MONTANA STATE UNIVERSITY

An evaluation of Yellowstone cutthroat trout fry recruitment related to water leases on four tributaries of the Yellowstone River
by Leanne Elizabeth Hennessey

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
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Abstract:
In 1989 the Montana Legislature passed House Bill 707, allowing Montana Fish, Wildlife and Parks to lease water rights to benefit fisheries. The first water leases on tributaries of the upper Yellowstone River were finalized in 1992 on Mill Creek, and in 1993 on Cedar Creek. The leases provide instream flows from May to October in an attempt to reestablish Yellowstone cutthroat trout (Oncorhynchus clarki bouveri) spawning runs. This study evaluated the existing leases' effect on fry recruitment. Recruitment to the Yellowstone River was measured in 1996 and 1997 on four tributaries: Locke, Mill, Cedar, and Mol Heron creeks. Since Yellowstone cutthroat trout fry move out of their natal tributaries soon after emergence, outmigration was monitored using traps located near the mouth of each stream. More fry were captured in 1997 than in 1996 in all but Mol Heron Creek. Mill Creek had the greatest percent increase in fry captured (4000%), followed by Locke Creek (300%), and Cedar Creek (200%). The lease on Cedar Creek prevented extended pre-emergence dewatering in 1996. The instream flow lease in Mill Creek was critical during fry outmigration in 1996, but not in 1997 because of unusually high discharge. For sampling protocol development, fry outmigration was broken into three stages based on observed patterns; the ascending limb, peak region and descending limb. Three pattern-based, and three systematic sampling protocols were evaluated in terms of their ability to provide a reliable estimate of fry outmigration with a minimum number of sample days. Mean estimates from four replications of each of the three pattern-based protocols were less variable and sampled fewer days than those from the three systematic protocols. Pattern-based protocol A, which concentrated sampling during the peak region of fry outmigration, and minimally sampled the descending limb, was chosen as the best protocol for all four streams because of the consistently narrow 95% confidence interval for its estimates, and was recommended to Montana Fish, Wildlife and Parks for adoption. Based on my results, other water leases should be pursued on creeks where dewatering is affecting fry recruitment, and fry outmigration should be monitored periodically to evaluate each lease's effectiveness.

AN EVALUATION OF YELLOWSTONE CUTTHROAT TROUT FRY RECRUITMENT RELATED TO WATER LEASES ON FOUR TRIBUTARIES OF THE YELLOWSTONE RIVER

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Leanne Elizabeth Hennessey

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APPROVAL

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Leanne Elizabeth Hennessey

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.

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VITA

Leanne Elizabeth Hennessey was born in Hattiesburg, Mississippi on April 3, 1965. She is the daughter of James Edward Hennessey and Susan Peters Hennessey. She attended Saint Martin's Episcopal School in Metairie, Louisiana and graduated Cum Laude in 1983. Leanne earned her Bachelor of Science in Biology at the University of Oregon-Eugene in 1988.

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ABSTRACT

In 1989 the Montana Legislature passed House Bill 707, allowing Montana Fish, Wildlife and Parks to lease water rights to benefit fisheries. The first water leases on tributaries of the upper Yellowstone River were finalized in 1992 on Mill Creek, and in 1993 on Cedar Creek. The leases provide instream flows from May to October in an attempt to reestablish Yellowstone cutthroat trout (*Oncorhynchus clarki bouveri)* spawning runs. This study evaluated the existing leases' effect on fry recruitment. Recruitment to the Yellowstone River was measured in 1996 and 1997 on four tributaries: Locke, Mill, Cedar, and Mol Heron creeks. Since Yellowstone cutthroat trout fry move out of their natal tributaries soon after emergence, outmigration was monitored using traps located near the mouth of each stream. More fry were captured in 1997 than in 1996 in all but Mol Heron Creek. Mill Creek had the greatest percent increase in fry captured (4000%), followed by Locke Creek (300%), and Cedar Creek (200%). The lease on Cedar Creek prevented extended pre-emergence dewatering in 1996. The instream flow lease in Mill Creek was critical during fry outmigration in 1996, but not in 1997 because of unusually high discharge. For sampling protocol development, fry outmigration was broken into three stages based on observed patterns; the ascending limb, peak region and descending limb. Three pattern-based, and three systematic sampling protocols were evaluated in terms of their ability to provide a reliable estimate of fry outmigration with a minimum number of sample days. Mean estimates from four replications of each of the three pattern-based protocols were less variable and sampled fewer days than those from the three systematic protocols. Pattern-based protocol A, which concentrated sampling during the peak region of fry outmigration, and minimally sampled the descending limb, was chosen as the best protocol for all four streams because of the consistently narrow 95% confidence interval for its estimates, and was recommended to Montana Fish, Wildlife and Parks for adoption. Based on my results, other water leases should be pursued on creeks where dewatering is affecting fry recruitment, and fry outmigration should be monitored periodically to evaluate each lease's effectiveness.

INTRODUCTION

Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) were indigenous to the Snake River above Shoshone Falls, Idaho and the Yellowstone River above its confluence with the Tongue River in Montana (Behnke 1992). Hadley (1984) showed that their current range is centered near Yellowstone National Park and comprises only 8% of their historic range. Genetic contamination, stream dewatering, exploitation, competition and habitat perturbations have contributed to the decline of the species (Varley and Gresswell 1988). In response to decreasing populations, angling regulations for the Yellowstone River from Yellowstone National Park to Springdale, Montana were changed to catch and release for Yellowstone cutthroat trout in 1984 (Clancy 1987).

Yellowstone cutthroat trout are tributary spawners; however, due to severe dewatering for irrigation, only 7 of the 18 Yellowstone River tributaries within their native range support spawning populations (Clancy 1988). Spawning occurs in early June or July, and fry remain in the gravel for up to 2 weeks after hatching. Emergence and outmigration begin approximately 40 to 60 d after fertilization, depending on water temperature (Byorth 1990; Kelly 1993). This results in embryo development, fry emergence and outmigration to the Yellowstone River coinciding with the greatest water demand for irrigation. In 1989, the Montana legislature passed House Bill 707, allowing Montana Department of Fish, Wildlife and Parks (MDFWP) to lease existing water rights to enhance or maintain streamflow for the benefit of fisheries. The first water leases were on Mill and Cedar creeks, tributaries to the Yellowstone River. The goal of the leasing program is to reduce incubation and outmigration losses in streams that have been chronically dewatered, such as Mill Creek. My study estimated the extent to which the leasing program has met its goal.

Water rights in Montana are based on the appropriative system which can be summarized as "first in time is first in right" (Getches 1990). The senior water right holder has the right to use all of the water claimed and used when the water right was filed. If a drought reduces the flow in a creek to 2.0 m^3/s, and the senior water right is for 2.0 m^3/s, the full flow of the creek may be diverted, regardless of any junior water right holders' claims. A drought in the late 1980's dewatered many Montana streams because the claimed water rights exceeded discharge. Part of the strategy in leasing water rights from landowners under House Bill 707 is to acquire the oldest or senior rights to ensure that leased water stays in the stream.

House Bill 707 tested the feasibility of encouraging more efficient water use by providing financial incentives in watersheds at high risk for stream dewatering. Before the Mill Creek Water and Sewer District constructed a pipeline and enclosed irrigation delivery system in 1992, an average of 90% of the creek flow was diverted during August (Soil Conservation Service 1986). Historically, this dewatered the lower reach of Mill Creek during a critical incubation period for Yellowstone cutthroat trout in 6 of 10 years (Soil Conservation Service 1986). After pipeline installation, a large amount of water was conserved and considered "salvage water". Salvage water belongs to the original water right holder and may be used for additional irrigation or sold to another after completion of a change of use permit (Getches 1990).

Montana's water lease program was pioneered on Mill Creek (Figure 1), a large tributary with over 100 claimed water rights. The first of three leases provides for a flow of up to 1.8 m^3/s (65 cfs) for a 48 h period to flush fry into the Yellowstone River in August (Table 1). This "flushing flow" lease involves 95 water rights owned among 48 individuals (Spence 1995). The other two leases on Mill Creek, totalling 0.25m^3/s (8.77 cfs) and including the most senior right, maintain flows in the lowest reach from spawning to outmigration (Table 1). Protecting the critical flows during incubation and outmigration and implementing the annual flushing flow, should improve recruitment of Yellowstone cutthroat trout from Mill Creek.

A lease on Cedar Creek was finalized in 1993 after the United States Forest Service (USFS) purchased the OTO ranch and its water rights (Environmental Quality Council 1996). This lease provides water from May through October, which encompasses the Yellowstone cutthroat trout spawning and outmigration periods. The OTO ranch's water lease varies from 0.18 m^3/s to 0.27 m^3/s (6.39 cfs to 9.64 cfs) throughout the summer (Spence 1995). In drought years, the available flow in Cedar Creek may fall below the amount leased. The Cedar Creek lease is in a change of use permit process to address the differences among the lease amount, the water available and the minimum needed to meet the intent of the lease (F. Nelson 1998, MDFWP, personal communication). The change would require a minimum of 0.04 m^3/s (1.3 cfs), as measured at the gauge downstream of the East River Road bridge, to remain in Cedar

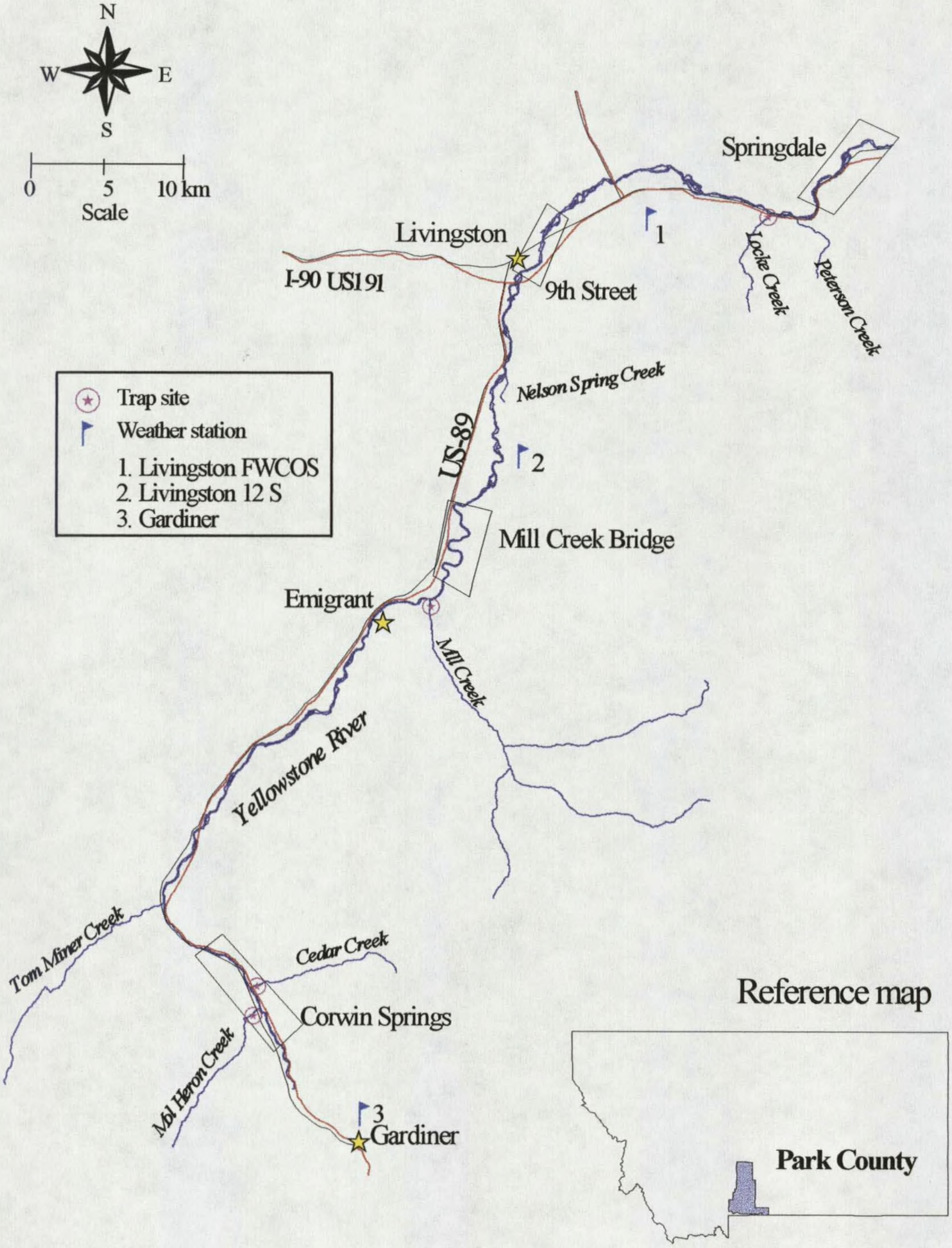

Figure 1. Map of the study area showing the four study streams (Locke, Mill, Cedar and Mol Heron creeks), trapsites, additional high quality spawning tributaries and electrofishing sections (enclosures) on the Yellowstone River.

Table 1. Summary of water leases on the four study streams (Spence 1995).

Location	Lessor	Priority of right	Total quantity	Period of use	Date
Mill Creek	Mill Creek Water & Sewer District	95 rights with various priorities	up to 65 cfs	48 hours in August	August, 1992
	individual	1880 and 1903	6.13 cfs	May 1 to October 4	October, 1992
	individual	1891	2.64 cfs	May 1 to October 19	August, 1995
Cedar Creek	USFS	1890, 1893, 1898,1904, 1972	a minimum of 1.3 cfs[a]	May 1 to October 15	December, 1993
Mol Heron Creek	Church Universal and Triumphant	1884 [b]	a minimum of 5 cfs		pending
Locke Creek	individual	1880 [c]	not yet defined		pending [d]

[a] As stated in the application for change of appropriation water right for the Cedar Creek lease.
[b] Sole water right held on Mol Heron Creek
[c] Sole water right held on Locke Creek
[d] Agreement will be with a chapter of Montana Trout Unlimited

Creek from May to October (Table 1). The revised lease level is based on Byorth's estimation that a discharge of 0.035 m^3/s is adequate to prevent redd dewatering in Cedar Creek (1990). By changing the lease to protect the instream flow required to keep incubating redds watered, MDFWP has shown that the leasing process is flexible and responsive to the needs of water users.

Increasing or maintaining flows via a water lease on Cedar Creek will enhance an already established spawning population (Clancy 1988; Byorth 1990; Shepard 1992). Trout response to the Mill Creek lease may be dependent upon straying adult Yellowstone cutthroat trout to found or revive the currently depleted population. Electrofishing surveys from 1990 to 1997 showed that numbers of Yellowstone cutthroat trout 17.5 cm (7 in) and larger per mile in the Mill Creek section of the Yellowstone River were much lower than in the Corwin Springs section (Figure 2) (Tohtz 1997). Two spawning surveys conducted in 1983 and 1993 indicated almost no use of Mill Creek by Yellowstone cutthroat trout (Clancy 1984; Wiltshire 1994). Two Yellowstone cutthroat trout egg plants were made in 1994 and one in 1995, but were unsuccessful (J. Tohtz 1996, MDFWP, personal communication). High flow during spring runoff precluded locating artificial redds in the main channel, and embryos were dewatered before emergence. A larval plant of 45,000 McBride Lake Yellowstone cutthroat trout fry was made on July 5, 1994. The estimated success of this plant was 10 to 15% (Wiltshire 1994).

Since resident Yellowstone cutthroat trout generally spawn in their natal tributaries or in those upstream of and near their home territories, the number of cutthroat

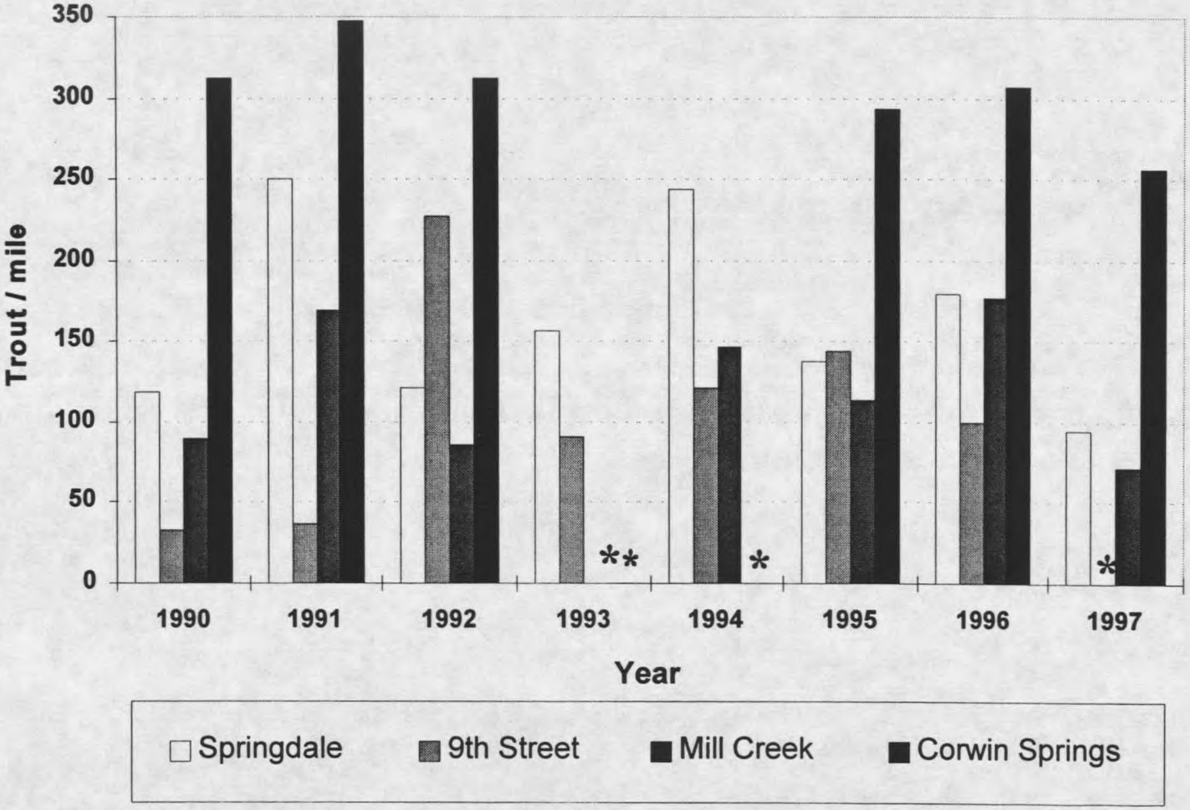

Figure 2. Density of Yellowstone cutthroat trout 17.5 cm (7 in) or longer for the four electrofishing sections in the upper Yellowstone River, 1990 to 1997 (Tohtz 1997). An "*" indicates no data available for a section.

trout spawning in Mill Creek will likely be low for several generations (Clancy 1984). In contrast, Cedar and Mol Heron creeks are located in the section of the Yellowstone River most densely populated by Yellowstone cutthroat trout, Corwin Springs (Figure 1). Both of these creeks have well documented spawning populations (Clancy 1984, 1985; Byorth 1990; Shepard 1992) that seem to be self-sustaining; therefore, water leases may not seem as vital an investment. The concern for Cedar and Mol Heron creeks arises from the potential for dewatering and the desire to preserve the current Yellowstone cutthroat trout spawning runs. The MDFWP is negotiating a lease with the Church Universal and Triumphant (Church), which has exclusive water rights on Mol Heron Creek and is capable of dewatering its lower reaches (Environmental Quality Council 1996). Water leases established now will provide consistent flows in Mol Heron Creek during future summers. The two irrigation diversion headgates on Mol Heron Creek present potential migration obstacles for spawning adults and outmigrating fry. The Church has expressed interest in modifying these structures to improve passage of migrating spawners and reduce fry losses as part of the MDFWP lease.

The fourth creek in this study, Locke Creek, may become one of the first sites where more recent water lease legislation is implemented. House Bill 472, passed in 1995, allows any association, organization or individual to lease water rights to improve fisheries (Environmental Quality Council 1996). Locke Creek has the potential for low flows in the summer due to irrigation withdrawals and has a spawning population of Yellowstone cutthroat trout (Clancy 1985; Shepard 1992). Montana Trout Unlimited received a Future Fisheries Fund grant in March of 1996 to improve the existing irrigation ditch that flows into Locke Creek. The ranch owner on Locke Creek has exclusive water rights because the creek is completely contained within his land, and he has agreed to allow any salvage water created by the ditch improvement to remain in the creek. Although this agreement is not a lease in the strictest sense, it will have the same result, and the ranch owner has expressed interest in formalizing the agreement as a lease.

Water leases are either in effect or in process on the four Yellowstone River tributaries monitored. The study streams do not represent a random sample; however, because all four are in the same drainage basin, and subject to similar flow regimes, I will be able to generalize how much the water leases are contributing to Yellowstone cutthroat trout reproductive success. The specific objectives are:

1. To evaluate the current water leases on Mill and Cedar creeks by monitoring reproductive success in terms of Yellowstone cutthroat trout fry outmigration to the Yellowstone River.
2. To monitor Yellowstone cutthroat trout fry outmigration from Mol Heron Creek, including fry lost to the irrigation ditches, and Locke Creek to provide baseline data for evaluation of future water leases or projects.
3. To develop and evaluate the reliability of sampling protocols that will provide an index of Yellowstone cutthroat trout fry outmigration for future monitoring.
4. To recommend the best timing for the Mill Creek flushing flow to facilitate downstream fry migration.

DESCRIPTION OF THE STUDY AREA

This study was conducted in Park County, Montana on four tributaries of the upper Yellowstone River (Figure 1). The highest flows on the Yellowstone River for this century occurred during the 2 years of this study. Discharge measured at the gauge near Livingston, Montana peaked on June 10, 1996 at 952 m^3/s (33,600 cfs) and on June 6, 1997 at 1,076 m^3/s (38,000 cfs) (USGS 1997). Flood threshold for the Yellowstone River at Livingston is 668 m^3/s (23,600 cfs) and mean annual discharge for early to mid - June is approximately 397 m^3/s (14,000 cfs) (USGS 1997). The hydrograph for 1996 declined steadily after the peak flow and dropped below flood stage within 7 d. After the peak in 1997, the flow fluctuated at or above flood stage for 22 d (Figure 3);(USGS 1997).

Study Streams

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.

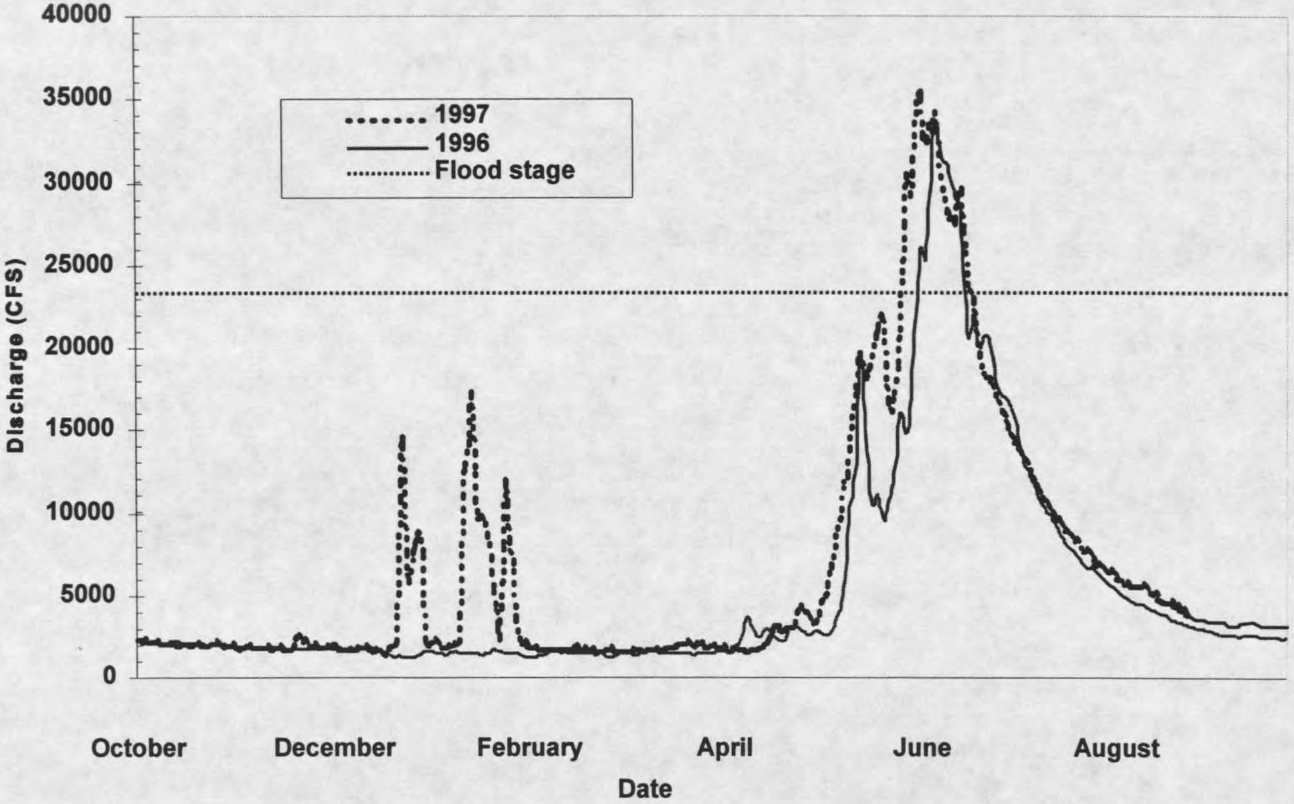

Figure 3. Hydrograph for the Yellowstone River near Livingston, Montana, for the 1996 and 1997 water years. (October to September) (USGS 1997).

Locke Creek

Locke Creek joins the Yellowstone River approximately 16.1 km (10 mi) downstream from Livingston, Montana (Figure 1). Locke Creek flows through a single ranch where the creek is used for irrigation. The creek is not usually dewatered during the critical times of fry development and outmigration. A proposed Future Fisheries Fund project will increase irrigation efficiency and further reduce the likelihood of dewatering. There are plans to install a fish ladder approximately 0.8 km (0.5 mi) upstream of the mouth to facilitate fish passage over a diversion dam (F. Nelson 1997, MDFWP, personal communication). Samples of outmigrating fry taken in 1996 and 1997 were shown to be Yellowstone cutthroat trout with no evidence of hybridization with rainbow trout (*Onchorynchus mykiss*); (Leary 1998). Genetics of these fry, and all other samples, were determined using horizontal starch gel electrophoresis at the University of Montana Wild Trout and Salmon Genetics Lab.

Locke Creek 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). Willow (*Salix* spp.), woods rose (*Rosa woodsii*) and grasses are the predominant riparian vegetation on Locke Creek.

Mill Creek

Mill Creek, located near Emigrant, Montana (Figure 1), is the largest tributary of the Yellowstone River in Park County. The headwaters of Mill Creek are within the Absaroka-Beartooth Wilderness Area and the Gallatin National Forest.

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 has a gradient of 0.6 to 1.2%. Stream gradient increases to 2.3% at the 13.5 km (8.4 mi) point where the creek flows through a narrow canyon. Just upstream of the canyon, Mill Creek returns to a low gradient (0.5%) profile as it flows though a flat open meadow. Riparian vegetation varies considerably over Mill Creek's length. Cottonwood (*Populus* spp.), willow and woods rose predominate in the lower sections of Mill Creek. Various coniferous trees replace the cottonwood, and vine maple (*Acer circinatum*) replaces the willow at higher elevations.

In 1995, a fish barrier was constructed at the National Forest Boundary, approximately 17.7 km (11 mi) from the mouth, to impede upstream passage of spawning rainbow trout. A pure strain population of Yellowstone cutthroat trout exists above this barrier (Clancy 1987). Samples of outmigrating fry collected from the mouth of Mill Creek in 1996 and 1997 were shown to be hybrid swarms of Yellowstone cutthroat trout and rainbow trout (Leary 1998). The lower 12.8 km (8 mi) of Mill Creek flows through private lands. There are several major irrigation diversions on Mill Creek, including the Mill Creek Water and Sewer District pipeline.

Cedar Creek

Cedar Creek, located near Corwin Springs, Montana (Figure 1), is a small tributary of the 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. Genetic analysis of fry from Cedar Creek in 1991 showed that the fish were approximately 96% Yellowstone cutthroat trout and 4% rainbow trout (Shepard 1992). Samples of outmigrating fry collected from the mouth of Cedar Creek in 1996 and 1997 were shown to be hybrid swarms of Yellowstone cutthroat trout and rainbow trout (Leary 1998).

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%. Stream gradient increases to 12% approximately 1.2 km (0.8 mi) from the mouth where the creek flows through a short, steep gorge. Above the gorge, the gradient decreases to 7.7%. Cottonwood and woods rose are the predominant riparian vegetation along the lower section of Cedar Creek.

Mol Heron Creek

Mol Heron Creek's entire length is within lands owned by the Church Universal and Triumphant. The Church maintains two irrigation diversion ditches within 1 km (0.6 mi) of the creek mouth. Samples of outmigrating fry collected from the mouth of Mol

Heron Creek in 1996 and 1997 were shown to be hybrid swarms of Yellowstone cutthroat trout and rainbow trout (Leary 1998).

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. The MDFWP staff gauge on Locke Creek was calibrated based on four discharge measurements taken in 1997. The Mol Heron Creek gauge was located on the old bridge abutment near the mouth and was calibrated based on four measurements taken in 1988 and one taken in 1997. Mean, minimum and maximum seasonal (July to September) discharges were estimated for both years. Onset Optic StowAway® thermographs were installed at each staff gauge location on July 1, 1996 and programmed to record at 30 minute intervals. In 1997, installation on Locke, Cedar and Mol Heron creeks occurred between June 12 and 23. 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. Spawning times on Locke and Cedar creeks were estimated using MDFWP data (Shepard 1992). As Locke Creek was the site farthest downstream, it was monitored first and used to gauge approximate spawning times for other study streams.

To verify the 0.035 m^3/s (1.2 cfs) instream flow recommendations from Byorth's (1990) study on Cedar Creek, a sample of redds was marked in 1996 with spray-painted rocks. Redds were checked for dewatering twice weekly until outmigration began.

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 as close to as possible to the mouth in each study stream. 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).

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 (Figure 24, Appendix A).

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 (Figure 1), 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. One trap was used in each of Locke and Cedar creeks, sampling approximately 50% of the width.

The two larger creeks, Mill and Mol Heron, required different strategies to minimize fry mortality due to high discharge. In 1996, a low velocity run section of Mill Creek was chosen as the trap site. Because Mill Creek was wider than the other study streams, two traps were used to sample a larger proportion of the flow. In 1997, the channel of Mill Creek split and a trap was placed in a pool in each branch. The traps in Mill Creek spanned approximately 10% and 33% of the channel width in the main and smaller branches, respectively.

In Mol Heron Creek, the main channel trap sampled approximately 25% of the width. The trap was moved from the thalweg near the right bank to a lower velocity area along the left bank in 1997 to reduce the high mortality observed in 1996, and a plywood baffle was added to further reduce stream velocity near the trap tail.

In 1996, the two irrigation ditches closest to the mouth of Mol Heron Creek were sampled because MDFWP had expressed concern that outmigrating fry were swimming into the ditches and being lost to recruitment. Traps spanned 45% and 90% of the large and small ditches, respectively. The larger ditch was not used for irrigation in 1997, and was not trapped.

Traps were placed on each study stream approximately 25 to 30 d after spawning activity was observed (Benson 1960). In Locke Creek, where no spawning was observed, temperature and historical fry trapping data were used to estimate the spawning date (Shepard 1992). Beginning on July 23, 1996, fry traps were set overnight once a week until fry were caught. Thereafter, traps were set and checked daily. In 1997, traps were set every third night beginning on July 1. Traps were checked early in the morning, at midday and in the evening during the first 2 weeks of trapping on Locke Creek to establish when the fry were moving downstream. No fry were trapped during the midday or evening sets and movement appeared to be concentrated overnight. Thereafter, an effort was made to check traps early in the morning to minimize fry stress. Number and species of fry caught, individual total lengths of a random subsample of 10 fry, air and water temperatures, and staff gauge readings were recorded.

Fry Length and Residence Time

The distribution of fry lengths was plotted in modified boxplots (Cleveland 1994), by week. Kelly (1993) found that newly emerged Yellowstone cutthroat trout fry measured less than 25 mm, and that length was used in this study as a separation between younger and older fry. Trends in mean length as outmigration progressed were examined for evidence of fry remaining in their natal stream to rear before outmigrating to the Yellowstone River.

Trap Efficiency

Trap efficiencies were calculated using two methods: marking and re-trapping of fry, and estimated percent of flow sampled by each trap. Three marking trials were completed during peak fry movement on each study stream. On each occasion, a second trap was placed in the next suitable pool, at least 40 m upstream of the established trap on each study stream. Fry caught in the upstream trap were marked by immersion in a 1:30,000 solution of Bismarck Brown Y dye for 1h. The upper trap was removed, and the dyed fry were released into a slow moving pool just downstream of the upper trap site. The 1:30,000 dye concentration made the fry distinguishable for at least 4 d (Ward and Verhoeven 1963);(Appendix B). The dye retention imposed a minimal 3 d interval between marking trials.

In addition to marking trials, flow measurements were used as an efficiency estimator. A Gurley AA flow meter was used to measure the total discharge moving through the cross section of each creek at the trap sites. Traps were left in place during the measurements to account for any impeding effect on flow. The proportion filtered by the trap was used to calculate percent efficiency.

Data Analysis and Model Building

Temperature Modeling

To predict missing intervals of daily mean water temperatures, air temperatures from the weather station closest to each study stream were used as parameters in linear regression analysis (Table 2). After a best model was chosen, regressions were extrapolated to predict mean water temperatures for the 30 d period before outmigration was detected in each creek to estimate when spawning was likely to have begun. The models were based on hydrologic studies that had shown stream water temperature to be most sensitive to air temperature and solar radiation (Sinikrot and Stephan 1994; Stoneman and Jones 1996). A multiple regression was developed for each study stream with actual mean water temperature as the response variable, using the statistical software program MINITAB® to generate and test the regression relations (Neter, Kutner, Nachtsheim, and Wasserman 1996). Daily mean, maximum, and minimum air temperatures, the daily range of temperatures, the previous day's minimum and maximum air temperatures, and a categorical variable for precipitation were included as possible predictor variables. The best subsets model selector was used for preliminary evaluation of combinations of predictor variables (MINITAB 1996). All tests were performed at an

α level of 0.05. Adjusted R^2, residuals and fits, P-values, Mallows Cp, and variance inflation factors were used to discriminate between closely ranked models (Neter, Kutner, Nachtsheim, and Wasserman 1996). The Durbin-Watson test for autocorrelation of error terms was used to evaluate the influence of the time series nature of the data (Neter, Kutner, Nachtsheim, and Wasserman 1996). A jacknife procedure that randomly excluded 10% of each data set and reconstructed the regression was run 100 times to examine the stability of the coefficients (SYSTAT 1997).

Table 2. Locations of weather observation stations used as sources of air temperature data to estimate mean daily water temperature for each study stream.

Study stream	Locke	Mill	Cedar	Mol Heron
Latitude	45°41'	45°25'	45°09'	45°08'
Longitude	110°17'w	110°38'w	110°48'30"w	110°48' w
Elevation (m)	1302	1463	1548	1549
Weather station	Livingston FWCOS	Livingston 12S	Gardiner	Gardiner
Latitude	45°42'	45°29'	45°02'	45°02'
Longitude	110°27'w	110°34'w	110°41'w	110°41'w
Elevation (m)	1418	1484	1608	1608

Fry Outmigration Sampling Protocols

Fry outmigration was broken into three stages for modeling purposes; the ascending limb of the curve, the peak region, and the descending limb (Figure 4). This

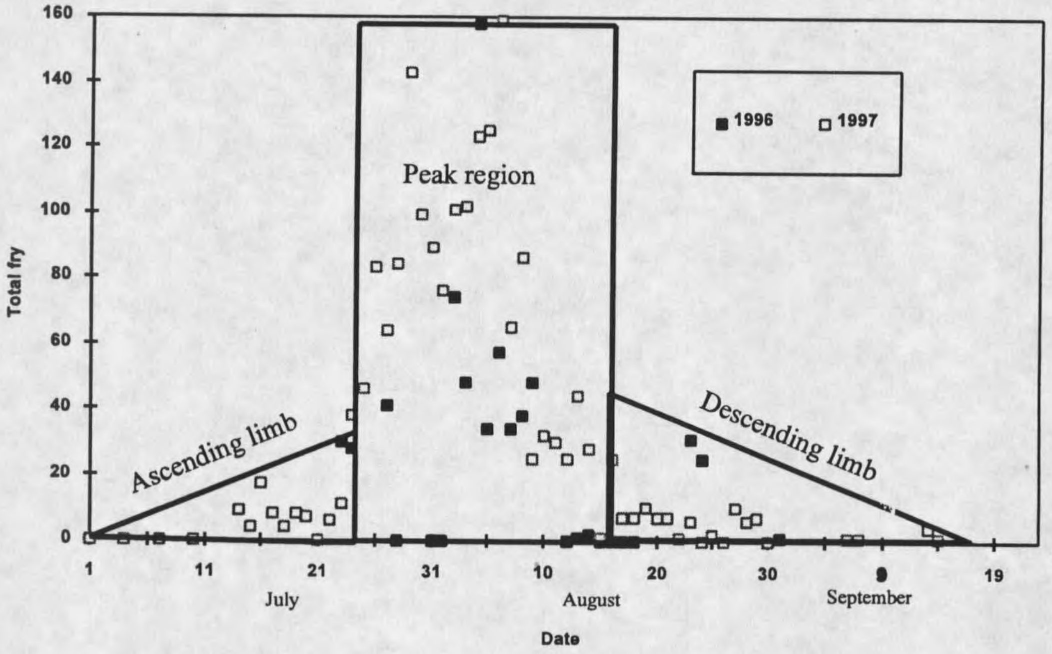

Figure 4. Example of the three regions in the observed pattern of fry outmigration used to develop sampling protocols for future monitoring in tributaries of the upper Yellowstone River.

pattern was consistent in all study streams for both field seasons and was supported by previous outmigration sampling (Byorth 1990; Shepard 1992). Once trapping had begun, a running 3 d mean was calculated. Days when trap catches were zero prior to the first successful trapping were not included in the 3 d means; however, once fry were trapped, zero trap catch days were included. The start of the peak region was defined as first day when trap catch was greater than the previous 3 d running mean, or 50 fry. The peak region ended on the first day when trap catch was less than 1/4 of the previous 3 d mean. Missing trap catch data were simulated using the mean of the 4 surrounding trapping occasions; 2 d preceding and 2 d following. All data sets used to evaluate protocols included some simulated data; however, most of the missing trap catch data were in the ascending and descending limbs during both field seasons.

Observed patterns in fry outmigration were used to develop the decision trees for pattern-based sampling protocols, with the goal of creating an index of fry outmigration from a creek given a minimal number of trapping days. Simulated data were not used to calculate the percent of total outmigration in each region, or for developing the decision trees. Pattern-based protocols were structured to identify the beginning of the peak region and to intensify sampling therein. An effort was made to decrease the overall sampling effort in these protocols. Pattern-based protocols differed in how the peak region was identified, how many peak region days were sampled, and whether sampling included the descending limb. Systematic protocols varied in the number of days sampled in a row and the number of days skipped between samples.

Each protocol was simulated between four and six times, beginning on sequential starting dates, until a pattern was repeated. In addition, each protocol was run beginning on the first day of the peak region to examine the loss in accuracy due to missing the ascending limb. The best three systematic and three pattern-based sampling protocols were compared. Protocols were ranked for each stream by their accuracy, cost effectiveness, and overall precision. Accuracy was defined as how similar the mean estimate of fry sampled by the protocol was to the total sampled by trapping every day. Precision was evaluated for each set of estimates by comparing the 95% confidence intervals and means for percent of outmigration sampled. Means and confidence intervals for evaluating protocol precision were constructed using the arcsine transformation of the percent values (Zar 1984). Cost-effectiveness was measured in terms of the number of days sampled.

Flushing Flow Monitoring

A 48 h flushing flow in Mill Creek is intended to help move recently emerged fry out to the Yellowstone River before flows drop to critically low levels during late summer irrigation. The flushing flow occurred from August 21 to 22 in 1996, and from August 24 to August 26 in 1997. In both years the flushing flow coincided with expected end of peak fry emergence based on outmigration patterns in other study area streams. During the flushing flow, all diversions were closed.

The success of 1996 flushing flow was evaluated with three traps; one set near the staff gauge below the East River Road bridge, and two set approximately 0.8 km (0.5 mi) below the gauge. The traps were checked at 4 h intervals for the first 12 h, and every 9 h throughout the remaining 36 h. Trapping for the flush was modified in 1997. No additional upstream traps were set, and the existing two traps near the mouth of Mill Creek were checked every 24 h. Catch records before and after the flush were used to evaluate its timing and effectiveness.

RESULTS

Stream Discharge and Temperature

Discharge

Stream discharge was greater in Locke Creek on comparative dates in 1997 than in 1996 (Figure 5). The pattern of discharge was similar between years except for a precipitous drop from September 1 to 9, 1997 when discharge decreased to 50% of the seasonal (July to September) mean during a period of high irrigation withdrawal. During the 1997 field season (July 1 to September 14) mean seasonal discharge was 26% higher than in 1996 and ranged from 0.04 m^3/s to 0.13 m^3/s (1.5 cfs to 4.5 cfs); (Table 3).

Flows on Mill Creek were highly variable throughout the 1997 field season with discharge ranging from 0.50 m^3/s to 2.7 m^3/s (18 cfs to 94 cfs); (Table 3). The maximum discharge in 1997 occurred on September 12 following a large thunderstorm. In contrast, the maximum flow for 1996 was 1.10 m^3/s (39 cfs) and was a result of the flushing flow. In both years, discharge dropped well below pre-flush levels within 24 h after the flush ended (Figure 6). The staff gauge below the East River Road bridge was washed away during the 1997 spring runoff and a pre-existing gauge attached to the bridge abutment was substituted for discharge measurements after being calibrated by the USGS

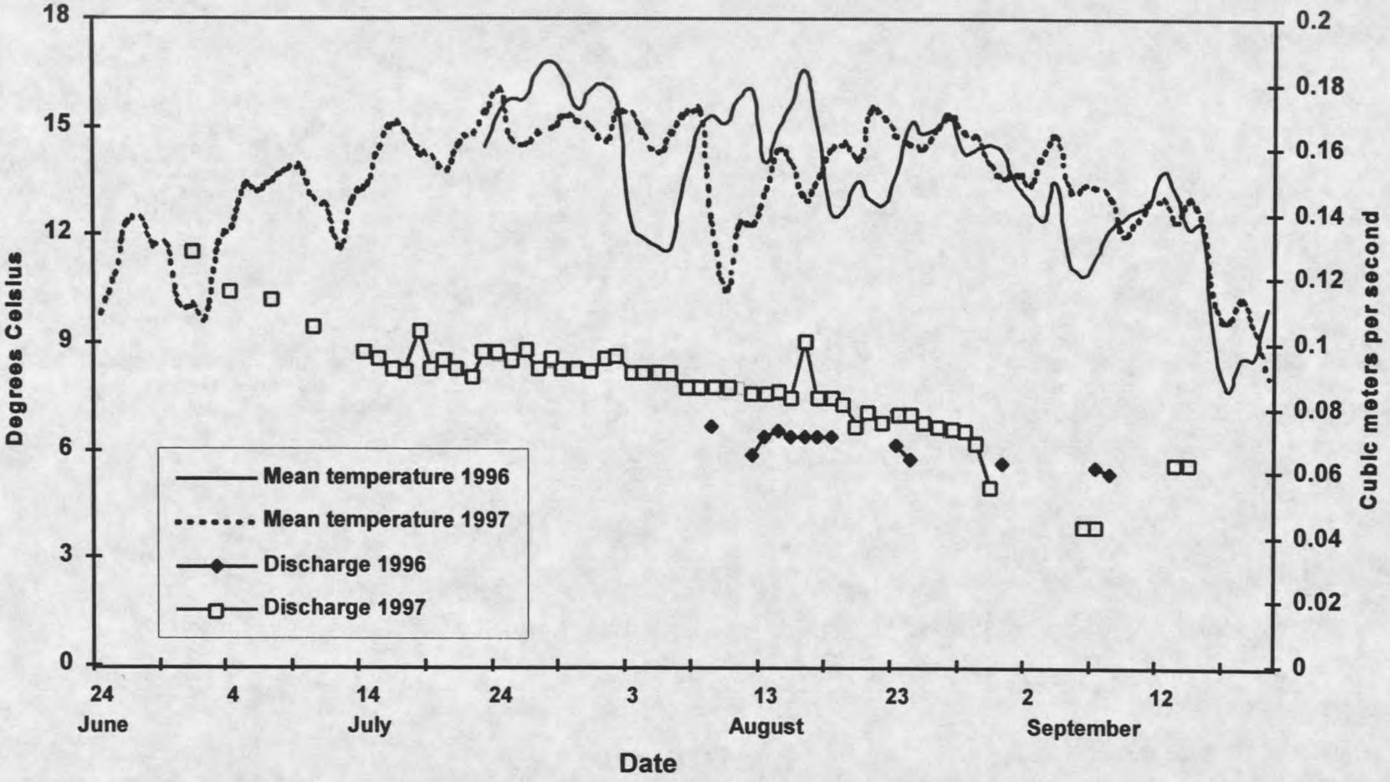

Figure 5. Daily discharge and mean daily water temperatures for Locke Creek, Montana, from June to September 1996 and 1997.

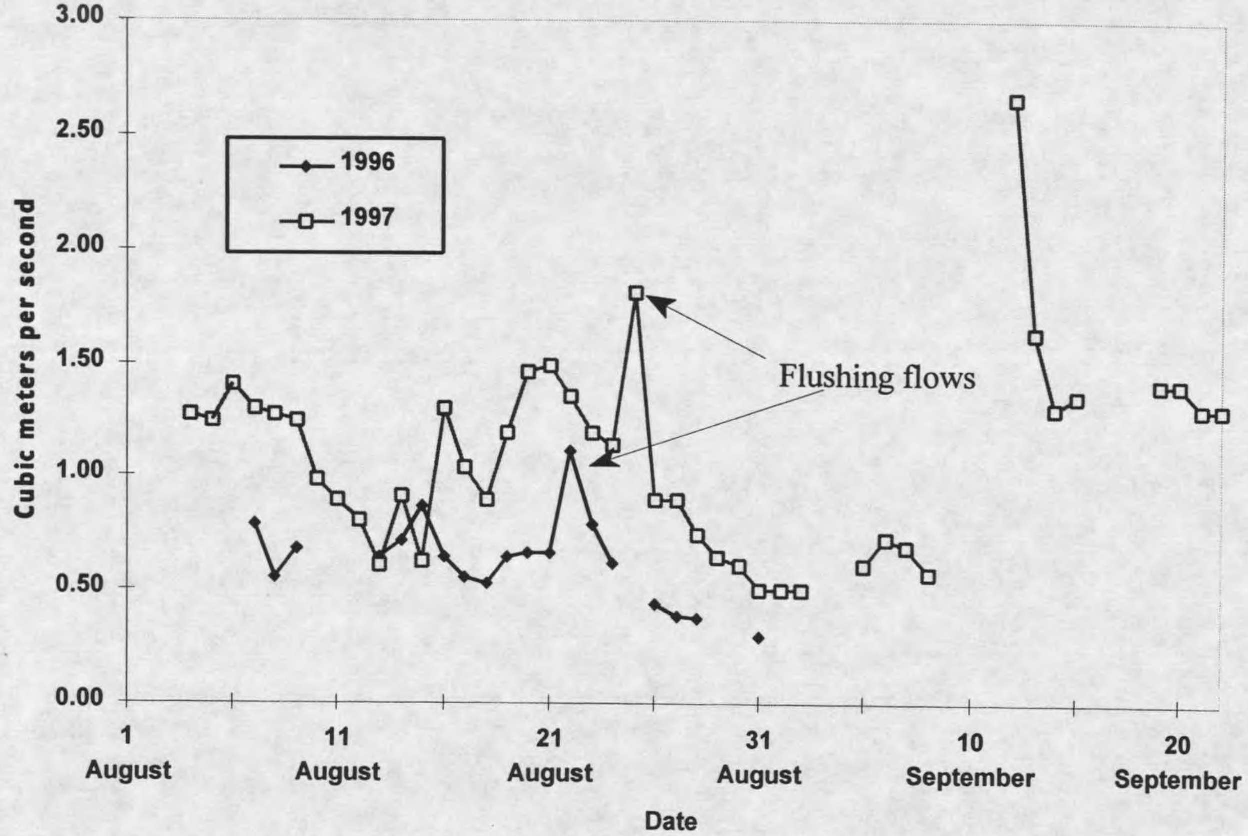

Figure 6. Daily discharge for Mill Creek, Montana, from August to September 1996 and 1997.

Table 3. Summary of discharge readings for the four study streams from July to September 1996 and 1997.

Study stream	Year	Seasonal mean (m^3/s)	Maximum (m^3/s)	Date	Minimum (m^3/s)	Date
Locke	1996	0.068	**		**	
	1997	0.086	0.127	July 1	0.043	September 7
Mill	1996	0.629	1.100	August 22	0.293	August 31
	1997	1.090	2.700	September 12	0.50	August 31
Cedar	1996	0.029	0.091	August 2	0.006	August 15
	1997	0.075	0.108	August 8	0.055	September 15
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

** no estimate

Discharge on Cedar Creek was consistently higher in 1997 than in 1996, with mean discharge more than twice that of 1996 (Figure 7). Irrigation withdrawals increased on August 13 and discharge dropped between then and August 15, 1996 (F. Nelson 1998, MTDFWP, personal communication). On August 15, it was estimated that at least 50% of the marked redds were dewatered. Discharge of 0.026 m^3/s was restored by August 17 in accordance with the water lease (Figure 7), but the redds were dewatered for at least 48 h. In 1996, flows ranged from 0.006 m^3/s (0.22 cfs) to 0.09 m^3/s (3.2 cfs), compared with the 1997 range of 0.06 m^3/s (1.9 cfs) to 0.11m^3/s (3.8 cfs); (Table 3).

Mean stream discharge in Mol Heron Creek was over 2.5 times greater in 1997 than in 1996. In 1997, discharge remained high throughout the field season (August 9 to September 22). Discharge varied from 0.46 m^3/s (16 cfs) to 0.69 m^3/s (24 cfs) in 1996,

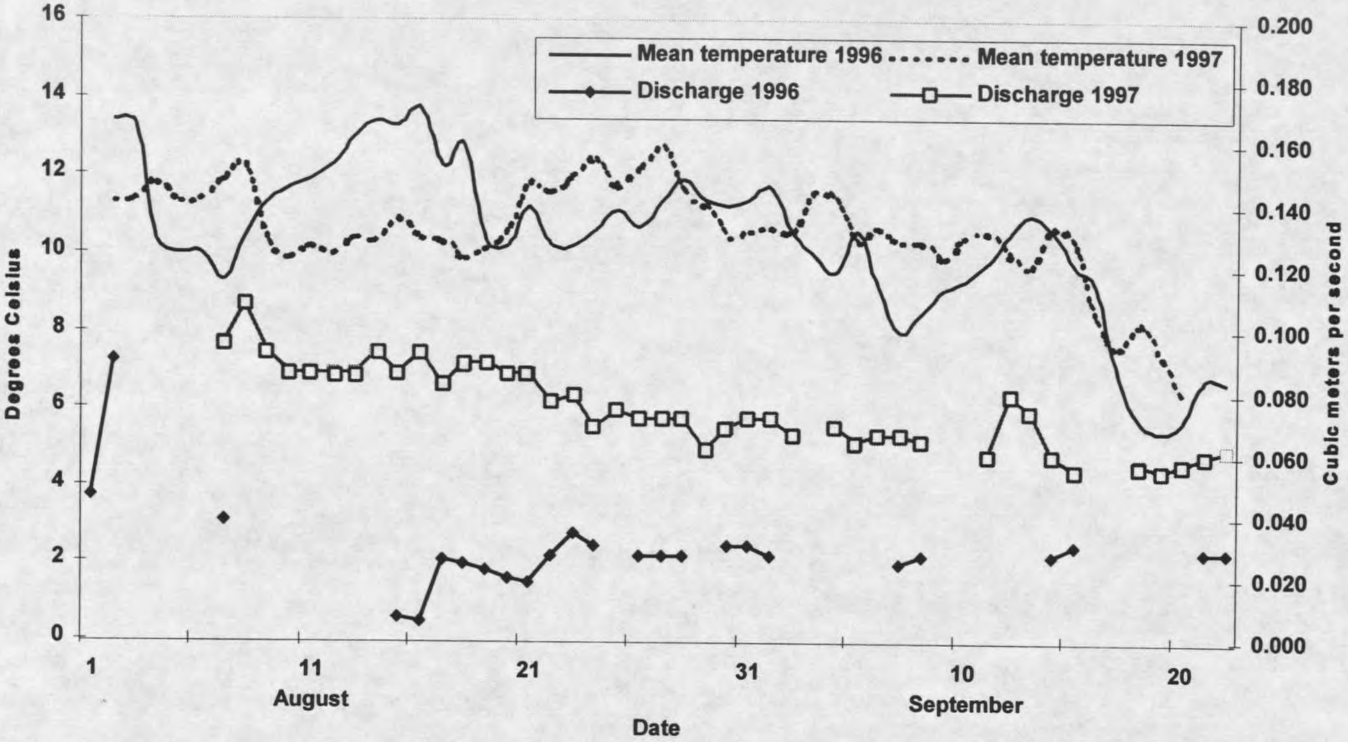

Figure 7. Daily discharge and mean daily water temperatures for Cedar Creek, Montana, from August to September 1996 and 1997.

and from 1.4 m^3/s (49 cfs) to 1.6 m^3/s (55 cfs) in 1997 (Figure 8).

Temperature

Temperature patterns in Locke Creek were similar in 1996 and 1997 (Figure 5). Mean daily water temperature fluctuated 5.2 °C in 1996 and 5.0 °C in 1997. The thermograph in Mill Creek malfunctioned in 1996 and collected data for mid-July only. Extreme high spring discharge in early June 1997 washed away the thermographs on Mill, Cedar and Mol Heron creeks. The Mill Creek thermograph was not replaced in 1997; therefore, daily mean water temperature data were not collected for 1996 or 1997. The replacement thermograph on Mol Heron Creek malfunctioned, and the stream temperature prediction model was used to estimate 1997 mean daily temperatures (Figure 8).

Trends in mean daily water temperature in Cedar Creek were similar for both years (Figure 7). However, in 1996 there was a 7 d period (August 9 to 16) of substantially higher water temperatures corresponding to the period of lowest flows for that year. Mean daily water temperature fluctuated 3.6 °C in 1996 and 3.2 °C in 1997.

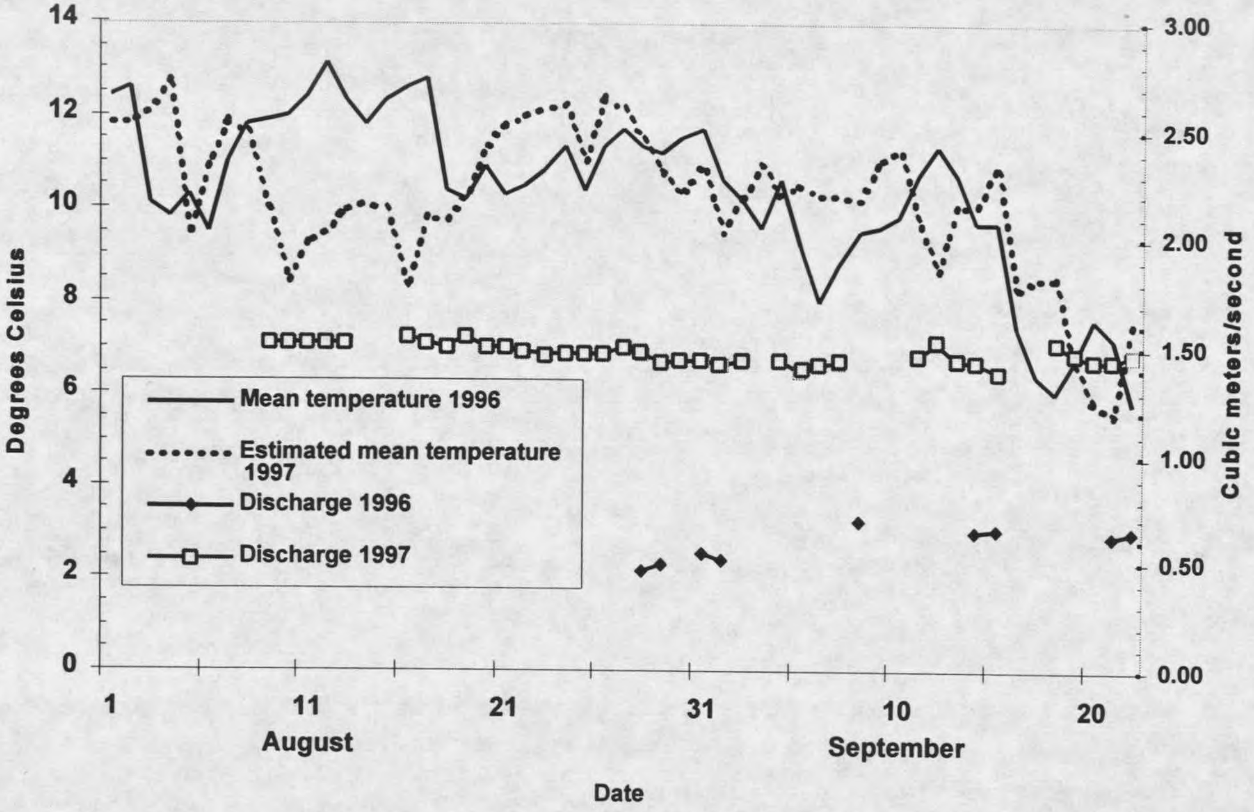

Figure 8. Daily discharge and mean daily water temperatures for Mol Heron Creek, Montana, from August to September 1996 and 1997. Water temperatures for 1997 were estimatesd using the regression : mean water temperature = 2.33 + 0.213 maximin air temperature + 0.218 minimum air temperature.

Spawning Activity

Spawning activity was observed in Cedar Creek on each day between July 1 and July 10, 1996 and on July 1, 2 and 4, 1997. Nineteen redds were marked within 210 m of the mouth in 1996. Turbidity and high discharge made it infeasible to locate spawning fish visually in Locke and Mill creeks during either field season. High flows and the resulting turbulence made locating spawning fish in Mol Heron Creek ineffective.

Yellowstone Cutthroat Trout Fry Recruitment

More fry were trapped per day of trapping in three of the four creeks in 1997 than in 1996 (Table 4). Outmigration was detected earlier, and continued longer in all creeks in 1997. Despite higher discharge levels in 1997, incidental trapping mortalities decreased from 1996 levels in all creeks .

Locke Creek

Approximately three times more fry were captured in Locke Creek in 1997 than in 1996. Catch per unit effort (CPUE) was 26 fry per day in 1996, and 33 fry per day in 1997. The pattern of outmigration was similar between years for the first 3 weeks of emergence; however, in 1996, trap catches dropped to zero during the fourth week and consequently, trapping effort was reduced. There was a small secondary spike in

Table 4. Summary of fry trapping results from July to September 1996 and 1997, 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
Mill Creek	1996	59	31	2	7	6	10.2
	1997	2,316	46	50	36	109	4.7
Cedar Creek	1996	13,251	24	552	20	74	0.5
	1997	25,781	41	629	35	89	0.3
Mol Heron Creek	1996	1,865	10	187	10	200	23.1
	1997	1,128	35	32	29	87	7.7

[a] Catch per unit effort

outmigration, consisting of larger (> 27 mm) fry, during late August, 1996. Outmigration tapered off more gradually and continued 2 weeks longer in 1997 (Figure 9).

In 1996, outmigration of Yellowstone cutthroat trout fry was first detected on July 23, the first day of trapping, at a mean water temperature of 13.8 °C. Fry catch peaked at 158 on August 4 and no fry were captured after September 1, 1996 (Figure 9). A total of 674 fry were caught during 26 trapping days (Table 4).

In 1997, fry outmigration was first detected on July 14 at a mean water temperature of 13.4 °C. Outmigration peaked at 159 fry captured on August 6 and no fry were captured after September 14 (Figure 9). In 1997, a total of 1,844 fry were caught during 56 trapping days (Table 4). Incidental mortality due to trapping decreased from 9.9% in 1996 to 1.8% in 1997.

Mill Creek

Almost 40 times more fry were captured in Mill Creek in 1997 than in 1996. CPUE was 2 fry per day in 1996, and 50 fry per day in 1997. In both years, peak outmigration occurred in late August. However, fry were caught a week earlier, and over a 29 d longer period in 1997. In 1996, fry outmigration was first detected on August 16, and peaked on August 17 with 23 fry captured. August 23 was the last successful trapping day in 1996 (Figure 10). A total of 59 fry were caught over 31 trapping days (Table 4).

In 1997, fry outmigration was first detected on August 5 and peaked on August 19 with 413 fry captured; no fry were captured after September 22 (Figure 10). A total of

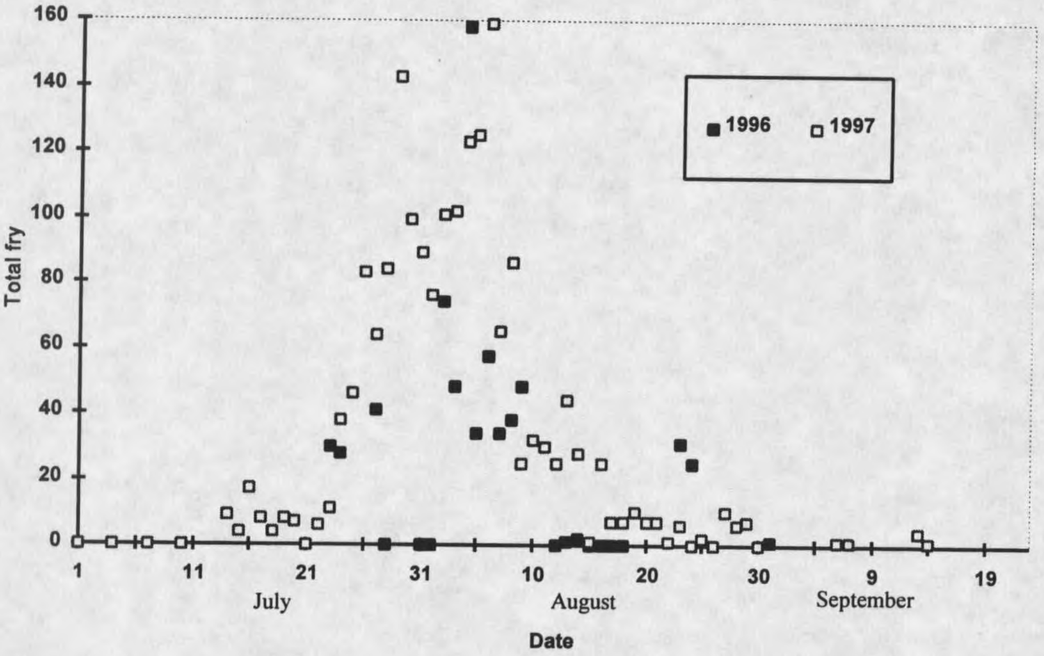

Figure 9. Number of Yellowstone cutthroat trout fry captured each day in a fry trap near the mouth of Locke Creek, Montana, from July to September 1996 and 1997.

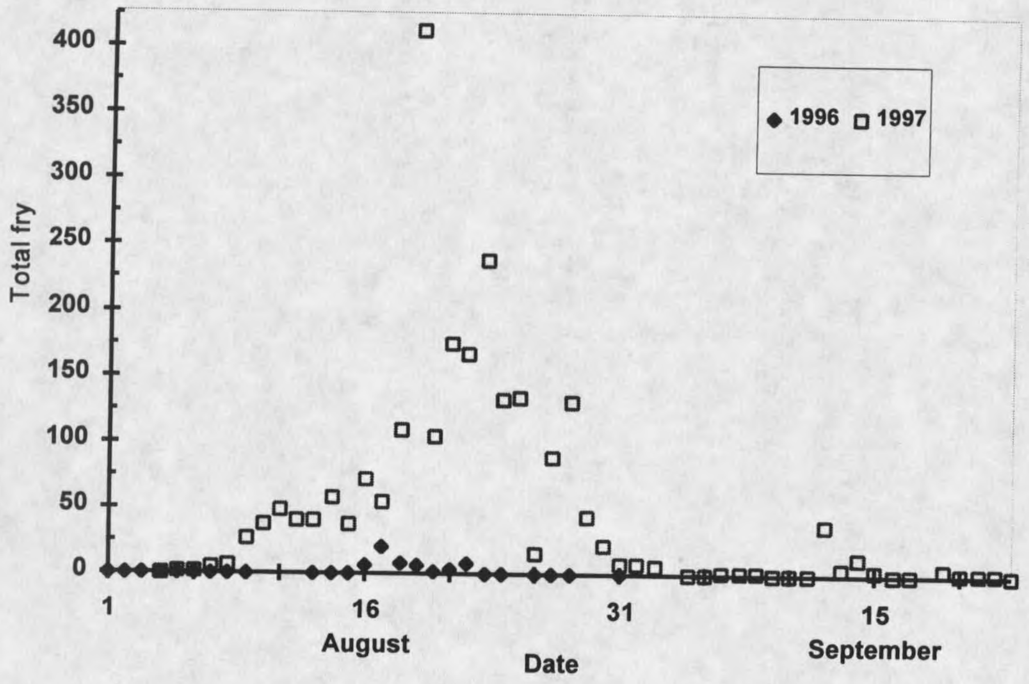

Figure 10. Number of Yellowstone cutthroat trout fry captured each day in two fry traps near the mouth of Mill Creek, Montana, from August to September 1996 and 1997.

2,316 fry were caught over 46 trapping days (Table 4). Incidental mortality due to trapping decreased from 10.2% in 1996 to 4.7% in 1997.

Cedar Creek

Approximately twice as many fry were captured in Cedar Creek in 1997 as in 1996. CPUE was 552 fry per day in 1996, and 629 fry per day in 1997. Fry were captured 1 week earlier in 1997, but trap catch peaks for both years were within 2 calendar days of each other. In 1996, fry outmigration was first detected on August 15 at a mean water temperature of 13.3 ° C. Outmigration peaked on August 31 with 2,032 fry captured, and was completed by September 22 (Figure 11). A total of 13,251 fry were caught over 24 trapping occasions (Table 4).

In 1997, fry outmigration was first detected on August 8 at a mean water temperature of 12.2 ° C. Outmigration peaked on August 28 with 2,956 fry captured, and small numbers of newly emerged fry were captured on the last day trapped, September 22 (Figure 11). A total of 25,781 fry were caught over 41 trapping occasions. Incidental mortality decreased from 0.5% in 1996 to 0.3% in 1997.

Mol Heron Creek

Fewer fry were captured in Mol Heron Creek in 1997 than in 1996, possibly because of the change in trap placement. CPUE was much higher in 1996 at 187 fry per day compared to 32 fry per day in 1997. The 1997 pattern of outmigration in Mol Heron Creek was different from that in any other study stream. In 1996 there was an obvious

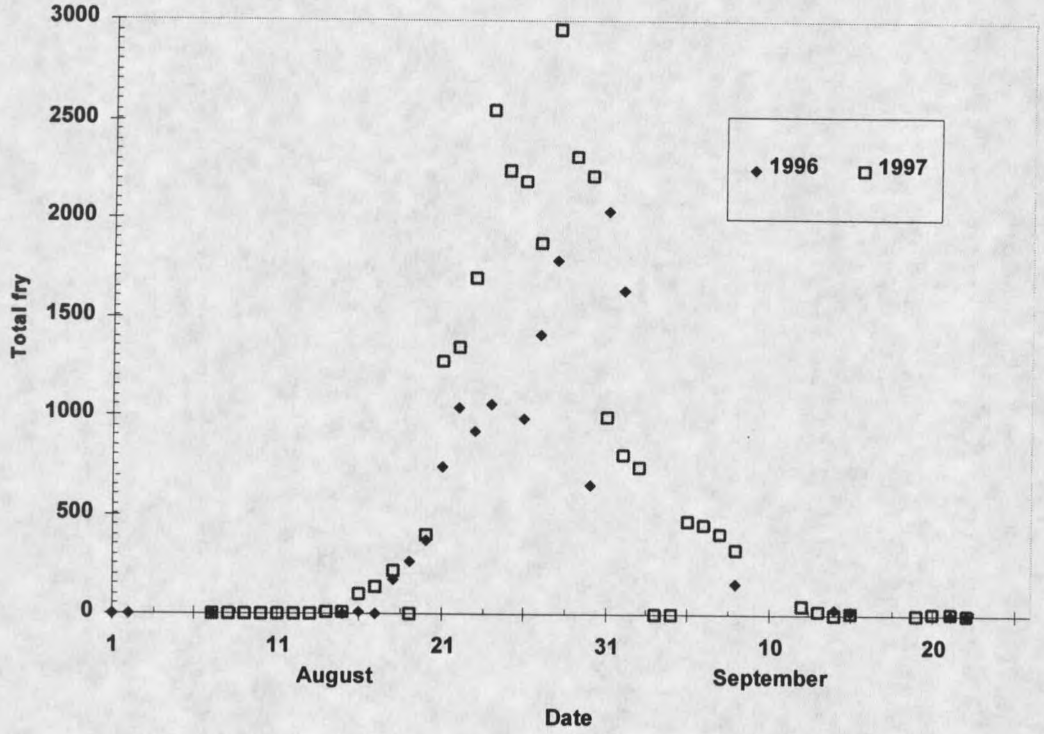

Figure 11. Number of Yellowstone cutthroat trout fry captured in a fry trap near the mouth of Cedar Creek, Montana, from August to September 1996 and 1997.

peak in outmigration similar to patterns in other study streams, but in 1997 the number of fry gradually increased and plateaued for 3 d with no distinct peak. In 1996, fry outmigration was first detected on August 28, the first day of trapping for that season at a mean water temperature of 11.3 °C. Outmigration peaked on August 30 with 1,015 fry captured, and a few fry were captured on the final trapping day, September 22 (Figure 12). In 1996 a total of 1,865 fry were caught over 10 trapping occasions (Table 4). Out of this total, 242 fry, or approximately 13%, were trapped within the two irrigation ditches.

In 1997, fry emergence was first detected on August 10, at a mean water temperature of 11.9 °C. Trap catch peaked on August 26 with 125 fry, and a few fry were captured between September 19 and 22, the last week trapped (Figure 12). In 1997, 1,128 fry were caught over 35 trapping occasions. Out of this total, 180 fry, or approximately 16%, were trapped within the smaller irrigation ditch; the larger ditch was not sampled in 1997. Incidental mortality decreased from 23% in 1996 to 7.7% in 1997.

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 Locke, Mill and Mol Heron creeks the final week of successful trapping did not include any newly emerged fry in 1996 or 1997 (Figures 13-16). In 1997, in all three of these creeks, mean length increased less than 3

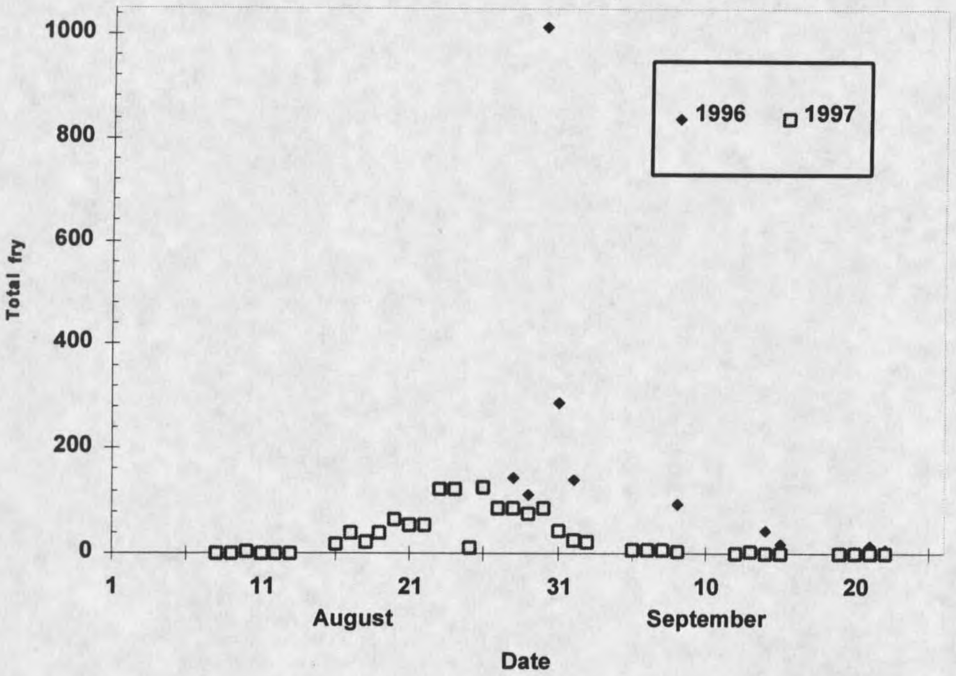

Figure 12. Total number of Yellowstone cutthroat trout fry captured each day in fry traps near the mouth and in two irrigation ditches in Mol Heron Creek, Montana, from August to September 1996 and 1997.

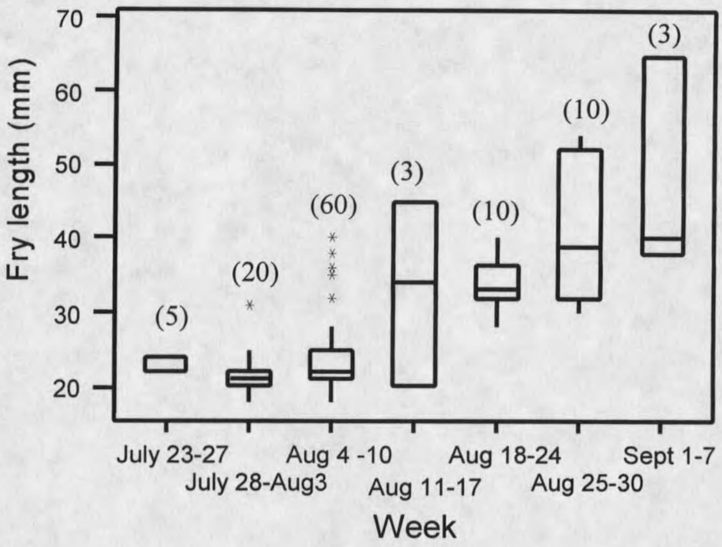

Figure 13. Weekly ranges of lengths of a random subsample of Yellowstone cutthroat trout fry captured in Locke Creek, Montana, in 1996. Sample size for each week is in parentheses. The box defines the interquartile range (middle 50%) with a line at the median. Outliers are marked with an asterisk.

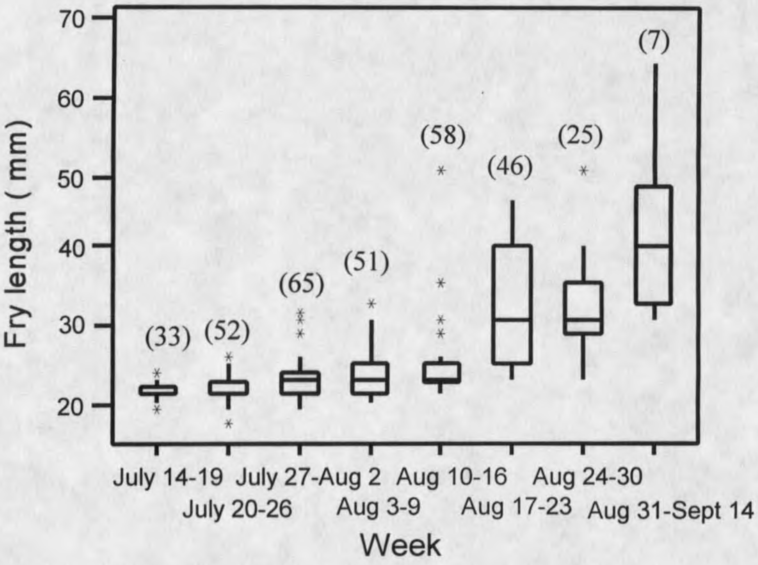

Figure 14. Weekly ranges of lengths of a random subsample of Yellowstone cutthroat trout fry captured in Locke Creek, Montana, in 1997. Sample size for each week is in parentheses. The box defines the interquartile range (middle 50%) with a line at the median. Outliers are marked with an asterisk.

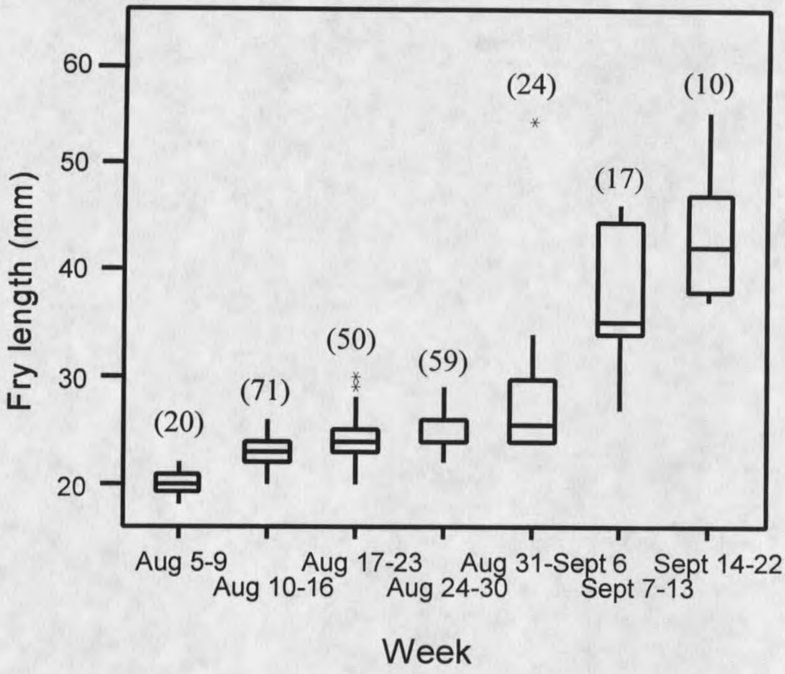

Figure 15. Weekly ranges of lengths of a random subsampleof Yellowstone cutthroat trout fry captured in Mill Creek, Montana, in 1997. The box defines the interquartile range (middle 50%) with a line at the median. Sample size for each week is in parentheses. Outliers are marked with an asterisk. Fry outmigration was too limited in Mill Creek in 1996 to plot weekly length ranges.

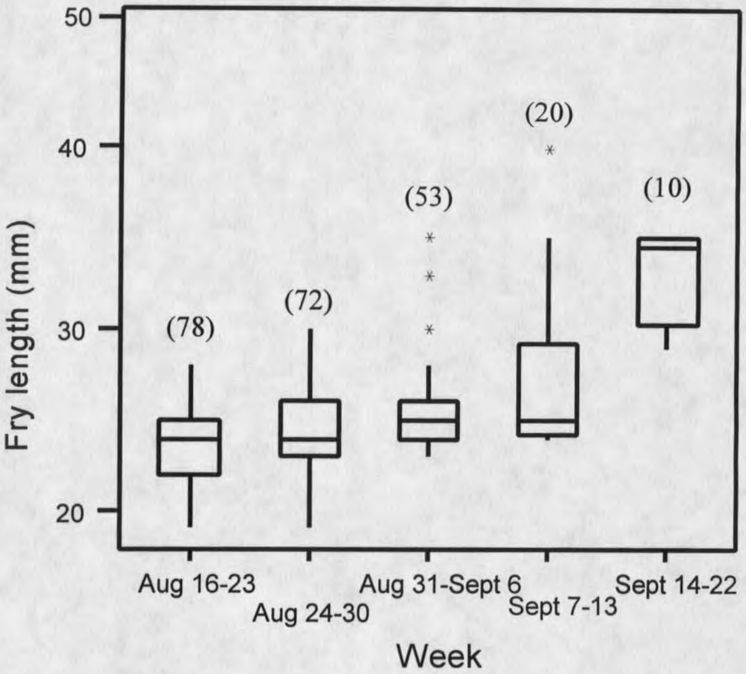

Figure 16. Weekly ranges of lengths of a random subsample of Yellowstone cutthroat trout fry captured in Mol Heron Creek, Montana, in 1997. The box defines the interquartile range (middle 50%) with a line at the median. Sample size for each week is in parentheses. Outliers are marked with an asterisk. Outmigration was trapped over too short a period in Mol Heron Creek in 1996 to plot weekly length ranges.

mm per week during the first 3 weeks of trapping and then jumped by 5 to 10 mm between weeks 4 and 6 (Figures 13-16). Individual lengths ranged from 18 mm to 40 mm during the first 3 weeks and from 29 mm to 65 mm during the last week trapped.

The Cedar Creek trap captured newly emerged fry throughout both field seasons. Ranges and trends in lengths were similar across both trapping seasons. Mean length increased by less than 1 mm per week during the 6 weeks of trapping, and never exceeded 26 mm (Figures 17 and 18). Individual fry lengths ranged from 19 mm to 29 mm during the first 3 weeks of trapping and from 20 mm to 40 mm during the last week trapped.

Trap Efficiency

The marking trials to estimate trap efficiency were inconclusive. The small sample size imposed by the 3 d minimum interval between trials, and the variability of the proportion of fry recaptured resulted in wide confidence intervals for Locke, Mill and Cedar creeks (Table 5). Confidence intervals were constructed using two standard deviations from the mean proportion recaptured as upper and lower bounds. All of the confidence intervals included zero (Table 5).

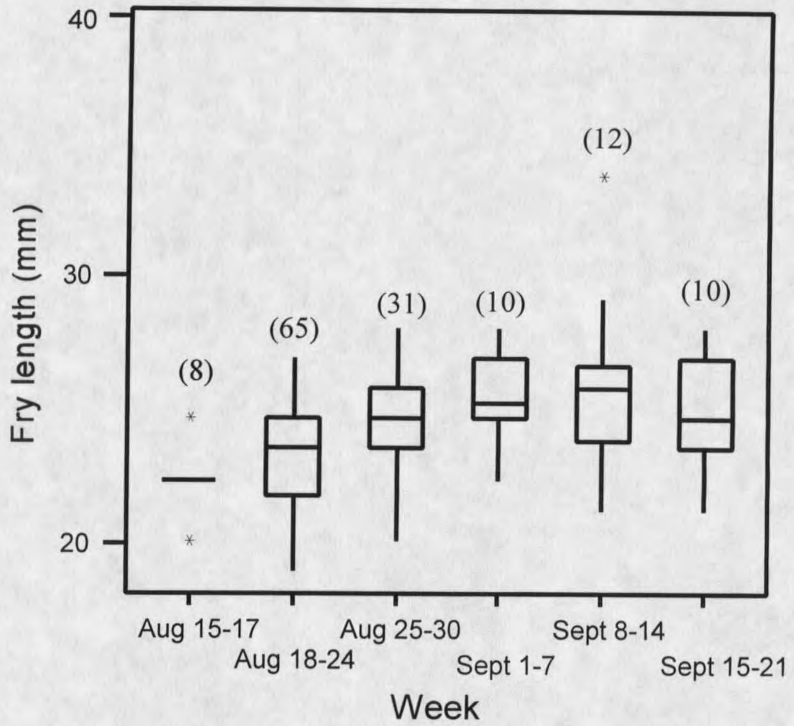

Figure 17. Weekly ranges of lengths of a random subsample of Yellowstone cutthroat trout fry captured in Cedar Creek, Montana, in 1996. Sample size for each week is in parentheses. The box defines the interquartile range (middle 50%) with a line at the median. Outliers are marked with an asterisk.

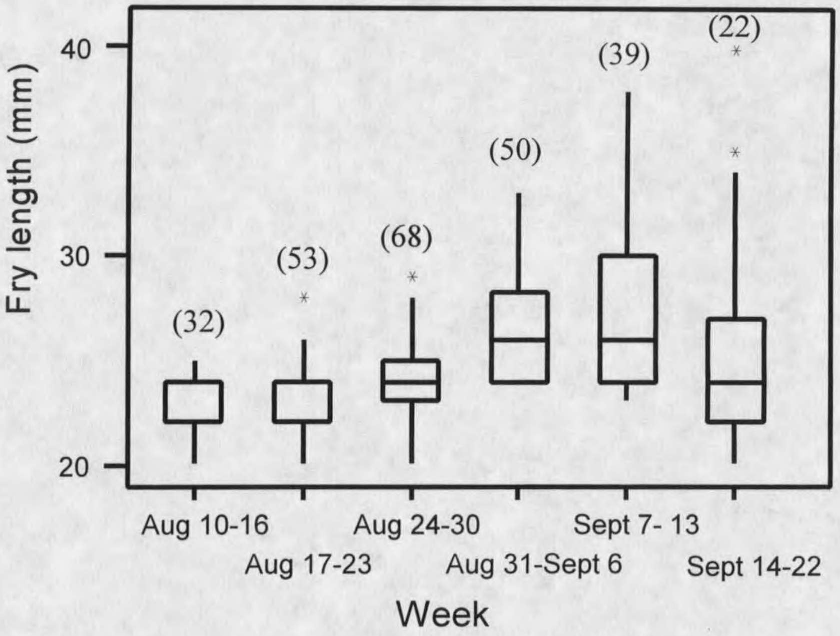

Figure 18. Weekly ranges of lengths of a random subsample of Yellowstone cutthroat trout fry captured in Cedar Creek, Montana, in 1997. Sample size for each week is in parentheses. The box defines the interquartile range (middle 50%) with a line at the median. Outliers are marked with an asterisk.

Table 5. Summary of three marking trials and the 95% confidence intervals (C.I.) for each of the four study streams used to calculate trap efficiency.

Study stream	M[a]	R[b]	p[c]	Discharge (m^3/s)	Total fry captured	95% C.I. (mean p +/- 2 S.D.)
Locke Creek	6	1	0.166	0.097	11	
	95	18	0.189	0.091	89	$0.00 < p < 0.67$
	106	54	0.509	0.090	159	
Mill Creek	6	0	0	0.807	45	
	100	19	0.190	0.892	366	$0.00 < p < 0.29$
	232	30	0.129	1.138	78	
Cedar Creek	131	14	0.107	0.089	217	
	636	358	0.563	0.069	2554	$0.00 < p < 1.00$
	916	728	0.795	0.069	2220	
Mol Heron Creek	38	0	0	1.48	98	
	86	3	0.035	1.50	76	$0.00 < p < 0.06$
	65	2	0.031	1.44	35	

[a] number marked in population
[b] number recaptured
[c] proportion recaptured

Trap efficiency estimates based on discharge were calculated as the ratio of flow sampled by the trap to the total discharge measured by each creek's staff gauge on the day when efficiency was estimated. The trap on Locke Creek sampled approximately 68% of the flow in 1997 when the discharge was 0.074 m^3/s (2.6 cfs). The traps in the large and small channels of Mill Creek sampled approximately 27% and 86% of the flow in their respective channels when total discharge was 0.62 m^3/s (22 cfs). The Cedar Creek trap sampled approximately 72% of the flow when discharge was 0.067 m^3/s (2.4 cfs). The single trap on Mol Heron Creek sampled approximately 18% of the total discharge when flows were 0.88 m^3/s (31 cfs). An efficiency estimate based on discharge for the trap in the small irrigation ditch on Mol Heron was not calculated because the channel was too shallow to use the Gurley AA meter.

Data Analysis and Model Building

Temperature Modeling

The regression of mean daily water temperature as measured by the in-stream thermographs against a combination of air temperature predictor variables from the nearest weather observation station provided reliable water temperature estimates for Locke, Cedar and Mol Heron Creeks (Figures 19-23). There was not enough water temperature data to construct a regression for Mill Creek. Of the three stream temperature prediction models developed, the Mol Heron model was the most precise, and included two predictors: maximum and minimum air temperatures (Table 6). An additional term, the previous day's minimum air temperature, improved the fit of the regressions for Locke and Cedar creeks (Table 6). In the regression equations the

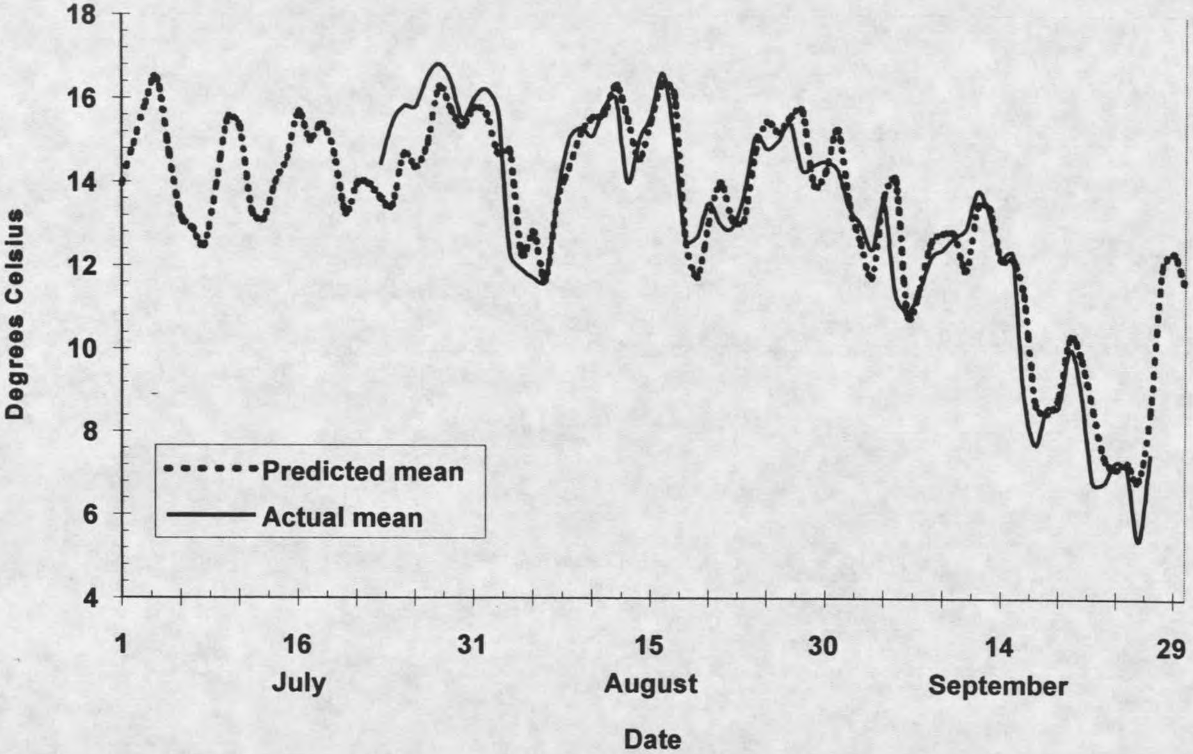

Figure 19. Actual and predicted daily mean water temperatures for Locke Creek, Montana, from July 1 to Sepember 30, 1996. Temperatures were predicted using the regression: Mean water temperature = 4.18 + 0.237 T_{max} + 0.162 T_{min} + 0.111 lagged T_{min}.

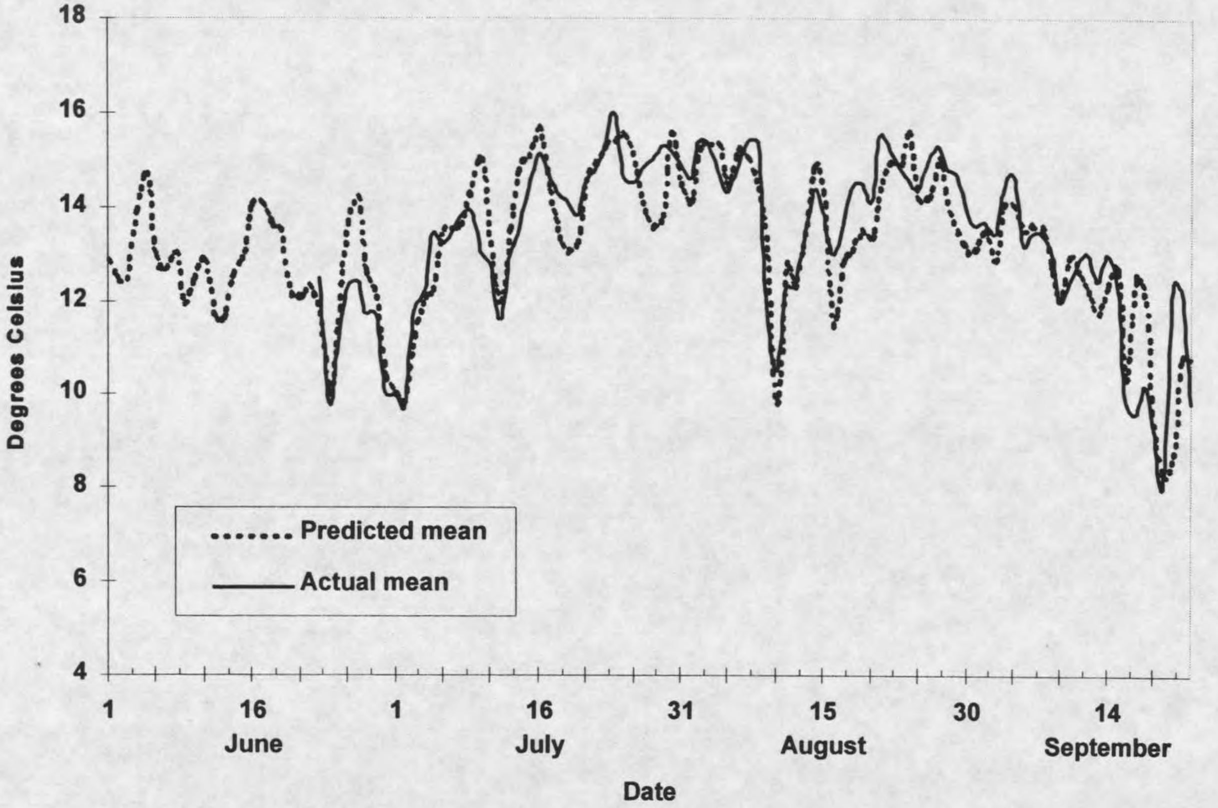

Figure 20. Actual and predicted daily mean water temperatures for Locke Creek, Montana, from June 1 to Sepember 20, 1997. Temperatures were predicted using the regression : Mean water temperature = 4.18 + 0.237 T_{max} + 0.162 T_{min} + 0.111 lagged T_{min}.

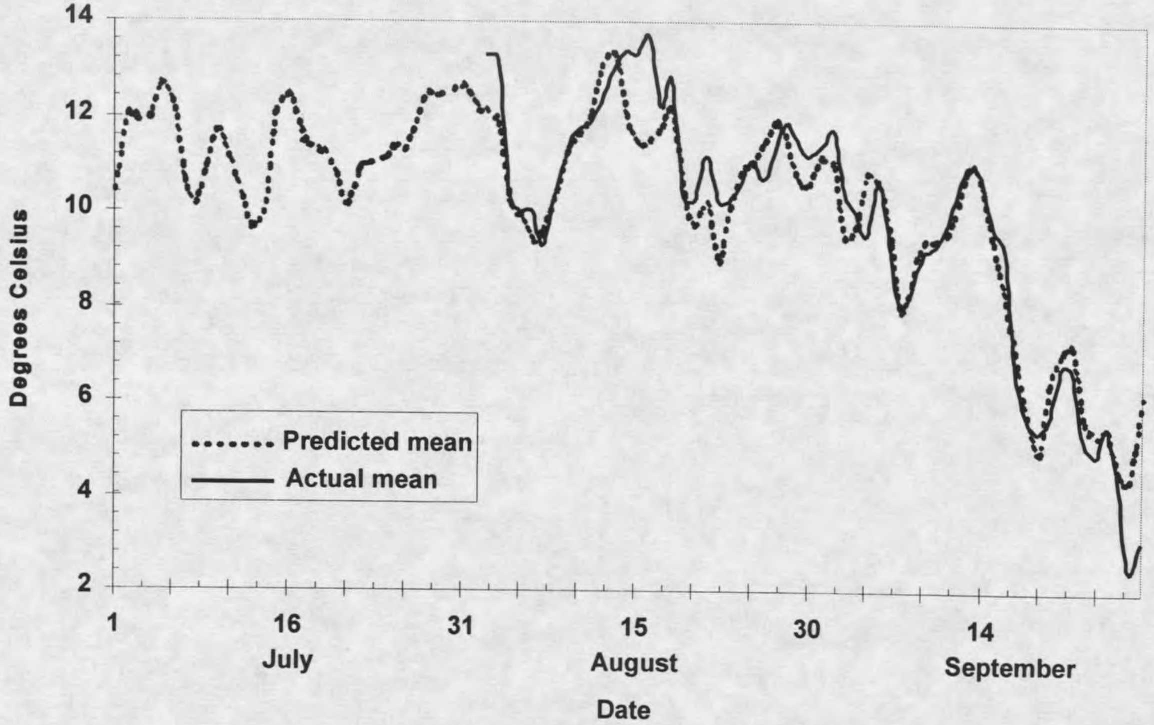

Figure 21. Actual and predicted mean daily water temperatures for Cedar Creek, Montana, from July 1 to September 28, 1996. Temperatures were predicted using the regresstion: Mean water temperature = 2.99 + 0.127 T_{max} + 0.161 T_{min} + 0.225 lagged T_{min}.

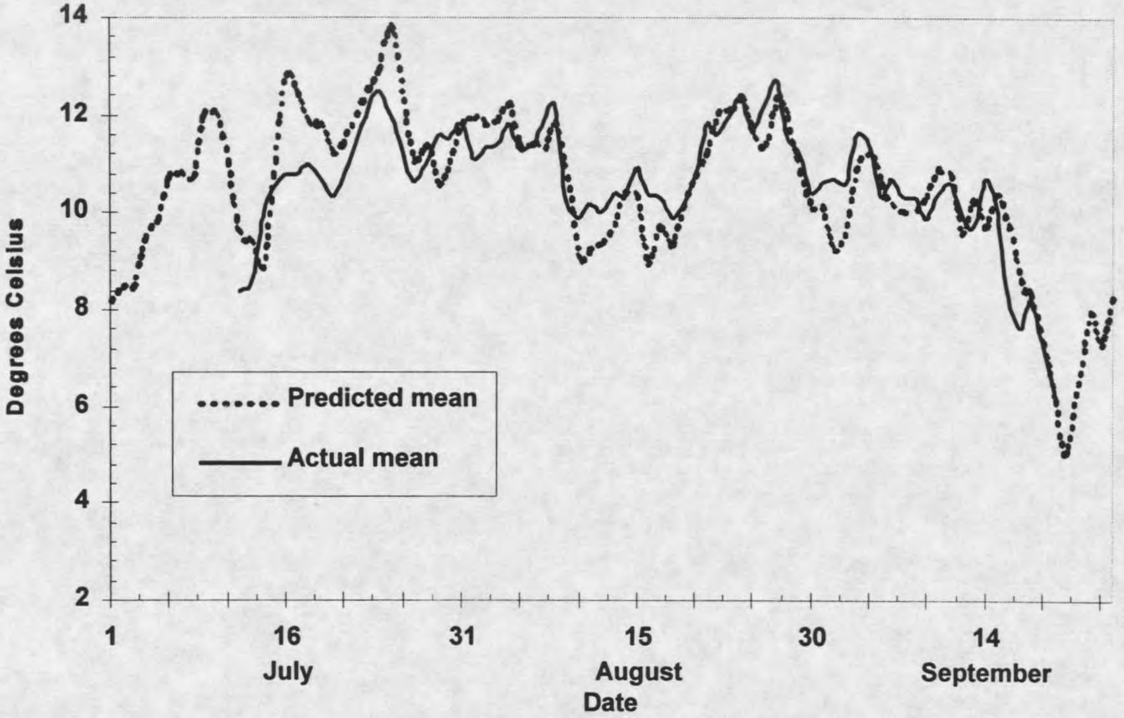

Figure 22. Actual and predicted mean daily water temperatures for Cedar Creek, Montana, from July 1 to September 28, 1997. Temperatures were predicted using the regression: Mean water temperature = 2.99 + 0.127 T_{max} + 0.161 T_{min} + 0.225 lagged T_{min}.

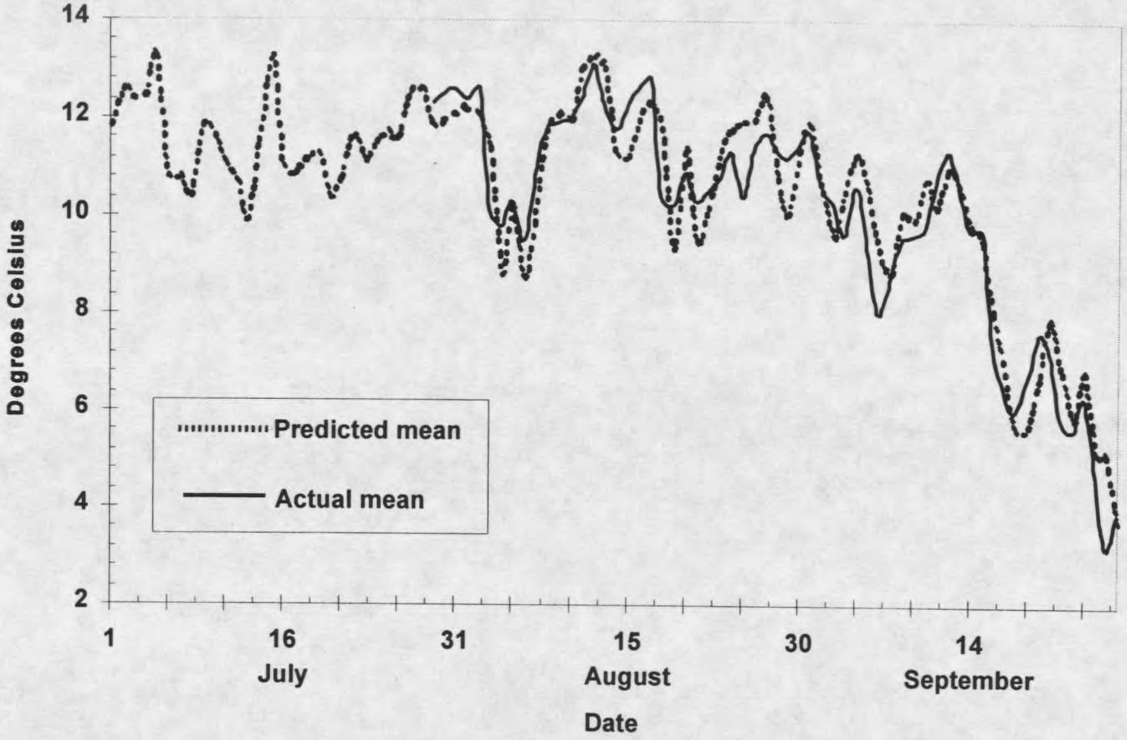

Figure 23. Actual and predicted mean water temperatures for Mol Heron Creek, Montana, from July 1 to September 29, 1996. Temperatures were predicted using the regression: Mean water temperature = 2.33 + 0.213 T_{max} + 0.218 T_{min}.

response variable and parameters were identified as:

H_2O mean = mean stream temperature (response variable)
T_{max} = maximum air temperature
T_{min} = minimum air temperature
lagged T_{min} = previous day's minimum air temperature; where

β_0, β_1, β_2 and β_3 are coefficients unique to each creek.

Table 6. Coefficients and statistical information for linear regression equations used to predict daily mean water temperatures for Locke, Cedar and Mol Heron creeks based on air temperature data from local weather observation stations. Temperature data from 1996 and 1997 were pooled for Locke and Cedar creeks.

Study stream	Locke[a]	Cedar [a]	Mol Heron [b]
df (total)	159	128	60
Intercept β_0 (se)	4.18 (0.35)	2.99 (0.35)	2.33 (0.44)
T_{max} β_1 (se)	0.237 (0.015)	0.127 (0.018)	0.213 (0.023)
T_{min} β_2 (se)	0.162 (0.022)	0.161 (0.029)	0.218 (0.034)
Lagged T_{min} β_3 (se)	0.111 (0.021)	0.225 (0.025)	-------
R^2 (adj.)	84%	86 %	90%
Maximum residual	3.66	2.17	1.87

[a] H_20 mean= $\beta_0 + \beta_1 T_{max} + \beta_2 T_{min} + \beta_3$ lagged T_{min}

[b] H_20 mean= $\beta_0 + \beta_1 T_{max} + \beta_2 T_{min}$

Mean air temperature and the range of temperatures were rejected as predictor variables because they introduced multicollinearity when used with maximum or minimum air temperatures and did not produce a better fit when used alone. The range of daily air temperatures, lagged maximum air temperature and the categorical precipitation variable did not improve the fit of the models and were dropped from consideration. As expected, the Dubin-Watson test for autocorrelation was positive, confirming that the time series nature of the data prevented independence of observations. However, cross-correlation results from the jacknife procedure showed that the coefficients were very stable, and indicates that the models are robust (SYSTAT 1997).

Predicted mean water temperatures followed actual mean water temperatures very closely for all chosen models (Figures 19-23). Adjusted R^2 values ranged from 84% to 90%, and maximum absolute values for the residuals ranged from 1.87 to 3.66 (°C) (Table 6).

Fry Outmigration Sampling Protocols

Pattern-based protocols outperformed systematic protocols in accuracy of total fry catch estimates, compared to trapping every day, minimizing the total number of days required for sampling, and consistency of the percent of outmigration sampled in all but the Mill Creek 1996 data set. Outmigration was too short, and daily trap catches were too low for any of the pattern-based protocols to identify a peak region for Mill Creek in 1996. The underlying assumption for using any of the sampling protocols to estimate fry outmigration is that the number of fry trapped in a creek is a good indicator of the number of fry moving out of the creek. The pattern in trap catch is assumed to mimic the true pattern of fry outmigration. Based on the patterns observed, a decision tree was drafted for the three chosen pattern-based protocols (Table 7). Mean estimates of fry sampled by pattern-based protocol A were closer to the totals obtained by sampling every day for Locke, Cedar and Mol Heron creeks in 1996 and 1997, and for Mill Creek in 1997 (Tables 8 and 9). Protocol precision rankings, based on width of 95% confidence intervals, were less definitive. Protocol A had the narrowest 95% confidence interval, and thus provided the most precise outmigration estimates for Locke Creek in 1996 and 1997, Cedar Creek in 1996, and Mol Heron Creek in 1997, while protocol B was most precise for Cedar Creek in 1996 and Mill and Mol Heron creeks in 1997. The number of days sampled did not differ by more than 3 d among pattern-based protocols within a creek (Tables 8 and 9).

The three systematic sampling protocols evaluated were: sample 2 d then skip 2 d, sample 3 d then skip 2 d, and sample 3 d then skip 3 d (Tables 10 and 11). Systematic protocols with greater than a 3 d skip interval showed a marked decrease in precision and were not used in the final comparisons. The mean percent of actual trap catch sampled for a data set was equal to the proportion of the monitoring period sampled, but individual estimates of percent sampled within a data set varied considerably (Tables 10 and 11). No one systematic protocol was most precise for a majority of the data sets, and the standard deviation of the best systematic protocol for a given data set was always at least 2 times greater than that for the best pattern based protocol.

Table 7. Decision tree for the three pattern-based protocols applied to actual and simulated fry outmigration trap catch data from each of the four study streams for 1996 and 1997.

Protocol	A	B	C
Ascending limb	Sample 2 d, then skip 2 d, repeat. After the first successful trapping day, begin calculating a 3 d running mean.		
Decision rule	When trap catch exceeds 1.5 times the previous 3 d mean, or is greater than 50 fry, go to peak region sampling.	When trap catch exceeds 2 times the previous 3 d mean, or is greater than 50 fry, go to peak region sampling.	
Peak region	Sample next 10 d.	Sample next 10 d, skip 2 d, sample next 5 d, stop.	Sample next 5 d, skip 2 d, sample 5 d, skip 2, sample 5 d, stop.
Descending limb	If 11th day's trap catch is greater than 0.25 times the previous 3 d mean, sample next 5 d. If 11th day's trap catch is less than 0.25 times the previous 3 d mean , stop.	no sampling	no sampling

Table 8. Comparison of the number of fry sampled by pattern-based protocols, mean percent of the total outmigration sampled, and the upper and lower bounds of 95% confidence intervals for Locke and Mill creeks. Protocols were applied to actual and simulated fry trap catch data. Mean percent sampled and bounds for 95% confidence intervals were calculated using an arcsine transformation. Outmigration in Mill Creek in 1996 was not estimated using the pattern based protocols.

Pattern -based protocols		Study stream			
		Locke		Mill	
Protocol	Parameter	1996	1997	1996	1997
Sample every day	Total estimate of fry sampled	909	1,850	54	2,295
	Days sampled	62	77	31	51
A (Table 7)	Mean estimate of fry sampled	649	1,538		1,996
	Mean % sampled (n)	71 (4)	83 (4)		87 (4)
	95% CI lower bound	61	81		75
	95%CI upper bound	81	85		95
	Days sampled	27	28		20
B (Table 7)	Mean estimate of fry sampled	527	1,314		1,699
	Mean % sampled (n)	58 (4)	71 (4)		74 (4)
	95% CI lower bound	38	66		69
	95%CI upper bound	76	76		79
	Days sampled	26	27		19
C (Table 7)	Mean estimate of fry sampled	591	1,277		1,584
	Mean % sampled (n)	65 (4)	69 (4)		69 (4)
	95% CI lower bound	48	58		48
	95%CI upper bound	81	79		87
	Days sampled	27	27		19

Table 9. Comparison of the number of fry sampled by pattern-based protocols, mean percent of the total outmigration sampled, and the upper and lower bounds of 95% confidence intervals for Cedar and Mol Heron creeks. Protocols were applied to actual and simulated fry trap catch data. Mean percent sampled and bounds for 95% confidence intervals were calculated using an arcsine transformation.

Pattern -based protocols		Study stream			
		Cedar		Mol Heron	
Protocol	Parameter	1996	1997	1996	1997
Sample every day	Total estimate of fry sampled	18,988	26,176	2,693	1,199
	Days sampled	53	47	42	46
A (Table 7)	Mean estimate of fry sampled	17,375	23,140	2,360	1,082
	Mean % sampled(n)	92 (4)	89 (4)	88 (4)	90(4)
	95% CI lower bound	89	73	75	86
	95% CI upper bound	94	98	97	94
	Days sampled	25	21	22	22
B (Table 7)	Mean estimate of fry sampled	15,054	19,090	2,320	975
	Mean % sampled (n)	79 (4)	73 (4)	86 (4)	81(4)
	95% CI lower bound	73	69	77	69
	95% CI upper bound	98	76	93	91
	Days sampled	24	20	21	21
C (Table 7)	Mean estimate of fry sampled	13,074	17,158	1,823	838
	Mean % sampled (n)	69 (4)	66 (4)	68 (4)	70 (4)
	95% CI lower bound	82	55	23	51
	95% CI upper bound	54	75	98	86
	Days sampled	24	20	19	21

Table 10. Comparison of the number of fry sampled by systematic protocols, mean percent of the total outmigration sampled, and the upper and lower bounds of 95% confidence intervals for Locke and Mill creeks. Protocols were applied to actual and simulated fry trap catch data. Mean percent sampled and bounds for 95% confidence intervals were calculated using an arcsine transformation.

Systematic protocols		Study stream			
		Locke		Mill	
Protocol	Parameter	1996	1997	1996	1997
Sample every day	Total estimate of fry sampled	909	1,850	54	2,295
	Days sampled	62	77	31	51
Sample 2d, skip 2 d	Mean estimate of fry sampled	454	923	27	1,148
	Mean % sampled (n)	50 (4)	50 (4)	50 (4)	50 (4)
	95% CI lower bound	28	42	1	21
	95% CI upper bound	72	58	99	79
	Days sampled	32	39	18	25
Sample 3d, skip 2d	Mean estimate of fry sampled	546	1,110	32	1,377
	Mean % sampled (n)	60	60	61	60
	95% CI lower bound	36	53	1	26
	95% CI upper bound	82	67	98	97
	Days sampled	37	45	19	30
Sample 3d, skip 3d	Mean estimate of fry sampled	455	923	27	1,148
	Mean % sampled (n)	50	50	55	50
	95% CI lower bound	30	43	5	37
	95% CI upper bound	70	57	98	63
	Days sampled	30	38	15	26

Table 11. Comparison of the number of fry sampled by systematic protocols, mean percent of the total outmigration sampled, and the upper and lower bounds of 95% confidence intervals for Cedar and Mol Heron creeks. Protocols were applied to actual and simulated fry trap catch data. Mean percent sampled and bounds for 95% confidence intervals were calculated using an arcsine transformation.

Systematic protocols		Study stream			
		Cedar		Mol Heron	
Protocol	Parameter	1996	1997	1996	1997
Sample every day	Total estimate of fry sampled	18,988	26,176	2,693	1,199
	Days sampled	53	47	42	46
Sample 2d, skip 2 d	Mean estimate of fry sampled	9,304	13,088	1,347	600
	Mean % sampled (n)	49 (4)	50 (4)	50 (4)	50(4)
	95% CI lower bound	31	31	4	32
	95% CI upper bound	66	69	96	68
	Days sampled	26	24	21	25
Sample 3d, skip 2d	Mean estimate of fry sampled	11,393	15,706	1,616	719
	Mean % sampled (n)	60 (5)	60 (5)	60 (5)	59 (5)
	95% CI lower bound	46	53	18	52
	95% CI upper bound	74	66	98	67
	Days sampled	32	28	24	22
Sample 3d, skip 3d	Mean estimate of fry sampled	9,494	13,349	1,131	611
	Mean % sampled (n)	50 (6)	51 (6)	42 (6)	51 (6)
	95% CI lower bound	41	41	12	43
	95% CI upper bound	59	60	75	60
	Days sampled	30	38	15	26

Accurately identifying the beginning of the peak region and sampling as many days as possible during the peak provided the most precise results. Sampling during the descending limb did not improve precision; therefore, pattern-based protocols sampled fewer days than the systematic protocols.

From 76% to 96% of the total trap catch fell within the peak region of fry outmigration for each creek in both years (Table 12). Peak region periods ranged from 6 to 17 d. Average combined percent of total trap catch from the ascending and descending limbs was less than 13%. Ascending limb periods ranged from 0 to 14 d. Descending limb periods ranged from 4 to 17 d.

Table 12. Number of days and percent of total trap catch in the peak region, ascending limb and descending limb for each of the four study streams, 1996 and 1997.

Study stream	Locke Creek		Mill Creek		Cedar Creek		Mol Heron Creek	
Year	1996	1997	1996	1997	1996	1997	1996	1997
Peak region (days)	8	16	6	17	11	14	6	17
% of total trap catch	76	80	89	82	95	91	96	95
Ascending limb (days)	6	14	13	5	8	13	0	7
% of total trap catch	15	4	11	<1	3	2	0	2
Descending limb (days)	22	26	6	27	5	14	4	12
% of total trap catch	9	16	0	17	2	7	4	3

Flushing Flows

All irrigation diversions on Mill Creek were closed at approximately 0600 hours on August 21 and reopened by 0700 hours on August 23, 1996. Discharge at the East River Road bridge increased from 0.66 m^3/s to 1.2 m^3/s by noon on August 21. Discharge had declined to pre-flush levels by 1000 hours on August 24. No fry were captured in the trap near the East River Road bridge, the farthest upstream of the three traps. A total of 8 fry (14% of the total for 1996) were trapped throughout the 1996 flushing flow. The first two fry were captured in the downstream trap at 2300 hours on August 21. Another five fry were captured in this trap between 2315 and 0300 hours the next morning. One fry was captured between 0315 and 0620 hours. No additional fry were captured after 0635 hours on August 22.

In 1997, the Mill Creek flush began at approximately 0700 hours on August 25 and ended at 1800 hours on August 26. Discharge increased from 1.14 m^3/s to 1.81 m^3/s by 1000 hours on August 26. Discharge had declined to 78% (0.89 m^3/s) of the pre-flush level by 1000 hours the next day. Since fry were not captured upstream of the regular trap site in 1996, no additional traps were set during the 1997 flush. A total of 134 fry (6% of the total for 1997) were trapped in the overnight set from 1100 hours on August 25 to 0800 hours on August 26. Only 17 of these fry were captured in the smaller channel trap. The trap in the larger channel was tampered with and effectively disabled sometime after resetting on August 26; however, it still caught seven fry. The trap on the smaller channel was untouched and also held seven fry on the morning of August 27.

DISCUSSION

The main objectives of this study were to assess how existing water leases affect Yellowstone cutthroat trout fry recruitment, review potential benefits of proposed water leases, and recommend sampling protocols for future recruitment estimates. During the dry summer of 1996, the water leases on Mill and Cedar creeks were particularly important to fry recruitment. In August of 1996, 10 of the 19 marked redds in Cedar Creek were dewatered, and would have remained dewatered if the lease had not been in effect. Once the 1996 lease level, 0.028 m^3/s (1.0 cfs), was restored, discharge was high enough to cover 90% of the marked redds and convey outmigrating fry to the Yellowstone River. This confirms Byorth's (1990) findings that discharge below 0.035 m^3/s (1.2 cfs) dewaters redds, and supports the proposed change in lease level to 0.04 m^3/s (1.4 cfs).

Discharge levels in Mill Creek during the 1996 fry outmigration dropped to less than 0.19 m^3/s (6.8 cfs) above the lease level of 0.25 m^3/s (8.8 cfs). Without the water leases, the lower portion of Mill Creek would have been dry or nearly dry. Discharge continued to decrease throughout August 1996, and at its lowest level was only 0.04 m^3/s (1.4 cfs) above the lease level. Although the timing of this low discharge did not overlap with the 1996 fry outmigration, if similar flow levels had occurred in 1997 when fry outmigration extended to late August, outmigrating fry would have been negatively affected.

The 1996 and 1997 water lease flushing flows were effective at moving fry out of Mill Creek and into the Yellowstone River. The function of the flush is to move recently emerged fry out of Mill Creek before irrigation withdrawals create extremely low flow conditions; therefore, its timing should correspond with the end of the peak region and the start of the descending limb of fry outmigration. If the flush is effective, fry outmigration, measured by trap catch, should decline after the flush. In 1996, measurable fry outmigration dropped to zero following the flushing flow on Mill Creek. In 1997, trap catch during the flush remained high, fluctuated for 4 to 5 d afterwards, and then dropped to near zero (Figure 10). Median fry length during the week of the flush was 25 mm, and 27 mm the week after (Figure 15), indicating that fry were continuing to emerge from redds in late August. The observed pattern of outmigration (Figure 10), and the size of the fry trapped suggest that the flush might have been more effective if it had been postponed 2 or 3 d in 1997. A natural flush caused by a thunderstorm on the night of September 11, 1997 (Figure 6), provided more information on Yellowstone cutthroat trout fry emergence and outmigration. After 8 d (September 4 to 11) of unsuccessful trapping on Mill Creek, trap catch increased to 38 fry on September 12, and 21 more fry were caught from September 13 to 15, 1997 (Figure 10). Median fry lengths for these trap catches were greater than during the rest of the outmigration period (Figure 15), indicating that some fry do not immediately outmigrate to the Yellowstone River.

Yellowstone cutthroat trout fry outmigration has been monitored at least once during the past 10 years in three of the four study streams, and all have been surveyed for spawning adults (Clancy 1984, 1985; Byorth 1990; Shepard 1992); (Table 13). Clancy (1984) reported only four Yellowstone cutthroat trout spawners captured during a 1983 spawning survey near of the mouth of Mill Creek. In contrast, 39 Yellowstone cutthroat trout spawners were captured in Mol Heron Creek and 118 in Cedar Creek during the same year, and 27 in Locke Creek in the following year. The 4,000% increase in trap catch from 1996 to 1997 (Table 13) suggests that the water lease, which ended decades of chronic dewatering of Mill Creek, has improved spawning, egg incubation and fry outmigration conditions. Yellowstone cutthroat trout originating from fry and egg plants made during 1994 would have reached the threshold spawning age in 1997 (Benson 1960; Varley and Gresswell 1988), and the increase in fry outmigration numbers may be the result of these adults returning to Mill Creek to spawn. Although unlikely, straying of Yellowstone cutthroat trout adults into Mill Creek cannot be dismissed as a possible explanation for the increase in spawning success. If this occurred, perhaps in association with the unusually high flows in 1997, the number of outmigrating fry should increase dramatically during 2000 when the 1997 year class reach spawning age. If the year class from the 1994 egg and fry plants was responsible, the number of spawners, and potentially of outmigrating fry would be expected to increase over the next 2 years since Yellowstone cutthroat trout are often repeat spawners and the average spawner is closer to age 4 or 5 (Benson 1960; Varley and Gresswell 1988).

Table 13. Summary of previous fry trapping in Locke, Cedar and Mol Heron creeks, and the catch per unit effort (CPUE) for each study.

Site	Year	Reference	Number of fry trapped	Total days trapped	CPUE (fry trapped per day)
Locke Creek	1997	This study	1,844	56	33
	1996		674	26	26
	1991	Shepard (1992)	972	6	162
Cedar Creek	1997	This study	25,781	41	629
	1996		13,251	24	552
	1991	Shepard (1992)	2,572	8	322
	1990		5,534	11	503
	1989	Byorth[a] (1990)	2,000	---	no estimate
	1988		14,000	---	no estimate
Mol Heron Creek	1997	This study	1,128	35	32
	1996		1,865	10	187
	1991	Shepard (1992)	11	8	1
	1990		1,199	11	109

[a] Number of fry was estimated using emergence traps placed directly over marked redds instead of outmigration trapping.

Locke and Mol Heron creeks maintained discharge levels high enough to meet Yellowstone cutthroat trout egg incubation and fry outmigration needs during both field seasons. Despite unusually high discharge levels, numbers of fry trapped in Locke and Mol Heron creeks during this study were above or within the range observed by other investigators (Shepard 1992); (Table 13).

Locke Creek is one of only three high quality spawning tributaries located between the Mill Creek and Springdale sections (Figure 1), a distance of approximately 40 km (25 mi); (Clancy 1988). Yellowstone cutthroat trout recruited from Locke Creek are important to this portion of the population because most will rear, live their life, and spawn within the section of river nearest their natal stream (Clancy 1988; Gresswell 1995).

The Corwin Springs section (Figure 1) maintains the highest Yellowstone cutthroat trout density in the Yellowstone River (Figure 2). Recruitment in this section also depends upon spawning success in a limited number of tributaries (Clancy 1988). If discharge levels in Mol Heron Creek are not protected, Yellowstone cutthroat trout recruitment to the Corwin Springs section would be primarily dependent upon conditions in Cedar Creek in drought years.

Platts and Nelson (1988) showed that populations of age 0 trout in the Northern Rockies and Great Basin exhibit large annual fluctuations in number and biomass. The Yellowstone cutthroat trout population that Platts and Nelson (1988) surveyed fluctuated between 126 and 288 % annually. Any long term monitoring program must take into account the range of fluctuation inherent in local populations when considering management decisions. A single season's data does not provide much information when removed from the context of the population's natural variability. Changes in the pattern of fluctuation, often not identified until several years of data are collected, can be more informative (Platts and Nelson 1988). If fry outmigration is to be used to evaluate the water leases' effect on Yellowstone cutthroat trout recruitment, then monitoring will have to be done consistently and repeatedly.

Annual variation in stream temperature and discharge affected the timing of fry outmigration from each study stream. However, across the four study streams and the two field seasons, the pattern of the proportion of fry leaving a creek on a given day once outmigration had begun was similar, and the majority of outmigration was concentrated in a short time. Structuring sampling plans to take advantage of this natural pattern not only saves time and money, it also provides a better index of recruitment than a random sample of the same number of days (Tables 8-11). A shorter, pattern-based sample period would make studying long term trends in Yellowstone cutthroat trout fry recruitment more feasible. Fry recruitment trends could be compared to studies of adult year class strengths from the annual electrofishing surveys to examine juvenile survival and identify where early life history bottlenecks occur.

Using a pattern-based sampling protocol is better than sampling randomly, but only if the pattern of outmigration is established first, as it was in my study, by sampling the entire outmigration period. The protocols suggested in this study should work well for the four study streams in the Yellowstone River in average to high water years, and may be applicable to other tributary streams in the upper Yellowstone basin. Low water years are associated with poorer recruitment (Clancy 1988; Byorth 1990), and trapping the full outmigration period during at least one low flow year would expand the inference space for these sampling protocols. The inability of the pattern-based protocols to detect a peak region, and the wide 95% confidence intervals of the systematic protocol estimates for the 1996 fry outmigration in Mill Creek (Table 10) demonstrates that in extremely poor recruitment years, more intensive sampling may be required to adequately monitor outmigration.

Detecting fry as they leave each creek is the key to estimating spawning success. Trap placement and timing influence the overall quality of final fry recruitment estimates. In the 2 years of my study only one trap was placed in the same location for both field seasons. Spring discharge changed the topography of the streambed each year in the four study steams, and thus affected trap placements. Moving the Mol Heron Creek trap away from the thalweg to reduce trap mortality seemed to dramatically reduce trap efficiency. At a smaller scale, variations in daily discharge affect the quantity of water flowing through the trap, the rate of flow and the location of the fastest current. Pink salmon fry (*Oncorhynchus gorbuscha*) are similar in size at emergence and in outmigration behavior to Yellowstone cutthroat trout fry, and have been shown to congregate in faster current during outmigration (Heard 1991). This suggests that placing a trap in the thalweg should provide the highest trap efficiency. However, if fry are moving downstream at densities proportional to the flow in a cross section of the creek, any shift in the thalweg of the stream should result in a change in the lateral distribution of fry. Since the trap cannot move in response to changes in flow, the proportion of water and of fry sampled by the trap changes. Based on the wide 95% confidence intervals (Table 5) for trap efficiency on each of the four study streams and the variation in flow throughout the sampling period, a single estimate of trap efficiency is not reliable for converting total trap catch to total outmigration estimates. Using more traps or modifying existing traps to sample a greater proportion of the flow might increase total efficiency, but efficiency would still vary over time, and from trap to trap. Both systematic and pattern-based protocols assume that trap catch is indicative of total fry outmigration, but the pattern-based protocols adapt sampling effort as outmigration progresses to maximize the information gained for each day sampled. The pattern-based sampling protocols provide an index of the number of outmigrating fry, not an exact estimate. However, the reliability of estimates obtained by using protocol A is high for the amount of effort invested, and should be adequate for monitoring recruitment over time.

Determining the timing of spawning in each tributary is important to predicting when outmigration will begin, and thus when to begin sampling. However, high water in both study years created extremely turbid conditions that precluded sighting spawning fish in Locke and Mill creeks. Yellowstone cutthroat trout spawn after peak spring runoff when stream temperatures approach 10 to 14 °C (Clancy 1984, 1985; Byorth 1990). Since temperatures warm and runoff peaks sooner in lower elevation areas, spawning occurs earlier in creeks such as Locke and Mill, than in higher elevation creeks. Turbidity from runoff in Locke and Mill creeks may be an obstacle to verifying spawning time visually in average to high runoff years. The water temperature prediction models for each creek are intended to act as a low cost back up for estimating spawning times. Since these models do not require field time, water temperature estimates can be made without driving to the study site each day. Individual stream temperature models predicted mean water temperatures to within +/-3.66 °C which should be adequate for estimating when to begin monitoring creeks for spawning Yellowstone cutthroat trout. Confidence in water temperature estimates is reinforced by the stability of the coefficients, established by cross-correlation of the models.

Using the temperature models to narrow the range of days when spawner observations should be attempted would reduce the total field effort needed to begin tracking accumulated Celsius thermal units (CTU) to predict fry emergence (Piper et al. 1982; Kelly 1993). If turbid conditions precluded sighting spawners, or if spawning monitoring could not be done because of budget constraints, the temperature prediction models could be used to estimate the time of spawning for CTU calculations and estimating emergence. In order to ensure trapping the onset of fry outmigration during my study, fry trapping was started early and conducted for up to 2 weeks in each creek before fry were caught. If spawning had been observed, or its timing estimated using the temperature prediction models, then the initial days of outmigration might have been more accurately predicted and less trapping effort wasted. Detecting the beginning of the peak region is the critical element in all of the pattern-based protocols. As long as trapping begins during the ascending limb (Figure 4), protocol A's reliability is not diminished. The temperature prediction models are meant to help select the first trapping day, thus avoiding unnecessary effort and reducing the total number of sampling days for protocol A.

Direct application of the temperature prediction models or the fry outmigration sampling protocols is limited to the creeks for which each model was developed. However, if one or more years is invested to confirm the relationships described here, then either model may be parameterized and applied to other streams. In addition, the outmigration models would benefit from periodic testing against sampling every day to confirm that the patterns observed in 1996 and 1997 were not anomalous. Constructing a stream temperature prediction model for other creeks would require collecting data for at least 1 year and locating a permanent weather observation station, or other reliable source for air temperature data, near the study site. However, the benefit of being able to track temperatures in remote streams without traveling periodically to the site to download information from a thermograph would make the time invested in constructing a model worthwhile. These temperature prediction models are meant to be used during the spring and summer to predict spawning times and their accuracy has not been tested during winter conditions.

Management Recommendations

The water leases on Mill and Cedar creeks have tested the effectiveness of augmenting seasonal instream flows as habitat improvement. Montana's water leasing program has served as an example for other western states faced with increasing water demands, and created opportunities for landowners, MDFWP, and conservation organizations to preserve fish populations and relations among varied land users. The cost of the leases is considerable, but is less expensive than purchasing water rights and removing agricultural land from use. Other states, such as California, have found that the economic value of instream water used for fisheries benefit and recreation activities was comparable to that used for agriculture (Loomis and Creel 1992). MDFWP has made an investment in the water leasing program and should continue to monitor fry outmigration in creeks with active water leases in order to justify that investment. Specific management recommendations based on this study include:

1. Use protocol A (Table 7) to monitor fry outmigration in Locke, Mill, Cedar and Mol Heron creeks.
2. Test the reliability and precision of protocol A (Tables 8 and 9) by double sampling for at least one outmigration season.
3. Use the stream temperature prediction models (Table 6) to estimate spawning times, best times to begin fry trapping, and as a back up for remote stream temperature data collection.
4. Test the stream temperature prediction models for accuracy in predicting temperatures during the early spring season and at lower discharge levels.
5. Continue to refine the timing of the Mill Creek flushing flow to better correspond with the end of the peak region and the beginning of the descending limb of fry outmigration.
6. Enforce existing water leases, particularly in low water years, to protect incubating Yellowstone cutthroat trout eggs and allow fry to outmigrate to the Yellowstone River, and renew the leases on Mill and Cedar creeks (Table 1) for the maximum allowable period.
7. Complete the Future Fisheries Fund project to increase flows on Locke Creek by improving irrigation efficiency to ensure that in drought years, at least one of the three lower tributaries successfully recruits Yellowstone cutthroat trout fry.

8. Finalize the MDFWP lease with the Church Universal and Triumphant to protect future spawning runs on Mol Heron Creek, and verify the minimal lease level of 0.14 m^3/s (5 cfs) as adequate to cover incubating eggs before it becomes part of the agreement. Although fry losses to the irrigation ditches were not extreme, rebuilding or modifying the irrigation headgates to prevent losses would be prudent since the lease agreement includes renovating the irrigation system to increase its efficiency.

APPENDICES

APPENDIX A

A FRY TRAP SUITABLE FOR USE IN SMALL STREAMS

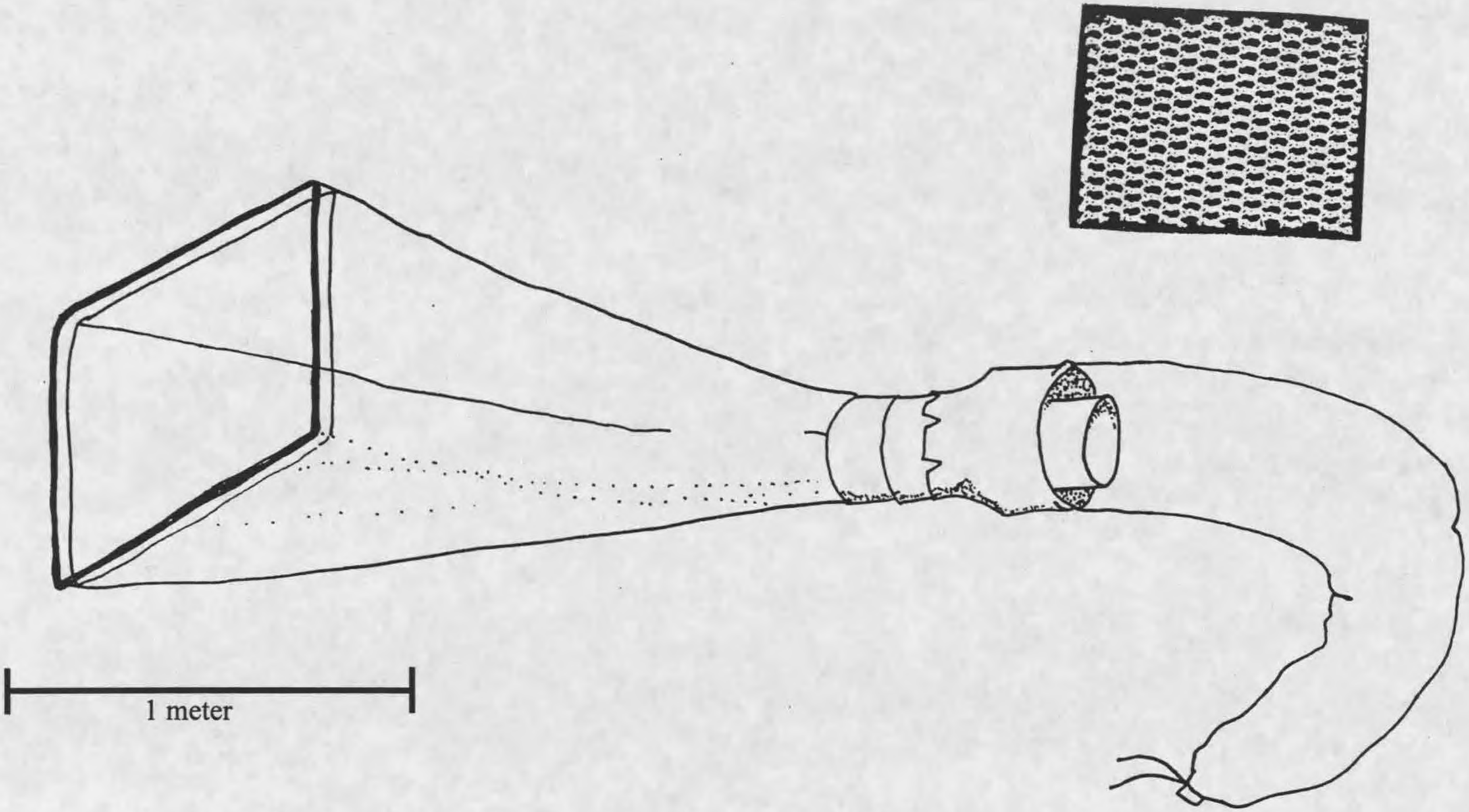

Figure 24. A fry trap suitable for use in small streams. Insert shows actual mesh size (1.6 mm) used for front and tail of trap.

APPENDIX B

USE OF BISMARCK BROWN Y DYE AS A SHORT-TERM FRY MARKER

A short-term marking method that could readily be completed in the field was needed for the marking trials for this study. An experiment was designed to determine the minimal concentration and exposure time for detectible coloration of fry lasting 1 to 4 d using Bismarck Brown Y dye. The experiment was conducted at the Bozeman Fish Technology Center using 25 to 45 mm rainbow trout fry as subjects and stream fed tanks divided into 3 sections as containers.

Concentrations and exposure times (Table 14) were based on similar experiments conducted by Lawler and Fitz-Earle (1968), and Ward and Verhoeven (1963) in which Bismarck Brown Y was evaluated as a marker for durations of 7 to 13 d. In this study, concentrations were lower and exposure times were shorter than those used by either author.

Samples of 100 fry were immersed in 1 L dye baths of differing dye concentrations for 1 to 2 h (Table 14). Control fry were placed in a 1 L bath of stream water for identical intervals. Fry were then removed to randomly assigned tank sections for 4 d. Ten dyed fry were randomly selected each day and compared with 10 control (undyed) fry. The number of dyed fry from the random sample that were distinguishable from undyed were recorded as well as a subjective dye retention ranking for each fry. Dye retention was ranked from 1 to 5 with higher rankings assigned to fry that retained more dye, and were easier to distinguish from undyed fry. Mortalities from each dye lot and controls were recorded daily. Initial mortalities due to dye exposure were recorded during the dye immersion and 1 h recovery period after removal from the dye bath.

Table 14. Summary of dye treatments, total mortalities and dye retention after 4 d for the Bismarck Brown Y dye retention study conducted at the Bozeman Fish Technology Center in January of 1997.

Dye concentration	Immersion time (hours)	Number of replicates	Total number of fry treated	Total mortalities	Mean dye retention on day 4[a]
1: 15,000	1	3	300	13	3.83
1: 30,000	1	3	300	4	3.43
1: 30,000	2	2	200	2	3.90
1: 60,000	2	1	100	1	2.5
Control (no dye)	1	3	300	8	1.65
Control (no dye)	2	1	100	2	1.20

[a] Dye retention was ranked on a scale of 1 to 5 as compared to undyed fry with 1= undistinguishable from undyed fry and 5 = easily distinguishable from undyed fry.

Dye retention declined steadily in treated fry, and fry from the 1:60,000 treatment were barely distinguishable from control fry by day 4 (Figure 25). Fry appeared to absorb dye in their fins, which made detecting them easier against a white background, such as a plastic bucket. A concentration of 1:30,000 and a 1 h immersion time was chosen for use in the marking trials during the field study because this combination yielded the best retention for the shortest immersion time, and had low associated mortality (Table 14).

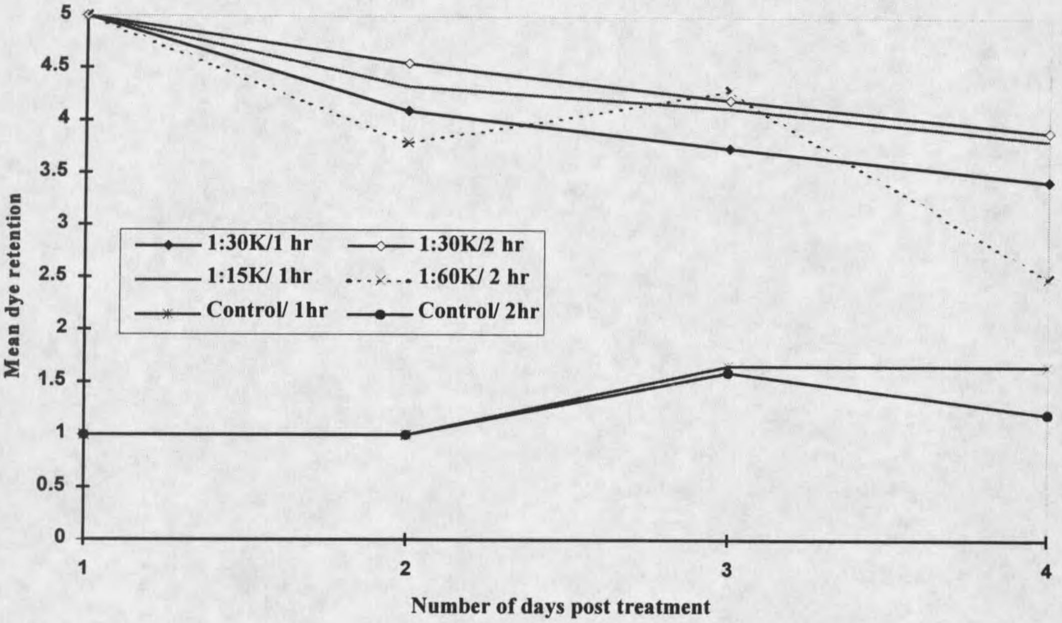

Figure 25. Mean Bismarck Brown Y dye retention by treatment for a random sample of 10 rainbow trout fry taken from each treatment tank and compared to undyed fry. Dye retention was ranked from easily distinguishable (5) to not distinguishable (1).

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