ENTRAINMENT LOSSES OF WESTSLOPE CUTTHROAT TROUT INTO SCREENED AND UNSCREENED IRRIGATION CANALS ON SKALKAHO CREEK, MONTANA

by

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ABSTRACT

Irrigation canals are known to entrain anadromous and potamodromous salmonids of all life stages during their annual migrations. Fish screens may reduce or eliminate entrainment, but few studies exist on their benefits and these have evaluated effects on anadromous populations only. Prior to my study, none existed on the benefits of fish screens for non-anadromous salmonids. Large numbers of post-spawn adult and downstream migrant juvenile westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) are potentially entrained into the seven irrigation canals on Skalkaho Creek, a tributary of the Bitterroot River. I quantified entrainment rates into the canals using telemetry and trapping before (2003) and after (2004) installation of three fish screens. I also examined the efficacy of the screens in returning downstream migrants to the stream. No telemetered adults were entrained in 2003, but most were residents and therefore did not migrate past the canals. In 2004, 79% of the telemetered adult migratory fish were entrained at either screened or unscreened canals, but all adults entrained in screened canals were successfully bypassed back to Skalkaho Creek. Only eight of 117 telemetered age-1 juveniles were entrained, whereas the others were residents and did not migrate. Only one of three age-1 juveniles entrained in 2004 was bypassed. The low number of migratory adult fish and age-1 juveniles I was able to telemeter suggests that the non-migratory, resident life history is now being selected for in this system, but screens should reverse this process. Downstream movement of age-0 westslope cutthroat trout in Skalkaho Creek increased their risk of entrainment. The Highline Canal entrained about 71% of age-0 westslope cutthroat trout moving downstream in 2003. If not for the screen to bypass them in 2004, 38% would have been entrained in the Highline Canal. A total of 6,049 age-0 westslope cutthroat trout were bypassed by all three screens. Most age-0 westslope cutthroat trout entrained at screened canals were successfully bypassed, whereas those entrained at unscreened canals were lost to the population. Fish screens were an effective management tool to reduce or eliminate entrainment at Skalkaho Creek and may be useful elsewhere to eliminate entrainment of inland salmonids.

INTRODUCTION

Irrigation canals are known to entrain anadromous and potamodromous salmonids of all life stages during their annual migrations (Thoreson 1952; Clothier 1954; Campbell 1959; Hallock and Van Woert 1959; Neitzel et al. 1991; McMichael et al. 2001; Schrank and Rahel 2004). Entrainment is the process by which aquatic organisms are diverted into irrigation canals or other structures at dams and irrigation facilities (Zydlewski and Johnson 2002).

Irrigation canals have been present in western Montana since 1842 (Hakola 1951). Historically, most irrigation occurred in the large valleys of western Montana (the Bitterroot, Flathead, and Deer Lodge), which contained much of the farmland (Hakola 1951). By 1870, 813 irrigation canals (2,042 km in length) had been built in the Bitterroot, Deer Lodge, Jefferson, Madison, Ruby, Prickly Pear, and Gallatin valleys. The total number of canals had increased to 1,689, totaling 4,482 km by 1880 (Howard 1992). The present number is unknown, but is presumed to be much greater.

Many competing demands, such as irrigation and recreation, are currently placed upon Montana's waterways. Conflicts arise over these competing demands, and methods to mitigate these conflicts need to be developed and implemented into management strategies (Reiland 1997). Fish losses to irrigation canals in Montana have been documented sporadically since the early 1950s (Thoreson 1952; Clothier 1954; Good and Kronberg 1986; Evarts et al.

1991 in Reiland 1997) and a solution that maintained water for irrigation use and reduced fish loss to irrigation canals was desired. One early attempt was legislation passed in Montana in 1893 requiring screens to be placed in canals from 1 September to 1 March (i.e., during the non-irrigation season) but it was revoked in 1897 (Clothier 1954). A federal bill was passed in 1938 that focused on preventing fish loss to irrigation canals, but was limited to streams with anadromous salmonids in Idaho, Oregon, and Washington. A current federal program dealing with fish loss to irrigation canals is the Fisheries Restoration and Irrigation Mitigation Act of 2000 (PL 106-502), administered in Idaho, Oregon, Washington, and western Montana. Its objectives are to increase fish survival, increase access to productive fish habitat, and reduce entrainment in water distribution systems, by creating passage for fish around irrigation devices or by installing fish screens.

A fish screen is a device installed in an irrigation canal to prevent entrainment and bypass entrained fish back to the main channel (Reiland 1997). Structures currently used to prevent entrainment into irrigation canals are physical barrier screens and behavioral guidance systems. Screens used as physical barriers include the rotary drum, vertical fixed-plate, vertical traveling (belt and panel), non-vertical fixed plate, horizontal fixed plate, eicher, modular inclined, and pump intake (Nordlund 1996). Rotary drum and vertical fixed-plate screens are the most widely used screen types in the Pacific Northwest (Nordlund 1996). Vertical fixed-plate screens have a mechanical cleaning system (paddle wheel) for debris removal. These screens seal tightly, because the mesh is fixed to the structural frame and no surface is exposed to wear and tear (Nordlund 1996).

The primary design factors influencing fish guidance in front of screens are approach velocities of fish, flow pattern just upstream of the screen mesh, and the uniform distribution of flow through the mesh area (Pearce and Lee 1991). If the velocity of water flowing through the screen is too high, fish have a greater chance of being impinged (physical contact with screens) onto the screen and being harmed (Zydlewski and Johnson 2002). If water velocity is too low while it flows through the screen, fish will not be diverted to the bypass pipe and will be trapped in the area between the headgate and screen, where piscivorous birds and fish may prey upon them (Nordlund 1996). Therefore, proper operation and maintenance of fish screens is critical, as regular maintenance and cleaning ensures that proper water flow is maintained. Lack of attention to proper operational maintenance has the likelihood to increase impingement, potentially killing large numbers of fish (Nordlund 1996).

Few studies exist on the benefits of fish screens (Moyle and Israel 2005), but screens that have been evaluated have shown potential to benefit anadromous fish populations (Campbell 1959; Corley 1962 in Schill 1984; Neitzel et al. 1991). For example, over a two-year period an estimated 370,500 juvenile chinook salmon (*Oncorhynchus tshawytscha*) were bypassed by 84 irrigation canal screens on the upper Salmon River, Idaho (Corley 1962 in Schill 1984). Also, a total of 234,346 chinook salmon and steelhead (*Oncorhynchus mykiss*) were bypassed by six fish screens in northeastern Oregon over a five-year period (Campbell 1959). Screens installed since 1992 in Idaho, Oregon, and Washington have increased the probability of survival of salmonids along with other species of fish (Nordlund 1996) and demonstrated the potential benefit fish screens may have for other migratory species. Currently, no studies exist on the benefits of fish screens for non-anadromous salmonids (Moyle and Israel 2005).

Westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) were historically widespread and abundant, but have experienced reductions in both abundance and distribution (Hanzel 1959; Liknes and Graham 1988; Shepard et al. 1997) and are now a “species of special concern” in Montana (MNHP 2004). The subspecies was considered for listing as a federally threatened species (USFWS 2003) resulting in an assessment by the Westslope Cutthroat Interagency Conservation Team, which estimated that westslope cutthroat trout currently occupy 53,913 km (59%) of 90,928 km of their historical habitat (Shepard et al. 2003). Habitat loss, dam construction, overharvest, and stocking of non-native fish are considered the greatest threats to persistence of westslope cutthroat trout and other cutthroat trout species (Behnke 1992). Habitat loss is probably the second greatest cause (after hybridization) of declines in westslope cutthroat trout populations, and has resulted from overgrazing, poor timber practices, oil and gas exploration, mining, development of riparian areas, construction of dams, and irrigation canals (Liknes and Graham 1988).

Westslope cutthroat trout have distinct migratory (fluvial and adfluvial) and nonmigratory ("resident") life history forms. Nonmigratory resident populations spend their entire lives within natal streams (Shepard et al. 1984), but may move within them. Many resident westslope cutthroat trout populations are currently confined to fragmented upper headwater habitats, thus increasing their risk of extinction (Rieman et al. 1993). The migratory form spends part of its life cycle outside its natal stream and can be separated into fluvial and adfluvial forms (Shepard et al. 1984; Liknes and Graham 1988; Behnke 1992). Adfluvial populations begin their lives in natal streams, move to lakes to mature and return to streams to spawn. Fluvial populations hatch in their natal streams, move to larger rivers to mature, and only return to streams to spawn (Liknes and Graham 1988; Brown and Mackay 1995; Schmetterling 2001).

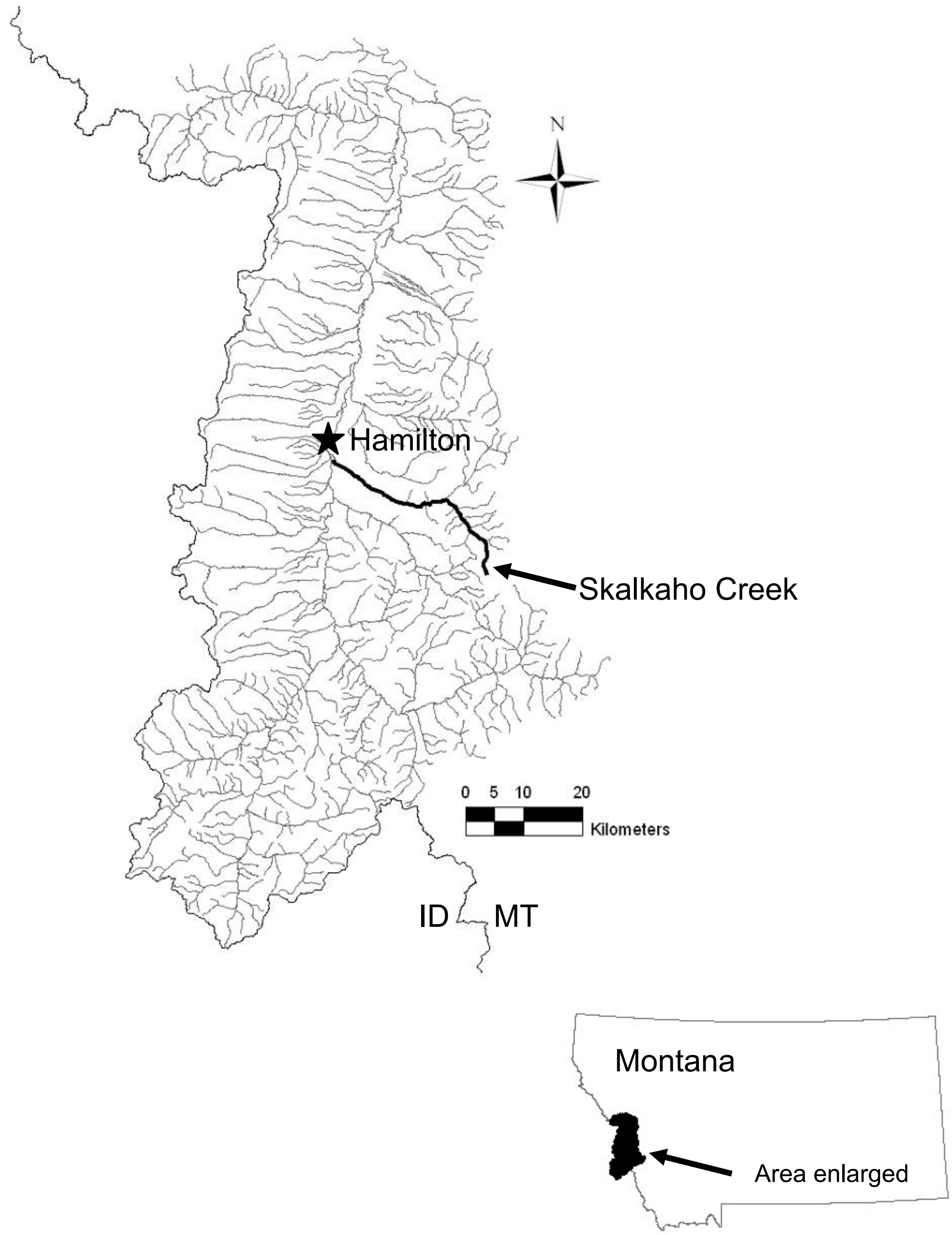
The timing of the spawning migration is dependent upon flow and water temperature; typically, adults start to move into tributaries when streamflows are high and spawn sometime from March to July (Roscoe 1974) when water temperatures are close to 10ºC (Scott and Crossman 1973). For example, in the upper Flathead River, fluvial adults started to move into tributaries when streamflows were high and spawning occurred during May and June. Spent adults left the tributaries soon after spawning, typically by the start of July (Shepard et al. 1984). In the Bitterroot River, upstream movement of fluvial adults to tributaries occurred from 26 May to 1 June during peak flows and most fish left spawning tributaries and returned to the Bitterroot River in June (Javorsky 2002).

Age-0 westslope cutthroat trout emerge from the gravel roughly 310 degree days (one degree day = one day at 1ºC above zero) after spawning (Smith et al. 1983), usually from early July to late August (the period of greatest water demand for irrigation) when they are about 20 mm in length. Some age-0 fish tend to move downstream, whereas others remain near spawning areas. After this initial downstream migration of age-0 fish, offspring of migratory westslope cutthroat trout may remain in their natal stream for one to four years (Averett and MacPhee 1971; Lukens 1978; Shepard et al. 1984; and Liknes and Graham 1988). When juveniles do migrate downstream it is usually during spring and early summer (Lukens 1978; Shepard et al. 1984; Liknes and Graham 1988), or autumn (Bjornn and Mallet 1964; Chapman and Bjornn 1969; Thurow 1976). Spring and autumn migrations can occur in the same stream (Nelson 1999).

Migratory adult westslope cutthroat trout are vulnerable to entrainment when passing irrigation canals while migrating upstream to spawn or moving downstream post-spawn. However, juvenile fish have the greatest probability of entrainment (Zydlewski and Johnson 2002), because they may not be able to escape high water velocity created near a headgate (Good and Krongberg 1986). Other significant migrations when westslope cutthroat trout may be susceptible to entrainment include age-0 postemergence dispersal (Northcote 1992), juvenile migrations after a "residency" period of one to three years (Shepard et al. 1984), downstream movements from headwater streams to overwintering habitats (Jakober et al. 1998), and movements to other habitats within a river (Liknes and Graham 1988). Migratory forms appear to have experienced the greatest reduction in numbers and need protection because migratory fish are important in genetic exchange and re-colonizing habitats after extinctions (Van Eimeren 1996).

Skalkaho Creek, a tributary to the Bitterroot River near Hamilton, Montana (Figure 1), supports a healthy resident population of westslope cutthroat trout, along with fluvial adults that rear in the mainstem Bitterroot River and migrate upstream to spawn in the creek (Clancy 2003). Historically, a large spawning run of migratory westslope cutthroat trout probably ascended Skalkaho Creek from the Bitterroot River (Chris Clancy, Montana Fish, Wildlife, and Parks, personal communication). However, the numbers have probably diminished, because of the selection pressure against downstream movement of fluvial adults (i.e., construction of lowhead diversion dams) since the late 1800's (Nelson et al. 2002). Post-spawn adult westslope cutthroat trout migrating back to the Bitterroot River, age-1 juveniles emigrating downstream from nursery reaches of Skalkaho Creek and its tributaries, and age-0 fish emigrating downstream after emergence are potentially entrained in the stream's irrigation canal system.

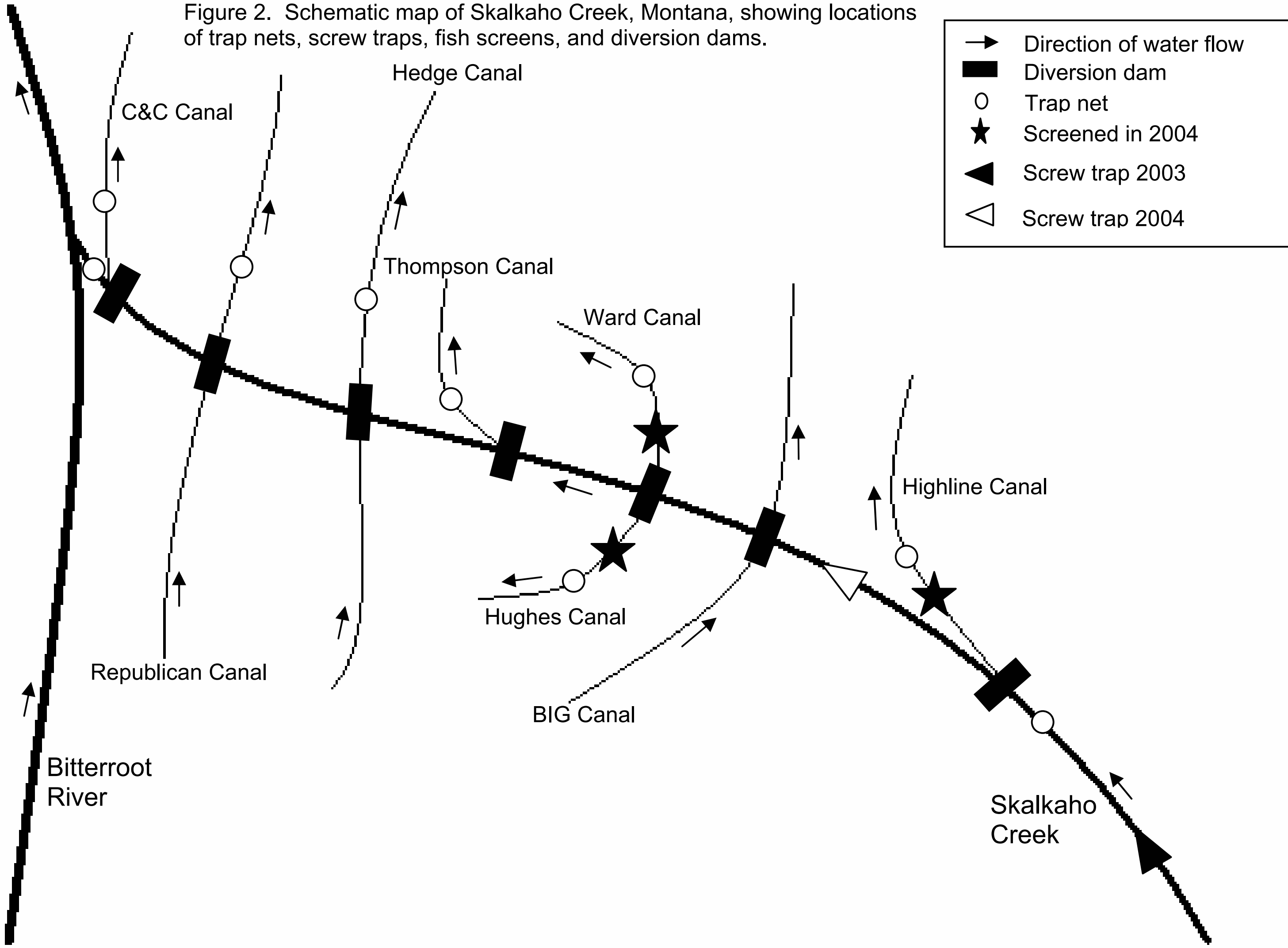
Figure 1. Map showing the Bitterroot River drainage, the location of Hamilton, Montana, and Skalkaho Creek.



Fish are known to be entrained into the major irrigation canals of Skalkaho Creek during the irrigation season (Nelson 1999; Clancy 2003) from April to September. Private landowners and irrigators in the drainage expressed concern over the loss of fish, and Montana Fish, Wildlife and Parks (MTFWP) installed vertical fixed-plate screens in the winter of 2003 in three canals, the Highline, Ward, and Hughes, to preclude such losses (Figure 2). Funds were allocated for maintenance throughout the life of the screens to ensure correct operation and effective bypassing of fish back to Skalkaho Creek. Skalkaho Creek presented a unique opportunity to study entrainment of westslope cutthroat trout at irrigation canals with and without screens.

My goal was to evaluate the benefits of installed fish screens. My specific objectives were to i) quantify and compare the magnitude of entrainment of adult, age-1, and age-0 westslope cutthroat trout into unscreened and screened irrigation canals, and ii) examine passage efficiency of installed fish screens.

Figure 2. Schematic map of Skalkaho Creek, Montana, showing locations of trap nets, screw traps, fish screens, and diversion dams.



STUDY AREA

The Bitterroot River flows north from the confluence of its East and West Forks near Conner, Montana, for 134 km through farm and ranch land to its confluence with the Clark Fork of the Columbia River near Missoula, Montana. The basin encompasses 7,288 km^2 of national forest, wilderness and private lands. Headwaters of the Bitterroot River are in two mountain ranges, the Bitterroot Range to the west and the Sapphire Range to the east. Water quality is excellent (Clancy 2001). The Bitterroot River has 27 major tributaries on the west side that originate in the Bitterroot Range and 12 that originate in the Sapphire Range. These tributaries support widespread populations of native westslope cutthroat and bull trout. Fluvial westslope cutthroat trout spawning migrations were documented in 2001 and 2002 up ten different tributaries of the Bitterroot River, which included Skalkaho Creek (Clancy 2003).

Five major canals and numerous smaller canals remove water from the mainstem Bitterroot River during the irrigation season. Many tributaries of the Bitterroot River are also diverted for irrigation during the summer months and contribute little streamflow to the river during that time. Therefore, both the tributaries and mainstem of the Bitterroot River are chronically dewatered during the irrigation season (Clancy 2001). Skalkaho Creek is one of these chronically dewatered tributaries. It is a 40.1-km long fifth-order stream, with a watershed area of 228 km^2, and its headwaters are located in the Sapphire Mountains. The historical average peak flow is about 20 m^3/s and the highest historical average monthly streamflow occurs in June (about 11 m^3/s).

Above river km 19, the stream runs through a narrow valley and has fast-water habitats. The lower 19 km runs through a wide valley floor and is composed of low-gradient riffles and runs. Several lowhead dams, along with other irrigation water diversion structures, are located in the lower 14 river km (Figure 2). The diversion dams from upstream to downstream are the Highline (rkm 14.48), BIG (rkm 8.78), Ward-Hughes (rkm 8.24), Thompson (rkm 5.71), Hedge (rkm 3.98), Republican (rkm 2.01), and C&C (rkm 0.11). Each diversion dam is constructed of different materials, has different dimensions, and diverts different amounts of water (Table 1). Of the three canals that received fish screens prior to the irrigation season in 2004, the Highline Canal diverts the most water (about 1.4 m^3/s), followed by the Ward (about 0.6 m^3/s) and Hughes (about 0.2 m^3/s). Entrainment was not assessed at the BIG Canal in this study. A headgate allows the BIG Diversion Dam to divert about 1.4 m^3/s from Skalkaho Creek during spring runoff about once every five years, but the canal primarily carries water that originates from Lake Como and is siphoned under the creek (Gary Shatzer, personal communication, Bitter Root Irrigation District). Water in the Hedge and Republican canals originates in the Bitterroot River and replaces Skalkaho Creek water where they intersect the creek. The Bitterroot River water in the canals empties into Skalkaho Creek and water from the creek is diverted out the other sides into the canals (Figure 2). These replacements may increase the temperature in downstream reaches (Figure 3), and do alter the conductivity of the creek water downstream (Table 2). Mean daily stream temperatures at sites downstream from the Ward-Hughes Diversion Dam approximated 18 to 20ºC during late summer whereas stream temperatures above the Ward-Hughes Diversion Dam were in the 12 to 16ºC range (Figure 3).

Skalkaho Creek supports native populations of westslope cutthroat trout, bull trout (*Salvelinus confluentus*), mountain whitefish (*Prosopium williamsoni*), northern pikeminnow (*Ptychocheilus oregonensis*), longnose sucker (*Catostomus catostomus*), longnose dace (*Rhinichthys cataractae*), redside shiner (*Richardsonius balteatus*), and slimy sculpin (*Cottus cognatus*). Non-native fish include rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*). Westslope cutthroat trout exist in large numbers from the headwaters downstream to river km 8.2 (Nelson 1999). Resident bull trout are present above river km 10, but they are rare or absent below river km 10. Brown trout dominate the fish assemblage in the lower 10 km, but are rare above river km 12. Rainbow trout and brook trout are common below the Republican Diversion Dam, but are rare further upstream (Nelson 1999).

Whereas not a focus of this study, bull trout are likely affected by irrigation withdrawals from Skalkaho Creek. Bull trout are federally listed as threatened and also are a “species of special concern” in Montana. Similar to westslope cutthroat trout, bull trout were formerly abundant throughout most major river basins of western Montana, but currently occupy about 42% of their historic distribution (Thomas 1992). Factors that led to the decline of westslope cutthroat trout have also adversely affected bull trout (Swanberg 1997).

Figure 3. Daily means from HOBO temperature loggers in 2004, Skalkaho Creek, Montana. Temperature loggers were placed above the diversion dams and they recorded water temperature from April to October. In addition, one temperature logger was placed upstream from the confluence with the Bitterroot River, which recorded water temperature from April to August.

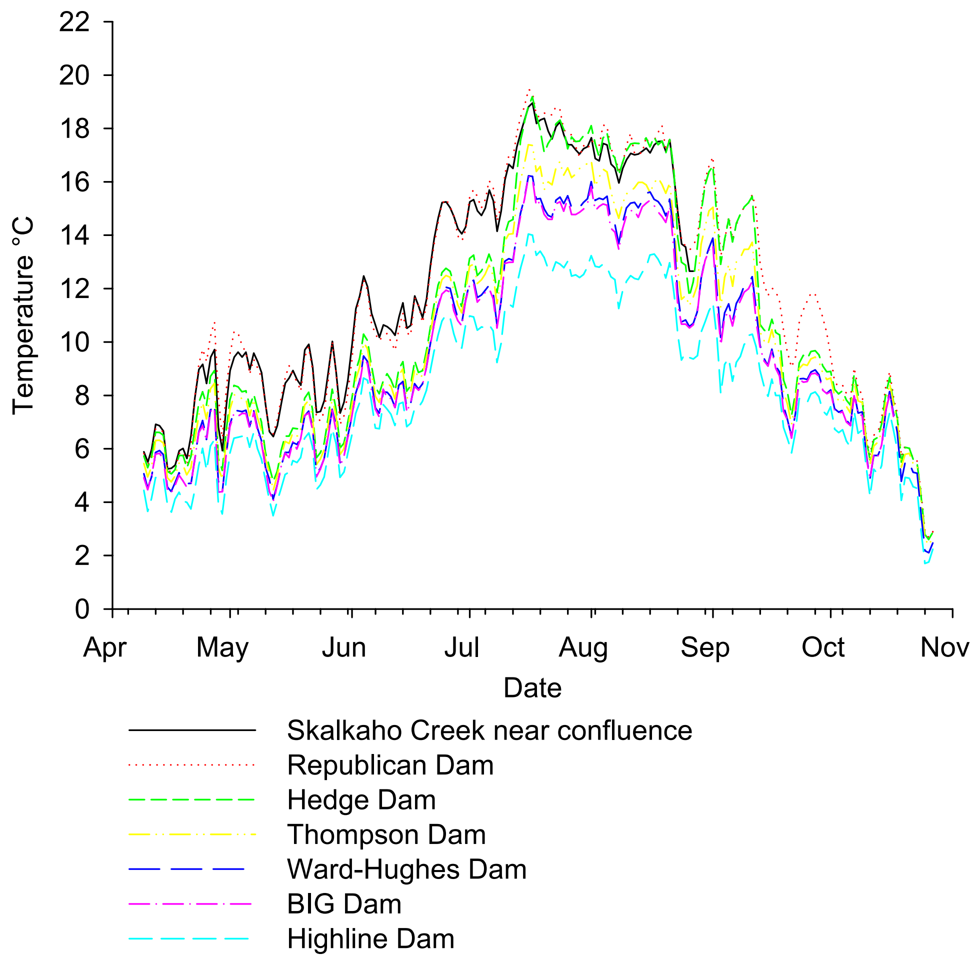


Table 1. Dimensions and other characteristics of irrigation diversion dams on Skalkaho Creek, Montana.

	Diversion dams						
	Highline	BIG	Ward-Hughes	Thompson	Hedge	Republican	C&C
Flow diverted (m^3/s)	1.4	1.4	Ward - 0.6 Hughes - 0.2	0.07	2.4	1.2	0.5
Construction materials	C, W	C, W, S	C, W, S	C	C, W, S	C, W, S	C
Substrate above	Co, G	Co, G	Co, G	Co, G	Co, G	Co, G	Co, G
Width (m)	12.9	16.6	13.5	13.2	23.2	19.0	5.0
Channel width above (m)	12.4	12.3	10.2	9.8	10.6	6.55	6.6
Gradient	2%	3%	2%	4%	3%	5%	1%
First spill height (m)	0.7	0.7	3.3	1.35	2.2	1.25	0.6
Splash pad	Yes	Yes	No	Yes	Yes	Yes	No
Splash pad length (m)	4.7	6.4	– –	4.0	4.7	2.5	– –
Splash pad width (m)	12.9	16.6	– –	13.2	10.8	6.2	– –
Second spill height (m)	– –	1.7	– –	0.4	– –	0.8	– –
Channel width below (m)	10.3	10.9	12.8	7.5	7.4	7.9	14.8
Substrate below	Co, G	Co, G	Co, G	Co, G	Co, G	Co, G	G, S

C = concrete
W = wood
S = Steel
Co = cobble
G = gravel
S = sand

Table 2. Conductivity measurements taken on 9 September, 2004, from locations (upstream to downstream) in Skalkaho Creek, and one measurement in the Bitterroot River, Montana.

Location of measurement	Conductivity µS/cm
Skalkaho Creek above Highline Diversion Dam	182.9
Skalkaho Creek below Highline Diversion Dam	182.9
Skalkaho Creek below Ward-Hughes Diversion Dam	197.2
Skalkaho Creek below Thompson Diversion Dam	214.0
Hedge Canal after mixing with Skalkaho Creek	97.1
Skalkaho Creek below Hedge Diversion Dam	82.8
Hedge Canal before mixing with Skalkaho Creek	82.1
Republican Canal after mixing with Skalkaho Creek	88.2
Skalkaho Creek below Republican Diversion Dam	80.2
Republican Canal before mixing with Skalkaho Creek	81.0
Skalkaho Creek near confluence with Bitterroot River	105.7
Bitterroot River near Hamilton, Montana	94.3

METHODS

Fish Losses to Irrigation Canals

All seven irrigation canals on Skalkaho Creek were unscreened in 2003. Fish screens were installed at three of the seven irrigation canals in 2004 (Highline, Ward, and Hughes). Entrainment losses of adult, age-1, and age-0 westslope cutthroat trout were assessed at unscreened and screened irrigation canals in 2003 and 2004.

Adult Westslope Cutthroat Trout

I telemetered adult westslope cutthroat trout to quantify the proportion of downstream migrating adults that were entrained in screened and unscreened canals. Adult fish were collected from May to June in 2003 and 2004, immediately below diversion dams or at potential spawning locations, which were within 5 rkm upstream of the Highline Diversion Dam. I expected fish captured below diversion dams to be spawning fluvial adults migrating upstream to spawn. Generally, adult westslope cutthroat trout greater than or equal to 350 mm in length were selected to receive radio tags (Table 3). Fish 350 mm or longer were expected to be fluvial fish from the Bitterroot River (Chris Clancy, MTFWP, personal communication).

Fish were collected using a Smith-Root LR-24 battery-powered backpack electrofisher, by bank electrofishing using a generator and a Coffelt VVP-15 electrofishing unit, and with a screw trap. Upon capture, selected adult westslope cutthroat trout were anesthetized with tricaine methanesulfonate (Finquel), and their lengths (mm) and weights (g) were recorded. Sex was determined by squeezing the abdomen of captured fish and noting extruded gametes. If gametes were not extruded, an otoscope was inserted into the incision made during surgery to attempt to identify testes or ovaries. Radio transmitters weighing 7.7 grams in air (Lotek Engineering, Inc.) were surgically implanted (Ross and Kleiner 1982; Schmetterling 2001). Tag weight never exceeded 3.2% of telemetered fish weights (Zale et al. 2005). In 2003, 30 adult westslope cutthroat trout were telemetered, and in 2004, 44 adults were tagged (Appendix A). A PIT tag (Biomark, Inc.) was inserted into each telemetered adult fish in 2004. Circular 35.5-cm diameter FS2001 PIT tag antennas (Biomark, Inc.) were attached to the bypass pipes at all three fish screens in 2004. They were connected to tuning boxes and FS2001FR/ISO readers housed in environmental enclosures, and powered by batteries recharged with solar panels. PIT-tag antennas at the Highline, Ward, and Hughes fish screens allowed me to determine when and how many PIT-tagged adult fish were bypassed back to Skalkaho Creek by each screen.

Table 3. Lengths and weights of migratory and non-migratory telemetered adult westslope cutthroat trout, Skalkaho Creek, Montana, 2003 and 2004.

	Migratory (n = 24)	Non-migratory (n = 50)
Mean length (mm ± SD)	367 ± 40	350 ± 29
Maximum length (mm)	446	413
Minimum length (mm)	282	290
Mean weight (g ± SD)	582 ± 282	443 ± 118
Maximum weight (g)	1614	873
Minimum weight (g)	250	240

Fish captured below diversion dams were transported to the next upstream dam after transmitter implantation and released. For example, a fish collected below the Republican Diversion Dam would be tagged and transported to the Hedge Diversion Dam and released just below the dam (Figure 2). This process insured that a telemetered fish that did not ascend the diversion dam it was placed below and simply moved back downstream was tracked as it moved downstream past at least one diversion dam and its associated canal or canals. No fish was transported upstream past more than one dam. Fish captured upon spawning grounds were tagged and released at the site of capture. Telemetered adults that moved downstream and encountered at least one diversion dam were counted as migratory fish, whereas telemetered fish that did not encounter a diversion dam were considered non-migratory. More migratory fish were captured in 2004 (19), than in 2003 (5) (Table 4). My ability to capture fish below diversions dams was hindered by high spring flows in 2003. Therefore, most fish were captured and tagged on spawning grounds. As a result, most were resident fish that did not move downstream. Lower spring discharges in 2004 increased capture success below diversion dams.

Table 4. Numbers of migratory and non-migratory telemetered adult westslope cutthroat trout, Skalkaho Creek, Montana, 2003 and 2004.

	2003	2004	Both years
Migratory	5	19	24
Non-migratory	25	25	50
Total	30	44	74

Of the five migratory adults telemetered in 2003, two were captured on spawning grounds 3 km above the Highline Diversion Dam, one below the Ward-Hughes Diversion Dam, and two below the Hedge Diversion Dam. Two migratory adults telemetered in 2004 were captured above the BIG Diversion Dam by the screw trap, nine below the Ward-Hughes Diversion Dam, one below the Thompson Diversion Dam, three below the Hedge Diversion Dam, and four below the Republican Diversion Dam. A majority (38 of 50) of telemetered non-migratory adults were captured and tagged above the Highline Diversion Dam on the spawning grounds (Appendix A). Migratory adults, on average, were longer and heavier than non-migratory adults (Table 3), although 56% of telemetered non-migratory adults were longer than 350 mm.

Left pectoral fin clips were taken from all telemetered adult westslope cutthroat trout except for the final seven fish telemetered in 2004. Of those seven fish, five were captured above the Highline Diversion Dam and two were captured by the screw trap above the BIG Diversion Dam. Fin clips were not taken from the final seven fish telemetered in 2004 because of lack of glass vials. Fin clips were analyzed with a PCR-based method, paired interspersed nuclear DNA elements (PINE), at the University of Montana Wild Trout and Salmon Genetics Lab (Spruell et al. 2001; Kanda et al. 2002). Because no evidence of genetic differences existed between samples collected in 2003 and 2004, they were combined for subsequent analysis. The combined sample was analyzed to determine the presence or absence of diagnostic DNA fragments, which included nine for Yellowstone cutthroat trout, seven for westslope cutthroat trout, and six for rainbow trout. When a fragment is detected, it denotes that the individual is either heterozygous or homozygous for that fragment (Kanda et al. 2002). Testing detected the presence of rainbow trout markers, but they were randomly distributed, indicating a very small rainbow trout genetic contribution. Overall, the sample tested 99.5% pure westslope cutthroat trout, with 0.5% rainbow trout introgression. In contrast, 12 telemetered fluvial adult westslope cutthroat trout from the Bitterroot River in 2004 tested 83% pure westslope cutthroat trout, with 17% rainbow trout introgression (Ben Wright, Wild Trout and Salmon Genetics Laboratory, unpublished data).

Radio tags implanted in 2003 had a battery schedule of 25 weeks on and 24 weeks off, with a daily schedule of 15 hours on starting at 0700 hours and 9 hours off starting at 2200 hours. The tags implanted in 2003 turned on about the start of May and turned off about the end of October. Twenty of the 30 tags used in 2003 turned back on in 2004 and were still in the original fish. These tags turned on at about the beginning of April and lasted until the end of October. Radio tags implanted in 2004 operated 24 hours, seven days a week and lasted throughout the remainder of the study.

Telemetered fish were tracked through the spawning period and through the following summer and autumn. Telemetered adults were located daily during the spawning season and once per week to once per month during summer and autumn using a vehicle-mounted omnidirectional antenna or by foot using a hand-held Yagi antenna. When detected, each adult was located to within one meter when conditions allowed. The location was recorded using a hand-held global positioning unit. In 2003, 603 relocations were made and in 2004, 690 relocations were made. Final fate of each individual was determined (i.e., in-river mortality, canal entrainment, in-river residence, or emigration to the Bitterroot River) (Appendix A).

Each instance in which a telemetered adult came to a diversion dam while moving downstream was considered an encounter. During an encounter, a telemetered adult could either move downstream over the dam without being entrained, it could be entrained, or it could be entrained and then bypassed back to Skalkaho Creek by a fish screen (in 2004). The number of telemetered adults entrained at each canal was divided by the number of encounters to determine the probability of entrainment at each canal.

Juvenile Westslope Cutthroat Trout

I telemetered age-1 juvenile westslope cutthroat trout to quantify how many downstream migrating juveniles were entrained in screened and unscreened canals. Juvenile westslope cutthroat trout to be telemetered were collected by backpack electrofishing and trap netting the Highline, Ward, and Hughes canals in 2003 and 2004. Fish were collected from these three canals because it was assumed that these fish were recently entrained and therefore migratory. Each trap net (Research Nets, Inc.) had a rectangular entrance 61 cm high x 91 cm wide with a 305-cm long net (1.6 mm mesh) attached to a PVC collar (11.4 cm diameter) that led to a 61 x 61 x 61 cm live box (1.6 mm mesh). This configuration had an open area ratio of 5:1, which created a filtering efficiency of 95% (Trantor and Smith 1968). Fish to be telemetered were collected during spring (May to June) and autumn (August to September) outmigrations when Nelson et al. (2002) trapped large numbers of juvenile westslope cutthroat trout moving downstream in Skalkaho Creek above the Highline and BIG diversion dams. Upon capture, selected juvenile westslope cutthroat trout were anesthetized with tricaine methanesulfonate (Finquel), and their lengths (mm) and weights (g) were recorded. Radio transmitters weighing 0.85 grams in air (Lotek Engineering, Inc.) were surgically implanted. Generally, juvenile westslope cutthroat trout weighing 16 to 35 g were selected to receive radio tags to ensure that radio transmitters did not exceed 5% of fish weight (Zale et al. 2005). A PIT tag (Biomark, Inc.) was inserted into each telemetered juvenile fish in 2004 to allow detection at screen bypasses. Telemetered juveniles were transported about 1 km upstream of the uppermost diversion dam (Highline) and released. These fish were expected to re-initiate their downstream movement. In 2003, 59 juvenile westslope cutthroat trout were telemetered, and 58 were telemetered in 2004, for a total of 117 (Appendix B). Four of the 58 telemetered fish in 2004 were tagged in the spring instead of the autumn. All four juvenile westslope cutthroat trout telemetered in the spring were non-migratory (Table 5).

Radio tags implanted in juveniles had a battery life of about 33 days, with 12 hours on starting at 0700 hours and 12 hours off starting at 1900 hours. Telemetered juvenile fish were relocated once per day to once per week using a hand-held Yagi antenna. Following detection, each juvenile was located to within one meter when conditions allowed. The location was recorded using a hand-held global positioning unit. In 2003, 369 relocations were made and 285 relocations were made in 2004. Of the 285 relocations in 2004, 33 occurred in the spring. Final fate of each individual was determined (i.e., in-river mortality, canal entrainment, in-river residence, or outmigration) (Appendix B). Very few migratory juvenile fish were telemetered in 2003 (5) and 2004 (3) as fish either died or did not move from release locations (Table 5). Telemetered migratory juveniles were similar in length and weight to telemetered non-migratory juveniles

(Table 6). The number of encounters and probability of entrainment at each canal was determined for juvenile telemetered fish as for telemetered adults.

Table 5. Numbers of telemetered juvenile westslope cutthroat trout that were migratory, non-migratory, or did not survive, Skalkaho Creek, Montana, 2003 and 2004.

	2003	Spring 2004	Autumn 2004	Both years
Migratory	5	0	3	8
Non-migratory	33	4	45	82
Died	21	0	6	27
Total	59	4	54	117

Table 6. Lengths and weights of migratory and non-migratory telemetered juvenile westslope cutthroat trout, Skalkaho Creek, Montana, 2003 and 2004.

	Migratory (n = 8)	Non-migratory (n = 109)
Mean length (mm ± SD)	128 ± 9	133 ± 16
Maximum length (mm)	147	218
Minimum length (mm)	118	112
Mean weight (g ± SD)	21 ± 4	24 ± 11
Maximum weight (g)	28	98
Minimum weight (g)	17	13

Twenty-one telemetered juvenile fish died in 2003. Five radio-tags were found with antennas tangled in woody debris or pinched between rocks. The antenna length of radio tags used in 2003 was 300 mm. Antenna lengths of 300 mm impaired swimming performance of juvenile rainbow trout and became entangled on standpipes of holding tanks (Murchie et al. 2004). Antennas were trimmed to 150 mm in 2004, which did not alter the detection range. Surgical staples were used in 2003 to close incisions using techniques described by Ross and Kleiner (1982) and Schmetterling (2001). Sutures (Summerfelt and Smith 1990) were used to close incisions in 2004 instead of surgical staples, because I thought staples may have been catching on debris and appeared to excessively tighten the incision. Only six telemetered juveniles died in 2004 (Table 5.)

Age-0 Westslope Cutthroat Trout

Trap nets were used to quantify entrainment of age-0 westslope cutthroat and other age-0 fish at screened and unscreened canals (Figure 2). Entrainment and downstream movement in Skalkaho Creek were assessed from 16 July to 20 September in 2003 and 28 June to 27 September in 2004. Supplemental sampling was conducted before and after this period to detect temporal trends.

Trap nets were set for 24 hours and were deployed one to three times per week at each site from late spring to early autumn, whereas the screw trap was set for 24-hr periods four to five times per week. For catches less than 200 individuals, all fish were identified to species, counted, measured (mm), and weighed (g) if length was greater than 100 mm. If a catch exceeded 200 fish, a haphazard subsample of 200 fish was identified to species, counted, measured, and weighed. Trap nets were set in Skalkaho Creek above all irrigation canals and below all irrigation canals (i.e., above the Highline Diversion Dam and near the confluence with the Bitterroot River) (Figure 2). The trap net above all irrigation canals gave an estimate of the total number or input of age-0 westslope cutthroat and other species moving downstream in Skalkaho Creek and into the reach affected by irrigation withdrawals. The trap net above all irrigation canals was deployed from 16 July until 14 August in 2003, and then replaced with a screw trap located about 1 rkm upstream of the Highline Diversion Dam, which was deployed from 18 August to 20 October. The screw trap was similar to those used in Alaska (Thedinga et al. 1994), but had a cone entrance 1.5 m in diameter instead of a 2.4-m diameter cone entrance. In 2004, at the request of the MTFWP, the screw trap was placed 0.7 rkm upstream of the BIG Diversion Dam and only a trap net was used in the creek above all irrigation canals. The screw trap location was moved to better monitor how many fish were moving downstream past the Highline Canal after a screen was installed there. Trap nets were also set in each of the seven irrigation canals to provide estimates of the numbers or proportion of age-0 westslope cutthroat or other species entrained. Lastly, the trap net below all irrigation canals gave an estimate of the total number or output of age-0 westslope cutthroat and other species moving downstream that migrated past all dams and canals.

Trap net efficiencies were calculated, because trap nets did not sample 100% of the flow except at the Thompson Canal (Table 7). If 10 or more age-0 fish were caught in a 24-hour sample, they were marked with Bismark Brown Y dye, and released 50 m upstream. The trap net was checked 24 hours later and the numbers of dyed and unmarked fish were counted. Efficiency trials were attempted only once per week, per site, if enough fish were captured, because dyed fish retain the dye for at least 4 days (Hennessey 1998). Trap efficiency was calculated by dividing the number of recaptured dyed fish by the total number of dyed fish released. Efficiencies of all trials conducted at a site were similar (chi-square test, $P > 0.05$). Therefore, data were pooled for each site. Pooling produced an overall weighted-average efficiency for each site (Table 8). Confidence intervals for trap efficiencies were calculated using the relationship between the F and the binomial distributions (Zar 1984). The number of fish entrained or moving downstream during a 24-hour deployment period was estimated by dividing the total number of captured fish by the weighted-average efficiency. The area-under-the-curve method (AUC) (Sigma Plot 9.0, English et al. 1992) was used to estimate the annual number of each species entrained or that moved downstream at each trap net location. Screw trap efficiencies and estimates were determined as per the methods used for trap nets.

If sufficient fish (i.e., > 10 per sample) to calculate an efficiency were never captured at a site, an efficiency rate from another similar site was substituted. Specifically, the efficiency of the net set in the creek above all diversions was substituted for the net set in the creek below all diversions and the efficiency of the C&C Canal trap net was substituted for the nets set in both the Ward and Hughes canals (Table 8). The Thompson Canal trap net was assumed to be 100% efficient, because the trap net sampled the entire flow of the canal.

Table 7. Capture efficiency trials by site in 2003 and 2004, Skalkaho Creek, Montana.

	2003			2004		
Trap site	Number marked	Number recaptured	Efficiency	Number marked	Number recaptured	Efficiency
Below all canals	63	0	0%	73	0	0%
				99	0	0%
C&C Canal	58	3	5.17%	20	0	0%
	42	6	14.28%	13	0	0%
	138	19	13.76%	135	15	11.11%
				304	26	8.55%
				322	36	11.18%
Republican Canal	90	8	8.88%	34	0	0%
	239	16	6.69%	34	1	2.94%
	159	8	5.03%	777	60	7.72%
				334	16	4.79%
Hedge Canal				56	0	0%
				159	1	0.62%
				87	1	1.14%
Thompson Canal[a]						
Hughes Canal[b]						
Ward Canal[b]						
Highline Canal	18	2	11.11%			
Above all canals	23	1	4.34%	19	1	5.26%
				11	1	9.09%
				7	0	0%
				13	0	0%
				9	0	0%
Screw trap[c]	24	1	4.16%	10	0	0%
	35	2	5.71%	10	1	10.00%
				12	2	16.66%
				82	8	9.75%
				14	4	28.57%
				19	4	21.05%

[a] Trap net at this site sampled entire flow in canal.
[b] Insufficient fish were captured to conduct efficiency trials.
[c] Screw trap placement differed between years.

Table 8. Overall efficiencies for all trap net sites and both screw trap locations, Skalkaho Creek, Montana.

	Overall	efficiencies		
Trap site	Number marked	Number recaptured	Efficiency	95% CI
Below all canals[a]			3.65%	0.76-10.32%
C&C Canal	1,032	105	10.17%	8.40-12.18%
Republican Canal	1,667	109	6.53%	5.40-7.83%
Hedge Canal	302	2	0.66%	0.08-2.37%
Thompson Canal[b]	– –	– –	100%	
Hughes Canal[c]	– –	– –	10.17%	8.40-12.18%
Ward Canal[c]	– –	– –	10.17%	8.40-12.18%
Highline Canal	18	2	11.11%	1.38-34.70%
Above all canals	82	3	3.65%	0.76-10.32%
Screw trap 2003	59	3	5.08%	1.06-14.15%
Screw trap 2004	147	19	12.92%	7.96-19.45%

[a] Substituted with “Above all canals” efficiency.
[b] Trap net at this site sampled entire flow, so it was assumed its efficiency was 100%.
[c] Substituted with “C&C Canal” efficiency.

Bypass Trapping

Bypass trapping was conducted in 2004 at all three screened canals to determine when, how many, what size, and what species were being bypassed. Modified trap nets were used to sample the outflow from the bypass pipe. Traps were attached to the 30.5-cm diameter PVC bypass pipes by wrapping the mouth of the net completely around the pipe and securing it with a rubber bungee cord, to ensure that 100% of the outflow was sampled. Bypass traps were set for 24 hours once a week at each fish screen until the canals were shut down for the irrigation season. The bypass trap at the Highline fish screen was set starting on

22 July 2004 and ending on 21 October 2004. Numbers of fish bypassed were counted at the Ward and Hughes fish screens from 22 July 2004 to 28 September 2004. All fish captured were identified to species, counted, measured (mm), and weighed (g) if length was greater than 100 mm. Total numbers bypassed at each fish screen were calculated using the AUC method.

Effectiveness of Screens

Screen efficiency trials were conducted at all screened irrigation canals (Highline, Ward, and Hughes) in 2004 to evaluate passage efficiency of each screen. At the Highline fish screen, two trials lasting two weeks were conducted using 50 fish per trial. At the Ward fish screen, the first trial lasted one week and used 51 fish and the second trial lasted two weeks using 50 fish. At the Hughes fish screen, the first trial lasted one week and the second trial lasted two weeks; both trials used 50 fish. Westslope cutthroat trout, bull trout, and brown trout of various lengths were collected by electrofishing, implanted with PIT tags (Biomark, Inc.), and then introduced into the area between the headgate and screen. PIT tag antennas and readers attached to bypass pipes at all three screens monitored when and how many fish were diverted down the bypass pipes and back to Skalkaho Creek. The area between the headgate and screen was electrofished one week after introducing the PIT-tagged fish and again at the end of the trial. The area was electrofished only once at the end of the one-week trials. Final fate of each individual was determined (i.e., successful bypass, headgate resident, never found, or swam out). A hand-held PIT-tag reader was used to read tags of captured fish. Screen efficiency was calculated for each species and for all species per trial by dividing the number of fish bypassed by the number introduced.

RESULTS

Fish Losses to Irrigation Canals

Adult Westslope Cutthroat Trout

Twenty-four migratory fish had a total of 34 downstream encounters in 2003 and 2004; 53% resulted in entrainment into irrigation canals, but entrainment only occurred in 2004. Five migratory fish had a total of six downstream encounters at diversion dams with unscreened canals in 2003, when all canals were unscreened. No fish were entrained and none returned to the Bitterroot River (Table 9). One was predated by an osprey, two were found dead of unknown causes, and two disappeared. The probability of entrainment into unscreened canals in 2003 was 0%. Nineteen migratory fish had a total of 28 downstream encounters in 2004; 14 at screened canals and 14 at unscreened canals. Of the 14 encounters at diversion dams with screened canals, nine resulted in entrainment. Most (13) of the encounters at diversion dams with screened irrigation canals occurred at the Ward-Hughes Diversion Dam; nine resulted in entrainment. Therefore, the overall probability of entrainment was high (69%; Table 9). However, all nine entrained fish were successfully bypassed by the Ward and Hughes fish screens reducing the functional entrainment rate to zero (Table 9). The single telemetered adult westslope cutthroat trout that encountered the Highline Diversion Dam was not entrained into the screened Highline Canal in 2004. Of the 14 encounters at diversion dams with unscreened canals, nine resulted in entrainment (Table 9). Eight of the nine encounters resulting in entrainment occurred at the Hedge and Republican diversion dams. Therefore, the probability of entrainment into the Hedge or Republican canal was high (80% at each; Table 9). Of the nine fish entrained into unscreened canals, two were entrained by swimming upstream into the Hedge Canal and one swam upstream into the Republican Canal. Fish #137 migrated back to the Bitterroot River by swimming upstream and out the Republican Canal (Figure 4). Fish #137 was the only fish of the nine entrained at unscreened irrigation canals that did not die in the canal it was entrained in. Fish #131's tag was found in the Bitterroot River, yet how it got there is unclear because its last recorded location was in the downstream portion of the Republican Canal, which does not reconnect to the Bitterroot River. Fifteen of the 19 (79%) migratory adults telemetered in 2004 were entrained at least once; three fish were entrained, bypassed, and entrained again further downstream at unscreened canals (Table 10). No telemetered fish encountered the C&C Diversion Dam in 2004 because no telemetered fish migrated that far downstream without being entrained elsewhere and dying (8), becoming residents (4), dying in Skalkaho Creek (3), being preyed upon (3), or returning to the Bitterroot River via the Republican Canal (1).

Generally, diversion dams that diverted larger volumes of water than others had higher probabilities of entrainment. At the Hedge and Republican diversion dams, where large proportions of Skalkaho Creek were diverted into unscreened canals, the overall probability of entrainment was high (80%) in 2004. Similarly, at the Ward-Hughes Diversion Dam (which diverted almost as much water as the Republican Diversion Dam) the overall probability of entrainment into the screened Ward and Hughes canals was high (69%). Conversely, the Thompson Diversion Dam, which diverts a small proportion of Skalkaho Creek, had a low (25%) overall probability of entrainment into the unscreened Thompson Canal (Table 9). In contrast, the Highline Diversion Dam diverts a large proportion of water from Skalkaho Creek, but no adult telemetered fish were entrained there.

Table 9. Number and result of downstream encounters (entrainment, successfully went over dam without being entrained, or successfully bypassed) that telemetered adult westslope cutthroat trout had with diversion dams on Skalkaho Creek, Montana, during 2003 and 2004. The probability of entrainment at each diversion dam is also shown.

Year	Diversion dam	Downstream encounters	Number entrained	Number that went over dam	Entrainment	Entrained and Bypassed
2003	Highline	3	0	3	0%	
	Ward-Hughes[a]	2	0	2	0%	
	Ward[b]		(0)			
	Hughes[c]		(0)			
	Thompson	0	0	0	– –	
	Hedge	1	0	1	0%	
	Republican	0	0	0	– –	
	C&C	0	0	0	– –	
	Total	6	0	6	0%	
2004	Highline - FS	1	0	1	0%	– –
	Ward-Hughes[a]	13	9	4	69%	9
	Ward[b] - FS		(7)		(54%)	(7)
	Hughes[c] - FS		(2)		(15%)	(2)
	Thompson	4	1[d]	3	25%	– –
	Hedge	5	4[e]	1	80%	– –
	Republican	5	4	1	80%	– –
	C&C	0	0	0	– –	– –
	Total	28	18	10	64%	9
2003/2004	Highline	4	0	4	0%	– –
	Ward-Hughes[a]	15	9	6	60%	9
	Ward[b]		(7)		(47%)	(7)
	Hughes[c]		(2)		(13%)	(2)
	Thompson	4	1[d]	3	25%	– –
	Hedge	6	4[e]	2	66%	– –
	Republican	5	4	1	80%	– –
	C&C	0	0	0	– –	– –
	Total	34	18	16	53%	9

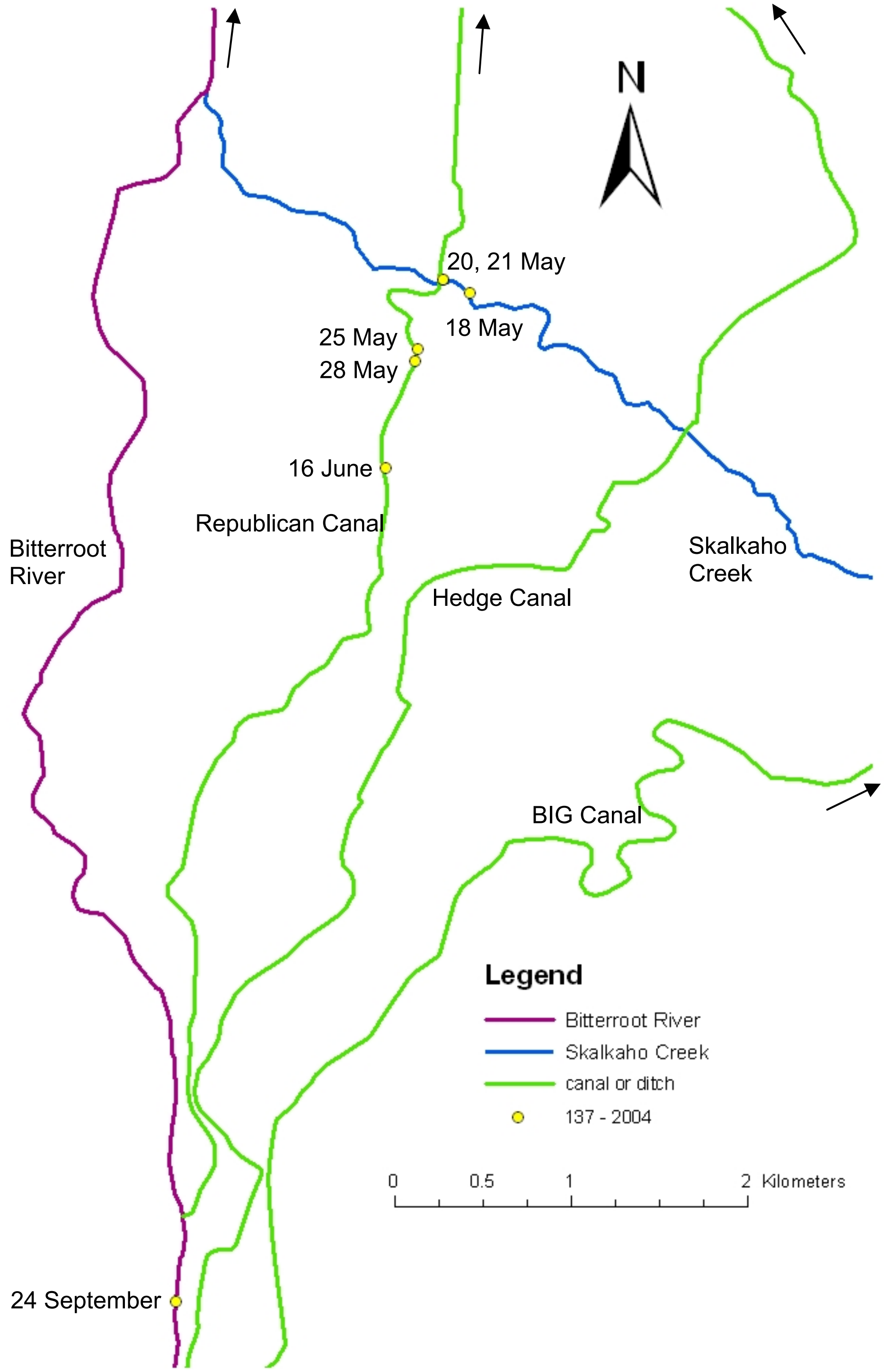
FS – Fish screen operational
[a] This diversion dam diverts water to two different canals instead of diverting water to one canal.
[b] Associated canal with Ward-Hughes Diversion Dam.
[c] Associated canal with Ward-Hughes Diversion Dam.
[d] This fish was bypassed by the Hughes fish screen, and subsequently entrained in Thompson Canal.
[e] Two of the four fish were first bypassed by the Ward fish screen and subsequently entrained in the Hedge Canal.

Table 10. Downstream encounter histories of telemetered migratory adult westslope cutthroat trout, Skalkaho Creek, Montana, from 2003 and 2004.

						Diversion dams				
Fish #	Year Tagged	Length (mm)	Weight (g)	Sex	Release location	Highline	Ward-Hughes	Thompson	Hedge	Republican
27	2003	439	1,000	M	Below Thompson Dam	WO				
23	2003	340	1,614	F	Below Thompson Dam				WO	
12	2003	292	268	– –	Below BIG Dam		WO			
18	2003	415	712	– –	Above Highline Dam	WO				
110	2003	371	483	M	Above Highline Dam	WO	WO - 2003			
							WO - 2004			
137	2004	375	500	– –	Below Hedge Dam					ESO
124	2004	325	380	– –	Below Hedge Dam					E
131	2004	385	640	M	Below Hedge Dam					E
132	2004	282	250	– –	Below Hedge Dam					WO
120	2004	370	538	– –	Below BIG Dam	WO	EB			
128	2004	370	520	– –	Below BIG Dam		WO			
135	2004	446	788	M	Below Thompson Dam				E	
259	2004	370	620	– –	Below Thompson Dam		EB	E		
134	2004	380	540	M	Below BIG Dam		EB			
244	2004	392	608	F	Below BIG Dam		EB			
138	2004	402	720	F	Below Thompson Dam		EB			
126	2004	378	570	F	Below BIG Dam			WO	WO	E
252	2004	411	750	F	Below BIG Dam		EB	WO	E	
136	2004	350	445	– –	Below Ward-Hughes Dam				E	
242	2004	365	540	– –	Below BIG Dam		EB			
123	2004	338	395	– –	Below BIG Dam		EB			
141	2004	367	464	F	Below BIG Dam		EB	WO	E	
264	2004	341	370	– –	Screw trap		WO			
245	2004	317	275	F	Screw trap		WO			

WO = Went over dam without being entrained
E = Entrained
EB = Entrained and bypassed by fish screen
ESO = Entrained and swam upstream out of canal back to the Bitterroot River

Figure 4. Relocations of fish #137 in 2004, Skalkaho Creek and the Bitterroot River, Montana.



Juvenile Westslope Cutthroat Trout

Eight migratory juveniles had a total of eight downstream encounters in 2003 and 2004, all encounters occurred at the Highline Diversion Dam and all resulted in entrainment into the Highline Canal. Five migratory juvenile westslope cutthroat trout had a total of five downstream encounters all resulting in entrainment into the unscreened Highline Canal in 2003. Therefore, the overall probability of entrainment was high (100%; Table 11). Three migratory fish had a total of three downstream encounters in autumn 2004 all resulting in entrainment into the screened Highline Canal. However, only one of the three entrained fish was successfully bypassed back to Skalkaho Creek; the other two fish died in the area between the headgate and the fish screen of unknown causes. Of the two fish that were entrained and died in the Highline Canal in 2004, one was entrained in late September and remained until the canal was shut down in October, whereas the other fish was found dead entrained one day after it was telemetered. The one bypassed fish was last located in Skalkaho Creek on 22 September and was bypassed by the Highline fish screen on 24 September. All downstream encounters at the Highline Diversion Dam resulted in entrainment into the screened Highline Canal in 2004; therefore the overall probability of entrainment was again 100% (Table 11). However, the probability of being bypassed was only 33%.

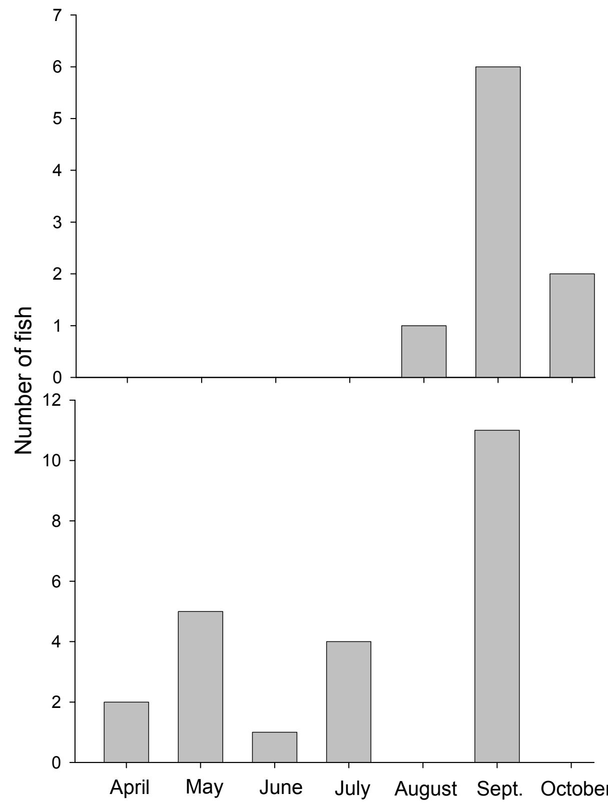
Table 11. Number and result of downstream encounters (entrainment, successfully went over dam without being entrained, or successfully bypassed) by telemetered juvenile westslope cutthroat trout with diversion dams, Skalkaho Creek, Montana, 2003 and 2004. The probability of entrainment at the Highline Diversion Dam is also shown.

Year	Diversion dam	Downstream encounters	Number entrained	Number that went over dam	Entrainment	Bypassed
2003	Highline	5	5	0	100%	– –
2004	Highline – FS	3	3	0	100%	1
Both years	Highline	8	8	0	100%	1

FS – Fish screen operational

Only about 7% of the age-1 juvenile westslope cutthroat trout that were telemetered were migratory. Similarly, very few juveniles were captured by the screw trap in both years and were only captured in one of the three bypass traps in 2004. Juvenile westslope cutthroat trout 100 to 200 mm in length (similar in size to those telemetered) were captured in the screw trap more frequently in the autumn in both 2003 and 2004, similar to when the few telemetered fish moved downstream (Figure 5). The Highline fish screen was the only screen to bypass juvenile westslope cutthroat trout 100 to 200 mm in length. Four were bypassed in September and one in October in 2004.

Figure 5. Westslope cutthroat trout from 100 to 200 mm in length captured in the screw trap in 2003 (top) and 2004 (bottom) in Skalkaho Creek, Montana.

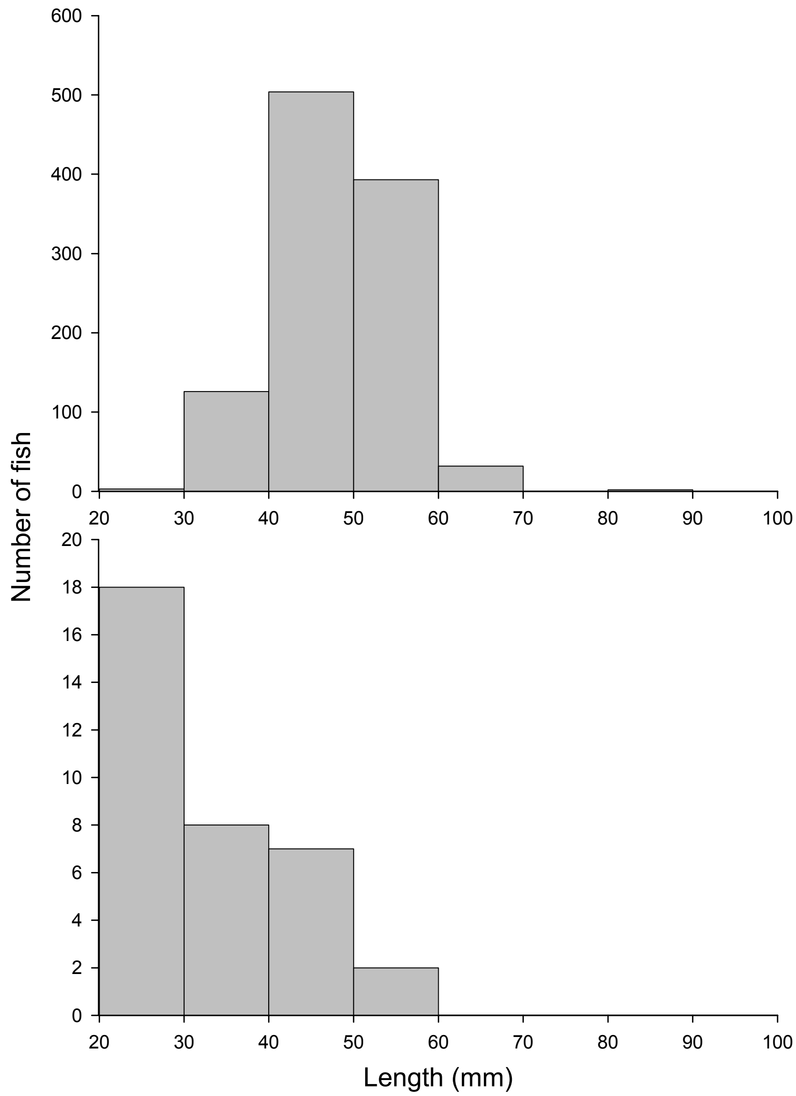


Age-0 Westslope Cutthroat Trout

In 2003, the screw trap was used in combination with the trap net above all irrigation canals to estimate the number of age-0 westslope cutthroat trout moving downstream. However, the numbers estimated were difficult to compare to 2004 when only a trap net was used to estimate the number of age-0 fish moving downstream in Skalkaho Creek. To illustrate, the screw trap was more effective at capturing fish in the autumn greater than 40 mm in length (Figure 6).

Therefore, only the total number of age-0 westslope cutthroat trout 40 mm or less moving downstream in Skalkaho Creek in 2003 were estimated.

Figure 6. Comparative size distributions of fish under 100 mm caught by the screw trap (top) and the instream trap net above all canals (bottom) during August 2003, Skalkaho Creek, Montana.



A substantial proportion (71%) of the age-0 westslope cutthroat trout moving downstream in Skalkaho Creek above all irrigation canals and into the reach affected by irrigation withdrawals in 2003 were entrained by the unscreened Highline Canal. The total number of age-0 westslope cutthroat trout estimated to have moved downstream into the reach was 12,709 (Table 12), and 8,964 were entrained in the Highline Canal (Table 13). Downstream movement (Figure 7) and entrainment (Figure 8) of age-0 westslope cutthroat trout peaked in late July, coinciding with emergence, as judged by length (about 20 mm) and presence of yolk sacs. A large autumn peak of age-0 westslope cutthroat trout (greater than 40 mm in length) moving downstream was also observed in mid-September in 2003, but entrainment as detected by trap nets did not increase (Figure 9), possibly because the screw trap was able to capture fish larger than 40 mm (Figure 6). Bull trout and slimy sculpin were also entrained in the unscreened Highline Canal in 2003 (Table 13).

Table 12. Estimated number of fish that moved downstream in Skalkaho Creek, Montana, from 16 July to 20 September in 2003. Lower and upper 95% confidence intervals are shown in parentheses.

Species	Above all canals	Below all canals
Westslope cutthroat trout	12,709 (4,505-61,099)	0
Bull trout	163 (59-800)	0
Brown trout	66 (24-329)	94 (31-458)
Longnose sucker	0	53,753 (18,934-257,355)
Longnose dace	0	3,633 (1,277-17,489)
Slimy sculpin	438 (157-2,151)	0
Unidentified	0	1,726 (610-8,289)
All species combined	13,431 (4,764-64,587)	58,926 (20,827-283,075)

Table 13. Total estimated numbers of age-0 fish entrained at trap net sites in canals on Skalkaho Creek, Montana, from 16 July to 20 September in 2003 and from 28 June to 27 September in 2004. Lower and upper 95% confidence intervals are shown in parentheses. No confidence intervals are shown for the Thompson trap net site because its efficiency was assumed to be 100%.

Species	Highline	Ward	Hughes	Thompson	Hedge	Republican	C&C	Total
				2003				
Westslope cutthroat trout	8,964 (2,840-72,141)	129 (112-157)	31 (28-38)	0	0	0	0	9,124
Rainbow trout	0	0	0	0	0	0	40 (36-49)	40
Unidentified *Oncorhynchus*	0	0	0	0	0	0	0	0
Bull trout	31 (7-252)	0	0	0	0	0	0	31
Brown trout	0	0	0	0	0	0	170 (148-207)	170
Mountain whitefish	0	0	0	0	0	0	31 (28-38)	31
Longnose sucker	0	0	0	0	4,918 (1,365-40,625)	159,674 (133,168-193,098)	57,653 (48,141-69,802)	222,245
Longnose dace	0	0	0	0	0	34,562 (28,823-41,798)	9,369 (7,823-11,345)	43,931
Slimy sculpin	94 (28-759)	119 (104-145)	381 (324-462)	4	0	0	0	598
Redside shiner	0	0	0	0	0	0	0	0
Unidentified species	0	0	0	0	1,969 (548-16,250)	130,869 (109,143-158,259)	22,789 (19,025-27,589)	155,627
All species combined	9,130 (2,892-73,484)	248 (216-302)	440 (372-533)	4	6,888 (1,913-56,875)	330,299 (275,455-399,425)	90,056(75,202-109,040)	431,797
				2004				
Westslope cutthroat trout	324 (87-2,598)	0	0	0	0	0	0	324
Rainbow trout	0	0	0	0	0	0	0	0
Unidentified *Oncorhynchus*	0	0	0	4	0	0	0	4
Bull trout	0	0	0	0	0	0	0	0
Brown trout	0	0	0	94	1,132 (315-9,375)	0	40 (36-49)	1,266
Mountain whitefish	0	0	0	0	0	45 (36-54)	31 (28-38)	76
Longnose sucker	0	0	0	0	4,763 (1,323-39,375)	163,745 (136,566-198,029)	52,905 (44,180-64,060)	221,413
Longnose dace	0	0	0	0	1,585 (441-13,125)	19,040 (15,876-23,025)	8,483 (7,079-10,275)	29,108
Slimy sculpin	0	0	0	12	0	45 (36-54)	0	57
Redside shiner	0	0	0	0	0	0	36 (32-44)	36
Unidentified species	0	0	0	0	0	0	0	0
All species combined	324 (87-2,598)	0	0	104	7,492 (2,079-61,875)	182,885 (152,524-221,175)	61,526 (51,376-74,493)	252,284

Figure 7. Estimated number of westslope cutthroat trout ≤ 40 mm in length that moved downstream daily above all canals, Skalkaho Creek, Montana, in 2003 (top). In 2003, the screw trap replaced the trap net on 18 August. Bottom graph shows the estimated number of westslope cutthroat trout that moved downstream daily above all canals in 2004. Error bars represent the upper and lower 95% confidence intervals and open circles represent a catch of zero.

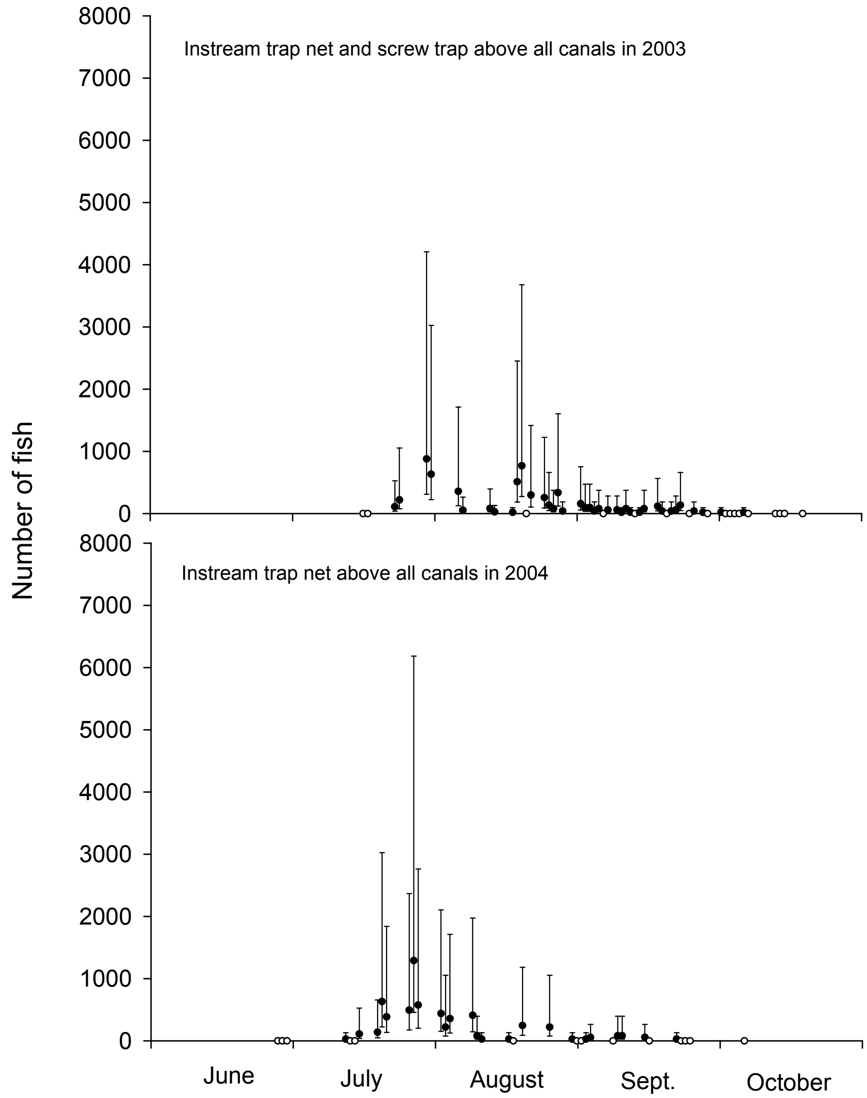


Figure 8. Estimated number of westslope cutthroat trout entrained daily in 2003 (top) and 2004 (bottom) at the Highline Canal, Skalkaho Creek, Montana. A fish screen was installed in the Highline Canal in 2004. Error bars represent the upper and lower 95% confidence intervals and open circles represent a catch of zero.

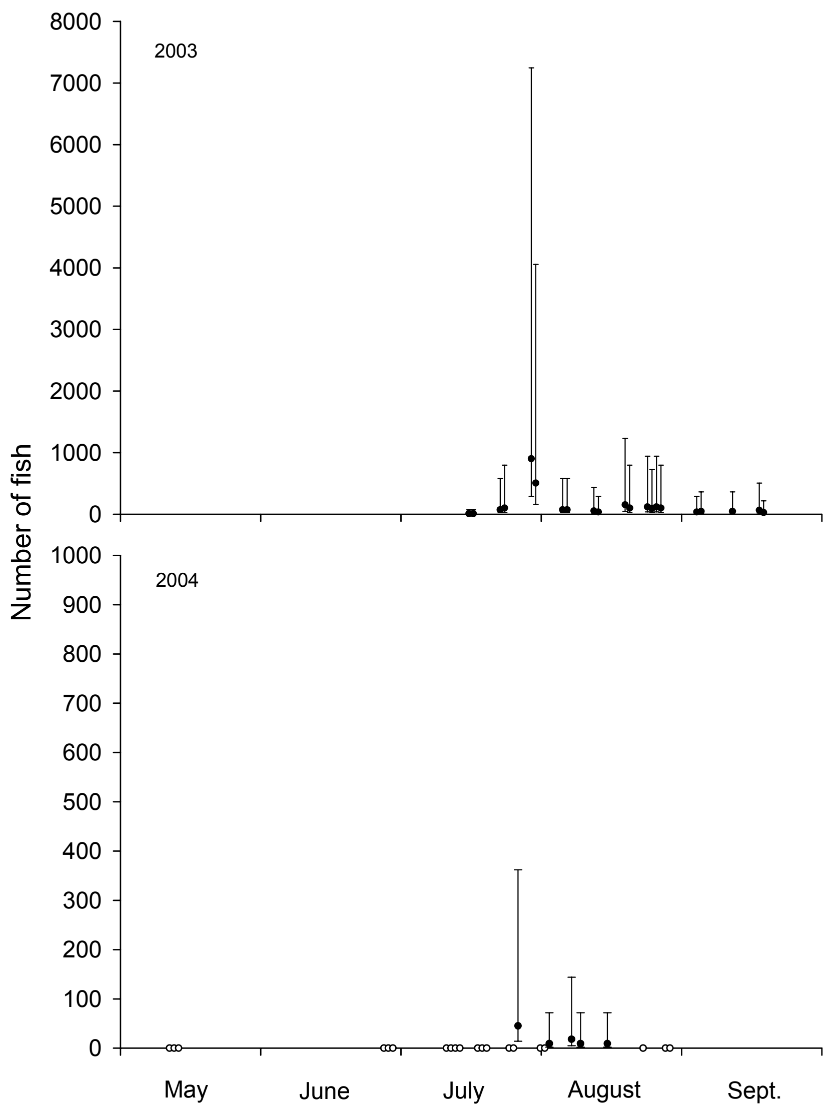
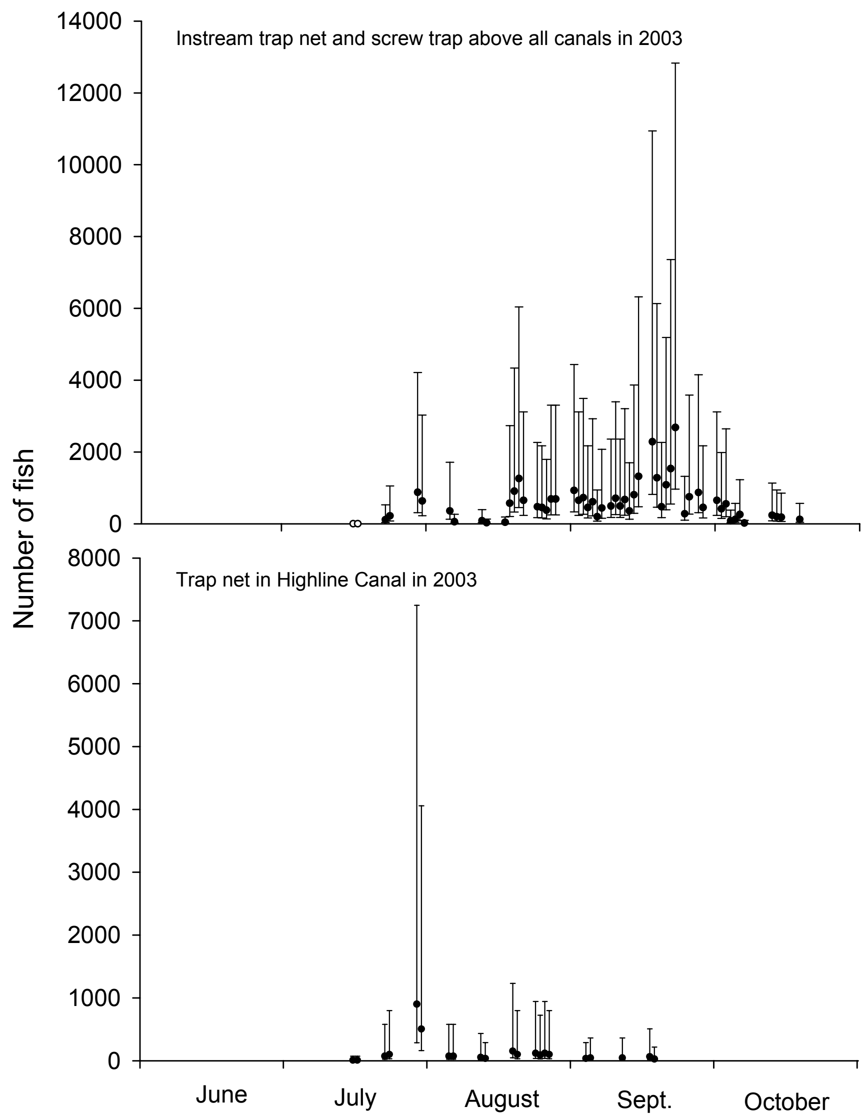


Figure 9. Estimated number of westslope cutthroat trout ≤ 100 mm in length that moved downstream daily above all canals in 2003 (top), Skalkaho Creek, Montana. In 2003, the screw trap replaced the trap net on 18 August. Bottom graph shows the estimated number of westslope cutthroat trout entrained daily in the Highline Canal in 2003, Skalkaho Creek. Error bars represent the upper and lower 95% confidence intervals and open circles represent a catch of zero.



The Highline Canal was screened in 2004, but an estimated 324 age-0 westslope cutthroat trout were nevertheless entrained in the canal downstream of the fish screen in late July and mid-August (Figure 8); this total was about 96% less than in 2003 (Table 13) and only 2% of the number moving downstream in 2004 (14,216; Table 14). Downstream movement of age-0 westslope cutthroat trout again peaked in late July (Figure 7).

The Highline fish screen did bypass a number of westslope cutthroat trout and other species, such as bull trout (Table 15). Numbers of westslope cutthroat trout bypassed varied during the sampling period, possibly in response to light intensity of the moon. Numbers bypassed peaked during periods of low light intensity associated with moon phases just before, during, and just after the new moon (Figure 10).

Table 14. Estimated number of fish that moved downstream in Skalkaho Creek, Montana, at three sites from 28 June to 27 September in 2004. Lower and upper 95% confidence intervals are shown in parentheses.

Species	Above all canals	Screw trap above BIG Dam	Below all canals
Westslope cutthroat trout	14,216 (5,004-68,389)	3,838 (2,552-6,217)	0
Rainbow trout	0	0	324 (108-1572)
Bull trout	513 (174-2,492)	28 (20-48)	0
Brown trout	0	421 (286-698)	446 (156-2169)
Mountain whitefish	0	0	81 (27-393)
Northern pikeminnow	0	0	81 (27-393)
Longnose sucker	0	0	22,471 (7,932-10,8061)
Longnose dace	0	0	3,382 (1,182-16,296)
Slimy sculpin	162 (57-789)	565 (385-943)	0
Redside shiner	0	0	175 (58-851)
All species combined	14,743 (5,193-70,950)	4,912 (3,252-8,000)	27,199 (9,592-130,822)

Figure 10. Westslope cutthroat trout, caught in bypass traps at the Highline (top), Ward (middle), and Hughes (bottom) fish screens in 2004, Skalkaho Creek, Montana. Open circles represent a catch of zero. The lunar cycle from July to October is shown at the top of the figure.

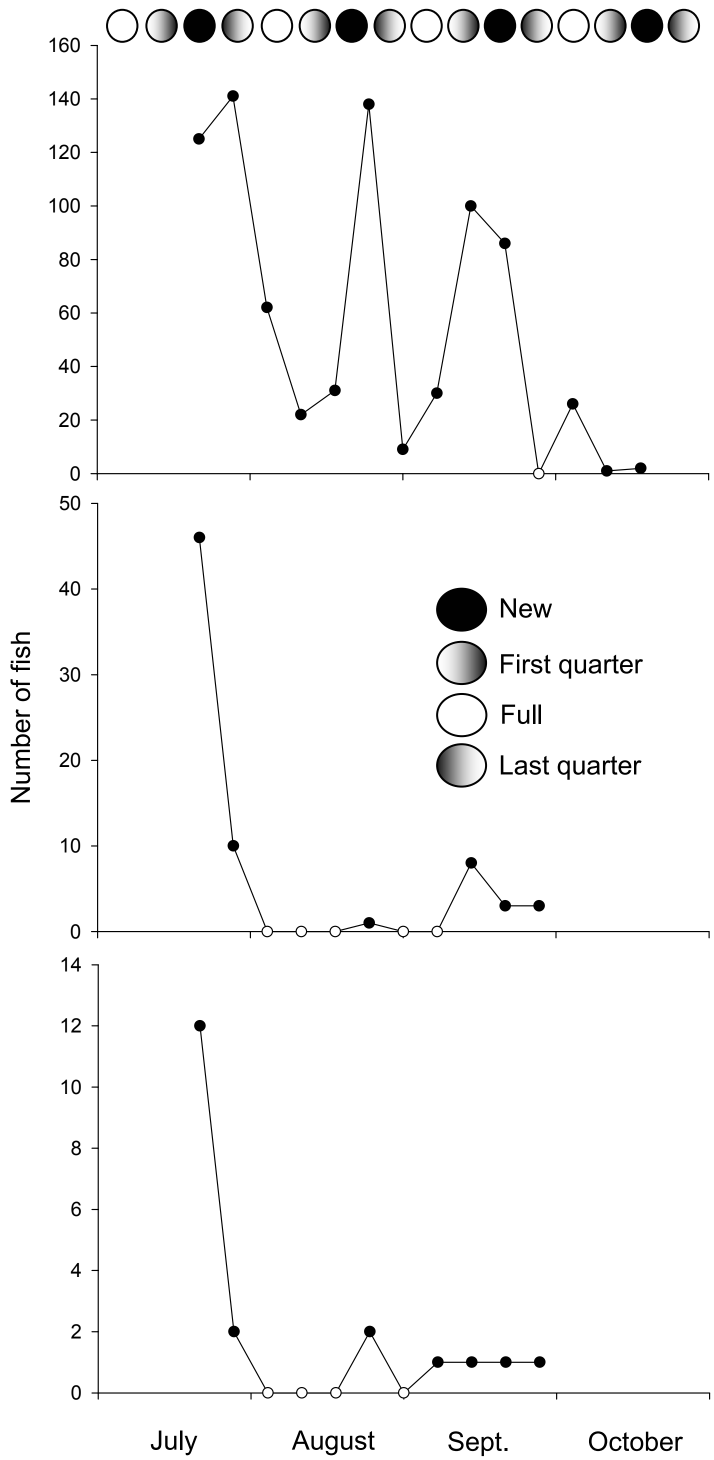


Table 15. Total estimated numbers of fish bypassed by the Highline (22 July to 21 October), Ward (22 July to 28 September), and Hughes (22 July to 28 September) fish screens in 2004, Skalkaho Creek, Montana.

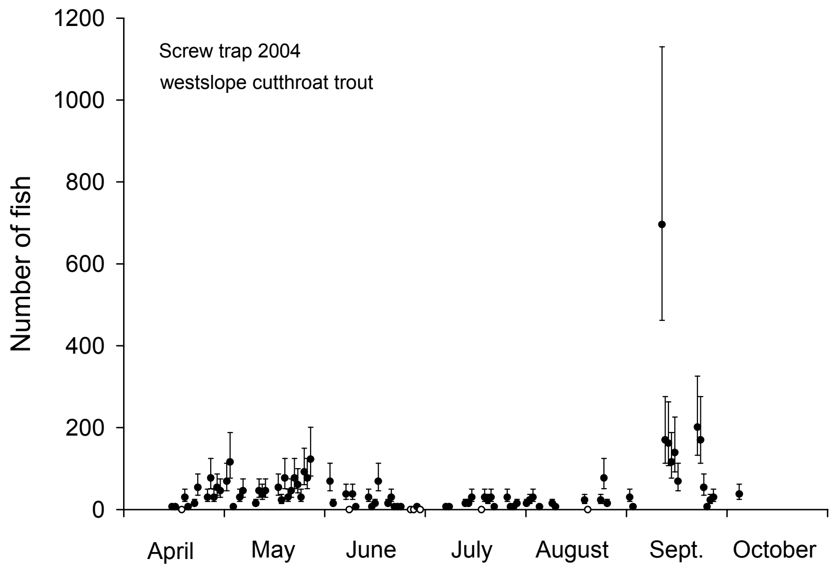
	Site			
Species	Highline	Ward	Hughes	Estimated total
Westslope cutthroat trout	5,411	486	137	6,049
Bull trout	196	7	7	210
Rainbow trout	0	0	14	14
Brown trout	7	35	7	49
Longnose sucker	14	0	7	21
Slimy sculpin	1,353	99	63	1,517
Estimated total	6,981	627	235	7,860

The number of age-0 westslope cutthroat trout entrained at the next two downstream irrigation canals in 2003 was minor in comparison to the number entrained at the Highline Canal that same year (Table 13). About 71% of the westslope cutthroat trout estimated to have been moving downstream in Skalkaho Creek were entrained into the Highline Canal in 2003, and therefore about 3,700 successfully moved downstream over the Highline Diversion Dam without being entrained. However, only a small proportion of these fish were entrained into the Ward (about 3%) and Hughes (about 1%) canals (Table 13). Westslope cutthroat trout and slimy sculpin were the only species entrained in the unscreened Ward and Hughes canals in 2003.

No fish were entrained in the screened Ward and Hughes canals in 2004. The total number of age-0 westslope cutthroat trout that moved downstream past the screw trap, located in Skalkaho Creek about 1.2 rkm above the Ward-Hughes Diversion Dam, was estimated to be 3,838 in 2004 (Table 14). However, only a small proportion of these fish were bypassed by the Ward (13%) and Hughes (4%) fish screens. The proportion entrained (Ward 4% and Hughes 1%) is even lower when calculated from the large number (13,789 = 5,411 bypassed by the Highline fish screen + 8,378 that went over the Highline Diversion Dam) of westslope cutthroat trout that had the potential to move downstream of the Highline Diversion Dam and potentially be entrained into the Ward and Hughes canals. Peak downstream movement and entrainment did not coincide with emergence. However, a peak in downstream movement did occur in mid-September when 25% of the total age-0 fish caught by the screw trap from 28 June to 27 September were caught in a 6-d period after a flushing-flow event caused by rainfall (Figure 11). The number of westslope cutthroat trout bypassed by the Ward fish screen also increased after the rain event, but the number bypassed at the Hughes Canal was not influenced (Figure 10).

The Ward and Hughes fish screens bypassed more age-0 westslope cutthroat trout than any other species (Table 15), but the total number bypassed was much lower than that bypassed at the Highline fish screen. Similar to what occurred at the Highline, numbers of age-0 westslope cutthroat trout bypassed peaked around the new moon (Figure 10). Even though the numbers bypassed were smaller when compared to the Highline, the fish screens in the Ward and Hughes canals effectively bypassed and precluded entrainment of all species.

Figure 11. Daily estimated number of westslope cutthroat trout that moved downstream in Skalkaho Creek, Montana, above the BIG Diversion Dam. Error bars represent the upper and lower 95% confidence intervals and open circles represent a catch of zero.



Most age-0 westslope cutthroat trout entrained at screened canals were bypassed back to Skalkaho Creek, whereas those entrained at unscreened canals were potentially lost to the population. The Highline, Ward, and Hughes canals entrained 9,818 fish in 2003 (about 2% of the total entrainment at all canals) but only 324 after fish screen installation; more importantly, 7,860 fish were bypassed. Specifically, 6,049 were westslope cutthroat trout; 5,411 by the Highline, 486 by the Ward, and 137 by the Hughes (Table 15). Most westslope cutthroat trout bypassed ranged in length from 20 to 60 mm.

No westslope cutthroat trout were entrained at unscreened canals downstream of the Ward-Hughes Diversion Dam in 2003 or 2004, even though age-0 westslope cutthroat trout that were bypassed by the Ward and Hughes fish screens had the potential to move downstream in 2004. Nevertheless, other fish species were entrained, and two of the more numerous were longnose dace and longnose sucker (Table 13). Furthermore, no westslope cutthroat trout were captured in the trap below all irrigation canals in Skalkaho Creek. Brown trout, longnose dace, and longnose sucker moved past this site in 2003 (Table 12). The same species were caught in 2004, as well as rainbow trout, mountain whitefish, northern pikeminnow, and redside shiner. Longnose dace and longnose suckers were the abundant species at this site in both years (Table 14).

Effectiveness of Screens

The efficiency of the Highline fish screen in bypassing fish was lower on average than the efficiencies of the Ward and Hughes fish screens (Table 16). It was difficult to assess the bypass efficiency of each screen because many of the PIT-tagged fish from the six PIT-tag efficiency trials were never found, and only a few were bypassed (Table 16). About 50% of all fish used in the six trials were never found. Fish never found may have swum out of the canal, evaded our electrofishing efforts, died in the canal, or suffered predation. The length of the Highline Canal from the headgate to the fish screen, about 150 m, made it difficult to recapture introduced fish if they remained in the canal. The Ward and Hughes fish screens are 33 m and 18 m from their headgates, respectively.

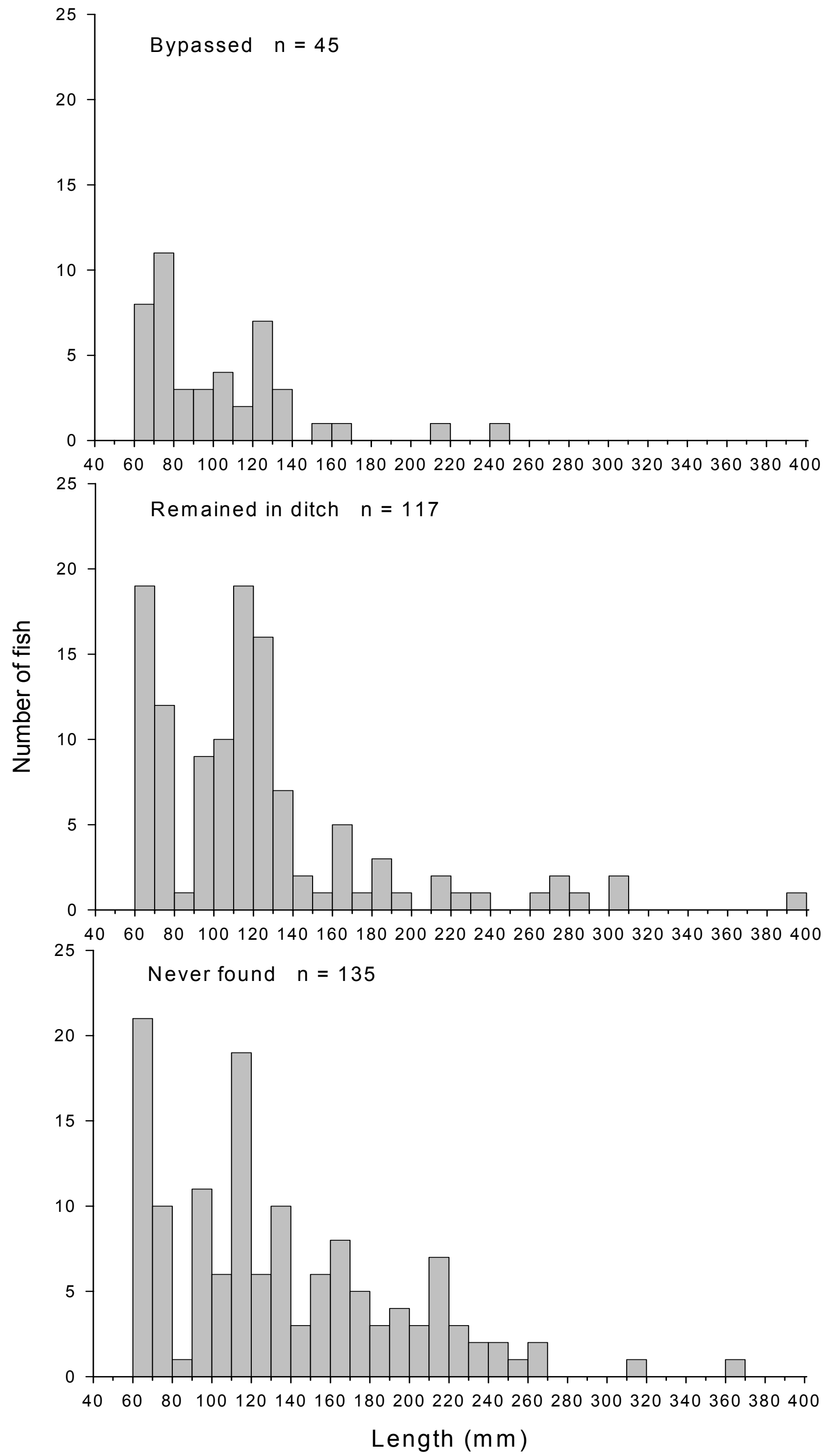
More fish were recaptured during trials in these canals, compared to trials conducted at the Highline Canal (Table 16). Westslope cutthroat trout were the only species that swam out of irrigation canals they were introduced into. Only about 8% of the westslope cutthroat trout used in all trials combined were bypassed, whereas bull trout and brown trout were bypassed more frequently (Table 16). With all species combined, the majority of fish bypassed ranged in length from 60 to 130 mm, whereas the sizes of fish that remained in the canals or were never found tended to be larger (Figure 12). Larger fish may have been able to swim out of the canals with less difficulty than smaller fish; however, westslope cutthroat trout that swam out during the trials were small with a mean length of 126 mm.

Table 16. Number and length of each species that were bypassed, remained in the canal, never found or swam out during PIT-tag efficiency trials conducted at all three fish screens in 2004, Skalkaho Creek, Montana.

	Trial					
	Highline 1	Highline 2	Ward 1*	Ward 2	Hughes 1**	Hughes 2
Westslope cutthroat trout	n = 39	n = 46	n = 35	n = 16	n = 38	n = 8
Mean length (mm)	186	141	119	123	126	166
Bypassed	1	1	4	4	4	1
Remained in the canal	15	20	16	7	19	1
Swam out	0	0	4[a]	0	1[b]	2[c]
Never found	23	25	11	5	14	4
Efficiency	3%	2%	11%	25%	11%	13%
Bull trout	n = 10	n = 4	n = 1	n = 1	n = 0	n = 0
Mean length (mm)	118	186	120	0	– –	– –
Bypassed	5	0	1	0	– –	– –
Remained in the canal	1	3	0	1	– –	– –
Swam out	0	0	0	0	– –	– –
Never found	4	1	0	0	– –	– –
Efficiency	50%	0%	100%	0%	– –	– –
Brown trout	n = 1	n = 0	n = 15	n = 33	n = 12	n = 42
Mean length (mm)	365	– –	121	78	95	85
Bypassed	0	– –	2	7	1	14
Remained in the canal	0	– –	4	13	6	11
Swam out	0	– –	0	0	0	0
Never found	1	– –	9	13	5	17
Efficiency	0%	– –	13%	21%	8%	33%
All species	n = 50	n = 50	n = 51	n = 50	n = 50	n = 50
Mean length (mm)	176	145	120	93	118	98
Bypassed	6	1	7	11	5	15
Remained in the canal	9	17	20	16	26	9
Swam out	0	0	4[a]	0	1[b]	2[c]
Never found	35	32	20	23	18	24
Efficiency	12%	2%	13%	22%	10%	30%

* Trial lasted one week, instead of two, and 51 fish were used instead of 50.
** Trial lasted one week, instead of two.
[a] All four fish swam out of Ward Canal and were captured in deep pool just upstream of Ward-Hughes Diversion Dam during trial.
[b] Fish swam out of Hughes Canal and was bypassed by Ward fish screen during trial.
[c] Both fish swam out of Hughes Canal and were captured in Ward Canal during trial.

Figure 12. Size distributions of fish used in PIT-tag efficiency trials, by fate, Skalkaho Creek, Montana.



DISCUSSION

Fish screens installed at the Highline, Ward, and Hughes canals were an effective management tool to reduce or eliminate entrainment of westslope cutthroat trout at Skalkaho Creek and should be recognized as a viable management tool to eliminate entrainment of potamodromous inland salmonids. Skalkaho Creek still supports a large population of westslope cutthroat trout despite their entrainment, but entrainment of migratory fish is of concern. Screens on irrigation canals may reverse this process and enhance the migratory component of the population.

The low number of telemetered fish that were migratory adults and juveniles suggests that the non-migratory, resident life history is predominant in this system. Irrigation diversion dams and associated canals fragment streams and rivers disrupting life-history movements (Northcote 1997; Nelson et al. 2002; Schmetterling and McEvoy 2000; Morita and Yamamoto 2001; Schrank and Rahel 2004), which can contribute to the decline of fish populations (Schlosser 1995) and influence the degree of residency in stream salmonids (Northcote 1992). The presence of irrigation canals for multiple generations in Skalkaho Creek has likely reduced the migratory component appreciably.

In 2004, 79% of the telemetered adult migratory fish were entrained at either screened or unscreened canals, a proportion which was considerably higher than in other studies. For example, 23% of telemetered Bonneville cutthroat trout (*Oncorhynchus clarkii utah*) attempting to move downstream after spawning in the Thomas Fork River drainage, Wyoming, were entrained (Schrank and Rahel 2004). Only 5% of telemetered Yellowstone cutthroat trout (*O. c. bouvieri*) were entrained in irrigation canals on spawning tributaries of the Yellowstone River, Montana (De Rito 2004). The difference may be attributable to the many canals on Skalkaho Creek that divert a large proportion of water.

Given that a few fluvial fish are still spawning in Skalkaho Creek, a small number of juvenile westslope cutthroat trout must be passing over the diversion dams and entering the Bitterroot River (Clancy 2003). Large numbers of age-1 and older juvenile westslope cutthroat trout were trapped moving downstream in Skalkaho Creek above the Highline and BIG diversion dams in the autumn of 1996 and 1997 (Nelson 1999). However, in my study only 8 of 117 age-1 juvenile westslope cutthroat trout telemetered in the autumn were migratory. In addition, only a small number of age-1 juvenile westslope cutthroat trout were captured by traps moving downstream in Skalkaho Creek in 2003 and 2004. Data from my study were insufficient to state that fish screens enhanced emigration of age-1 juvenile westslope cutthroat trout to the Bitterroot River, but over time such benefits may materialize.

Only one of three age-1 juvenile westslope cutthroat trout entrained in 2004 was bypassed by screens. Low bypass efficiency of the Highline fish screen may have been influenced by the length of canal between the headgate and the screen (about 150 m) and abundant suitable habitat in the canal, such as undercut banks and shade provided by overhanging vegetation. Entrained fish may have taken up residency in this habitat. Fish that do not migrate out of the canal before the end of the irrigation season would be expected to die upon dewatering.

Downstream movement of large numbers of age-0 westslope cutthroat trout in Skalkaho Creek increased their risk of entrainment. The Highline Canal entrained about 71% of age-0 westslope cutthroat trout moving downstream in 2003. If not for the screen to bypass them, 38% would have been entrained in the Highline Canal in 2004. About 20% and 41% of outmigrating age-0 rainbow trout were diverted into the Woodside Canal on Blodgett Creek, a tributary of the Bitterroot River, in 1991 and 1992, respectively (Chris Clancy, MTFWP, personal communication). Also, 16% of age-0 Yellowstone cutthroat trout outmigrating from Mol Heron Creek, Montana, were entrained in a small irrigation canal (Hennessey 1998).

The difference between the proportion of age-0 westslope cutthroat trout entrained in 2003 and 2004 may be attributable to annual differences in summer precipitation. The 2003 spring hydrograph increased and descended rapidly with little precipitation adding to summer flows. Therefore, in July 2003 when age-0 westslope cutthroat trout were emerging from the gravel, most of Skalkaho Creek was being diverted into irrigation canals. In contrast, multiple spring freshets and ample summer precipitation in 2004 caused more water to flow over the diversion dams in July than during 2003, thereby decreasing the probability of an age-0 westslope cutthroat trout moving downstream being entrained.

Age-0 westslope cutthroat trout movement downstream of the Highline Diversion Dam may be unnaturally altered through predation by introduced brown trout, dewatering, or other unknown causes. For example, although 71% of emigrating age-0 westslope cutthroat trout were entrained in the Highline Canal in 2003, very few were entrained at the next two downstream canals (Ward and Hughes). In addition, about 5,500 westslope cutthroat trout were bypassed by the Highline fish screen in 2004, but only about 600 were bypassed by the Ward and Hughes fish screens and no westslope cutthroat trout were entrained in canals further downstream. Furthermore, the typical peak in downstream movement coinciding with emergence of age-0 westslope cutthroat trout observed above all irrigation canals was not observed in the reach affected by irrigation withdrawals. Unaccounted for fish may have been lost to predation by bull or brown trout between the Highline and Ward-Hughes diversion dams, their emigration may have been delayed until higher discharge during autumn or the following spring, or they may have become residents. An increase in movement after a rain event in September 2004 suggested that migration may be delayed until higher discharges. The full potential of the Ward and Hughes screens will not be realized if natural migration is being altered.

Age-0 westslope cutthroat trout made downstream movements in the autumn, but entrainment thereof was difficult to assess because of the inability of trap nets to capture larger age-0 westslope cutthroat trout. Trap nets were ineffective at capturing age-0 westslope cutthroat trout larger than 40 mm. A better understanding of the migration dynamics of age-0 westslope cutthroat trout is needed to assess their entrainment. Such a study is currently ongoing (Ryan Harnish, Montana Cooperative Fishery Research Unit, personal communication).

The total estimated number of fish entrained at all seven unscreened irrigation canals (431,797) was greater than the total estimated to have been entrained after three of the seven were screened (252,284) in 2004 (Table 14). Although screens did reduce the number of fish entrained, especially in the Highline Canal, the large reduction in the total number entrained from 2003 to 2004 was probably not a result of screening. It was likely more related to annual differences in recruitment than to the presence of fish screens. Age-0 trout abundances in the Northern Rockies exhibit large annual fluctuations in numbers and biomass (Platts and Nelson 1988) as do other fish populations. Recruitment of longnose sucker and longnose dace was most likely higher in the Bitterroot River in 2003 and as a result more entered Skalkaho Creek from the Hedge and Republican ditches than in 2004. Therefore, more were also entrained in the Hedge and Republican ditches in 2003 than in 2004.

A relationship may exist between the number of fish entrained over an irrigation season and the proportion of water diverted from Skalkaho Creek. For example, when downstream movement occurs during periods of low water, entrainment is more likely because a larger proportion of water is diverted

(Thurow 1980 and 1981; Nordlund 1996; Schrank and Rahel 2004). The peak spring discharge in 2003 was three times more than in 2004 in Skalkaho Creek. Therefore more water was flowing over the dams during post-spawn downstream movement of telemetered adult westslope cutthroat trout, which may explain why none were entrained at unscreened canals in 2003. Similarly, of the three screened canals, the Highline Canal diverts the most water and entrained the majority of age-0 westslope cutthroat trout in 2003 prior to screening. Larger canals originating from the Big Wood River, Idaho, generally entrained more fish (Megargle 1999). Conversely, a relationship did not exist between the proportion of juvenile chinook salmon entrained in a canal on the Sacramento River, California, and the corresponding proportion of flow diverted (Hanson 2001). In my study, of the unscreened canals, the Hedge Canal diverts the most water from Skalkaho Creek, but the Republican Canal, which is second in volume, entrained the majority of fish. A majority at both canals were longnose suckers and longnose dace, which were observed entering Skalkaho Creek from the Hedge and Republican canals where they intersect the creek.

Assessing bypass efficiency of the screens was hampered by an inability to find many PIT-tagged fish. Evidence suggested that some fish were able to exit the canals by swimming back up through the headgates and thereby evaded detection, which was unexpected. In the same manner, 12 of 30 telemetered rainbow trout exited canals and reentered the Big Wood River, Idaho (Megargle 1999). Even though fish screen bypass efficiencies were low, screens may have facilitated return of fish to Skalkaho Creek by preventing transport further down the canals. The fish screens increased the proximity of an entrained fish to the headgate, which increased the probability that the fish would swim back out the headgate. Fish entrained in unscreened canals would not be similarly limited.

The lunar cycle may possibly be influencing downstream movement of age-0 westslope cutthroat trout, as was evident from the temporal variation in numbers bypassed at the Highline, Ward, and Hughes fish screens, which peaked at times during and surrounding the new moon phase. Salmonid fry presumably try to reduce their vulnerability to predators by emigrating under low light conditions (McDonald 1960). For instance, sockeye salmon (*Oncorhynchus nerka*) fry that encountered artificially lighted areas while emigrating downstream at night held their position in low velocity areas and delayed their migration (Tabor et al. 2004). Age-0 westslope cutthroat trout may emigrate downstream in Skalkaho Creek during the new moon to avoid predation by brown and bull trout. Predation on salmonid fry increases with increasing light intensity (Patten 1971; Ginetz and Larkin 1976). Salmonid predators are primarily visual predators and may have an advantage at higher light intensities (Tabor et al. 2004). Consequently, irrigators in coordination with fishery managers may be able to reduce entrainment at unscreened irrigation canals by reducing irrigation withdrawals during periods surrounding the new moon, when downstream migration is greatest.

High temperatures in downstream reaches may act as a barrier for westslope cutthroat trout in Skalkaho Creek. Most of the resident westslope cutthroat trout population of Skalkaho Creek exists above the Ward-Hughes Diversion Dam (Chris Clancy, MTFWP, personal communication). This is apparent when looking at the species composition of trap net catches from Skalkaho Creek and from trap net catches in irrigation canals above and below the Ward-Hughes Diversion Dam. Coldwater species (westslope cutthroat trout and slimy sculpin) dominated catches above the Ward-Hughes Diversion Dam, whereas warmer water species (longnose dace and longnose sucker) dominated below the dam. In tributaries of the Madison River, Montana, westslope cutthroat trout were associated with habitats with maximum daily stream temperatures below 16ºC from July to September (Sloat et al. 2005). On average, maximum daily stream temperatures above the Ward-Hughes Diversion Dam were less than 16ºC from July to September in 2004, whereas below the dam they were greater than 16ºC. One reason for high temperatures downstream of the Ward-Hughes Diversion Dam, besides the dewatering of the creek for irrigation purposes, is the influence of warmer Bitterroot River water emptying into Skalkaho Creek from the Hedge and Republican canals.

Three telemetered adult westslope cutthroat trout were entrained after spawning by swimming upstream into canals that originate from the Bitterroot River and intersect Skalkaho Creek. Bitterroot River water emptying into Skalkaho Creek from the Republican and Hedge canals may cause this unusual migration pattern. River water entering Skalkaho Creek may offer olfaction cues similar to the Bitterroot River thereby attracting emigrating fluvial westslope cutthroat trout and inducing them to swim upstream in the canals back to the Bitterroot River. Perhaps fish with a fluvial life-history have been maintained in Skalkaho Creek in this way. Olfaction is important for fishes because their extreme chemosensitivity is a key feature in their use of stream odors for migration purposes (Lucas and Baras 2001). For example, streams possess unique odors derived from their environmental surroundings that are imprinted on age-0 fish and attract migrating adult salmonids back to their natal streams to spawn (Hasler 1966). In this instance, the stream odors may be guiding emigrating adults back to their summer habitat. In addition to affecting emigration, the alteration of physical and chemical properties of Skalkaho Creek through the addition of Bitterroot River water from the Hedge and Republican canals likely affects the ability of westslope cutthroat trout and bull trout to home to Skalkaho Creek for spawning. Installation of siphons (projected for 2006 or 2007) to carry Hedge and Republican canal water past Skalkaho Creek without mixing should preclude olfaction and temperature influences from the Bitterroot River water and eliminate entrainment into these canals.

Temporal and spatial isolation (caused by diversion dams on Skalkaho Creek) may be maintaining the genetic integrity of westslope cutthroat trout by acting as selective barriers preventing invasion of and introgression with rainbow trout (Heggberget et al. 1988; Quinn et al. 2000; Mackey et al. 2001; De Rito

2004). Artificial barriers protect native fish populations from non-native fish invasion (Thompson and Rahel 1998; Nakamura 2001) and potential hybridization. Low flows during the spawning migration of rainbow trout may inhibit their ability to ascend the diversion dams. Rainbow trout spawn during stable flows prior to spring peak discharge (Downing et al. 2002) whereas fluvial westslope cutthroat trout move into spawning tributaries during high streamflows (Roscoe 1974). Rainbow trout spawning in the Bitterroot drainage commences in early March, peaks in mid-April in most streams, and generally tapers off in mid-May (Clancy 1993). Fluvial westslope cutthroat trout were first captured below the lower diversion dams in Skalkaho Creek from the third week of May through June in 2003 and 2004. Historically, mean monthly streamflow in Skalkaho Creek is 0.7 m^3/s in March, 1.5 m^3/s in April, 6.6 m^3/s in May, and 10.6 m^3/s in June. Therefore, considerably more water is flowing over the diversion dams during the spawning migration of westslope cutthroat trout (May to June) facilitating their upstream passage, than during the spawning migration of rainbow trout (March to April). Although no rainbow trout have been telemetered to track their progress up Skalkaho Creek, I documented that telemetered adult westslope cutthroat trout successfully ascended the Thompson, Ward-Hughes, BIG, and Highline diversion dams. Clancy (2003) documented successful ascent of all dams on Skalkaho Creek by an adult westslope cutthroat trout, with the possible exception of the C&C Diversion Dam, which diverts water from a side-channel. In the absence of diversion dams on Skalkaho Creek, rainbow trout and westslope cutthroat trout would most likely spawn in the same locations, increasing the risk of introgression during periods of spawning overlap. Yellowstone cutthroat trout and rainbow trout spawned in the same locations of tributary streams of the Yellowstone River, Montana (De Rito 2004).

Irrigation canals entrained westslope cutthroat trout, bull trout, and considerable numbers of non-game fish from Skalkaho Creek. Over time, such entrainment may negatively affect the overall fishery of the Bitterroot River. For instance, the decrease in connectivity (Rieman and Dunham 2000) to the Bitterroot River exposes the remaining population in Skalkaho Creek to a higher risk of extinction over time. The addition of fish screens may increase the persistence of fluvial cutthroat trout in the Bitterroot drainage as would the installation of irrigation siphons, by reconnecting Skalkaho Creek to the Bitterroot River. Maintaining connectivity of habitats necessary for all life-histories is crucial to the conservation and longevity of inland salmonid populations (Rieman and Dunham 2000; Schrank and Rahel 2004). Therefore, it is important to pursue restoration efforts on tributary streams for the promulgation of fluvial westslope cutthroat trout in the Bitterroot drainage (Javorsky 2002).

Skalkaho Creek is not the only heavily irrigated tributary of the Bitterroot River containing westslope cutthroat trout and bull trout populations. Preliminary electrofishing surveys of irrigation canals on a number of tributaries have been conducted (Rokosch 2004), but a better assessment of entrainment is needed at canals on important spawning tributaries for fluvial westslope cutthroat trout.

Blodgett, Lost Horse, and Tin Cup creeks are still used by fluvial westslope cutthroat trout for spawning (Javorsky 2002) and post-spawn adults and downstream migrant juveniles are at high risk of entrainment in these systems. Screens could be used on irrigation canals originating from Blodgett, Lost Horse, and Tin Cup creeks to eliminate entrainment of westslope cutthroat trout and bull trout and possibly elsewhere in the Bitterroot drainage.

Several unexpected problems occurred during the first season of use of fish screens on Skalkaho Creek. A local boy was caught in the paddlewheel of the Highline Canal screen and pinned underwater on 23 May 2004. Larry Trexler, ranch manager for Skalkaho Ranch, was able to free the boy from the wheel. After this incident, a steel guard was installed that covers the paddlewheel and a fence was put around the fish screen. A fence also surrounds the Ward fish screen. Guards and fences should be installed at all screens accessible to the public. Another problem was debris. The Ward and Hughes fish screens were able to operate during spring runoff and associated high debris loads, whereas the Highline fish screen had excessive debris build-up. Large debris loads washed into Skalkaho Creek during rain events or spring runoff clogged the Highline fish screen causing more water to exit bypass pipes, with less water entering the canal for irrigators. The Highline fish screen had been designed to handle an average discharge of 1.4 m^3/s, but the Daly Ditch Company has a highwater right allowing them to divert 1.7 m^3/s during runoff. The problem was addressed by the addition of check boards at the entrances to the bypass pipes during periods of high debris loads. These raised the water level, decreasing pressure on the vertical faces of the Highline fish screen and prevented clogging. Lastly, the paddlewheel of the Ward fish screen stopped working because the gears had not been greased properly upon installation. All three paddlewheels were regreased and ran smoothly for the remainder of the irrigation season. Preventative maintenance is essential to the operational longevity of fish screens (Nordlund 1996).

Before management actions (e.g., fish screens and irrigation siphons) are initiated, managers must first understand the temporal variation in movement patterns of the targeted salmonid species (Schrank and Rahel 2004). Fish screens and irrigation siphons could be valuable management tools in the recovery of inland salmonids. However, the extent of entrainment must be assessed before such tools are employed. In addition, post-installation monitoring is needed to determine the biological success of actions (Moyle and Israel 2005).

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APPENDICES

APPENDIX A

TELEMETERED ADULT WESTSLOPE CUTTHROAT TROUT

Fish number	Length (mm)	Weight (g)	Sex	Capture location	Release location	Capture Date	Final fate	Migratory or Non-migratory
27	439	1000	M	Below Hedge Dam	Below Thompson Dam	5/19/03	Missing	M
23	340	1614	F	Below Hedge Dam	Below Thompson Dam	5/20/03	Dead found in osprey nest	M
12	292	268	U	Below Ward-Hughes Dam	Below BIG Dam	5/29/03	Found tag	M
114	295	334	M	Below Republican Dam	Below Hedge Dam	6/4/03	Dead	Non-m
15	308	292	F	Below Republican Dam	Below Hedge Dam	6/5/03	Found tag	Non-m
111	355	431	M	Above Highline Dam	At capture location	6/16/03	Resident	Non-m
25	329	348	M	Above Highline Dam	At capture location	6/16/03	Resident	Non-m
211	350	424	F	Above Highline Dam	At capture location	6/17/03	Resident	Non-m
213	377	611	M	Above Highline Dam	At capture location	6/17/03	Resident	Non-m
24	370	560	M	Above Highline Dam	At capture location	6/17/03	Resident	Non-m
13	364	479	F	Above Highline Dam	At capture location	6/17/03	Missing	Non-m
29	362	454	F	Above Highline Dam	At capture location	6/17/03	Resident	Non-m
17	350	410	U	Above Highline Dam	At capture location	6/17/03	Missing	Non-m
14	400	512	U	Above Highline Dam	At capture location	6/18/03	Resident	Non-m
28	362	474	U	Above Highline Dam	At capture location	6/18/03	Found tag in gravel	Non-m
26	359	424	U	Above Highline Dam	At capture location	6/23/03	Resident	Non-m
19	370	464	U	Above Highline Dam	At capture location	6/23/03	Resident	Non-m
115	400	639	U	Above Highline Dam	At capture location	6/23/03	Resident	Non-m
22	351	548	M	Above Highline Dam	At capture location	6/23/03	Found tag out of water (Predator)	Non-m
18	415	712	U	Above Highline Dam	At capture location	6/25/03	Found fish dead	M
110	371	483	M	Above Highline Dam	At capture location	6/25/03	Missing	M
21	360	464	U	Above Highline Dam	At capture location	6/26/03	Missing	Non-m
212	370	502	U	Above Highline Dam	At capture location	6/30/03	Dead	Non-m
16	323	298	U	Above Highline Dam	At capture location	6/30/03	Missing	Non-m
210	324	291	U	Above Highline Dam	At capture location	7/1/03	Missing	Non-m
113	320	310	U	Above Highline Dam	At capture location	7/1/03	Resident	Non-m
215	322	324	U	Above Highline Dam	At capture location	7/1/03	Resident	Non-m
112	313	304	U	Above Highline Dam	At capture location	7/1/03	Resident	Non-m
216	365	480	U	Above Highline Dam	At capture location	7/1/03	Resident	Non-m
214	320	349	U	Above Highline Dam	At capture location	7/1/03	Resident	Non-m
137	375	500	U	Below Republican Dam	Below Hedge Dam	5/17/04	Swam out of Republican Canal to Bitterroot River	M
124	325	380	U	Below Republican Dam	Below Hedge Dam	5/17/04	Found tag in Republican Canal	M
131	385	640	M	Below Republican Dam	Below Hedge Dam	5/20/04	Found tag in Bitterroot River	M
129	332	425	M	Below Republican Dam	Below Hedge Dam	5/24/04	Found tag out of water (Predator)	Non-m

Fish number	Length (mm)	Weight (g)	Sex	Capture location	Release location	Capture Date	Final fate	Migratory or Non-migratory
132	282	250	U	Below Republican Dam	Below Hedge Dam	5/25/04	Found tag	M
263	389	590	F	Below Ward-Hughes Dam	Below BIG Dam	5/26/04	Found tag out of water (Predator)	Non-m
120	370	538	U	Below Ward-Hughes Dam	Below BIG Dam	5/26/04	Resident	M
128	370	520	U	Below Ward-Hughes Dam	Below BIG Dam	5/26/04	Resident	M
135	446	788	M	Below Hedge Dam	Below Thompson Dam	5/26/04	Entrained in Hedge Canal (river side)	M
117	305	296	M	Below Hedge Dam	Below Thompson Dam	5/26/04	Resident	Non-m
259	370	620	U	Below Hedge Dam	Below Thompson Dam	5/27/04	Found fish dead in Thompson Canal	M
134	380	540	M	Below Ward-Hughes Dam	Below BIG Dam	5/27/04	Resident	M
244	392	608	F	Below Ward-Hughes Dam	Below BIG Dam	6/2/04	Found fish dead	M
138	402	720	F	Below Hedge Dam	Below Thompson Dam	6/2/04	Found tag out of water (Predator)	M
253	332	367	M	Below Hedge Dam	Below Thompson Dam	6/2/04	Resident	Non-m
122	358	520	F	Below Hedge Dam	Below Thompson Dam	6/2/04	Resident	Non-m
126	378	570	F	Below Ward-Hughes Dam	Below BIG Dam	6/3/04	Entrained in Republican Canal (Skalkaho creek side)	M
252	411	750	F	Below Ward-Hughes Dam	Below BIG Dam	6/3/04	Found tag in Hedge Canal	M
136	350	445	U	Below Thompson Dam	Below Ward-Hughes Dam	6/4/04	Found tag in Hedge Canal	M
265	290	240	M	Below Hedge Dam	Below Thompson Dam	6/4/04	Found tag	Non-m
242	365	540	U	Below Ward-Hughes Dam	Below BIG Dam	6/10/04	Found tag	M
123	338	395	U	Below Ward-Hughes Dam	Below BIG Dam	6/10/04	Found tag out of water (Predator)	M
141	367	464	F	Below Ward-Hughes Dam	Below BIG Dam	6/15/04	Entrained in Hedge Canal (river side)	M
125	317	380	F	Above Highline Dam	At capture location	6/17/04	Resident	Non-m
119	322	340	F	Above Highline Dam	At capture location	6/17/04	Resident	Non-m
127	376	512	M	Above Highline Dam	At capture location	6/17/04	Resident	Non-m
121	383	575	F	Above Highline Dam	At capture location	6/17/04	Found tag out of water (Predator)	Non-m
248	338	358	M	Above Highline Dam	At capture location	6/17/04	Resident	Non-m
243	395	650	M	Above Highline Dam	At capture location	6/17/04	Resident	Non-m
118	345	422	M	Above Highline Dam	At capture location	6/17/04	Resident	Non-m
250	332	350	U	Above Highline Dam	At capture location	6/21/04	Found tag	Non-m
261	342	425	M	Below Highline Dam	At capture location	6/22/04	Found tag	Non-m
258	372	465	U	Below Highline Dam	At capture location	6/22/04	Resident	Non-m
139	335	365	F	Above Highline Dam	At capture location	6/22/04	Resident	Non-m
249	402	622	M	Above Highline Dam	At capture location	6/22/04	Found fish dead	Non-m
264	341	370	U	Screw trap	At capture location	6/23/04	Found tag out of water (Predator)	M
260	348	472	U	Above Highline Dam	At capture location	6/23/04	Resident	Non-m
140	350	448	M	Above Highline Dam	At capture location	6/23/04	Found tag out of water (Predator)	Non-m
257	383	530	M	Above Highline Dam	At capture location	6/23/04	Found tag	Non-m

Fish number	Length (mm)	Weight (g)	Sex	Capture location	Release location	Capture Date	Final fate	Migratory or Non-migratory
266	413	873	M	Above Highline Dam	At capture location	6/23/04	Resident	Non-m
256	329	370	U	Above Highline Dam	At capture location	6/23/04	Resident	Non-m
245	317	275	F	Screw trap	At capture location	6/25/04	Resident	M
251	359	421	U	Screw trap	At capture location	7/14/04	Resident	Non-m

APPENDIX B

TELEMETERED JUVENILE WESTSLOPE CUTTHROAT TROUT

Fish number	Length (mm)	Weight (g)	Capture location	Capture Date	Final fate	Migratory or Non-migratory
256	116	20	Highline Canal	8/20/03	Resident	Non-m
258	132	24	Highline Canal	8/20/03	Resident	Non-m
244	120	22	Highline Canal	8/20/03	Resident	Non-m
247	125	20	Highline Canal	8/20/03	Found tag	Non-m
250 (A)	124	19	Highline Canal	8/21/03	Found tag	Non-m
373	139	29	Highline Canal	8/21/03	Resident	Non-m
381	129	20	Highline Canal	8/21/03	Resident	Non-m
379	121	17	Highline Canal	8/21/03	Dead, found fish	Non-m
380	130	24	Highline Canal	8/21/03	Resident	Non-m
382	140	30	Highline Canal	8/21/03	Resident	Non-m
377	140	30	Ward Canal	8/26/03	Resident	Non-m
378	121	17	Ward Canal	8/26/03	Dead, found fish, antenna stuck	Non-m
259 (A)	128	19	Ward Canal	8/26/03	Found tag	Non-m
260	130	24	Ward Canal	8/26/03	Entrained in Highline Canal	M
375	123	20	Ward Canal	8/26/03	Found tag, antenna stuck	Non-m
254 (A)	128	19	Ward Canal	8/26/03	Found tag	Non-m
376	121	18	Ward Canal	8/26/03	Entrained in Highline Canal	M
257	126	19	Ward Canal	8/26/03	Entrained in Highline Canal	M
255	118	17	Ward Canal	8/26/03	Resident	Non-m
374	119	17	Hughes Canal	8/26/03	Resident	Non-m
366	125	20	Highline Canal	8/27/03	Resident	Non-m
368	130	25	Highline Canal	8/27/03	Resident	Non-m
369	143	30	Highline Canal	8/27/03	Found tag	Non-m
372 (A)	142	29	Highline Canal	8/27/03	Found tag	Non-m
367	119	16	Highline Canal	8/27/03	Found tag	Non-m
370	163	39	Highline Canal	8/27/03	Resident	Non-m
238	124	19	Highline Canal	8/27/03	Entrained in Highline Canal	M
240	134	23	Highline Canal	8/27/03	Resident	Non-m
246 (A)	121	19	Highline Canal	8/27/03	Dead, found fish	Non-m
249	141	38	Highline Canal	8/27/03	Resident	Non-m
239	118	17	Highline Canal	8/27/03	Resident	Non-m
245	138	24	Highline Canal	8/27/03	Resident	Non-m
371 (A)	120	18	Highline Canal	8/27/03	Found tag	Non-m
379	123	18	Highline Canal	8/27/03	Resident	Non-m
362 (A)	125	20	Ward Canal	8/28/03	Dead, found fish, antenna stuck	Non-m
364	134	28	Ward Canal	8/28/03	Resident	Non-m
365	152	32	Ward Canal	8/28/03	Found tag	Non-m
233	156	38	Highline Canal	8/29/03	Resident	Non-m
243	145	28	Highline Canal	8/29/03	Resident	Non-m
242	125	20	Highline Canal	8/29/03	Missing	Non-m
363	142	34	Highline Canal	8/29/03	Resident	Non-m
253	133	22	Highline Canal	8/29/03	Found tag	Non-m
252	142	27	Highline Canal	8/29/03	Resident	Non-m
248	138	22	Highline Canal	8/29/03	Resident	Non-m
241	137	28	Highline Canal	8/29/03	Entrained in Highline Canal	M
361	123	18	Highline Canal	8/29/03	Missing	Non-m

Fish number	Length (mm)	Weight (g)	Capture location	Capture Date	Final fate	Migratory or Non-migratory
251	127	20	Highline Canal	8/29/03	Resident	Non-m
134	123	19	Highline Canal	8/29/03	Resident	Non-m
237	140	26	Highline Canal	8/29/03	Found tag	Non-m
232	120	17	Highline Canal	8/29/03	Resident	Non-m
235	127	19	Highline Canal	8/29/03	Found tag	Non-m
234	135	22	Ward Canal	9/13/03	Found tag	Non-m
371 (B)	128	18	Ward Canal	9/13/03	Resident	Non-m
259 (B)	124	18	Ward Canal	9/13/03	Resident	Non-m
254 (B)	151	35	Highline Canal	9/13/03	Resident	Non-m
246 (B)	141	25	Highline Canal	9/13/03	Resident	Non-m
372 (B)	137	23	Highline Canal	9/13/03	Found tag, antenna stuck	Non-m
362 (B)	128	20	Highline Canal	9/13/03	Found tag	Non-m
250 (B)	126	17	Highline Canal	9/13/03	Dead, found fish, antenna stuck	Non-m
3133	133	25	Screw trap	5/12/04	Resident	Non-m
3109	116	14	Screw trap	5/28/04	Found tag	Non-m
3113	115	14	Screw trap	5/28/04	Resident	Non-m
3130	154	38	Screw trap	6/8/04	Resident	Non-m
3115	136	26	Ward Canal	8/17/04	Resident	Non-m
3128	132	22	Hughes Canal	8/17/04	Resident	Non-m
289	125	18	Highline Canal	8/18/04	Resident	Non-m
288 (A)	120	18	Highline Canal	8/18/04	Resident	Non-m
293 (A)	175	52	Highline Canal	8/18/04	Dead, found fish	Non-m
295	132	26	Highline Canal	8/18/04	Resident	Non-m
2103	124	22	Highline Canal	8/18/04	Resident	Non-m
2105	167	52	Highline Canal	8/18/04	Resident	Non-m
294	121	20	Highline Canal	8/18/04	Found tag	Non-m
3108 (A)	129	29	Highline Canal	8/18/04	Resident	Non-m
3110	166	44	Highline Canal	8/18/04	Resident	Non-m
3125	119	18	Highline Canal	8/18/04	Resident	Non-m
3131	120	16	Highline Canal	8/18/04	Resident	Non-m
2106	124	19	Highline Canal	8/25/04	Resident	Non-m
3127	152	31	Highline Canal	8/25/04	Resident	Non-m
3114	125	19	Highline Canal	8/25/04	Resident	Non-m
3111	118	17	Highline Canal	8/25/04	Resident	Non-m
3129 (A)	121	19	Highline Canal	8/25/04	Dead, found fish	Non-m
3126	118	17	Highline Canal	8/25/04	Entrained in Highline Canal, but never bypassed	M
299	124	20	Highline Canal	8/25/04	Resident	Non-m
2101 (A)	128	20	Highline Canal	8/25/04	Dead, found fish, Entrained in Highline Canal	M
296	130	20	Highline Canal	8/25/04	Resident	Non-m
283	120	15	Highline Canal	9/1/04	Resident	Non-m
3122	127	20	Highline Canal	9/1/04	Resident	Non-m
3117	132	25	Highline Canal	9/1/04	Resident	Non-m
3112	141	29	Highline Canal	9/1/04	Resident	Non-m
3123	139	28	Highline Canal	9/1/04	Resident	Non-m
3121	142	30	Highline Canal	9/1/04	Resident	Non-m

Fish number	Length (mm)	Weight (g)	Capture location	Capture Date	Final fate	Migratory or Non-migratory
291	124	18	Highline Canal	9/1/04	Resident	Non-m
2107 (A)	116	15	Highline Canal	9/3/04	Dead, found fish	Non-m
284	125	21	Highline Canal	9/3/04	Resident	Non-m
298	120	18	Highline Canal	9/3/04	Resident	Non-m
3119	116	16	Highline Canal	9/3/04	Resident	Non-m
3132	180	62	Highline Canal	9/10/04	Resident	Non-m
3124	173	56	Highline Canal	9/10/04	Resident	Non-m
2102	147	26	Highline Canal	9/10/04	Bypassed by Highline fish screen	M
297	123	20	Highline Canal	9/10/04	Resident	Non-m
286	120	16	Highline Canal	9/10/04	Resident	Non-m
2100	112	13	Highline Canal	9/10/04	Resident	Non-m
292	118	16	Highline Canal	9/10/04	Resident	Non-m
2104	144	31	Highline Canal	9/10/04	Resident	Non-m
3116	113	13	Highline Canal	9/10/04	Resident	Non-m
285	218	98	Screw trap	9/13/04	Resident	Non-m
3118	115	13	Screw trap	9/13/04	Resident	Non-m
288 (B)	127	19	Screw trap	9/13/04	Resident	Non-m
287	125	20	Screw trap	9/13/04	Dead, found fish	Non-m
2107 (B)	163	39	Screw trap	9/17/04	Resident	Non-m
290	140	26	Screw trap	9/17/04	Resident	Non-m
293 (B)	138	21	Highline Canal	9/17/04	Resident	Non-m
3129 (B)	147	30	Highline Canal	9/17/04	Resident	Non-m
3108 (B)	147	29	Highline Canal	9/17/04	Resident	Non-m
294	155	34	Highline Canal	9/17/04	Resident	Non-m
3120	148	32	Highline Canal	9/17/04	Resident	Non-m
2101 (B)	158	40	Highline Canal	9/17/04	Resident	Non-m