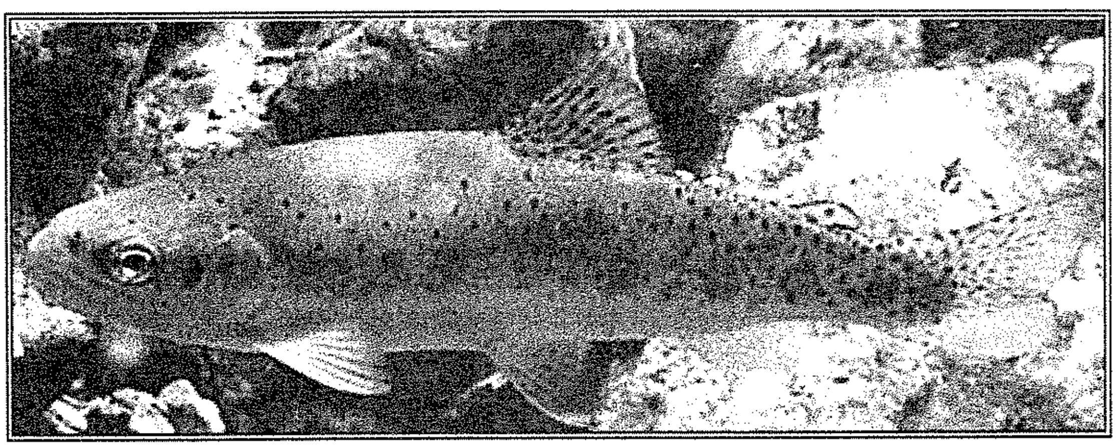
An Evaluation of Yellowstone Cutthroat Trout Fry Outmigration from Four Tributaries of the Upper Yellowstone River During a Low Water Year



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Abstract

Yellowstone cutthroat trout fry outmigration was monitored on Locke, Mill, Cedar, and Mol Heron creeks during 1998 and compared to data from 1996 and 1997 to evaluate the effect of current water leases on fry recruitment to the Yellowstone River, Montana. This study examined how the climatic difference affected Yellowstone cutthroat trout fry outmigration from these four tributaries from July 6 to September 17, 1998. The summer of 1998 was warmer and drier than the two previous summers, although it was not a drought year. Total numbers of fry captured were down from surveys conducted in1996 and 1997 in all creeks except Mol Heron. As compared to 1997 counts, the number of fry trapped decreased 97% in Locke Creek, 77% in Mill Creek, and 85% in Cedar Creek. The number of fry trapped in Mol Heron Creek increased by 11% from the count in 1997, but was 31% lower than the count in 1996. High daytime temperatures in July and dramatic declines in streamflow in Locke, Mill and Cedar creeks may have contributed to lower outmigration. Mean stream temperatures in Locke Creek exceeded 17 C from July 3 to August 18, encompassing the entire outmigration period. Despite the water lease, Mill Creek was dry for at least 48h during mid-September and many young of the year Yellowstone cutthroat trout, along with other trout species and sculpin, were found dead as a result. Flows in Cedar Creek dropped below the lease level of 0.04 m^3/s for 7 d in early August, resulting in prolonged dewatering of redds. However, in contrast to the disastrous effects of prolonged inadequate flows seen on Locke Creek, the water leases on Mill, Cedar and Mol Heron Creeks prevented greater Yellowstone cutthroat trout fry losses by mitigating flow levels during July and August.

Introduction

Water leases were in effect in 1998 on Mill, Mol Heron and Cedar creeks, and a verbal agreement had been made between Joe Brooks Trout Unlimited and Peterson Ranch to attempt to maintain flows on the lower portion Locke Creek The Church Universal and Triumphant had decided not to irrigate in 1998, further decreasing demands on Mol Heron Creek (F. Nelson 1998, MDFWP, personal communication). These water leases and agreements were established to provide in-stream flows for Yellowstone cutthroat trout (*Onchorynchus clarki bouvieri)* reproduction and to generally benefit the Yellowstone River fishery (Spence 1996). This study sought to examine how well the leases functioned during a lower water year, and to evaluate the effects of potentially lower flows on Yellowstone cutthroat trout fry recruitment. Data from 1998 was compared to a similar study completed in 1997 to judge the impact of lower flows, if any (Hennessesy 1998). The specific objectives of this study were:

1. To monitor fry outmigration from Locke, Mill, Cedar and Mol Heron creeks, and compare them to results from the two previous years.
2. To monitor flow regimes from the four tributaries, and compare them to regimes from the two previous years.
3. To assist in the timing for the Mill Creek flushing flow and to monitor fry outmigration to assess its effectiveness.
4. To examine climate data to evaluate whether 1998 was in fact a lower than aver

Study Area

This study was conducted in Park County, Montana on four tributaries of the upper Yellowstone River (Figure 1). Locke, Cedar and Mol Heron creeks are considered high quality spawning areas for Yellowstone cutthroat trout as defined by Clancy (1988). Lower Mill Creek was excluded from this distinction because of decades of dewatering. A detailed description of each of the four study streams, including results from electrophoretic testing of fry, is included in the study completed by Hennessey (1998).

Locke Creek joins the Yellowstone River approximately 16.1 km (10 mi) downstream from Livingston, Montana and is a third order stream based on the occurrence of perennial streams on U.S. Geological Survey 1:24,000 scale topographic maps with an approximate length of 9.5 km (5.8 mi). The lower 5 km (3.1 mi) of Locke Creek has a gradient of 1.5 to 3.0%. The stream gradient increases to 10% in the upper 4.5 km (2.7 mi).

Mill Creek, located near Emigrant, Montana (Figure 1), is the largest tributary of the Yellowstone River in Park County. Mill Creek is a fourth order stream based on the occurrence of perennial streams on U.S. Geological Survey 1:24,000 scale topographic maps with an approximate length of 34 km (21 mi) and a mean annual discharge of 4.5 m^3/s (160 cfs) (Parrett 1985). The lower 2.3 km (1.4 mi) of Mill Creek, where this study was conducted, has a gradient of 0.6 to 1.2%. There are several major irrigation diversions on Mill Creek, including the Mill Creek Water and Sewer District pipeline.

Cedar Creek, located near Corwin Springs, Montana (Figure 1), is a small tributary of the

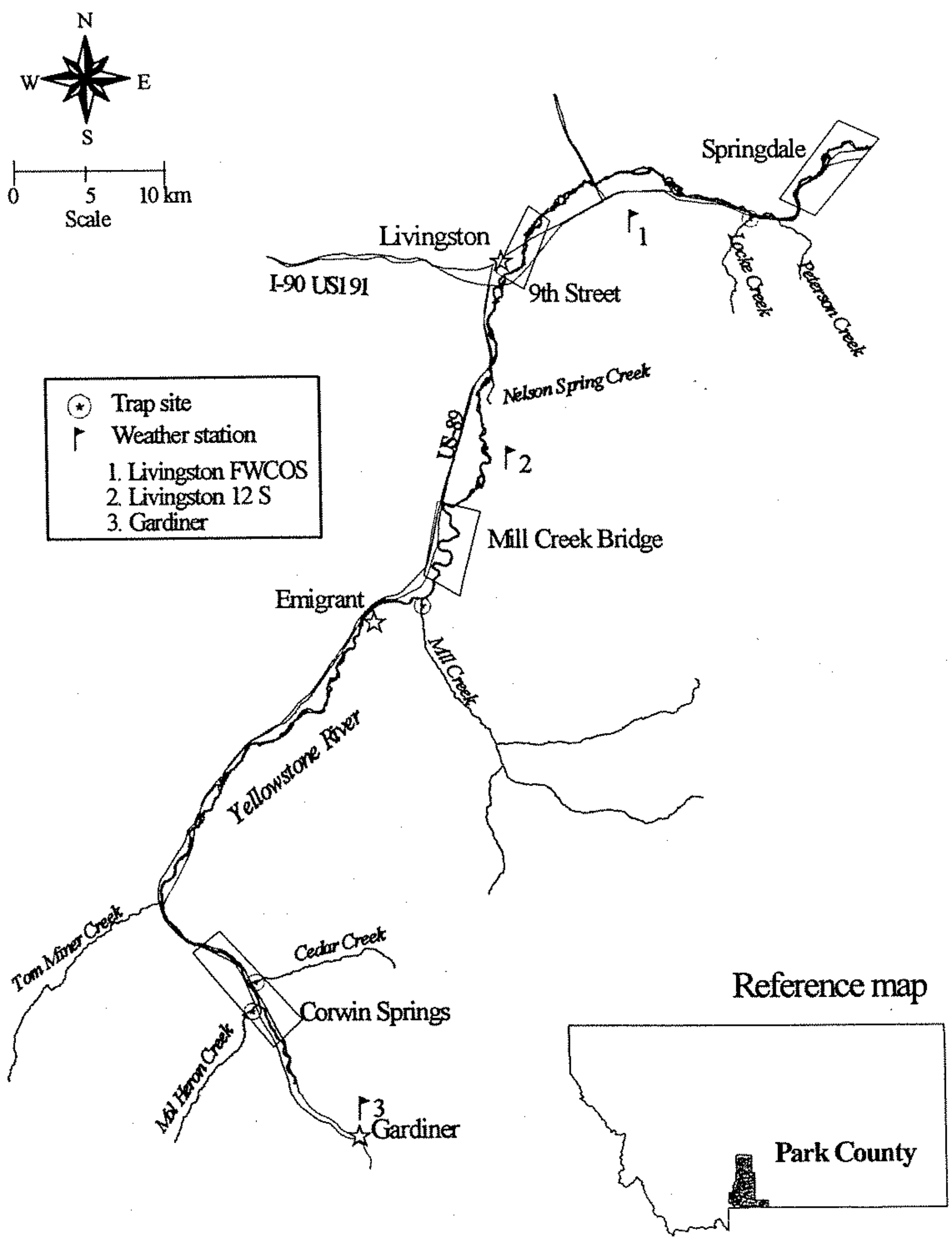

Figure 1. Map of the study area showing the four study streams (Locke, Mill, Cedar and Mol Heron creeks), trapsites, additional high quality spawning tributaries and electrofishing sections (enclosures) on the Yellowstone River.

Yellowstone River. Most of Cedar Creek, including the headwaters, is within USFS lands. The lowest 2 km (1.2 mi) of Cedar Creek flows through private land and several irrigation diversions exist within 1 km (0.6 mi) of its mouth. Cedar Creek is a fourth order stream based on the occurrence of perennial streams on U.S. Geological Survey 1:24,000 scale topographic maps with an approximate length of 12 km (7.5 mi) and a mean annual discharge of 0.26 m^3/s (9.1 cfs) (Parrett 1985). The lower 0.67 km (0.41 mi) of Cedar Creek has a gradient of 2.7%.

Mol Heron Creek's entire length is within lands owned by the Church Universal and Triumphant (Church). The Church maintains two irrigation diversion ditches within 1 km (0.6 mi) of the creek mouth. Mol Heron Creek is a fifth order stream based on the occurrence of perennial streams on U.S. Geological Survey 1:24,000 scale topographic maps with an approximate length of 18 km (11 mi). Mol Heron Creek has a mean annual discharge of 0.69 m^3/s (25.4 cfs); (Parrett 1985). The stream gradient varies from 4.1 to 5.7% over its entire length with the steeper sections occurring in the lowest 2 km (1.2 mi).

Methods

Stream Discharge and Temperature

Discharge was monitored daily in each study stream. Staff gauge readings were recorded and converted to discharge using United States Geological Survey (USGS) rating curves for Mill and Cedar creeks. MDFWP rating curves were used for estimating discharge on Locke and Mol Heron creeks. Mean, minimum and maximum seasonal (July to September) discharges were estimated. Onset Optic StowAway® thermographs were installed at each staff gauge location on June 6, 1998 and programmed to record at 30 minute intervals. Thermographs measured temperatures ranging from -40° C to 75° C with an accuracy of +/- 0.2 ° C and +/- 0.33 min/d.

Spawning Activity

Spawning was monitored by walking sections of each creek once a week, beginning in mid-June, until activity was detected. After spawning fish were observed, daily monitoring was continued for up to 1 week. As Locke Creek was the site farthest downstream, it was monitored first and used to gauge approximate spawning times for other study streams.

Yellowstone Cutthroat Trout Fry Recruitment

Fry recruitment, defined as the number of fry outmigrating from a tributary and entering the mainstem of the Yellowstone River, was estimated by setting fry traps within each study stream, as close as possible to the mouth. Yellowstone cutthroat trout fry begin downstream outmigration after emergence from the gravel, and move into the mainstem within a short time (Thurow, Corsi, and Moore 1988). The number of fry trapped was used as an index of total fry recruitment (Byorth 1990; Shepard 1992; Hennessey 1998).

Fry recruitment was estimated using fry traps with openings 80 cm (2.3 ft) by 47 cm (1.5 ft), framed with 5 mm diameter metal rods (McMullin and Graham 1981). A 1.4 m (4.5 ft), 1.6 mm mesh, net was sewn around the frame. The tapered net ended in a 10 cm (4 in) threaded

PVC and metal collar connected to the tail of the trap by screwing into a matching PVC pipe. The tails were approximately 1m (3 ft) in length, made of the same netting as the trap, and had a drawstring closure (Hennessey 1998).

Traps were placed by pounding a 1m (3 ft) length of rebar into the streambed on either side of the trap mouth. The frame rested against the rebar and was secured with wire. Current flowing through the trap kept it open and straight. The bottom of the trap frame was covered with rocks to prevent fry from swimming under the trap. Captured fry were retained in the tail of the trap where the PVC collar presented a velocity barrier to escapement.

Traps were placed near the first suitable pool upstream from the mouth, so that the tails sat in the deepest portion of the pool just below a riffle. Care was taken not to place the trap over an active redd. Whenever possible, traps were placed in the same location as in previous surveys (Hennessey 1998). Two traps were used in Locke Creek to determine whether spawning was occurring above the uppermost diversion structure on the Peterson Ranch. One trap was set near the mouth of Locke Creek at the same site used in 1996 and 1997, and an additional trap was placed at the head of a pool immediately above the uppermost diversion structure. Each of the two Locke Creek traps sampled approximately 50% of the width. The single trap in Cedar Creek was placed in the same location as in 1996 and 1997, and sampled approximately 50% of the width (Hennessey 1998).

In 1998, the main channel of Mill Creek was blocked by a rock berm constructed by a landowner, and all of the flow was diverted to the North channel. A pool at the end of a low velocity riffle section in the newly widened North channel of Mill Creek was chosen as the1998 trap site. The two traps used in Mill Creek spanned a total of approximately 20% of the channel width.

In Mol Heron Creek, a single trap was placed in the thalweg near the left bank to increase trap efficiency, and two plywood baffles were added to reduce stream velocity near the trap tail. The trap sampled approximately 25% of the creek width.

Traps were placed on each study stream approximately 25 to 30 d after spawning activity was observed (Benson 1960). In Cedar and Mill creeks, where no spawning was observed, temperature and historical fry trapping data were used to estimate the spawning date (Shepard 1992; Hennessey 1998). Beginning on July 1, 1998, fry traps were set overnight every third night until fry were caught. Thereafter, traps were set and checked daily. An effort was made to check traps early in the morning to minimize fry stress (Hennessey 1998). Number and species of fry caught, individual total lengths of a random subsample of 10 fry, water temperatures, and staff gauge readings were recorded.

Climatic Data

Climate data from the three weather stations in the upper Yellowstone River region, Livingston FAA, Livingston 12S, and Gardiner, were compiled for 1998 and compared to the average readings over the life of the climate stations. The Livingston FAA and Gardiner stations have been gathering data for close to 50 years, while the Livingston 12S station has records dating back 16 years (WRCC 1998). Data examined included average maximum and minimum daily temperature, monthly precipitation, and annual precipitation. At the time of this report not all of the data for 1998 was available. Therefore, only trends from January to August were examined.

Results

Stream Discharge and Temperature

Discharge

Stream discharge was lower in Locke Creek on comparative dates in 1998 than in 1997 (Figure 2). Discharge dropped after irrigation began on July 13, and remained low throughout the rest of the summer. During the 1998 field season (July 1 to August 15) mean seasonal discharge was 63 % lower than in 1997 and ranged from 0.01 m^3/s to 0.08 m^3/s (0.5 cfs to 2.8 cfs); (Table 1).

A late snowmelt created extreme high flows in Mill Creek in early July, 1998, peaking on July 7 at 8.5 m^3/s (300 cfs);(Table 1). Flows declined rapidly from this peak, but discharge on August 1 was still well above flows in early August for either of the two previous summers (Figure 3). Flows on Mill Creek declined consistently throughout the 1998 field season with discharge during dates comparable to 1996 and 1997 ranging from 0.0 m^3/s to 2.2 m^3/s (0 cfs to 79 cfs); (Table 1). As in the two previous years, discharge dropped well below pre-flush levels within 24h after the flush ended (Figures 3 and 4).

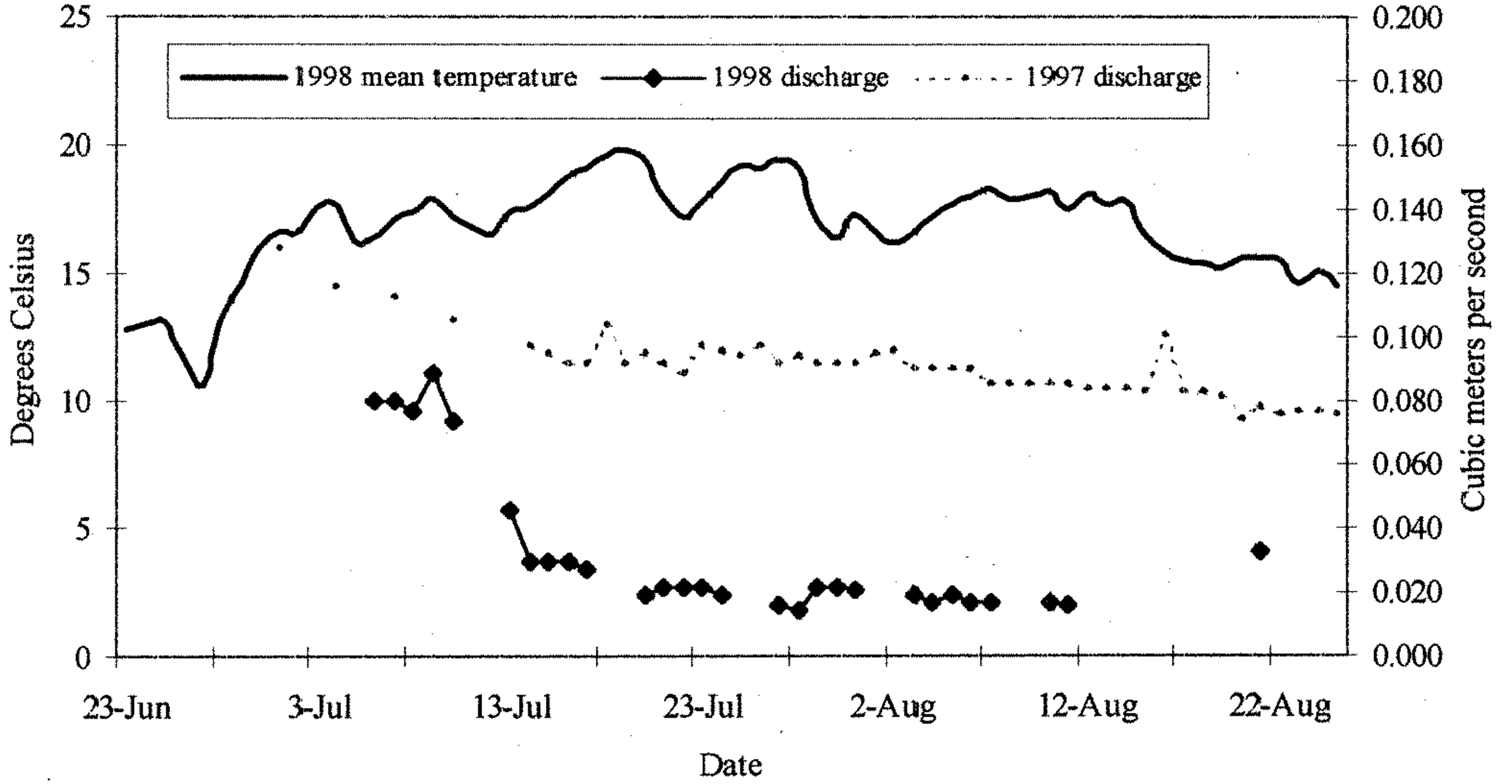

Figure 2. Daily discharge and mean daily water temperature for Locke Creek, Montana, from June to September, 1998. Discharge on comparative dates from 1997 is included for contrast.

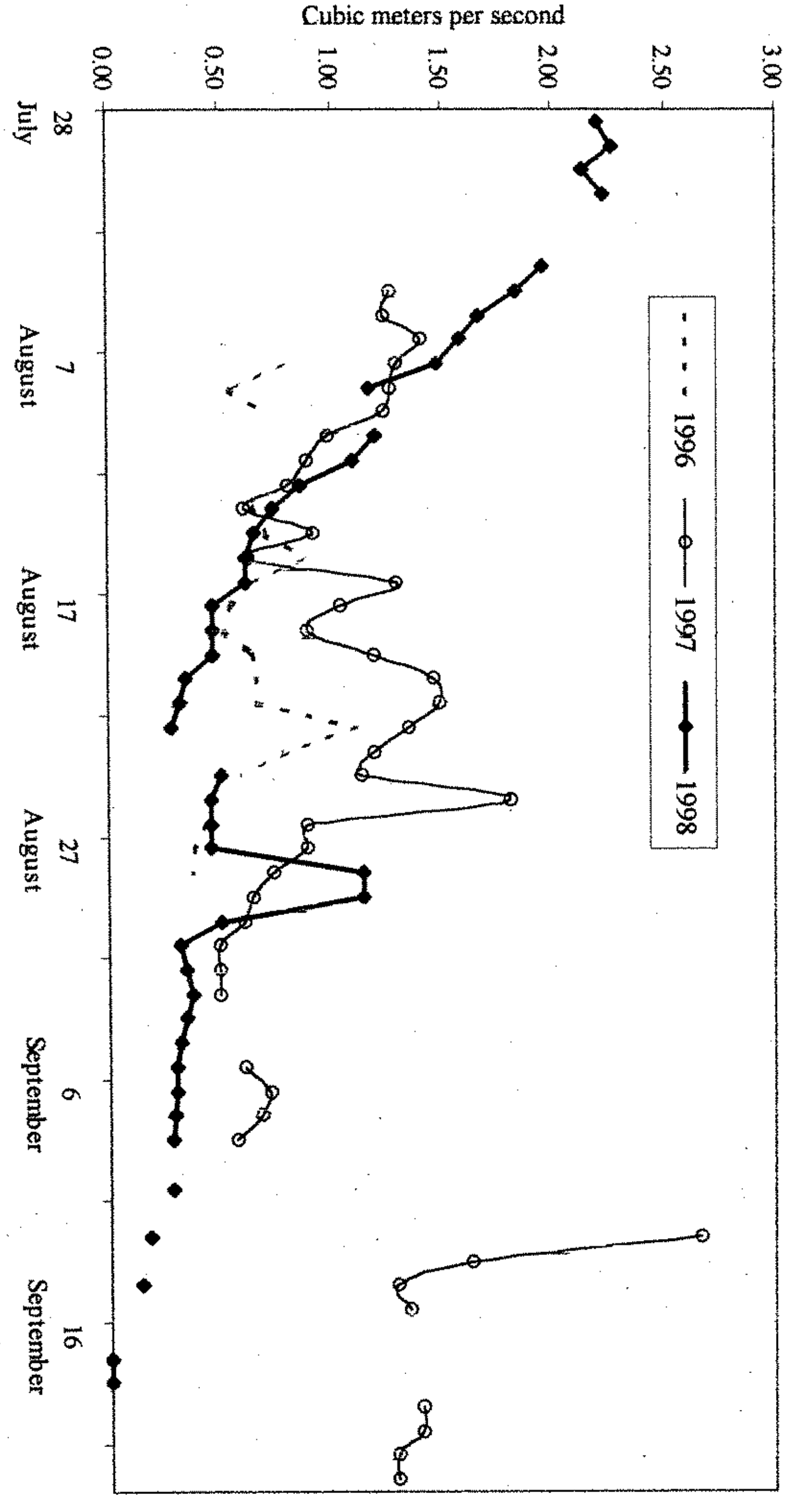

Figure 3. Comparison of daily discharge readings for Mill Creek, Montana from July to September 1996 to 1998.

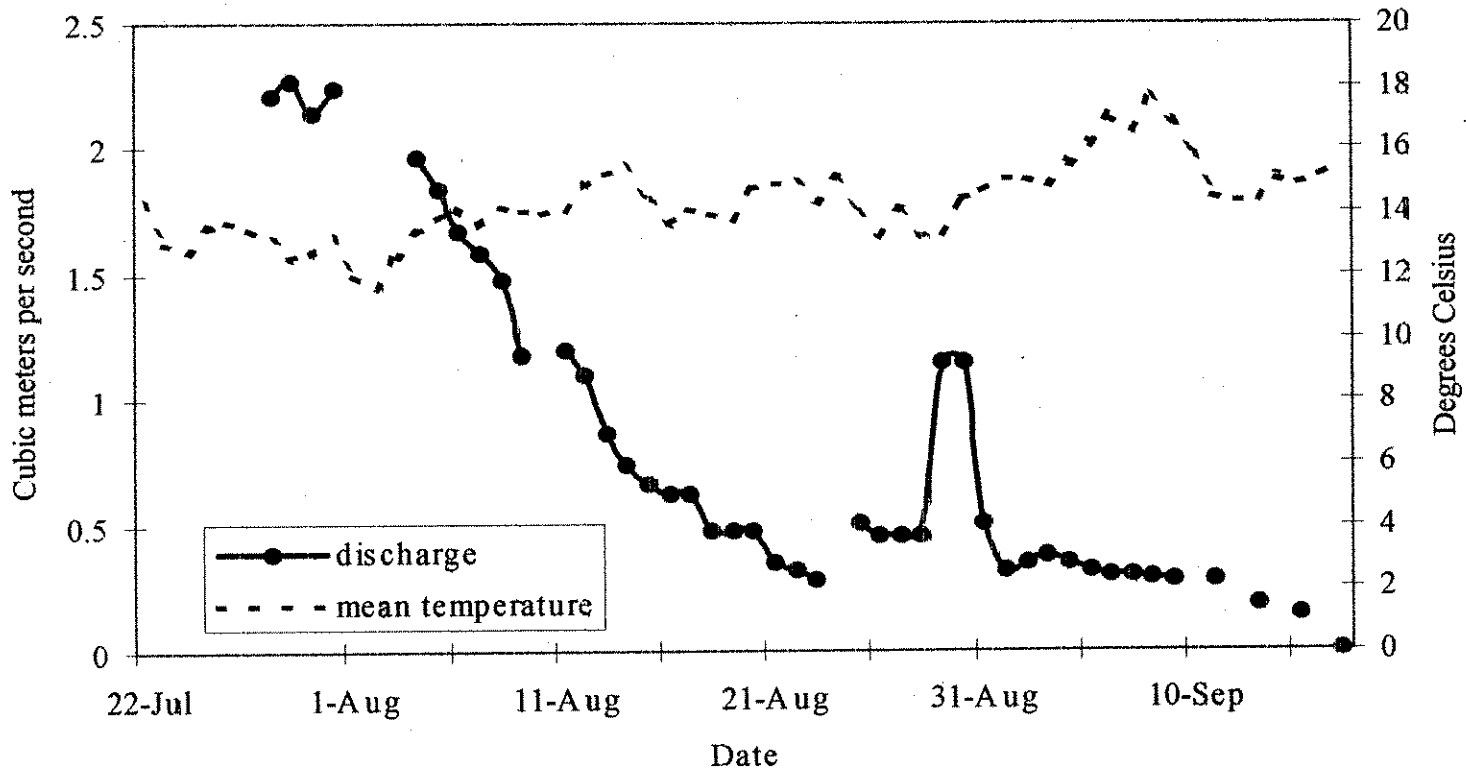

Figure 4. Daily discharge and mean daily water temperature for Mill Creek, Montana, from July to September, 1998

Table 1. Summary of discharge readings for the four study streams from July to September 1996, 1997 and 1998.

Study stream	Year	Seasonal mean (m³/s)	Maximum (m³/s)	Date	Minimum (m³/s)	Date
Locke	1996	0.068	**		**	
	1997	0.086	0.127	July 1	0.043	September 7
	1998	**0.033**	**0.089**	**July 9**	**0.015**	**July 28**
Mill	1996	0.629	1.100	August 22	0.293	August 31
	1997	1.090	2.700	September 12	0.50	August 31
	1998	**1.23** [a] **(0.791)** [b]	**10.400 (2.23)** [b]	**July 7 July 31**	**0**	**September 17 & 18**
Cedar	1996	0.029	0.091	August 2	0.006	August 15
	1997	0.075	0.108	August 8	0.055	September 15
	1998	**0.145** [a] **(.053)** [b]	**1.55 (0.08)** [b]	**July 7 August 24**	**0.011**	**August 23**
Mol Heron	1996	0.586	0.691	September 8	0.459	August 28
	1997	1.474	1.550	August 16 &19	1.392	September 15
	1998	**0.886**	**1.096**	**August 19**	**0.713**	**September 17**

** no estimate
[a] includes peak flows from early July
[b] mean and maximum for dates comparable to 1996 and 1997 surveys.

Despite the large amount of water early in the 1998 season, Mill Creek was completely dry on September 17 and18, resulting in the death at least 146 fish, including brook (*Salvelinus fontinalis*), Yellowstone cutthroat, and rainbow trout (*Onchorynchus meeki*) and sculpin (*Cottus* sp.) in two pools near the mouth (Table 2). A brief visual survey on September 18 indicated that, at a minimum, Mill Creek was completely dry from the mouth to the upper end of Mr. William Warfield's property, a distance of over 1.7 km (1 mi).

Table 2. Species and size class of fish found dead in two pools near the mouth of Mill Creek, Montana on September 18, 1998.

Species	<65mm	70-100mm	100-150mm	Totals
brook trout	2	0	1	3
Yellowstone cutthroat trout	83	5	13	101
rainbow trout	0	10	1	11
sculpin	30	2	0	32

Flows on Cedar Creek exceeded 1.1 m^3/s (40 cfs) from July 3 to July 20, 1998, encompassing the historical spawning period (Byorth 1990; Shepard 1992; Hennessey 1998) Discharge on Cedar Creek dropped rapidly as irrigation withdrawals increased in early August, but was restored to lease levels on August 24 (Figure 5). No redds were marked in 1998, but based on previous year's data, substantial dewatering of redds can be assumed (Byorth 1990; Hennessey 1998). After August 24, discharge slowly delined, and remained consistent with 1997 levels (Figure 6). In 1998, flows during August and September ranged from 0.01 m^3/s (0.4 cfs) to 0.08m^3/s (3.0 cfs), compared with the 1997 range of 0.06 m^3/s (1.9 cfs) to 0.11 m^3/s (3.8 cfs); (Table 1).

Mean stream discharge in Mol Heron Creek was 40% lower in 1998 than in 1997 (Table 1). However, the 1998 pattern of discharge in Mol Heron Creek was similar to that of 1997 (Figure 7). Discharge varied from 0.71 m^3/s (25 cfs) to 0.1.10 m^3/s (39 cfs) in 1998, and from 1.4 m^3/s (49 cfs) to 1.6 m^3/s (55 cfs) in 1997 (Table 3).

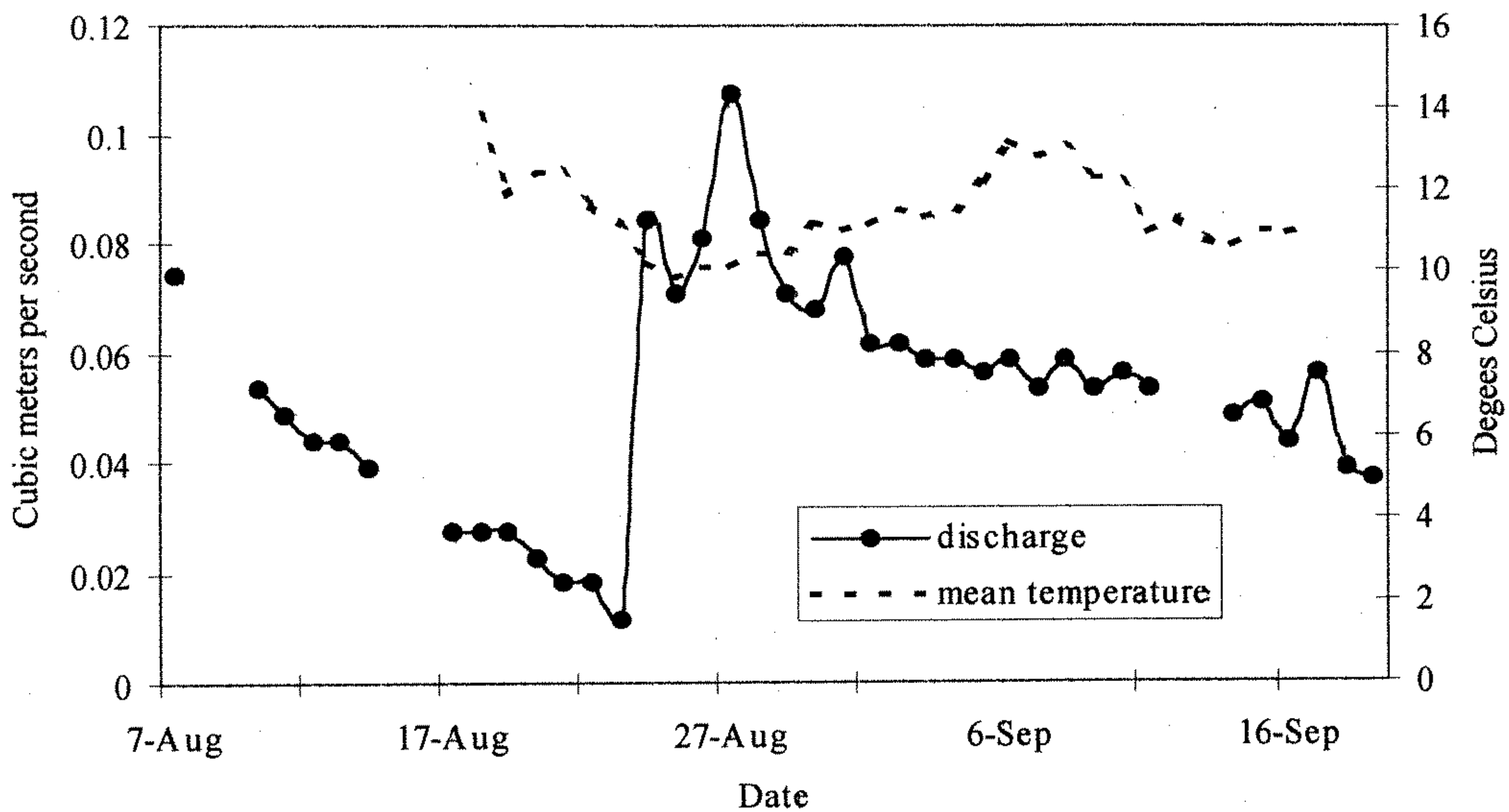

Figure 5. Daily discharge and mean daily water temperature for Cedar Creek, Montana, from August to September, 1998

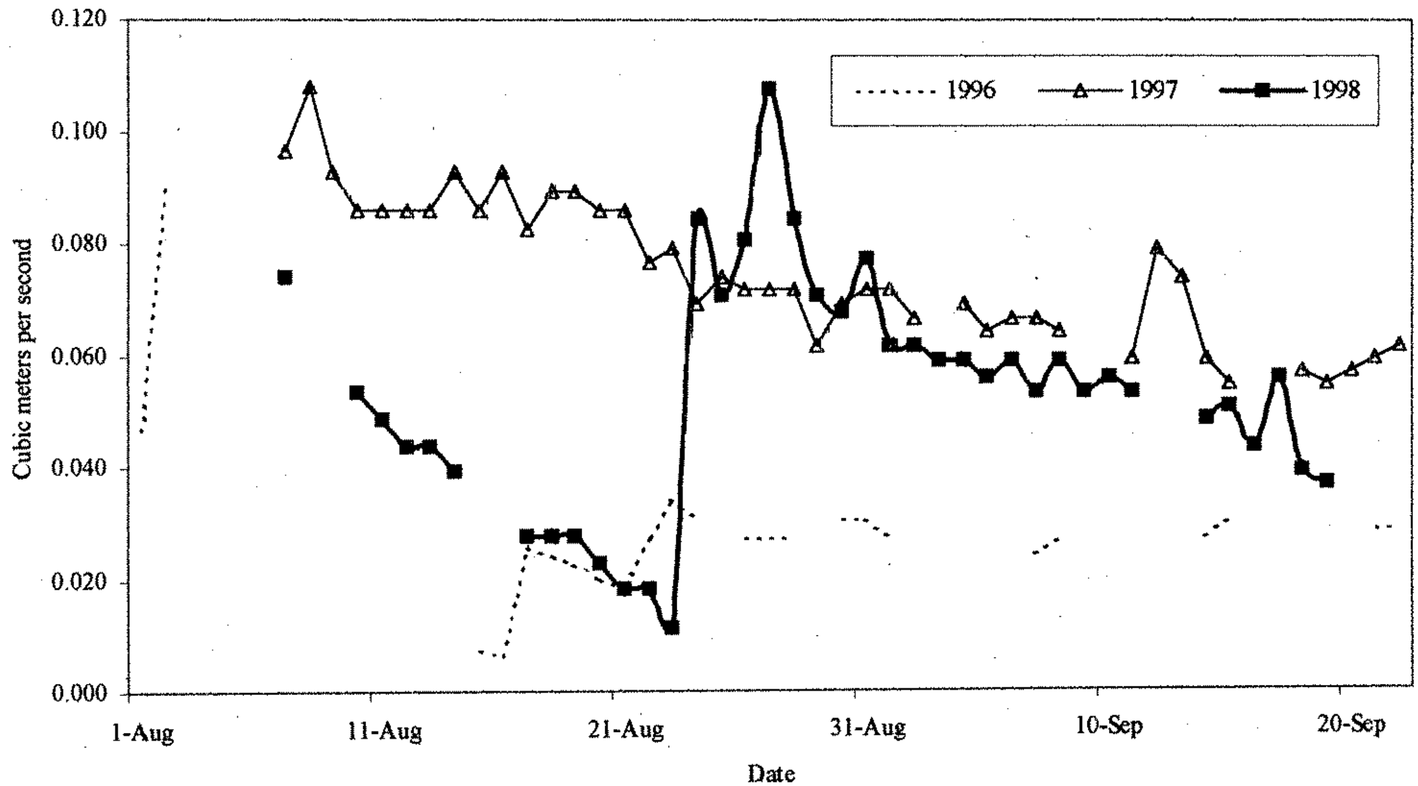

Figure 6. Comparison of daily discharge readings for Cedar Creek, Montana, from August to September, 1996 to 1998.

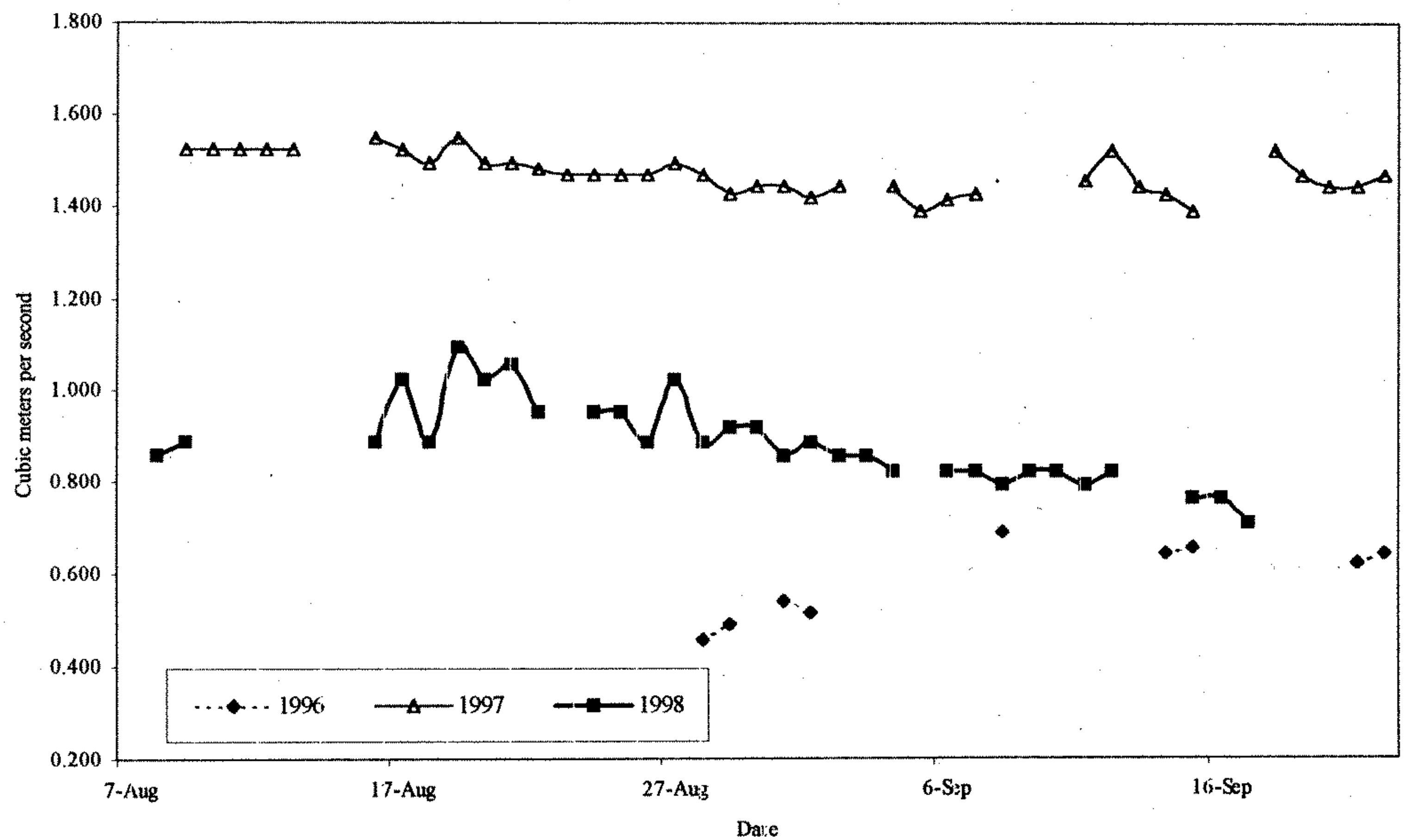

Figure 7. Comparison of daily discharge readings for Mol Heron Creek, Montana from August to September, 1996 to 1998.

Temperature

Temperatures in Locke Creek averaged 2.8 °C warmer on comparative dates in 1998 than in 1996 or 1997 (Figure 8). Mean daily water temperatures began increasing in late June, 1998, remained above 16 °C until mid-August, and exceeded 19 °C several times in July (Figure 8). Water temperature fluctuated an average of 5.6 °C per day in 1998 compared to 5.2 °C in 1996 and 5.0 °C in 1997.

Water temperatures in Mill Creek were fairly consistent until flows became restricted in late August. Mean temperatures exceeded 16 °C for seven consecutive days in early September (Figure 4). The average daily water temperature fluctuated 6.9 °C in 1998.

Mean daily water temperatures in Cedar and Mol Heron creeks varied little throughout the field season and never exceeded 14 °C (Figures 5 and 9). Daily water temperature fluctuation in Cedar Creek averaged 3.7 °C in 1998, compared to 3.2 °C in 1997. Daily water temperature fluctuation in Mol Heron Creek averaged 5.3 °C in 1998.

Spawning Activity

Two possible redds were identified in Locke Creek on June 10, and three spawning fish were observed on June 14, 1998. Cedar Creek was monitored on July 3, 5, 7, and 10, but no spawning activity was observed. Turbidity and high discharge made it infeasible to locate spawning fish visually in Cedar and Mill creeks during the 1998 field season. High flows and the resulting turbulence made locating spawning fish in Mol Heron Creek ineffective.

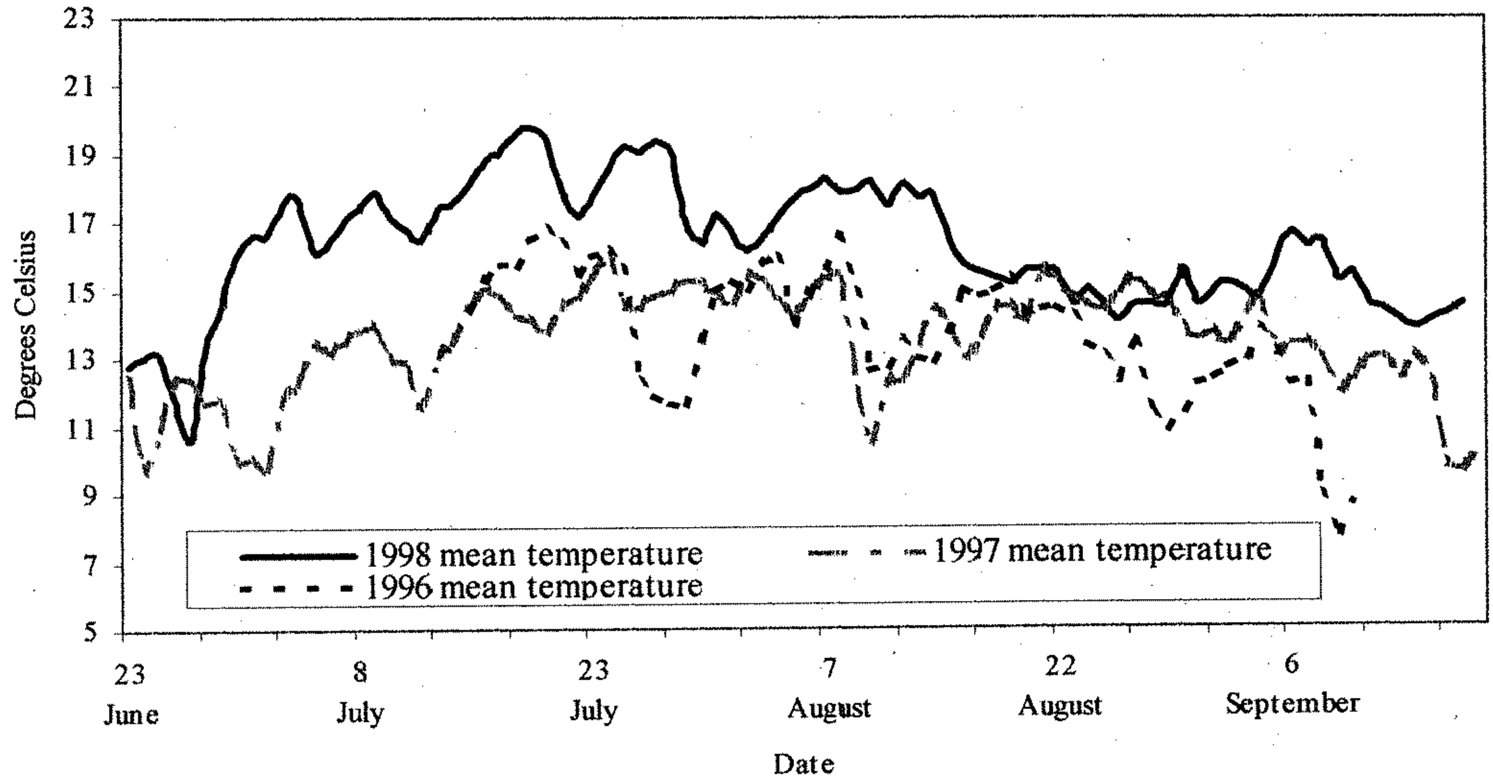

Figure 8. Comparison of mean daily water temperatures in Locke Creek, Montana from July to August, 1996 to 1998.

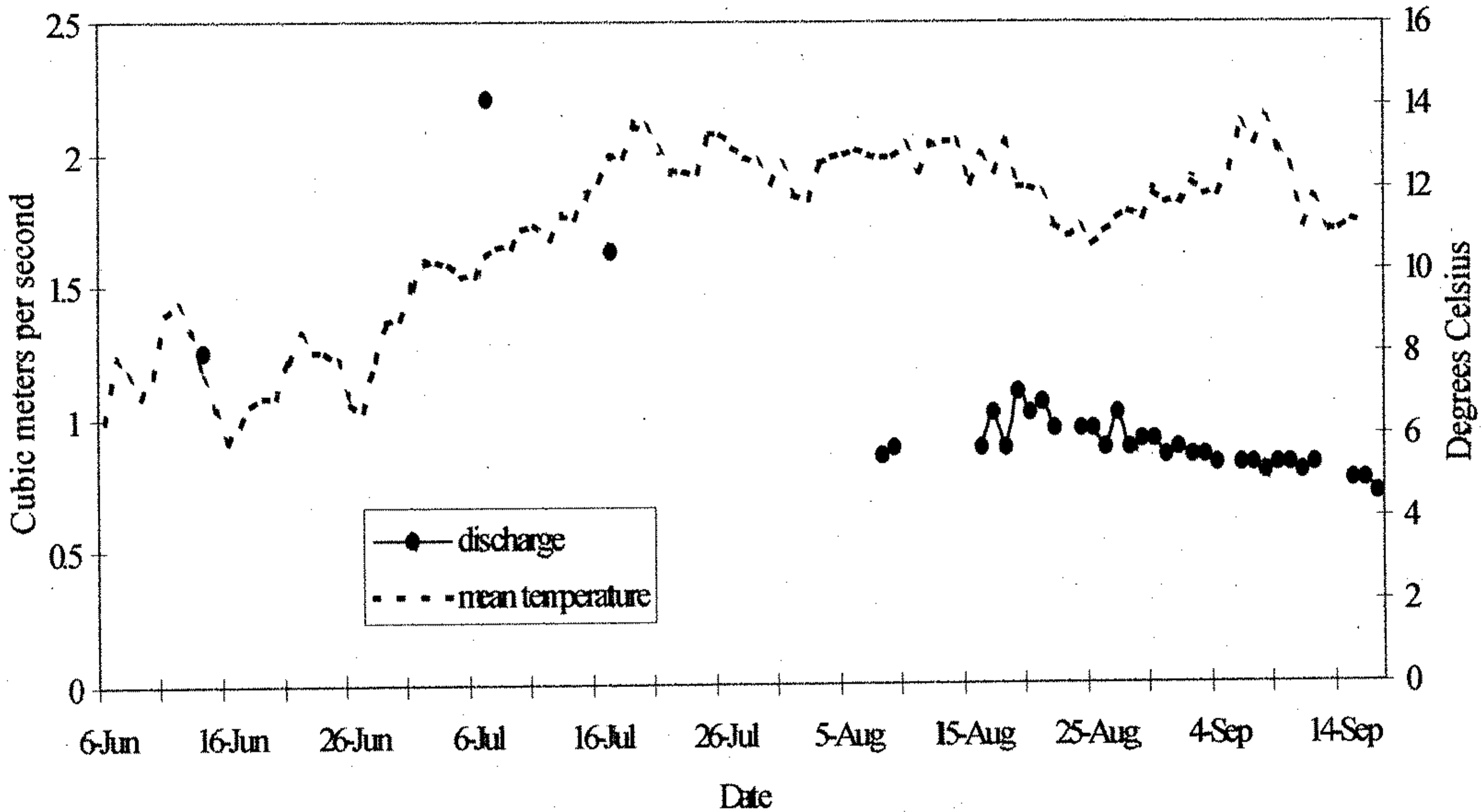

Figure 9. Daily discharge and mean daily water temperature for Mol Heron Creek, Montana, from June to September, 1998.

Yellowstone Cutthroat Trout Fry Recruitment

Fewer fry were trapped per day of trapping in three of the four creeks in 1998 than in 1997. Outmigration was detected later, and over a shorter period in all but Mol Heron Creek in 1998. Incidental trapping mortalities were very low in all creeks .

Locke Creek

A total of 6 fry were captured in the trap nearest the mouth of Locke Creek in 1998 (Figure 10). No fry were captured above the uppermost diversion structure. Each of the 6 fry was trapped on a separate day, and fry length increased as the season progressed (Table 3). Catch per unit effort (CPUE) was 0.22 fry per day in 1998, compared to 26 fry per day in 1996, and 33 fry per day in 1997 (Table 4). Flows of less than 0.02 m^3/s (0.70 cfs) were common near the mouth of Locke Creek after August 1, 1998 and were insufficient for fry trapping. Accumulations of up to 5.5 cm of fine sediments were measured in areas where the substrate had been predominately gravel in 1996. The large deposits of fines flattened the topography of the stream bottom, effectively widening the channel and further reducing stream depth. Locke Creek has begun downcutting into softer, finer soil layers between the two lowest diversion structures over the past two years, and this section has required substantial earthmoving for repairs (R. Peterson, ranch owner, personal communication). Extremely low flows, high water temperatures and large deposits of fine sediment may have contributed to the low recruitment observed in 1998.

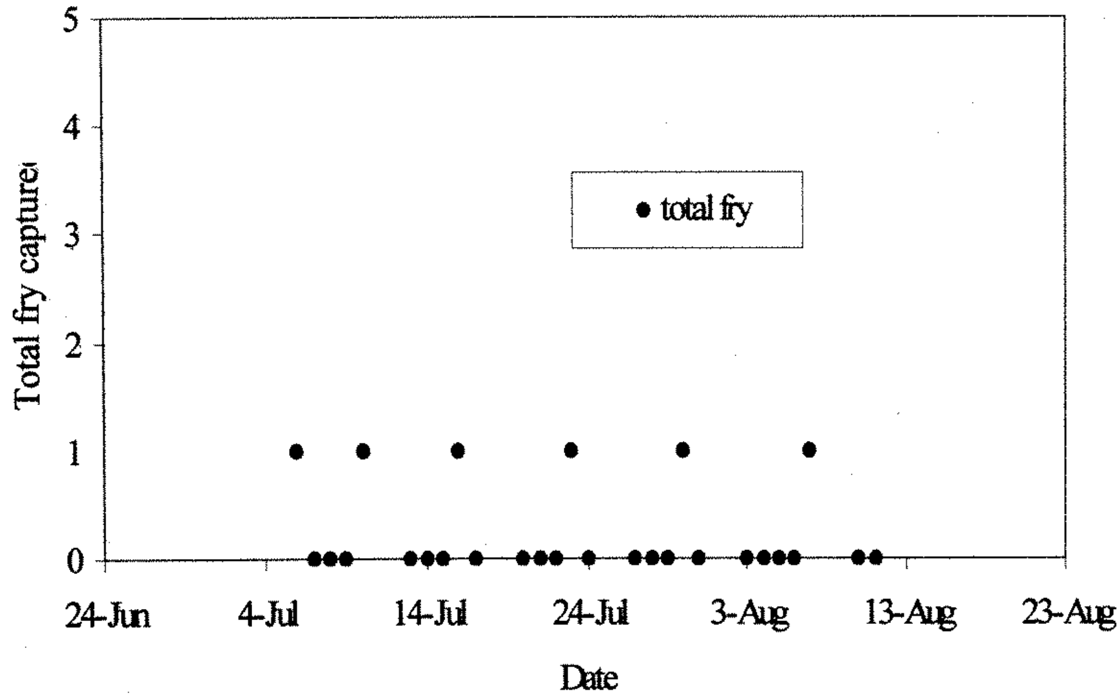

Figure 10. Total fry captured per day in Locke creek, Montana from July to August, 1998.

Table 3. Lengths of individual fry captured in Locke Creek, Montana from July to August, 1998.

Date	July 6	July 10	July 16	July 23	July 30	August 7
Fry length (mm)	18	18	18	30	35	45

In 1998, outmigration of Yellowstone cutthroat trout fry was first detected on July 6, the first day of trapping, at a mean water temperature of 16.4 °C. Individual fry were caught on July 6, 10,16, 23, 30, and August 7 (Figure 10). The 6 fry were caught during 27 trapping days (Table 4). There was one incidental mortality due to trapping (16.7%) in 1998.

Mill Creek

Total fry trap catch was less than 1/3 that captured in Mill Creek in 1998. CPUE was 21 fry per day in 1998, compared to 50 fry per day in 1997 (Table 4). Peak outmigration occurred in mid-August, approximately 5 d earlier than in 1997 (Figure 11). Fry outmigration was first detected on August 5, and peaked on August 16 with 172 fry captured. Outmigration was shorter than in 1997, with the majority of fry being trapped over 11 d in 1998, compared to 29 d in 1997. September 2 was the last successful trapping day in 1998 (Figure 11). A total of 752 fry were caught over 36 trapping days (Table 4). Incidental mortality due to trapping decreased from 4.7% in 1997 to 0.9% in 1998.

Cedar Creek

Total fry captured in Cedar Creek in 1998 was less than 15% of that captured in 1997. CPUE was 100 fry per day in 1998, and 629 fry per day in 1997 (Table 4). The first fry was captured on the same calendar day as in 1997, and trap catch peaks were within 3 d of each

Table 4. Summary of fry trapping results from July to September 1996,1997, and 1998 for the four study streams.

Study stream	Year	Total fry caught	Total days trapped	CPUE[a] (fry/day trapped)	Total days fry caught	Incidental mortalities	% mortality
Locke Creek	1996	674	26	26	19	66	9.9
	1997	1,844	56	33	49	34	1.8
	1998	**6**	**27**	**0.2**	**6**	**1**	**16.7**
Mill Creek	1996	59	31	2	7	6	10.2
	1997	2,316	46	50	36	109	4.7
	1998	**752**	**36**	**21**	**20**	**7**	**0.9**
Cedar Creek	1996	13,251	24	552	20	74	0.5
	1997	25,781	41	629	35	89	0.3
	1998	**3,791**	**38**	**100**	**27**	**49**	**1.3**
Mol Heron Creek	1996	1,865	10	187	10	200	23.1
	1997	1,128	35	32	29	87	7.7
	1998	**1251**	**31**	**40**	**20**	**3**	**0.2**

[a]Catch per unit effort

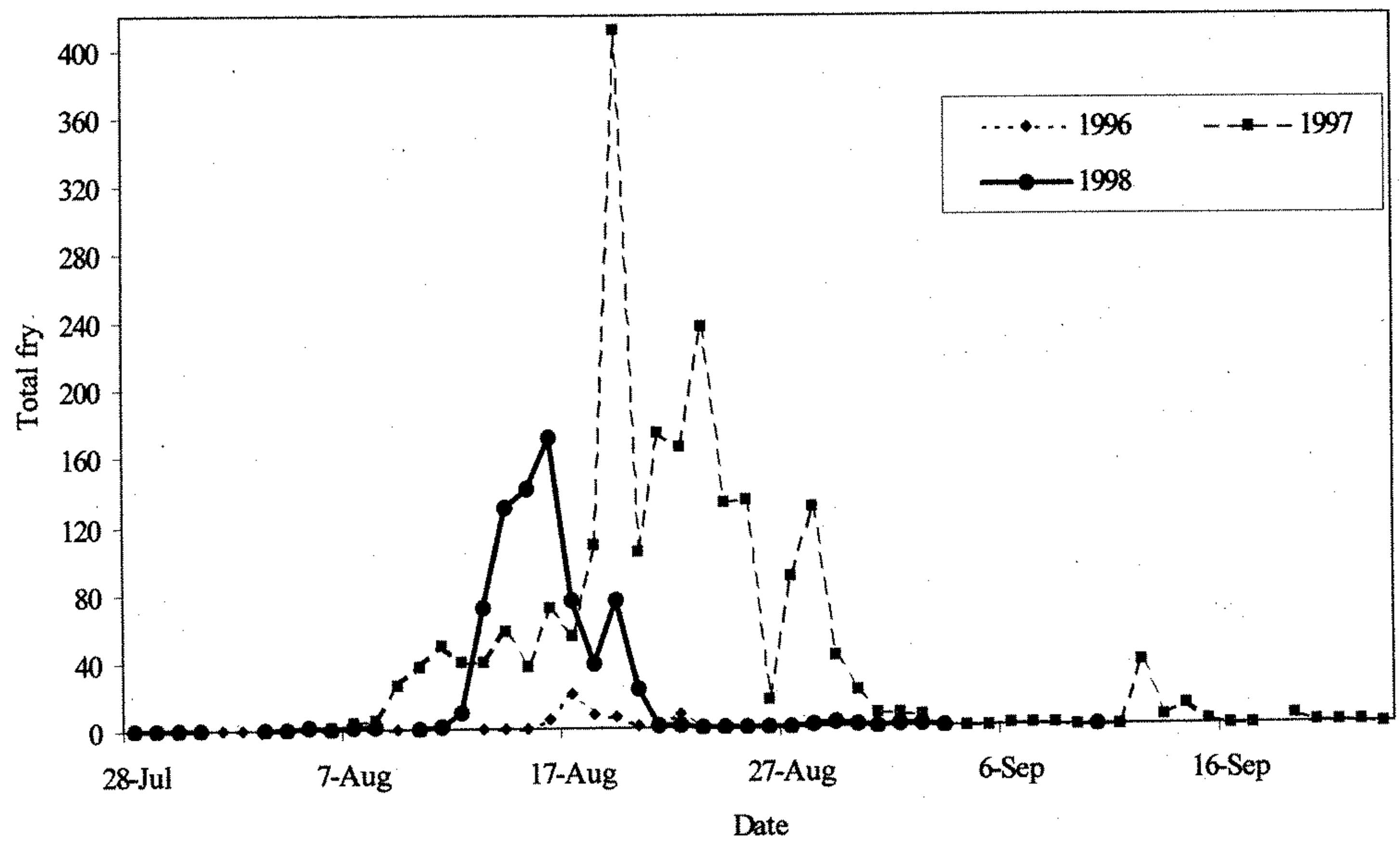

Figure 11. Comparison of the total fry captured per day in Mill Creek, Montana from July to September, 1996 to 1998.

other, but in 1998 there was an 11 d lag between the first fry capture and the characteristic increase in outmigration observed in previous studies (Figure 12); (Byorth 1990; Hennessey 1998). In 1998, fry outmigration was first detected on August 7; a mean water temperature was not available. Outmigration peaked on August 30 with 467 fry captured, and was completed by September 19 (Figure 12). A total of 3,791 fry were caught over 38 trapping occasions (Table 4). Incidental mortality increased from 0.3% in 1997 to 1.3% in 1998.

Mol Heron Creek

Slightly more fry were captured in Mol Heron Creek in 1998 than in 1997, possibly because of the change in trap placement. CPUE was higher in 1998 at 40 fry per day compared to 32 fry per day in 1997 (Table 4). The peak in outmigration was much higher and more distinct in 1998 than in1997(Figure 13). In 1998, fry outmigration was first detected on August 16, at a mean water temperature of 12.2 °C. Outmigration rapidly increased and peaked on August 19 with 252 fry captured, then dropped just as rapidly with trap catches in the single digits by August 29. The last fry was captured on September 17 (Figure 13). A total of 1,251 fry were caught over 31 trapping occasions (Table 4). Despite the trap's location within the thalweg, incidental mortality decreased from 7.7% in 1997 to 0.2% in 1998.

Fry Length and Residence Time

In all study streams, mean fry length and the range of lengths increased as outmigration progressed. Newly emerged fry (< 25 mm TL) were less common during the last weeks of trapping in each creek. In 1998, in all three of these creeks, the rate of mean length increase

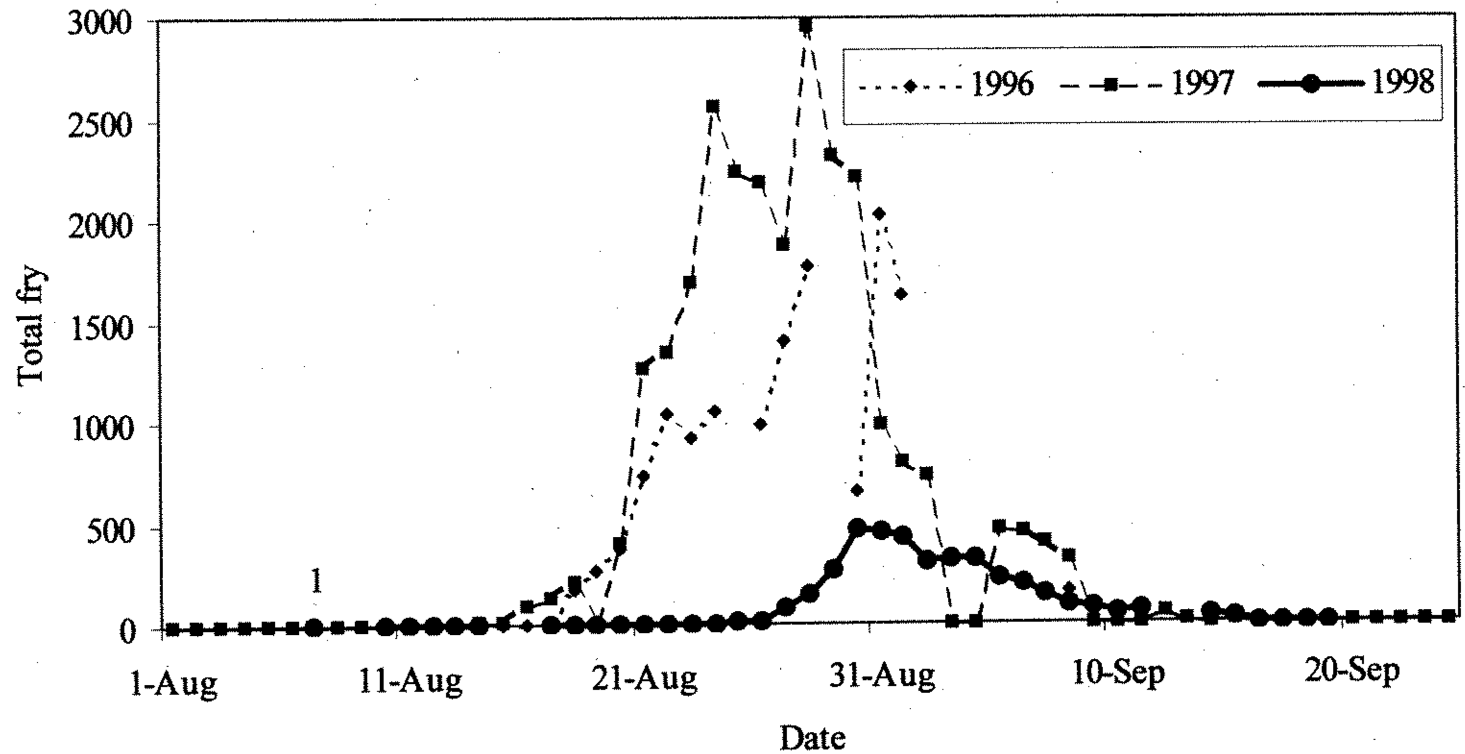

Figure 12. Comparison of the total fry captured per day in Cedar Creek, Montana from August to September, 1996 to 1998. The "1" marks the first day fry were captured in 1997 and 1998.

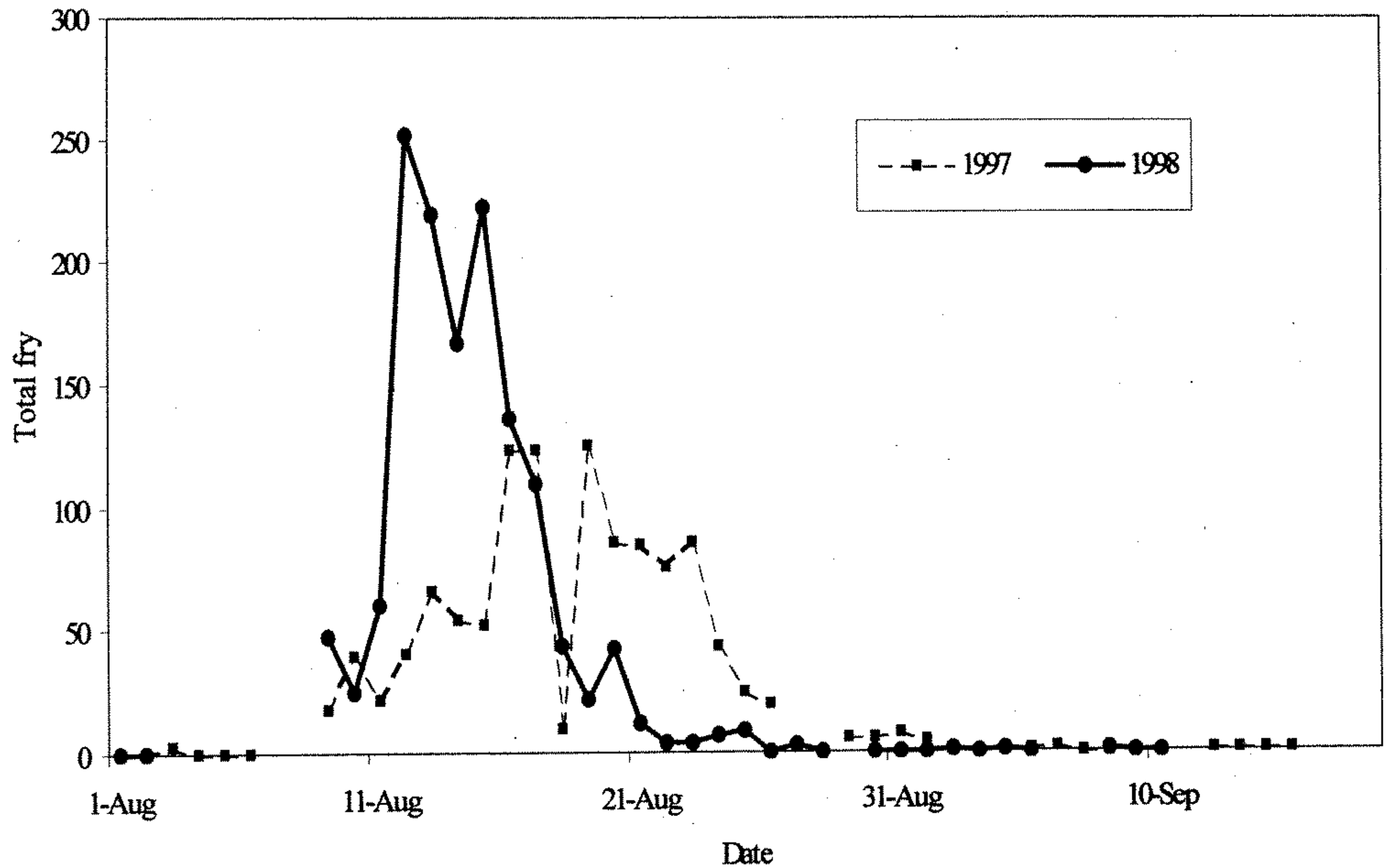

Figure 13. Comparison of the total fry captured per day in MolHeron Creek, Montana from August to September, 1997 and 1998.

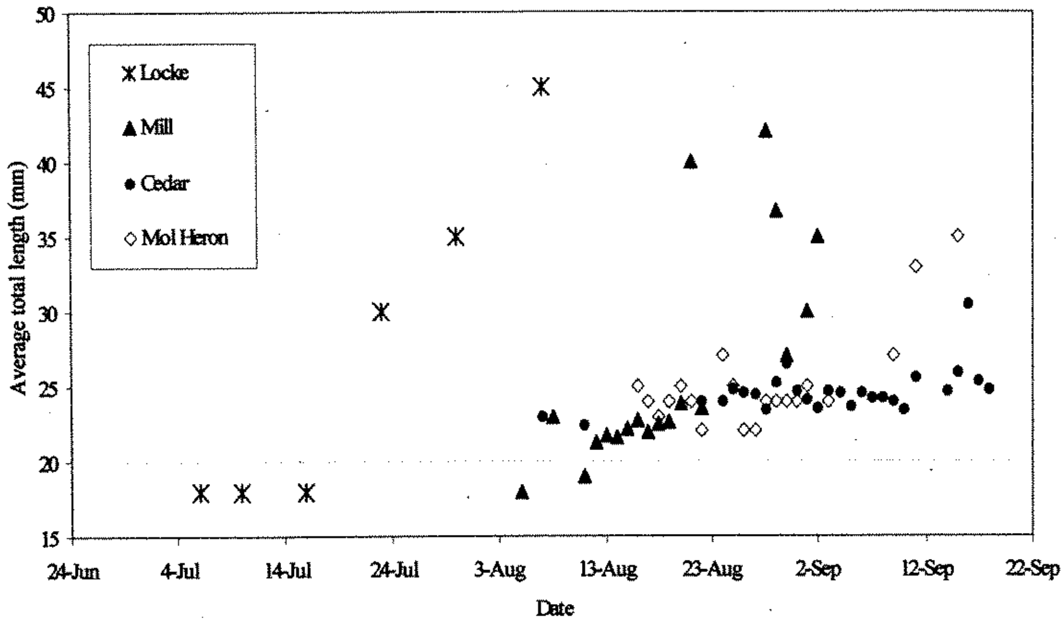

Figure 14. Average total length of a random subsample of Yellowstone cutthroat trout fry by date collected for the four study streams in Montana, 1998.

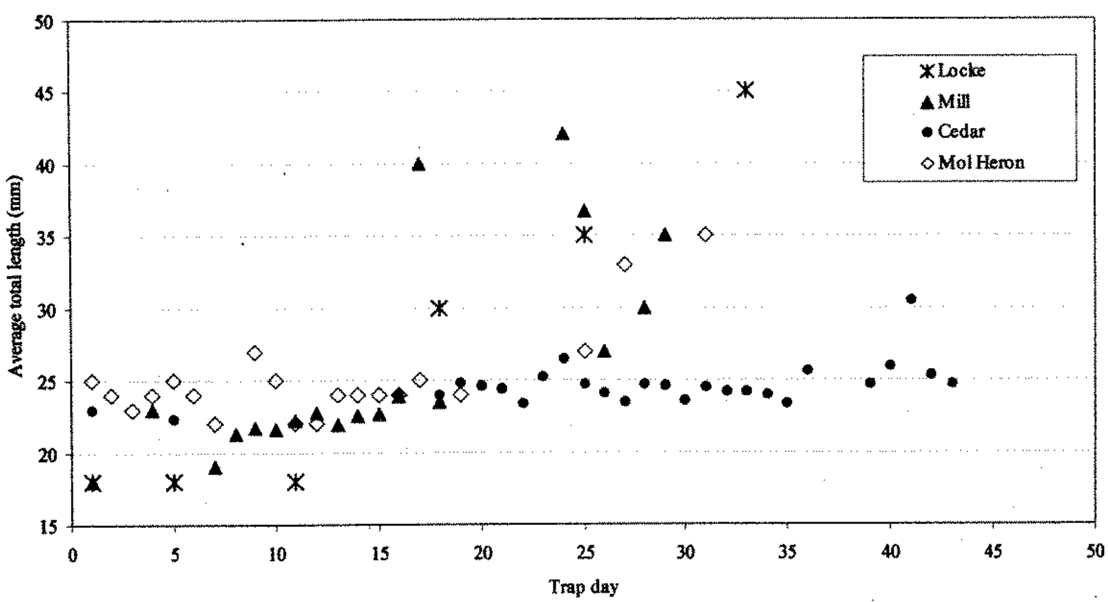

Figure 15. Average total length of a random subsample of Yellowstone cutthroat trout fry by day of sampling period collected for the four study streams in Montana, 1998

escalated as the trap season progressed (Figures 14 and 15).

The Cedar Creek trap captured newly emerged fry throughout the field season. Mean length increased by less than 1 mm per week during trapping, and never exceeded 26 mm (Figures 14 and 15).

Flushing Flows

All irrigation diversions on Mill Creek were closed at approximately 0600 hours on August 28 and reopened by 0700 hours on August 30, 1998. Discharge at the East River Road bridge increased from 0.45 m^3/s to 1.15 m^3/s by 1000 hours on August 28 (Figure 3). Discharge had declined to pre-flush levels by 1000 hours on August 30. A total of 4 fry were trapped throughout the 1998 flushing flow. No fry were captured during the 5 d before the flush, and only 2 more fry were trapped after August 30.

peak day was Aug. 16.

Climatic Data

Trends in mean maximum daily temperatures were consistent across all three climatic data stations. Mean maximum daily temperatures were slightly above normal from January to May of 1998, and were an average of 2.3 °C higher than average in July, 1998 (Figures 16, 17, and 18). Precipitation was more variable from station to station, but some trends were consistent. All three stations had much lower precipitation than average in May 1998, while June had above average precipitation(Figures 16, 17, and 18). Despite the month to month variation, total precipitation accumulated in August was within 1 standard deviation of the mean for all 3 sites (WRCC 1998). The Gardiner station set a record for the lowest mean daily temperature and the highest total precipitation in 43 years during June, 1998 (WRCC 1998). Average minimum air temperatures for 1998 were at least 1 degree cooler in June, and 1 degree warmer in July than the historic averages at all climate stations (Table 5).

Table 5. Deviation of the 1998 average maximum and minimum air temperatures from the historic averages for three climate stations in the upper Yellowstone River area . All temperatures are in degrees Celsius. Data for August of 1998 was not available at the time of this report. (WRCC 1998)

		Livingston FAA, AP			Livingston 12S			Gardiner		
		50 year average	1998 average	Deviation	16 year average	1998 average	Deviation	43 year average	1998 average	Deviation
May	Maximum	18.0	21.3	3.3	18.5	20.4	1.9	19.1	20.9	1.7
	Minimum	3.8	3.2	-0.6	3.2	3.0	-.2	3.5	4.5	1.0
June	Maximum	23.0	20.0	-3.0	22.8	18.0	-4.8	24.5	19.8	-4.7
	Minimum	7.8	6.3	-1.5	6.9	5.6	-1.3	7.4	5.9	-1.5
July	Maximum	28.1	30.7	2.6	26.8	29.4	2.6	29.6	31.1	1.5
	Minimum	10.6	11.9	1.3	9.4	10.9	1.5	10.6	12.3	1.7
August	Maximum	28.1	---		27.0	---		28.8	---	
	Minimum	5.2	---		8.7	---		9.9	---	

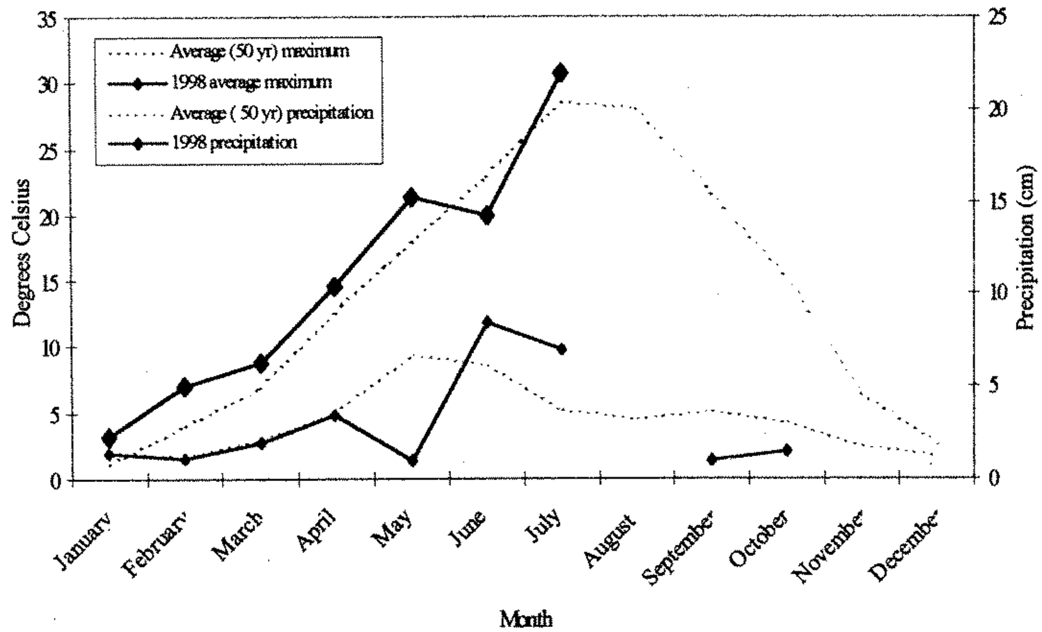

Figure 16. Comparison of the average daily maximum temperature and monthly precipitation for the 50 years of record for Livingston FAA, AP (airport) climate station with the data collected from January to October, 1998.

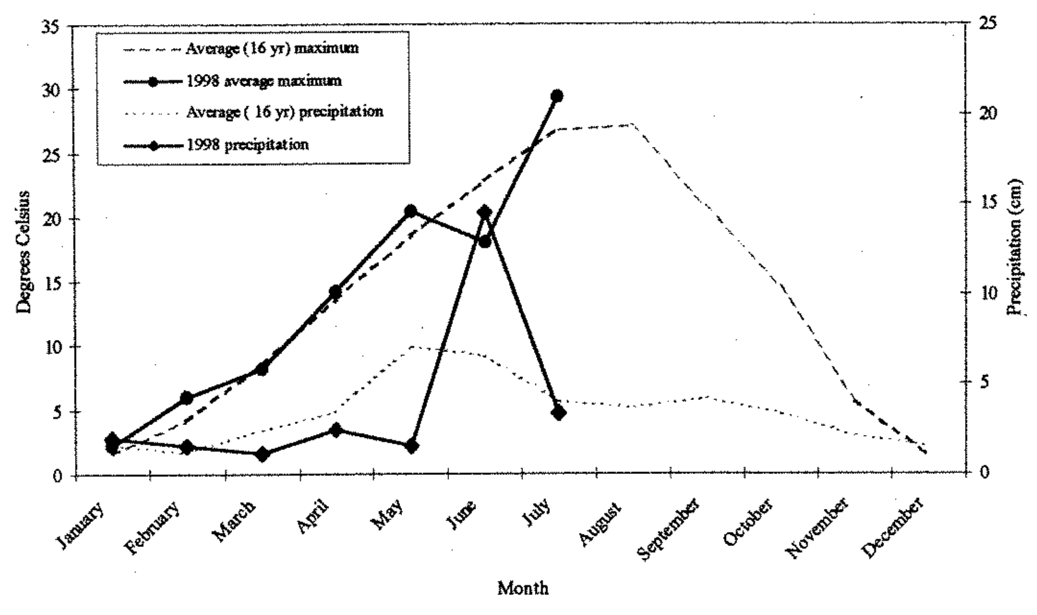

Figure 17. Comparison of the average daily maximum temperature and monthly precipitation for the 16 years of available record for Livingston 12S climate station with the data collected from January to October, 1998.

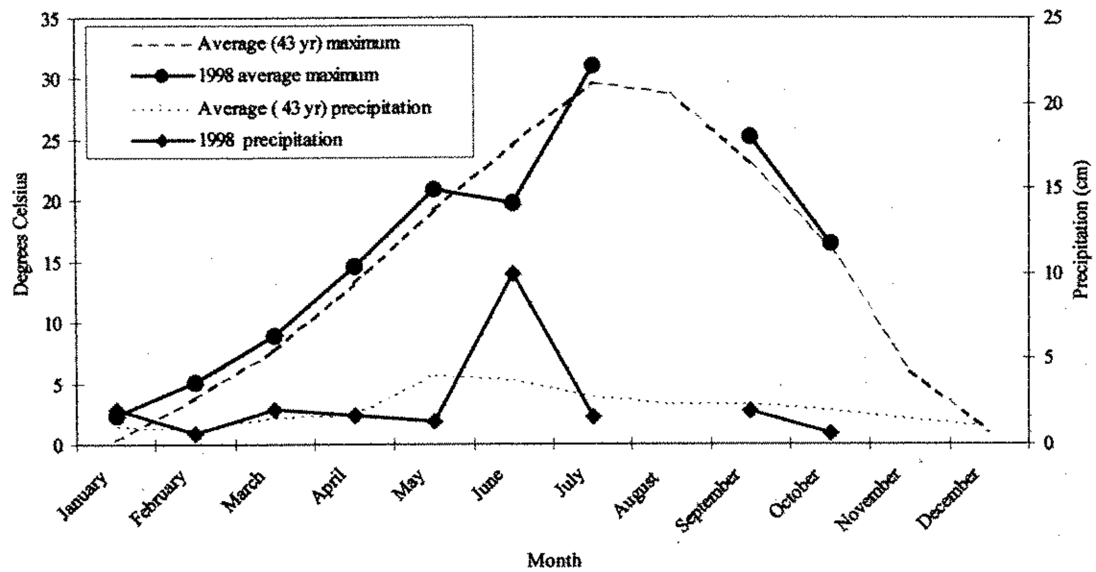

Figure 18. Comparison of the average daily maximum temperature and monthly precipitation for the 43 years of record for Gardiner climate station with the data collected from January to October, 1998

Discussion

Average snowpack coupled with a long, warm summer set the stage for prolonged irrigation demands in the upper Yellowstone River basin. Lower spring runoff and late arrival of spring rains created the perception that 1998 would be a low water year; a perception possibly exaggerated by the recent memory of record high flows. Evening air temperatures throughout Park County remained above freezing into late September, extending the irrigation season (USGS 1998). However, 1998 was not a low water year in terms of annual precipitation, nor was it below average for spring or summer precipitation overall (WRCC 1998). Water availability was not extremely low, but warmer maximum and minimum air temperatures created a larger water demand than in past years (Table 5).

Water leases were definitely responsible for preventing greater Yellowstone cutthroat trout recruitment losses in 1998. Without the lease on Cedar Creek the period of low flows would almost certainly have been longer. Without the lease on Mill Creek, early declines in August would not have been augmented by closure of lessors ditches, and the creek would have dried up weeks earlier. Without the Mill Creek flushing flow to spur outmigration of this year's fry, the eventual dewatering would have killed more fish. Nonetheless, the data from the 1998 season suggests that the water leasing program could be improved.

Locke Creek experienced almost complete Yellowstone cutthroat trout year class failure in 1998. Climatic circumstances contributed to the striking decline in outmigration, but with no formal agreement to maintain flows in lower Locke Creek, MDFWP was unable to mitigate the situation. In July and August stream discharge near the mouth of Locke Creek dropped to less than 40% of 1997 levels (Hennessey 1998). Extreme warm water temperatures were probably responsible for the lack of recruitment, but the increase in the amount of fine sediments in lower Locke Creek is also cause for concern. The owners of the ranch served by Locke Creek are interested in managing the creek and its flows for fishery benefit, and a formal agreement including a documented minimum recommended flow could provide the guidance they need to avoid poor recruitment in future years. Locke Creek is home to one of the few confirmed pure populations of Yellowstone cutthroat trout (Leary 1998; Hennessey 1998). Preservation of this spawning run may be critical to the species. MDFWP should attempt to assist the Peterson Ranch in managing their creek for reduction of downcutting and take advantage of their current enthusiasm for trout conservation. A cursory electofishing survey in the spring of 1998 found a significant population of Yellowstone cutthroat trout in the upper reaches of Locke Creek (B. Shepard, MDFWP, unpublished data). Although no fry were observed outmigrating from the upper reaches to the mainstem, a study of the resident Yellowstone cutthroat trout population's reproductive success and age structure would be useful in terms of developing a conservation plan for Locke Creek

The Mill Creek water lease is intended to provide in-stream flows sufficient to allow the creek to connect with the Yellowstone river from May to October in 8 out of 10 years (Shepard 1990; Spence 1996). This implies that in average water years, the water lease, coupled with natural flows, should be adequate to maintain minimal flows in lower Mill Creek from May to September (Spence 1996). It is disturbing to note that in 1998, an average to low-average year, the water leases were not sufficient, and the creek went dry. Climatic circumstances did affect the duration and intensity of irrigation, particularly in the Mill Creek area, but if flows were compromised in 1998, then it is reasonable to think that in a true drought year or series of drought years, that the water leases may be ineffective. After 5 years of water lease implementation, numbers of Yellowstone cutthroat trout fry outmigrating from Mill Creek per year increased from less than 100 to over 2,000 (Table 4); (Hennessey 1998). If the Mill Creek population of Yellowstone cutthroat trout is to continue to recover, it is imperative that flows for incubation and outmigration be maintained (Clancy 1988; Hennessey 1998). The flushing flow provides a cue for fry to move out of the creek and into the Yellowstone. However, in 1998 fry and several sub-adult fish that did not pick up on this cue were lost to recruitment because of dewatering in September (Table 3). The flushing flow prevented greater losses of Yellowstone cutthroat trout fry, and served its intended purpose. However, the subsequent dewatering of Mill Creek created a human-imposed crisis for many fry that had already survived one of the most precarious portions of their life history.

Cedar Creek has a water lease in place that works well, but communication among the water users needs improvement to prevent flow reductions during critical periods. In 1996 and in 1998 the cause of major flow reductions during Yellowstone cutthroat trout egg incubation was the unauthorized opening of a ditch (Hennessey 1998). In both cases the owner of the ditch complied with the lease without incident, but the reduced flows may have contributed to recruitment losses. Cedar Creek furnishes an example of why water leases require good relations between MDFWP, the lessors, and other water right holders to work well.

Mol Heron Creek did not have significant irrigation withdrawals in 1998, in contrast to the other three study streams. Flows were more consistent in Mol Heron Creek than in the other study streams (Figures 1, 3, 4 and 8). Yellowstone cutthroat trout fry recruitment from Mol

Heron Creek did increase slightly, but cannot be fully attributed to the flow regime because of the change in trap location (Figure 12). The three years of study suggest that Mol Heron is an important source of trout recruitment for the Yellowstone River and does supplement the fry produced by Cedar Creek. If Mol Heron Creek continues to be spared from irrigation withdrawals, its importance as a spawning tributary may improve. If irrigation resumes, the water lease on Mol Heron ensures more consistent quality and quantity of spawning and rearing habitat.

Concern for the quality of spawning and early rearing habitat is at the heart of the water leasing process (Shepard 1990; Spence 1996; Hennessey 1998). The recruitment results for 1998 demonstrate that water leases alone cannot completely guarantee Yellowstone cutthroat trout reproductive success (Table 4). In Locke, Mill, and Cedar creeks the most likely factors contributing to lower recruitment were human water use combined with climatic variation. MDFWP cannot control the climate, and some water use is beyond its control as well. As water use increases in watersheds throughout Montana, it may be time for MDFWP to pursue water use conservation and education as part of its efforts to sustain fish populations.

It is evident that the water lease program does benefit fisheries. It is also evident that the program does not prevent all potential losses, nor is this its purpose. Based on the information gained from the1998 season, management recommendations to improve the influence of the water leases in the upper Yellowstone area are:

1. Continue any and all water leases currently in force.
2. Pursue additional water leases on impaired rivers and streams.
3. Encourage water conservation and educate lessors and potential lessors in water

conservation methods. Coordination with the DNRC may be beneficial.

4. Increase or establish more regular monitoring of stream levels on streams with active leases.

5. Pursue methods to enforce water leases during high demand periods.

6. Conduct a study of the resident Yellowstone cutthroat trout population in Locke Creek to determine its health, reproductive success, and contribution to the Yellowstone River population.

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