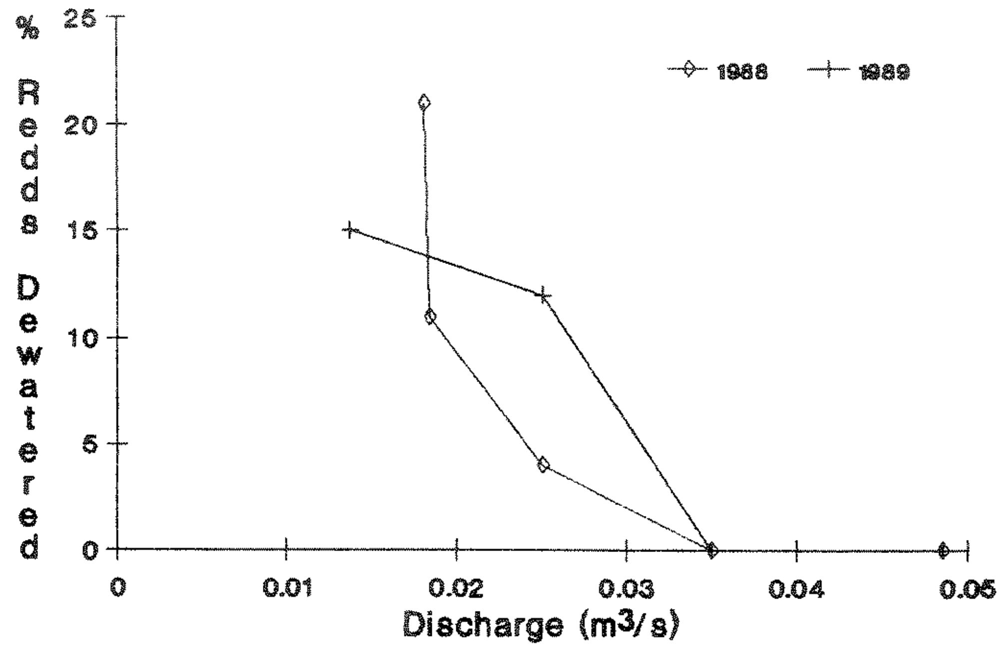

Figure 9. Percentage of cutthroat trout redds dewatered at discharge rates measured in Cedar Creek, Montana, 1988 and 1989.

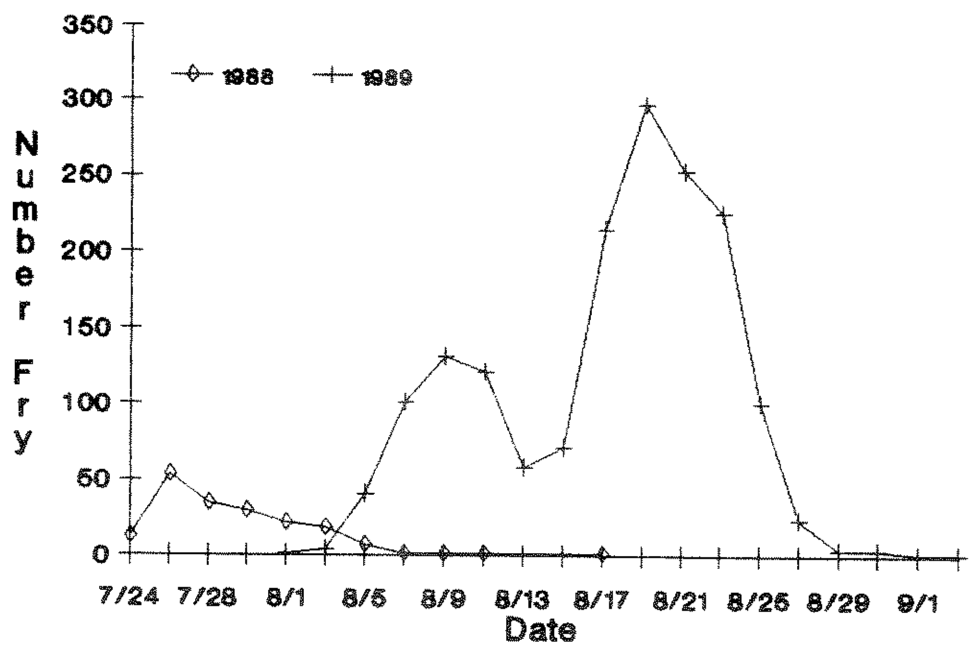

Figure 10. Number of cutthroat trout fry captured in 5 and 13 emergence traps in Cedar Creek, Montana, 1988 and 1989, respectively.

Table 8. Summary of cutthroat trout fry production parameters in Cedar Creek, Montana, 1988 and 1989.

	Year	
Parameter	1988	1989
Number of redds trapped	5	13
Number of producing redds	4	9
Mean (SD) emergence*		
All redds	36.4(43.8)	118.1(98.6)
Producing redds	45.5(41.4)	170.6(52.6)
Estimated production	2,000	14,000

* Number of fry per redd

An estimate of the number of fry lost to redd dewatering was obtained by multiplying the mean emergence for all redds by the estimated number of redds dewatered in each year. Approximately 546 and 2,125 fry were lost in 1988 and 1989, respectively.

Habitat parameters of 40 newly emerged fry were measured in 1989. Fry selected shallow, low velocity areas over heterogeneous substrate (Table 9), similar to the results reported by Moore and Gregory (1988a, 1988b).

Fry began to emigrate to the Yellowstone River shortly after emerging (Figure 11). Approximately 95% of emigrating fry captured were trapped prior to August 17, 1988, the end of the emergence period. In 1989, emigration was also greatest early and decreased near the end of the emergence period.

Table 9. Habitat parameters of 40 newly emerged cutthroat trout fry in Cedar Creek, Montana, 1989.

Parameter	Mean	SD	Min.	Max.
Depth (cm)	11.26	4.14	3.0	18.3
Velocity (cm/s)	3.0	3.0	0.0	10.5
Substrate				
% Fines	21.73	23.26	0.0	75.0
% Gravel	31.60	22.49	0.0	75.0
% Cobble	39.08	21.25	10.0	85.0
Cover				
Organic debris (cm^2)	189.48	234.76	0.0	1000.0
Rock (cm^2)	2395.31	1716.16	0.0	7065.0

Several investigators have reported that cutthroat trout fry emigrate from natal streams shortly after emergence. Benson (1960) reported that the largest emigration of juvenile Yellowstone cutthroat trout in Arnica Creek, Yellowstone National Park occurred in mid-summer, followed by a smaller migration in early fall. Thurow et al. (1988) state that juvenile cutthroat trout migrate in response to declining water temperature and exhibit density-dependent migration associated with limited habitat. Moore and Gregory (1988a) found the greatest densities of cutthroat fry immediately following emergence.

Cutthroat trout fry were found in Cedar Creek throughout the fall and into spring, indicating that a group of fry remain in the stream through winter. A portion of young-of-the-year cutthroat trout overwinter in Arnica Creek, Yellowstone National Park (Benson 1960).

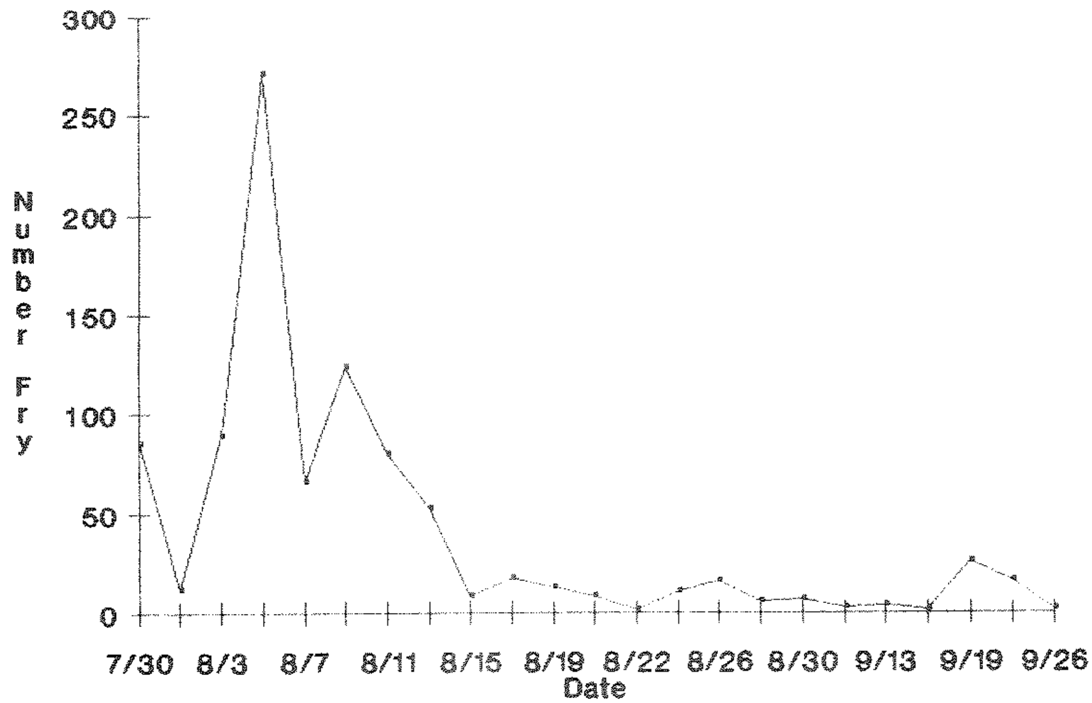

Figure 11. Number of emigrating cutthroat trout fry captured in Cedar Creek, Montana, 1988.

Tom Miner Creek

Discharge and Water Temperatures

Although Tom Miner Creek was relatively unaffected by irrigation withdrawals, it was the stream most affected by drought in 1988. The headwaters of Tom Miner and Big Creeks received below average precipitation in 9 months of the 1988 water year (USDA 1988). Although the maximum flow was recorded on the same date in both years, 1988 peak discharge may have occurred before June 10, when the field season began. Peak flow recorded in 1989 was three times as great as in 1988 (Figure 12). Base discharge in 1989 was four times greater and occurred approximately 2 weeks later than in 1988.

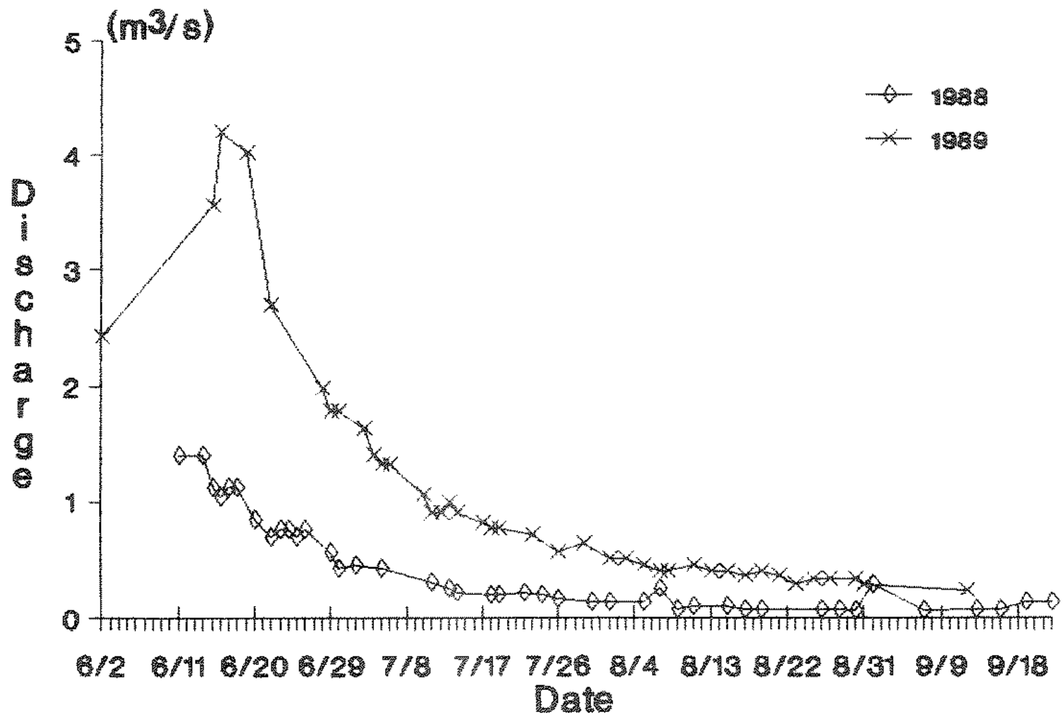

Figure 12. Daily discharge in Tom Miner Creek, Montana, 1988 and 1989.

Although temperatures increased at a faster rate in 1988, maximum water temperatures were nearly equivalent in both years and occurred on the same date (Figure 13). Similarly, minimum temperatures were within 1 °C and occurred during the same week in both years. In 1988 and 1989, MDF were 6.4 and 9.4 °C, respectively.

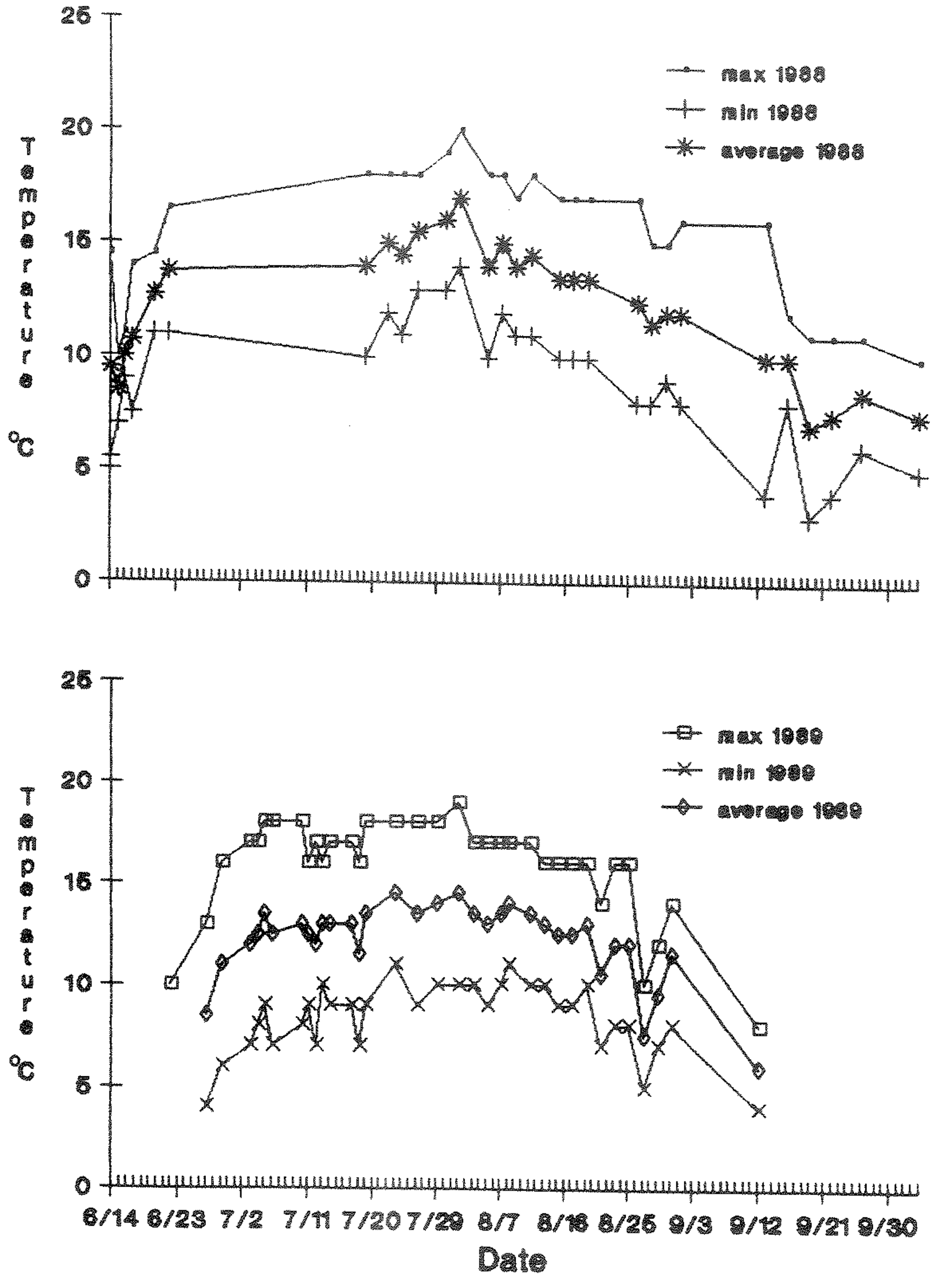

Figure 13. Water temperatures in Tom Miner Creek, Montana, 1988 and 1989.

Spawning Censuses

In 1988, 24 spawners were trapped in Tom Miner Creek between June 9 and 25. In 1989, a total of 49 spawners were captured by electrofishing on June 23 and 30. The length-frequency distribution of cutthroat trout captured in both years is presented in Figure 14. In both years, approximately 50% of spawners were 320 to 369 mm in length.

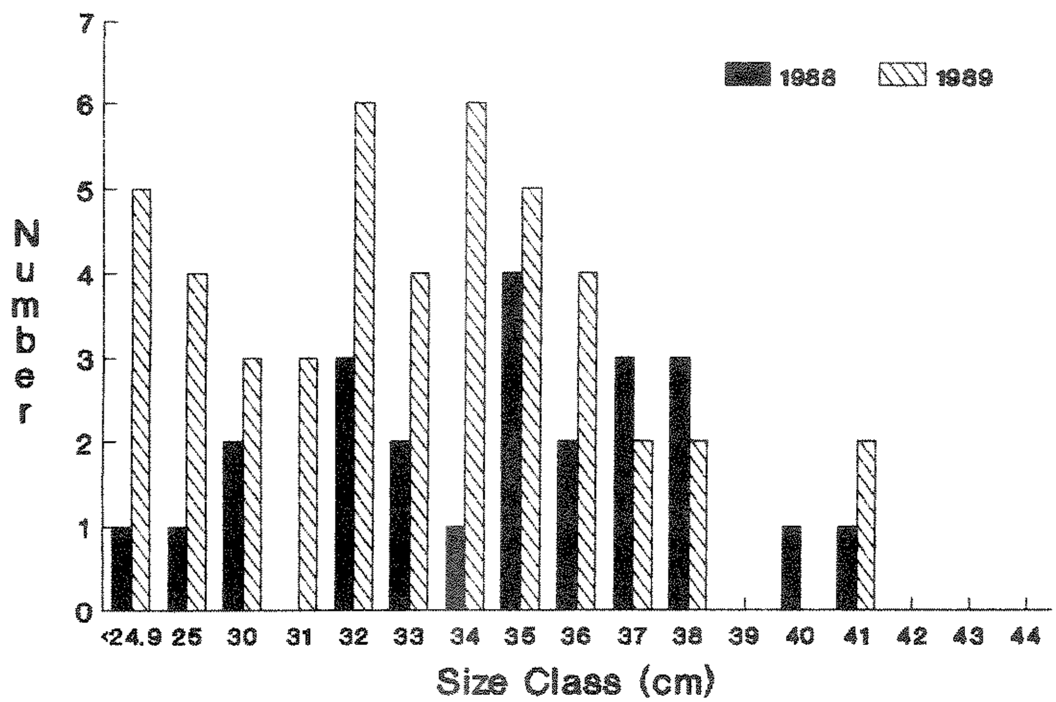

Figure 14. Length-frequency distribution of spawning cutthroat trout captured in Tom Miner Creek, Montana, 1988 and 1989.

Mean length and weight of spawning male cutthroat trout (Table 10) decreased significantly from 1988 to 1989 (t_l=2.67, p=0.011, and t_w=2.431, p=0.026). As in Cedar Creek, the number of males less than 300 mm increased from

0 in 1988 to 4(16%) in 1989, which shifted mean size downward. Mean lengths and weights of female spawners did not change between years (t_l=0.840, p=0.403, and t_w=1.153, p=0.253). In 1988, no rainbow trout in spawning condition were captured, but in 1989 a ripe male rainbow trout was captured during the cutthroat trout spawning season.

Table 10. The mean (standard deviation) total lengths and weights of cutthroat trout spawning in Tom Miner Creek, Montana, 1988 and 1989.

	Males		Females	
	1988	1989	1988	1989
Number caught	12	25	8	19
Mean (SD)				
length (mm)	368(26)*	336(37)*	348(25)	344(52)
weight (g)	498(106)*	373(110)*	456(100)	544(231)

* Indicates significant difference.

Cutthroat Trout Redds

Approximately 46 and 60 cutthroat trout redds were found in Tom Miner Creek in 1988 and 1989, respectively. Aggregations of redds were common, preventing an exact count in both years. Redds were found June 22-July 13, 1988 and July 6-14, 1989. In 1988, 57% of redds located in 1988 were built during the last week in June. In 1989, high flows and turbidity made it difficult to detect redds until July 6, when runoff subsided, and fresh redds were located as late as July 14. In general, it appears that redd construction occurred during the same period in both years. The distribution of redds within the upper 350 m of the study section was similar in both years, but differed in the lower 500 m (Figure 15). In 1988, only 3 redds (7%) were located in the lower 500 m of the study section whereas, approximately 15 (25%) redds were found there in 1989.

Water depth and velocity were measured at 22 redds in 1988 (Table 11). Depths varied from 9.1-30.5 cm, while velocities were 0.144-0.713 m/s. Both mean depth and mean velocity were significantly greater than those recorded in Cedar Creek (t_d=4.421, p=0.00 and t_v=4.354, p=0.00).

Substrate composition was dominated by gravel, comprising 50.3-97.5% of total sample weight, while fines were 2.5-31.6%. Cobbles were 0-42.5% of substrate samples, by weight. Substrate in Tom Miner Creek did not differ from those in Cedar Creek for gravel (t=1.005, p=0.327), cobble (t=-0.602, p=0.555), or fines (t=-2.027, p=0.057).

Approximately 50 and 15% of marked redds were dewatered in 1988 and 1989, respectively (Figure 16). Although fewer individual redds were observed to be dewatered in 1989, several large aggregations of redds were dewatered. Minimum discharges of 0.316 and 0.820 m^3/s protected all redds in 1988 and 1989, respectively.

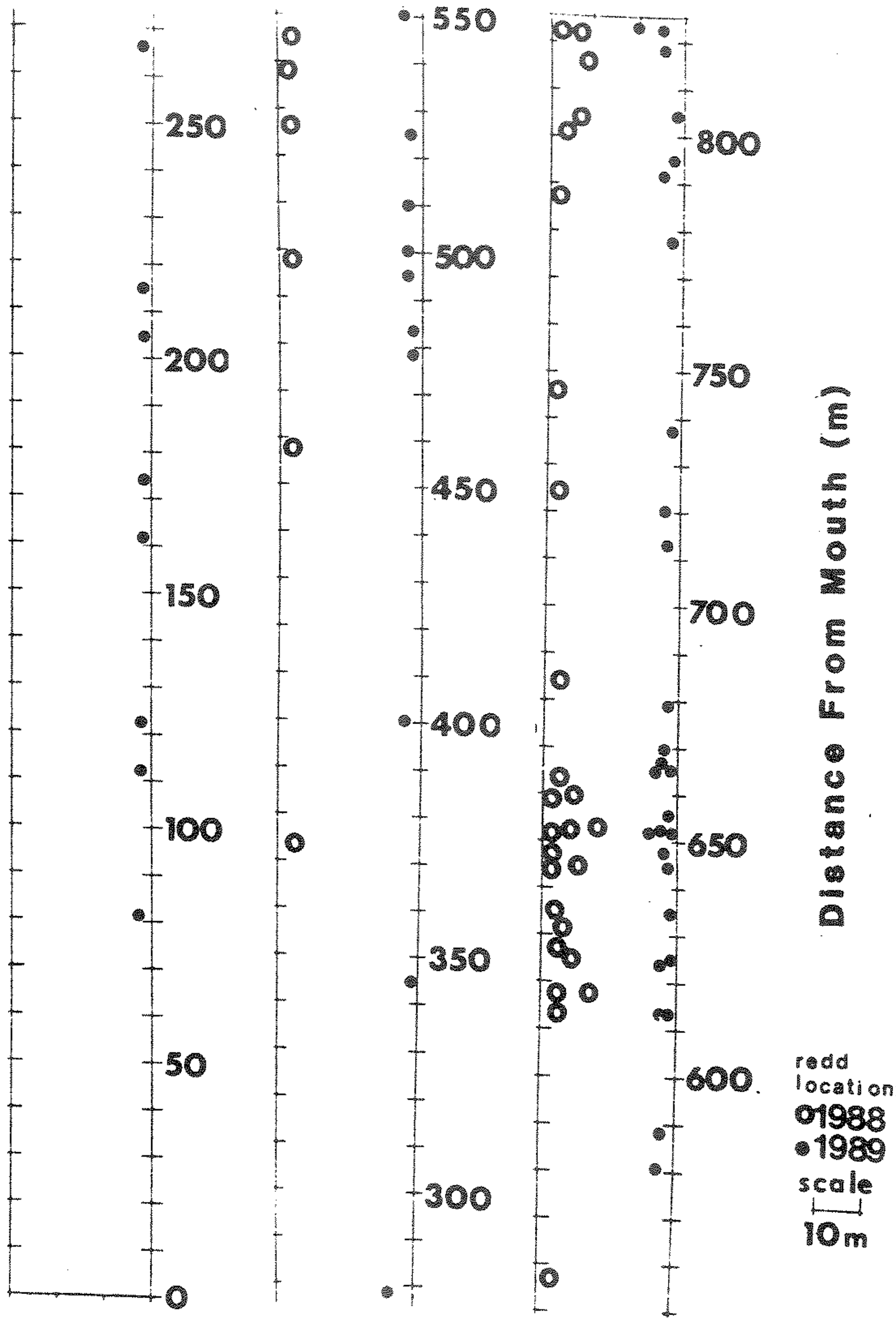

Figure 15. Longitudinal distribution of cutthroat trout redds in Tom Miner Creek, Montana, 1988 and 1989.

Table 11. Means (standard deviation) of selected characteristics in a sample of cutthroat trout redds from Tom Miner Creek, Montana, 1988 and 1989.

Parameter	1988	N	1989	N
Depth (cm)	15.7(5.80)	22		
Velocity (m/s)	0.377(0.14)	22		
Substrate				
% weight cobble			8.24(15.45)	10
% weight gravel			78.77(16.89)	10
% weight fines			12.99(8.71)	10

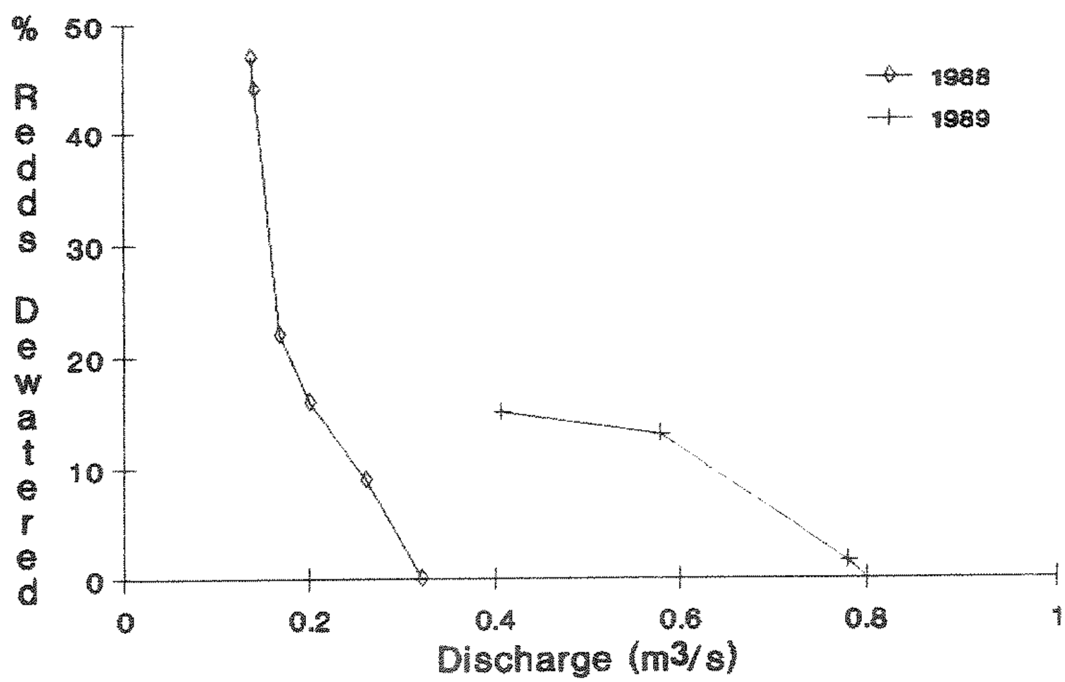

Figure 16. Percentage of cutthroat trout redds dewatered at discharge rates measured in Tom Miner Creek, Montana, 1988 and 1989.

Cutthroat Trout Fry

In Tom Miner Creek, cutthroat trout fry emerged between mid- and late August, 1988 (Figure 17). As with Cedar Creek, emergence in 1989 was delayed until August 1 and continued through the month. Contrary to the case in Cedar Creek, mean emergence per redd declined from 1988 to 1989 in Tom Miner Creek (Table 12).

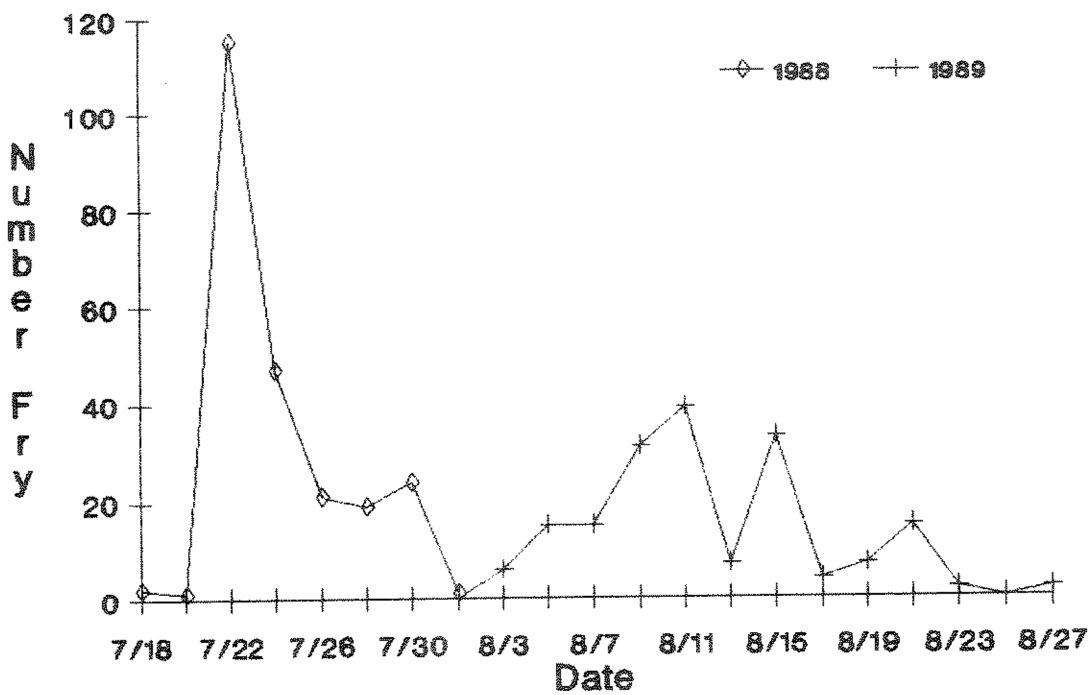

Figure 17. Number of cutthroat trout fry captured in 5 and 10 emergence traps in Tom Miner Creek, Montana, 1988 and 1989, respectively.

Estimates of fry production lost to redd dewatering were greater in 1988 than in 1989, because a greater number of redds were dewatered, and mean emergence per redd was greater in 1988. An estimated 574 fry and 136 fry failed to emerge due to redd dewatering in 1988 and 1989, respectively. These estimates are conservative due to problems experienced in identifying individual redds among large aggregations.

Table 12. Summary of cutthroat trout fry production parameters in Tom Miner Creek, Montana, 1988 and 1989.

	Year	
Parameter	1988	1989
Number of redds trapped	6	10
Number of producing redds	4	5
Mean (SD) emergence*		
All redds	38.3(68.5)	15.2(24.6)
Producing redds	57.5(79.6)	30.4(25.2)
Estimated production	781-1,323	684-1,368

* Number of fry per redd

After emergence, fry in Tom Miner Creek (Table 13) used habitat similar to that reported for Cedar Creek. Mean depth and velocity did not differ significantly between streams (t_d=0.583, p=0.562 and t_v=-0.748, p=0.451). However, they did differ from habitat parameters for newly emerged cutthroat trout fry reported elsewhere. Whereas Moore and Gregory (1988a) reported that average focal velocity for cutthroat trout fry never exceeded 2 cm/s in their study, 52.5 and 45% of fry locations in Cedar and Tom Miner creeks, respectively, were observed at velocities exceeding 2 cm/s. They found post-emergent fry in water 6-11 cm deep, while 52 and 42% of fry observed in Cedar and Tom Miner creeks, respectively, were at depths greater than 12 cm.

Table 13. Habitat parameters of locations used by newly emerged cutthroat trout fry in Tom Miner Creek, Montana, 1989.

Parameter	N	Mean	SD	Min.	Max.
Depth (cm)	40	10.62	5.46	3.0	24.4
Velocity (cm/s)	40	5.2	10.94	0.0	67.5
Substrate					
% Fines	40	50.35	24.50	0.0	100.0
% Gravel	40	14.88	20.66	0.0	70.0
% Cobble	40	22.65	19.34	0.0	90.0
Cover					
Organic debris (cm^2)	40	203.00	465.88	0.0	2500.0
Rock (cm^2)	40	1235.88	1673.32	0.0	5887.5

Substrate at fry locations differed in Cedar and Tom Miner creeks. In Cedar Creek, fine sediments were observed at significantly fewer locations (t=-5.292, p=0.0) than in Tom Miner Creek, while gravel and cobbles were observed at a significantly greater number of fry locations in Cedar Creek (t=3.42, p=0.0 (gravel), and t=3.57, p=0.0, (cobble). The greater occurrence of fines at fry locations in Tom Miner Creek most likely reflects the effects of deposits from high turbidity in the stream. Greater levels of fines may represent a decline in rearing habitat quality, as cutthroat trout fry prefer gravels over fines (Griffith

1970). Moore and Gregory (1988a) suggest that cutthroat trout fry prefer heterogeneous (i.e. gravel and cobbles) over homogeneous substrates (silt).

Fry emigration from Tom Miner Creek occurred shortly after emergence. This was similar to the pattern found in Cedar Creek (Figure 18).

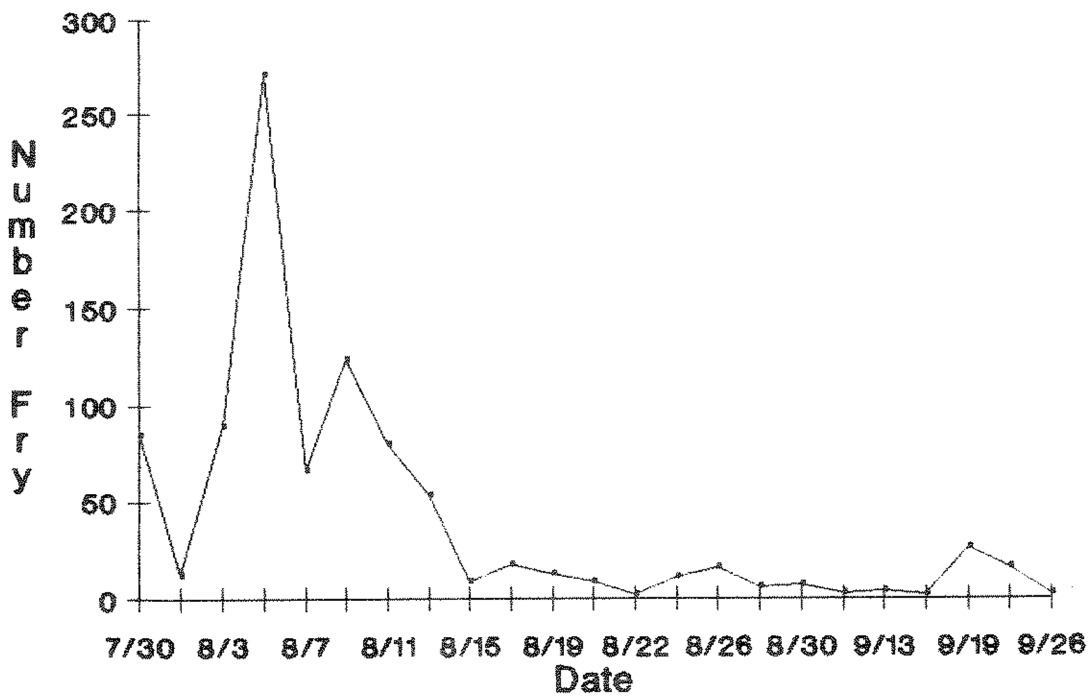

Figure 18. Numbers of emigrating cutthroat trout fry trapped in Tom Miner Creek, Montana, 1988.

Approximately 85% of fry were captured prior to August 15, 1988. A similar trend occurred in 1989, although sampling techniques differed. As in Cedar Creek, over 95% of emigrating fry were captured during the night. Although fry produced in Tom Miner Creek were not readily captured there during the late fall and spring, it appeared that a group of fry remained there through winter of 1988.

Big Creek

Discharge and Water Temperature

Discharge in Big Creek was generally lower in 1988, the drought year, than in 1989 (Figure 19). Peak discharge was recorded on the same date in both years, but 1989 discharge peaked approximately 21% higher than in 1988.

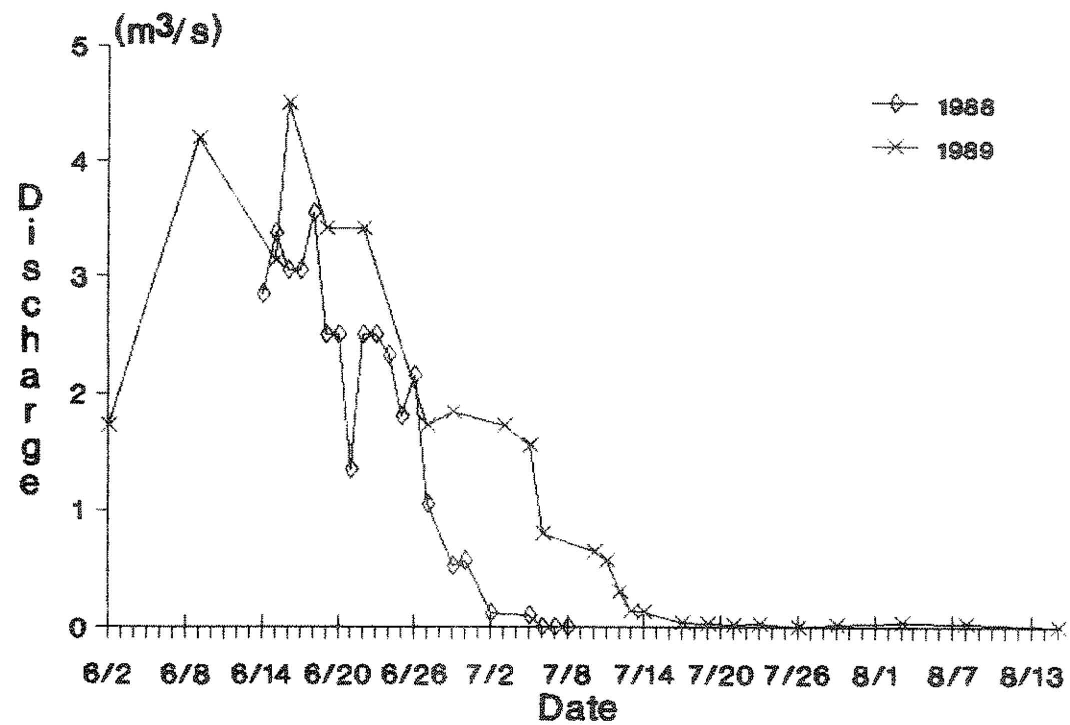

Figure 19. Daily discharge in Big Creek, Montana, 1988 and 1989.

The lower 2 km of Big Creek became completely dewatered on July 11, 1988, and remained so through mid-October. In 1989, the lower 1.6 km was intermittently dewatered from July 26 through mid-August. During this period, a trickle of flow extended 1 km downstream from the lower diversion. On July 12, 1989, discharge was 2.345 m^3/s above, and 0.302 m^3/s below all diversions, indicating that 96% of instream flow was withdrawn for irrigation.

Water temperatures in Big Creek peaked 10 °C higher and 2 weeks later in 1989 than in 1988 (Figure 20). In 1989, water temperatures exceeded the range considered optimal for adult and incubating cutthroat trout (Hickman and Raleigh 1982). Minimum temperature was 4 °C cooler in 1988 than in 1989, although both were recorded on nearly the same date. The MDF were 6.5 and 7.3 °C in 1988 and 1989, respectively.

Spawning Census

Only 5 cutthroat spawners were trapped in Big Creek in 1988. Two males were captured, one was 402 mm and 670 g and the other was 403 mm and 650 g. Three females had a mean length of 356(SD=19.3) mm and mean weight of 485(SD=30.4) g.

Cutthroat Trout Redds

A total of 27 cutthroat trout redds were found in Big Creek between June 21 and July 5, 1988. About 80% of these redds were located during the last week in June. Thirty-nine redds were located July 5-11, 1989. This indicated that spawning occurred 1 to 2 weeks later in 1989, as in Cedar and Tom Miner creeks.

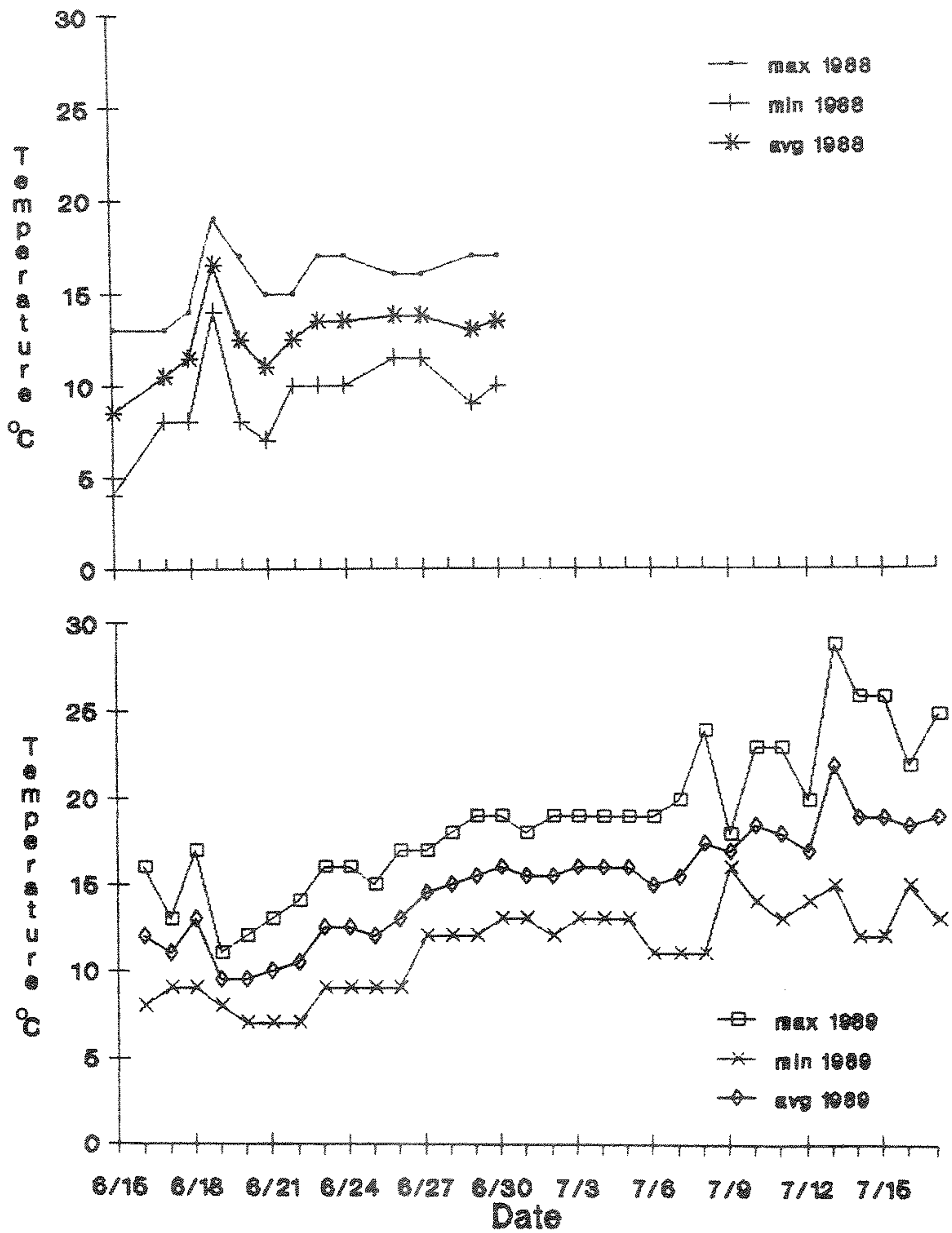

Figure 20. Water temperatures in Big Creek, Montana, 1988 and 1989.

The distribution of redds was similar within the lower 350 m of the study section between years (Figure 21). In 1989, 12 redds were marked in the upper 2 km of the study section, as opposed to 1 in 1988. This may have been due to trap leads discouraging spawning further upstream in 1988.

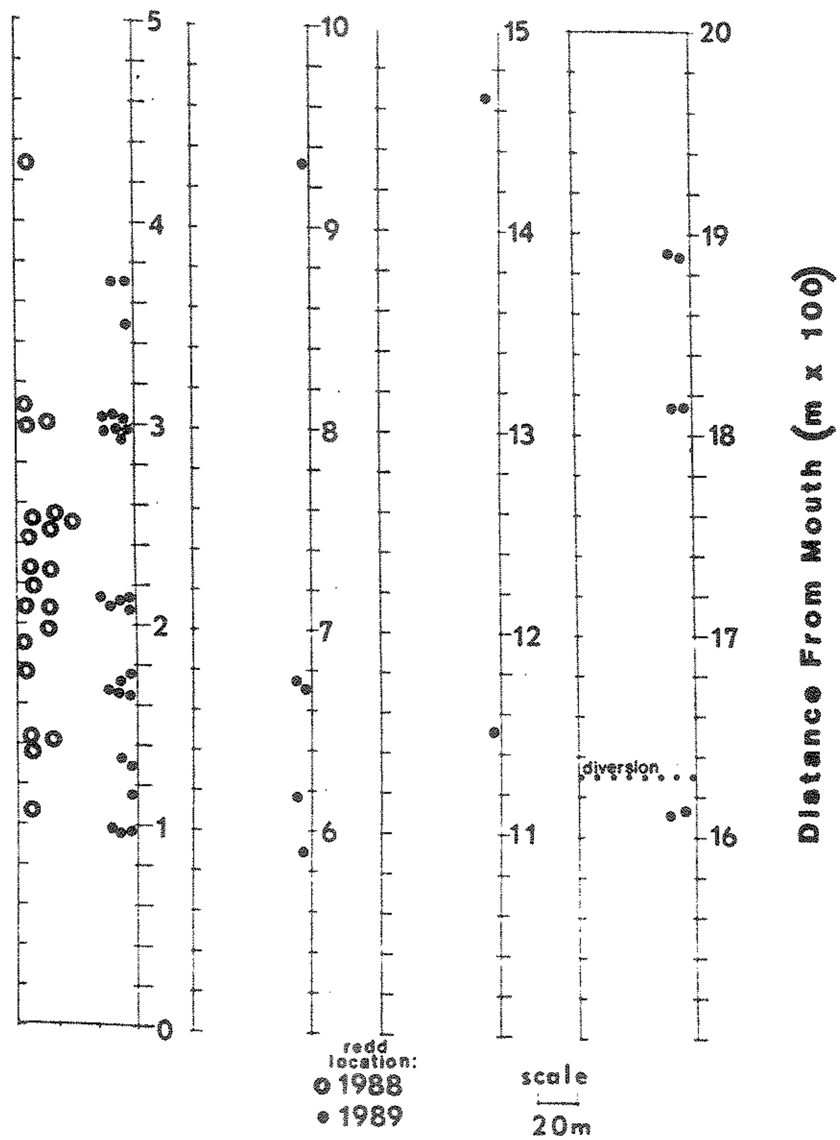

Figure 21. Longitudinal distribution of cutthroat trout redds in Big Creek, Montana, 1988 and 1989.

Water depth and velocity were measured at 21 redds in 1988 (Table 14). Depth ranged from 6.1-19.3 cm, while velocities ranged from 0.160-0.546 m/s. Mean depth of redds in Big Creek were significantly different from those recorded in Cedar Creek (t=-2.343, p=0.021), but were not significantly different from those measured in Tom Miner Creek (t=-1.462, p=0.105). Mean velocity recorded at redds in Big Creek also differed from those in Cedar Creek (t=-2.598, p=0.021), but not Tom Miner Creek (t=-1.246, p=0.220).

Table 14. Means (standard deviation) of selected characteristics in a sample of cutthroat trout redds from Big Creek, Montana, 1988 and 1989.

Parameter	1988	N	1989	N
Depth (cm)	13.5(0.035)	21		
Velocity (m/s)	0.327(0.115)	21		
Substrate				
% weight cobble			20.7(23.0)	10
% weight gravel			73.3(20.2)	10
% weight fines			5.9(3.7)	10

Gravel dominated the substrate composition in redds in Big Creek. Its proportion did not differ significantly from samples in Cedar Creek (t=-0.050, p=0.961), nor Tom Miner Creek (t=-0.631, p=0.536). Mean percentage of cobbles did not differ from those measured in Cedar Creek (t= -0.427, p= 0.674), nor Tom Miner Creek (t= 1.371, p=0.187). Substrate samples in Big Creek contained the lowest mean percentage of fines of the three study streams, but the percentage of fines in Big Creek redds did not differ significantly from redds in Cedar Creek (t=0.595, p=0.559). It was significantly less than in Tom Miner Creek (t=-2.329, p=0.032).

One hundred percent of redds were dewatered in Big Creek in 1988 (Figure 22). Isolated pools and persistent flows in the upper 1.4 km of the study section prevented 8% of redds from becoming dewatered in 1989. A minimum flow of 0.570 m^3/s was sufficient to protect all redds in both years. However, a minimum discharge of 0.302 m^3/s was observed to protect all but 1 redd (3%) from being dewatered in 1989.

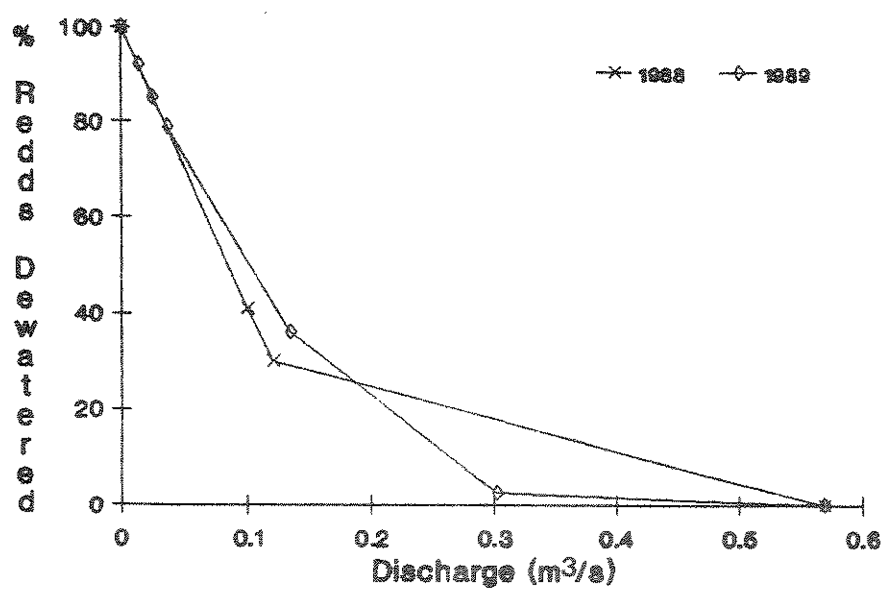

Figure 22. Percentage of cutthroat trout redds dewatered at discharge rates measured in Big Creek, Montana, 1988 and 1989.

DISCUSSION

Cedar Creek

Of the study streams, Cedar Creek was estimated to produce the greatest number of cutthroat trout fry. About 2,000 fry were estimated to have been produced in 1988, a drought year. Although estimates derived from emergence traps and fry traps were similar, both undoubtedly underestimated true fry production. The emergence traps used in 1988 failed to capture all emerging fry, and did not exclude all predators, thus reducing the mean number of emergent fry per redd used in that calculation. The fry trap occasionally overflowed allowing fry to escape, and sculpins caught in the trap had gorged on fry. Finally, some fry remained in the stream.

In 1989, fry production was estimated to be seven times greater than in 1988. A greater number of redds were found in 1989, and a smaller portion of these became dewatered. The number of fry that emerged per redd was also greater in 1989. An increase in discharge in mid-August, 1989 may have facilitated greater emergence than in 1988.

The factor limiting fry production in Cedar Creek was a lack of sufficient flow necessary to protect redds. In 1988, 21% of the redds located became dewatered, which therefore, reduced fry production by approximately the same amount. In 1989, 13% of the redds were dewatered until mid-August, when discharge increased and rewatered most of the redds. The increase in flow may have prevented complete loss of fry within dewatered redds. It is possible that eggs within dewatered redds survived the period of dewatering until discharge increased sufficiently to allow fry to emerge. Salmonid eggs have been shown to be resistant to periods of dewatering if substrate remains moist and if temperatures remain within normal incubating range (Reiser and White 1981, Becker et al. 1983, Reiser and White 1983).

Cedar Creek should receive high priority for protection and restoration of instream flow by reservation or lease. Current fry production is relatively high and could be improved with a small increase in instream flow. A minimum discharge of 0.036 m^3/s from June through August should provide adequate protection for nearly all cutthroat trout redds in Cedar Creek.

Hybridization now threatens the genetic integrity of Yellowstone cutthroat trout spawning in Cedar Creek. Although the spawning run was believed to be composed of a pure strain of cutthroat trout, four ripe male rainbow trout were captured during the 1989 cutthroat spawning run.

This is the first time rainbow trout were recorded in the cutthroat trout spawning run in Cedar Creek.

Tom Miner Creek

Tom Miner Creek is second to Cedar Creek for cutthroat fry production. Production, estimated as the product of the mean number of fry emerging per redd and the number of non-dewatered redds, was 781 in 1988. Traps at the mouth of the stream captured 924 emigrating fry. Both of these figures are likely to be underestimates. High turbidity during surveys prevented complete enumeration of redds, and aggregations of redds were common in Tom Miner Creek, making it difficult to identify individual redds. It is probable that the large aggregations of redds produced a substantial amount of fry that were not included in the estimates. Also the small sample of redds capped with emergence traps may have provided an underestimate of the number of fry produced per redd. In addition, not all emigrating fry were captured and some remained in the stream.

Based on mean emergence and the number of water covered redds, an estimated 684 fry were produced in Tom Miner Creek in 1989. Based on catch-per-unit-effort from fry trapping, an estimated 3,413 fry were produced in, and emigrated from Tom Miner Creek. Again, for reasons stated above, production estimates derived from emergence traps are conservative. Emigration rates probably provided a more reasonable estimate of production in 1989.

Fry production in Tom Miner Creek appears to be limited by natural factors. During the drought in 1988, 50% of the marked redds were dewatered, in spite of a lack of significant irrigation withdrawals. A minimum discharge of 0.316 m^3/s would have been sufficient to prevent any redds from being dewatered.

In 1989, with normal precipitation, only 15% of cutthroat trout redds became dewatered. A minimum discharge of 0.829 m^3/s was required to protect all redds during this year. The difference in minimum flows needed to protect redds between years may have been due to lower flows that occurred early in 1988, which prevented spawning in areas that were available in 1989. Since the impacts of irrigation withdrawals are minimal, especially during years with normal precipitation, an instream flow lease would be impractical in Tom Miner Creek.

Fry production may be further limited by accumulation of fine sediments in redds. Extensive fine sediment deposition in spawning gravels of Tom Miner Creek may account for lower mean emergence per redd than in Cedar Creek, especially in 1989. Six of 10 redds sampled in 1989 contained greater than 10% fines (<2.0 mm) by weight, with some containing as high as 31.6% fines. Fine sediments have been reported to have deleterious effects on developing salmonid embryos. As the percentage of fines increases, embryo survival decreases (Phillips et al. 1975, Reiser and White 1988). Excessive fine sediments restrict intragravel flow which provides oxygen to, and removes metabolites from, the egg surface (Hall and Lantz 1969, Hausle and Coble 1976, Sowden and Power 1985, Chapman 1988). Recently hatched alevins may become entrapped by fines, inhibiting emergence (Phillips et al. 1975, Hausle and Coble 1976). Any reduction in sediment loads may increase fry production in Tom Miner Creek; however, controlling erosion from a slump of this magnitude may be difficult.

The potential exists for introgression by rainbow trout in Tom Miner Creek cutthroat trout populations. Yellowstone cutthroat trout populations in its headwaters are known to be pure strain (Leary et al. 1989), but ripe male rainbow trout taken in the study section during the 1989 cutthroat trout spawning run may indicate a future threat to their purity.

Big Creek

Presently, cutthroat trout production in Big Creek is minimal due to severe dewatering for irrigation. However, it appears that some fry are produced because an annual spawning run exists. Apparently redds above the irrigation diversions and those spared by intermittent flows below provide sufficient production to propagate this spawning run. Because Yellowstone cutthroat trout home specifically to natal streams it is unlikely that the spawning run represents transient spawners (Benson 1960, Hadley 1984, Varley and Gresswell 1988, Leary et al. 1989).

Although current fry production is minimal, Big Creek could produce a stronger spawning run if sufficient flows were made available. A minimum discharge of 0.570 m^3/s was observed to protect 100% of redds in the lower 2.2 km of the stream during both field seasons. However, a minimum of 0.302 m^3/s, from June through August, would have provided sufficient flow to protect 97% of redds in 1989.

This discharge was established at a transect 300 m upstream from the mouth of Big Creek, and may not apply to the entire 2.2 km section. However, it would protect the highest concentration of redds which was found within the lower 300 m.

Spawning gravel appeared to be limited in Big Creek. Recurring dewatering may prevent distribution of smaller substrate suitable for spawning. If gravel availability is not improved with persistent flows, adding gravel to the stream bed should be considered.

The potential for hybridization between cutthroat and rainbow trout also exists in Big Creek. Populations of cutthroat trout are already extensively hybridized in the upper reaches (Leary et al. 1989). Presently few resident trout exist in the isolated pools and trickles within the lower 2 km of Big Creek. But, if persistent flows were available, this reach would certainly be colonized from upstream, increasing the possibility of introgression into pure strain adfluvial Yellowstone cutthroat trout.

Big Creek should receive a high priority for instream water lease, because of the potential to enhance present cutthroat trout fry production. However, to restore the spawning run, a substantial instream flow will be required.

LITERATURE CITED

Becker, C. D., D. A. Neitzel, and C. S. Abernathy. 1983. Effects of dewatering on chinook salmon redds; tolerance of four development stages to one-time dewatering. N. Am. Jour. Fish. Man. 3:373-382.

Belford, D. A. 1986. Abilities of trout to swim through highway culverts. M.S. Thesis, Mont. State Univ., Bozeman, 67 pp.

Benson, N. G. 1960. Factors influencing production of immature cutthroat trout in Arnica Creek, Yellowstone National Park. Trans. Am. Fish. Soc. 89:168-175.

Berg, R. K. 1975. Fish and game planning, upper Yellowstone and Shields river drainages. Fisheries inventory and planning, Fed. Aid. Proj. no. FW-3-R, Job no. I-a. Mont. Dept. of Fish and Game, Helena, 125 pp.

Bisson, P. A., J. L. Nielson, R. A. Palmason, and L. E. Grove. 1981. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 _in_ N. B. Armantrout, ed. Acquisition and utilization of aquatic habitat inventory information; Proceedings of a symposium. Portland, Oreg.

Chapman, D. W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Trans. Am. Fish. Soc. 117(1):1-21.

Clancy, C. G. 1987. Southwest Montana fisheries investigations. Inventory and survey of waters of the project area. Project no. F-9-R-35, Job 1-C. Mont. Dept. of Fish, Wildl. and Parks, Helena.

———. 1988. Effects of dewatering on spawning by Yellowstone cutthroat trout in tributaries to the Yellowstone River, Montana. Am. Fish. Soc. Symposium 4:37-41.

Fraley, J. J., M. A. Gaub, and J. R. Cavigli. 1986. Emergence trap and holding bottle for the capture of salmonid fry in streams. N. Am. Jour. Fish. Manage. 6:119-121.

Griffith, J. S. jr. 1972. Comparative behavior and habitat utilization of brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in northern Idaho. Jour. Fish. Res. Bd. Can. 29:265-273.

Hadley, K. 1984. Status report on the Yellowstone cutthroat trout (Salmo clarki bouveri). Prog. Rep. to Mont. Dept. of Fish, Wildl., and Parks, Helena.

Hall, J. D., and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. in T. G. Northcote, ed. Symposium on salmon and trout in streams. Inst. of Fish., Univ. of B.C., Vancouver.

Hausle, D. A., and D. W. Coble. 1976. Influence of sand on survival and emergence of brook trout (Salvelinus fontinalis). Trans. Am. Fish. Soc. 105:57-63.

Hickman, T., and R. F. Raleigh. 1982. Habitat suitability index models: cutthroat trout. U. S. Fish and Wildl. Serv. FWS/OBS-82/10.5. 38 pp.

Holton, G. 1980. The riddle of existence: fishes of "special concern". Mont. Outdoors 11(1):2-6, 26.

Javorsky, L. D. 1984. The trout fishery on a reach of the upper Yellowstone River, Montana, during 1982. M.S. Thesis, Mont. St. Univ., Bozeman, 67 pp.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1989. Genetic divergence among Yellowstone cutthroat trout populations in the Yellowstone River, Montana: update. Population Genetics Lab. Report 89/2. Div. of Biol. Sci., Univ. of Mont., Missoula.

Lund, R. E. 1987. MSUSTAT. Mont. St. Univ., Bozeman.

Mohrman, J., R. Ewing, and D. Carty. 1988. Sources and quantities of suspended sediment in the Yellowstone River and selected tributary watersheds between Yellowstone Lake outlet, Wyoming, and Livingston, Montana: 1986 Annual Progress Report. Aquatic Ecology Technical Report Number 4. U.S. Fish and Wildl. Serv., Yellowstone National Park, Wyoming.

Moore, K. M. S., and S. V. Gregory. 1988a. Summer habitat utilization and ecology of cutthroat trout fry (*Salmo clarki*) in Cascade mountain streams. Can. Jour. Fish. Aq. Sci. 45:1921-1930.

———. 1988b. Response of young-of-the-year cutthroat trout to manipulation of habitat structure in a small stream. Trans. Am. Fish. Soc. 117:162-170.

Phillips, R. W., R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Am. Fish. Soc. 104(3):461-465.

Reiser, D. W., and R. G. White. 1981. Incubation of steelhead trout and spring chinook salmon eggs in a moist environment. Prog. Fish Cult. 43(3):131-134.

———. 1983. Effects of complete redd dewatering on salmonid egg-hatching success and development of juveniles. Trans. Am. Fish. Soc. 112:532-540.

———. 1988. Effects of two sediment size-classes on survival of steelhead and chinook salmon eggs. N. Am. Jour. Fish. Manage. 8(4):432-437.

Sando, S. K. 1981. The spawning and rearing habitats of rainbow trout and brown trout in two rivers in Montana. M.S. Thesis, Mont. St. Univ., Bozeman, 67 pp.

Smith, O. R. 1941. The spawning habits of cutthroat and eastern brook trout. Jour. Wildl. Manage. 5(4):461-471.

Sowden, T. K., and G. Power. 1985. Prediction of rainbow trout embryo survival in relation to groundwater seepage and particle size of spawning substrate. Trans. Am. Fish. Soc. 114:804-812.

Thurow, R. F., C. E. Corsi, and V. K. Moore. 1988. Status, ecology, and management of Yellowstone cutthroat trout in the upper Snake River drainage, Idaho. Am. Fish. Soc. Symposium 4:25-36.

USDA, Soil Conservation Service. 1988. Montana water supply outlook. Bozeman, Mont. 7 pp.

———. 1989. Montana water supply outlook. Bozeman, Mont. 8 pp.

U. S. Geological Survey. 1977. National handbook of recommended methods for water-data acquisition. U. S. Geol. Surv. v. p.

Varley, J. D., and R. E. Gresswell. 1988. Ecology, status, and management of Yellowstone cutthroat trout. Am. Fish. Soc. Symposium 4:13-24.

Welch, P. S. 1948. Limnological methods. McGraw-Hill Book Co. New York. 382 pp.

Wolf, P. 1950. A trap for the capture of fish and other organisms moving downstream. Trans. Am. Fish. Soc. 80:41-45.