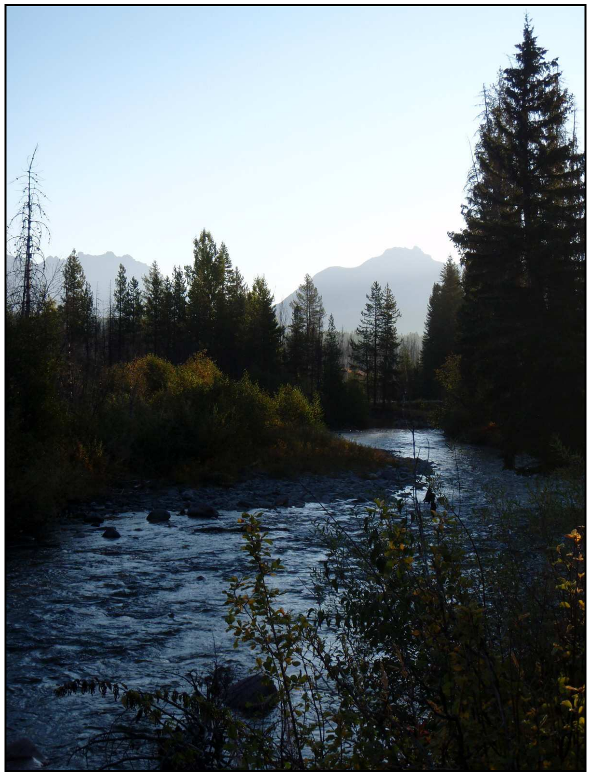
INVESTIGATIONS OF THE HUNGRY HORSE MITIGATION PROGRAM



2007-2008 ANNUAL REPORT

JUNE 2009

Amber Steed
Durae Belcer
Rick Hunt
Steve Glutting
Matthew Boyer

Montana Fish, Wildlife and Parks
490 North Meridian Road
Kalispell, Montana 59901

BPA—199101903
MFWP—31002

This document should be cited as:

Steed, A., D. Belcer, R. Hunt, S. Glutting, and M. Boyer. 2009. Investigations of the Hungry Horse Mitigation Program, 2007-2008 Annual Report. BPA Project number 199101903.

Bonneville Power Administration
PO Box 3621
Portland, Oregon 97208

The Hungry Horse Mitigation Program (project number 199101903) is funded by Bonneville Power Administration (BPA) as a part of BPA's program to protect, mitigate for, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities in the Columbia River Basin.

TABLE OF CONTENTS

TABLE OF CONTENTS—continued

LIST OF TABLES

Page

LIST OF TABLES—continued

LIST OF FIGURES

Page

Page

Acknowledgments

We would like to thank the Bonneville Power Administration for funding the investigations of the Hungry Horse Mitigation Program. We also appreciate the significant contributions Ben Davis, Kris Tempel, Lynda Fried, Gary Michael, Mark Schnee, and others who provided technical and manual support.

INVESTIGATIONS OF HYBRIDIZATION BETWEEN NATIVE WESTSLOPE CUTTHROAT TROUT AND NON-NATIVE RAINBOW TROUT IN THE FLATHEAD RIVER SYSTEM

Populations of many native salmonids in the western United States are threatened by introgression with introduced rainbow trout (RBT). The Flathead River system in northwest Montana is recognized as a regional stronghold for migratory westslope cutthroat trout (WCT) throughout their historic range (Shepard et al. 1984; Liknes and Graham 1988). However, hybridization between RBT and WCT is prevalent in the Flathead River upstream of Flathead Lake (Deleray et al. 1999; Hitt et al. 2003). Native populations have declined as a result of habitat degradation and fragmentation, angler exploitation, and most notably the introductions of non-native salmonids. Hybridization is perhaps the primary threat facing WCT persistence (Allendorf and Leary 1988), yet the temporal and spatial distribution of hybridized populations is inadequately understood. A comprehensive investigation of fish spawning movements and relative abundances will allow managers to identify mechanisms responsible for genetic introgression and streams containing hybrids for removal or suppression programs by implementing the Hungry Horse Mitigation Program.

Movement of spawning westslope cutthroat trout, rainbow trout, and hybrids

Introduction and Methods

Population demographics of westslope cutthroat trout (WCT) detected in the South Fork Flathead River below Hungry Horse Dam are not well understood. Limited data exists on residence time in the South Fork, habitat use, diet, growth, survival, and spawning movements. An investigation of pre- and post-spawning movements, growth, and survival was initiated in spring 2008 to describe these metrics in this portion of the Flathead River system most directly affected by Hungry Horse Dam operations. This research will continue through 2010, followed by a food habits study to be launched that same year.

Sixteen adult WCT were caught in February 2008 by angling on the South Fork of the Flathead River immediately downstream of the Hungry Horse Dam. Fish were anaesthetized with tricaine methane sulfonate (MS-222), surgically implanted with transmitters according to the methods described by Muhlfeld et al. (2003), and released near their capture location. Mean transmitter dry weight to body weight ratio was 1.9% (range 1.4-2.1%). Sexual maturity was identified using an otoscope through a small abdominal surgical incision; only mature fish were tagged. The transmitters emitted a unique code in the 148.740 MHZ frequency range (with 5 second burst rates), had expected battery lives of 804 d and weighed 8.0 g (air weight). Tags were programmed to shut off in October 2008, turning back on in January 2009 to capture 2 consecutive years of spawning data. Each radio-tagged fish received a passive integrated transponder (PIT) tag for supplemental identification in the event of radio tag loss and to provide growth data upon potential recapture (if radio tag had terminated or been shed). Scales were collected for age and growth calculations in addition to fin clips for genetic analyses. Genetic purity was analyzed at the Conservation Genetics Laboratory at the University of Montana, Missoula. Five fish tagged in 2007 with 2-year radio tags are also included in the results below. Two of these fish were WCT and three were westslope trout x rainbow trout hybrids (HYB).

Radio-tagged fish were relocated three to five times per week during the spring spawning period by jet boat, vehicle access points along waterways, and by foot using a Lotek (model SRX-400) scanning receiver equipped with an ATS 3- element Yagi antenna or omni directional whip antenna. Aerial surveys were conducted to locate fish that were missing for more than one week and to survey remote and inaccessible areas throughout the upper portions of the river system including British Columbia, Canada, Waterton-Glacier International Peace Park, and the Bob Marshall Wilderness complex. Additionally, three permanent telemetry ground stations were installed near the mouths of the North, Middle, and South forks. Additionally, two permanent stations were installed on the Mainstem Flathead River—one immediately upstream of Flathead Lake and one just above the confluence of the South Fork with the Mainstem Flathead River. These ground stations continuously monitored fish movements within 250 m of the antenna. Each ground station consisted of a Lotek data-logging receiver equipped with a 3-element directional Yagi antenna powered by a 12-volt deep cycle marine battery. Geo-referenced locations were obtained at each fish location using a global positioning system (GPS) unit.

It was impossible to conclusively identify the exact time and location of spawning for many radio-tagged fish because of high and turbid flows, inclement weather conditions (which precluded some aerial surveys), and the extensive size and complexity of the stream system. However, we assumed that a fish had spawned if it made a pronounced movement upstream from its release location in the Mainstem into a tributary or to the mouth of a tributary. All remaining fish were classified as non-spawners.

Results and Discussion

Genetics analyses confirmed that all 16 fish tagged in 2008 were pure WCT. The five fish tagged in 2007 made upstream migrations in 2008. Of the 16 newly-tagged WCT, 8 fish made upstream migrations and were located in or near spawning tributaries. The remaining 8 fish never left the South Fork Flathead River near Hungry Horse Dam, went missing immediately after tagging, or moved downstream but never made a spawning migration.

Hybrids

Three HYB fish tagged in 2007 were detected in 2008 (Table 1). Hybrids migrated relatively short distances to spawn (mean = 37.8 km, range = 23.6-56.7 km) relative to

WCT (mean = 111.4 km, range = 66.3-192.0 km). Two HYB returned to their 2007 spawning grounds in Anaconda Creek. The remaining fish went to Abbot Creek and was captured in the migrant trap. This fish spawned in Camas Creek the previous year. Figure 1 illustrates numbers of rainbow trout and hybrids found spawning in tributaries of the Flathead River system.

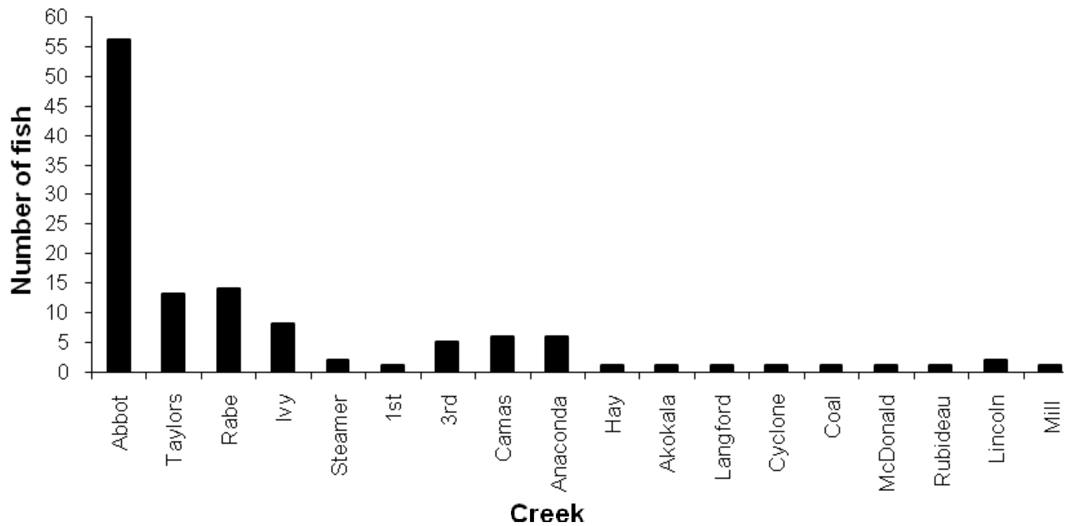


Figure 1. Tributaries in the Flathead River system used by rainbow trout or hybrid fish (N = 121) for spawning from 2000–2008.

Westslope cutthroat trout

Eighteen radio-tagged WCT were tracked in 2008 (16 fish tagged in 2008, 2 tagged in 2007), 10 of which moved upstream to presumably spawn (Table 2). WCT migrated during the ascending limb and peak of the hydrograph and spawned as flows declined (Figure 2). Two of the ten spawning sites in the Flathead River were not identified because of logistic constraints. However, these two fish made substantial upstream movements into the Middle Fork of the Flathead River above the wilderness boundary. The remaining 8 WCT used 7 different tributaries (Figure 3). North Fork Flathead River tributaries included Hay, Coal, and Kishenehn creeks (US) as well as Burnham and Commerce creeks (BC) (Figure 3). Middle Fork Flathead River tributaries included Coal and Lodgepole creeks (Figure 3). Both WCT that were originally tagged in 2007 made their 2nd documented migration to the same Canadian tributaries in 2008. As stated previously, many WCT migrated substantially farther than RBT or HYB to spawn and did not demonstrate the tendency to stray as seen in RBT and HYB.

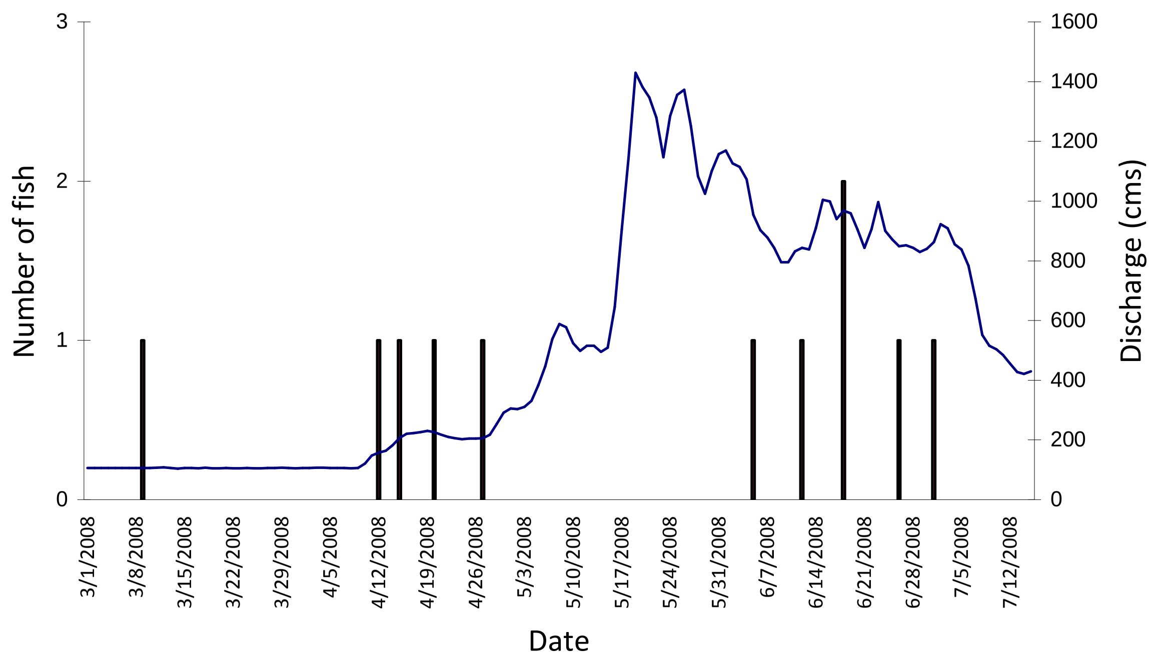


Figure 2. Spawning dates for westslope cutthroat trout in the Flathead River system relative to flows in the Mainstem Flathead River near Columbia Falls, MT.

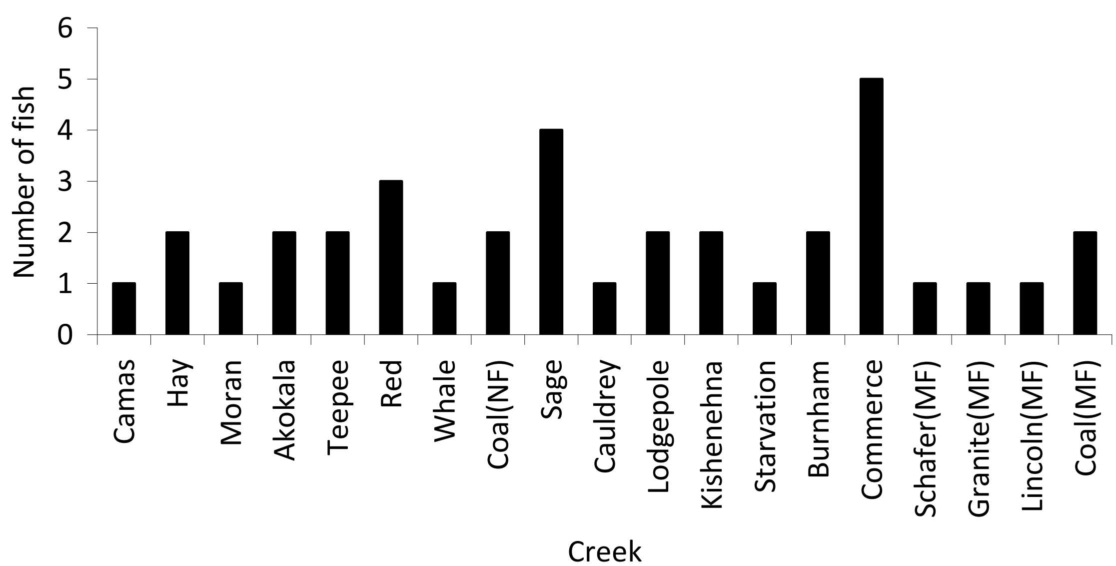


Figure 3. Tributaries in the Flathead River system used by westslope cutthroat trout (n = 36) during 2000-2001 and 2006-2008.

Table 1. Spawning dates for rainbow trout (RBT) and hybrids (HYB) (pooled) collected using radio telemetry from 2000 through 2008 in the Flathead River system. Ranges are shown in parentheses.

Year	Number of RBT/HYB tagged	Mean total length (mm)	Number of fish spawned	Median migration date	Median spawn date
2000	11	396 (363-427)	9	4/11/2000	5/4/2000
2001	26	392 (347-477)	18	4/17/2001	5/8/2001
2002	26	402 (343-545)	21	4/17/2002	5/24/2002
2003	25	413 (317-561)	20	4/9/2003	5/3/2003
2004	25	383 (293-538)	19	4/11/2004	5/3/2004
2005	20	406 (332-480)	14	4/7/2005	4/30/2005
2006	16	427 (367-502)	7	4/7/2006	4/21/2006
2007	16	427 (375-551)	13	4/21/2007	5/13/2007
2008	3	422 (375-477)	3	5/4/2008	5/11/2008

Table 2. Spawning dates for westslope cutthroat trout (WCT) collected using radio telemetry from 2000 through 2008 in the Flathead River system. Ranges are shown in parentheses.

Year	Number of WCT tagged	Mean total length (mm)	Number of fish spawned	Median migration date	Median spawn date
2000	7	410 (362-514)	7	4/11/2000	6/6/2000
2001	6	394 (335-437)	6	4/27/2001	6/6/2001
2006	7	425 (367-510)	7	4/26/2006	6/14/2006
2007	15	421 (345-499)	13	4/3/2007	6/1/2007
2008	18	374 (339-472)	10	5/25/2008	6/18/2008

Population trends for rainbow trout and hybrids in the Mainstem Flathead River

Introduction and Methods

Relative abundance and catch-per-unit effort (CPUE) of rainbow trout and hybrids (westslope cutthroat trout x rainbow trout) was estimated in 2008 in the Mainstem Flathead River to investigate population trends and monitor the efficacy of suppression efforts. Methodology of previous surveys was replicated to standardize comparisons (McMullin and Graham 1981; Deleray et al. 1999; Steed et al. 2008) (Figure 4).

Surveys began at dark and continued until two passes were completed on each bank (four passes total) per night, with two boats simultaneously surveying each bank. Electrofishing was performed from jet boats rigged with fixed-boom anodes. The Coffelt M22 unit used was operated to produce straight DC at 3 to 5 amperes in adherence to recent MFWP electrofishing policy dictating the use of straight DC or pulse rates $\leq$ 30 Hz when sampling waters with native fishes. Although McMullin and Graham (1981) did not specify the waveform or type and power levels used during their sampling, a pulsed DC waveform (60 Hz) was most likely used.

Passes began at the upstream boundary of each section and progressed downstream along one of the banks to the lower boundary. Shock-time for each pass was recorded to estimate CPUE. All trout were netted, measured for total length (mm), weight (g), scale-sampled for age and growth analyses, fin-clipped for species identification using genetic analyses (RBT, hybrids, and WCT), and marked with a fin clip during the mark run. Passive integrated transponder (PIT) tags were inserted in most RBT and hybrids from 2004-2007 to estimate annual growth of recaptured fish. Fish were examined upon collection after the recapture run to determine recapture status and subsequently returned to the river. The Schnabel multiple census method was used in 2000 and 2004 whereas the Lincoln-Peterson method was used from 2001-2003 and from 2005-2007 (Ricker 1975).

Catch-per-unit-effort was calculated as the number of a given fish species (RBT and hybrids were combined) captured divided by the time (hr) spent electrofishing and the length of the sample section (km)(McMullin and Graham 1981). Abundance estimates were calculated for two size classes of RBT and hybrid fish, respectively (fish < 300 mm and fish > 299 mm). Temperature (°C) and flow (cfs) on the sampling nights were also compared to abundance estimates.

Results and Discussion

A decline in the combined estimated RBT and hybrid abundance was detected after 2000 (Table 3, Figure 5). This sharp decline may be attributable to the RBT suppression program initiated in spring 2000, involving the physical removal of RBT and hybrid fish by trapping and electrofishing at the mouth of Abbot, Rabe, Third, and Ivy Creeks. Redd counts, electrofishing surveys, and telemetry data have indicated that these four tributaries support relatively strong populations of RBT and hybrid trout. Increases in estimated CPUE for WCT after 2000 further support the efficacy of RBT and hybrid trout suppression (Figure 6). However, estimated abundances increased in 2004 and have fluctuated at lower levels since then (Figure 5). Further, trends should be interpreted with caution because of variation in discharge and temperature likely resulted in differential conductivity, affecting CPUE comparisons. Seasonal movement of migratory WCT in the Flathead River system also violates the assumptions associated with mark and recapture and CPUE estimate comparisons (Ricker 1975). However, the relatively high recapture rates of RBT and hybrids support estimate validity and continued collection of these long-term data may provide valuable relative indices of RBT suppression success and site fidelity.

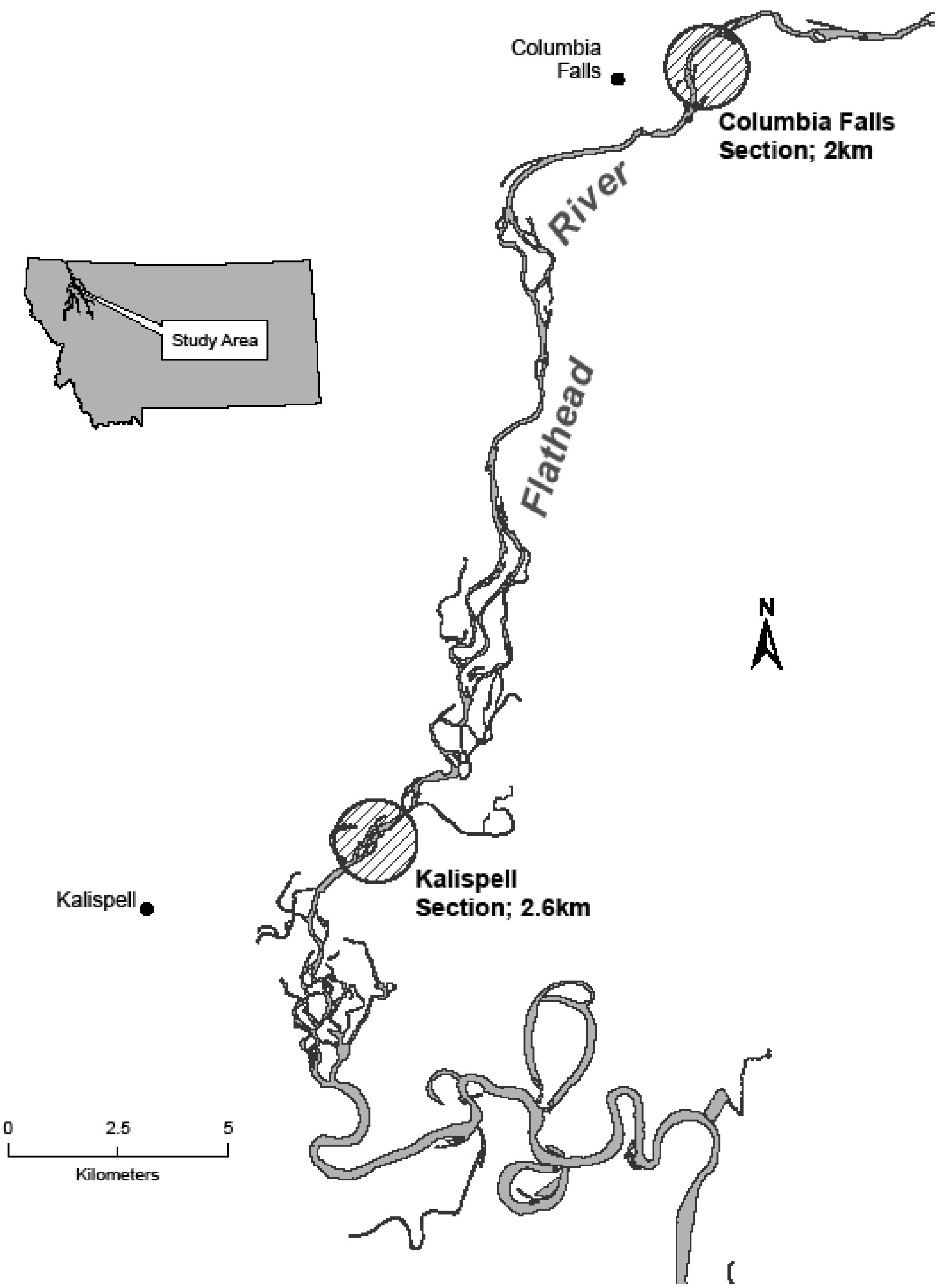


Figure 4. Spring electrofishing sections in the Mainstem Flathead River. Only the Columbia Falls section was surveyed in 2008.

Table 3. Estimated abundances and associated 95% confidence intervals of rainbow and hybrid trout in the Columbia Falls, MT electrofishing section of the Mainstem Flathead River, by year. Temperature is presented as the average between the mark and recapture runs because differences in values were negligible.

Year	Fish/km	95% CI	Temperature °C
2000	350	(86, 506)	3.6
2001	310	(281, 329)	3.0
2002	94	(91, 97)	2.0
2003	71	(68, 74)	2.8
2004	149	(93, 301)	3.5
2005	122	(114, 130)	4.0
2006	150	(146, 154)	2.8
2007	123	(119, 127)	3.8
2008	203	(198, 208)	3.5

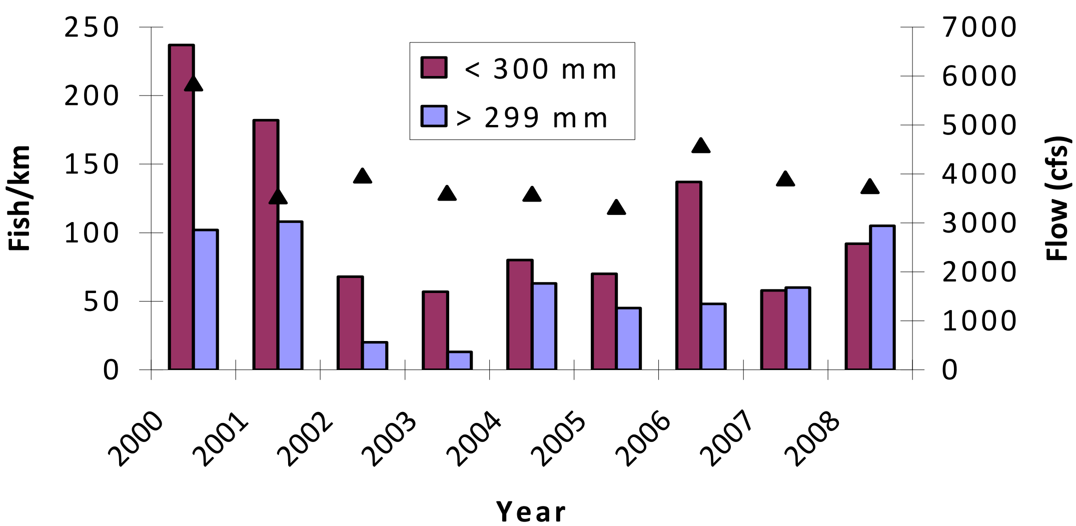


Figure 5. Estimated abundances of juvenile and adult rainbow trout and hybrids (rainbow trout x westslope cutthroat trout), combined, in the Columbia Falls, MT electrofishing section of the Mainstem Flathead River, by year. Triangles represent mean flows (cfs) during sample periods.

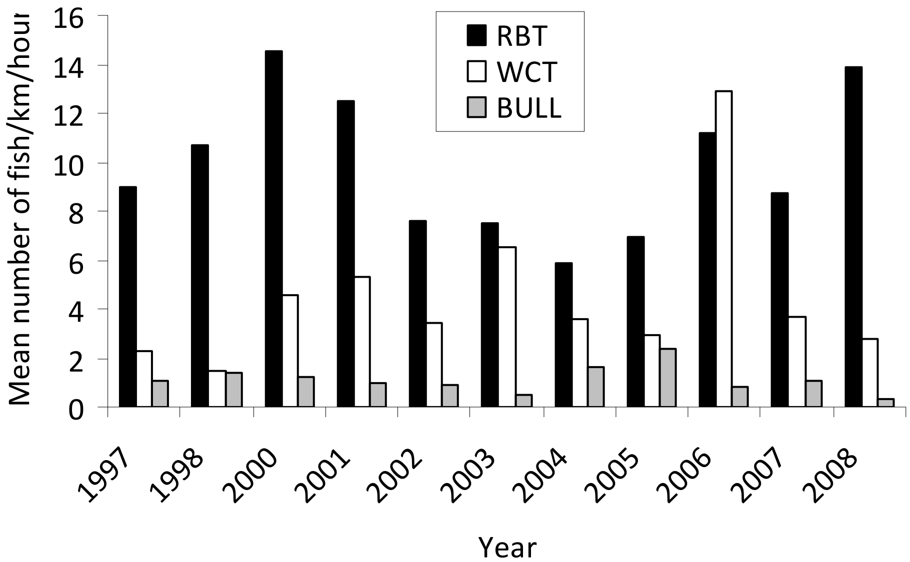


Figure 6. Mean catch-per-unit-effort for westslope cutthroat trout (WCT), rainbow trout (RBT) and hybrids (RBT x WCT) combined (shown together as RBT), and bull trout (BULL) captured in the Columbia Falls, MT electrofishing section of the Mainstem Flathead River, by year.

Trapping and Suppression Efforts

Abbot Creek and selected North Fork Flathead River tributaries

Introduction and Methods

Fish suppression in Abbot Creek, a RBT-dominated tributary to the Mainstem Flathead River near Coram, Montana, has been ongoing since 2000. Multi-year radio telemetry efforts and results of genetic analyses have confirmed that this stream is the main source-population for introduced RBT genes within the drainage and has resultantly been the focus of suppression since 2000 (Steed et al. 2008). Rainbow trout and hybrids were removed from Abbot Creek by migrant-trapping and boat electrofishing in 2008. In addition to Abbot, four other Mainstem tributaries and one lower North Fork tributary were identified through genetic analyses as hybridization “hot spots”. These streams have subsequently been actively suppressed by electrofishing since 2005. All fish captured not phenotypically identified as WCT were reported as RBT because in-field determinations between RBT and hybrids are unreliable.

Migrant trapping

A migrant trap to capture upstream-bound fish was deployed on 29 February 2008 in Abbot Creek. It was placed downstream of the barrier, approximately 25 m upstream of the confluence with the Mainstem to capture spawning RBT migrating into Abbot Creek. The trap was checked once a week and total length (mm), weight, sexual maturity, and fin clips for genetic analyses were taken from all captured fish. RBT and hybrids were removed and transported to a children's fishing pond (Dry Bridge Slough) in Kalispell.

Boat electrofishing

RBT and hybrids were targeted near tributary mouths by electrofishing conducted from an 18' jet boat rigged with fixed-boom anodes. The Coffelt M22 rectifying unit produced straight DC at 3 to 5 amperes. Effort was concentrated in the main river within 50 m of the mouths of Abbot, Rabe Creek, Ivy, and Third creeks, and Sekokini Springs. Total length, weight, sexual maturity, and fin clips for genetic analyses were taken from all RBT and hybrids. RBT and hybrids were removed and transported to Dry Bridge Slough.

Results and Discussion

A total of 71 adult RBT were captured and removed from Abbot Creek during spring 2008 (Figure 7). Forty-six adult fish were captured in the trap and 25 fish were captured during electrofishing surveys. The trap was continuously run for a total of 131 days until 9 July 2008. Although the majority of hybrids have been removed from Abbot Creek since 2000, this is a function of localized effort and more recently targeted tributaries have yielded annually comparable numbers (Figure 7).

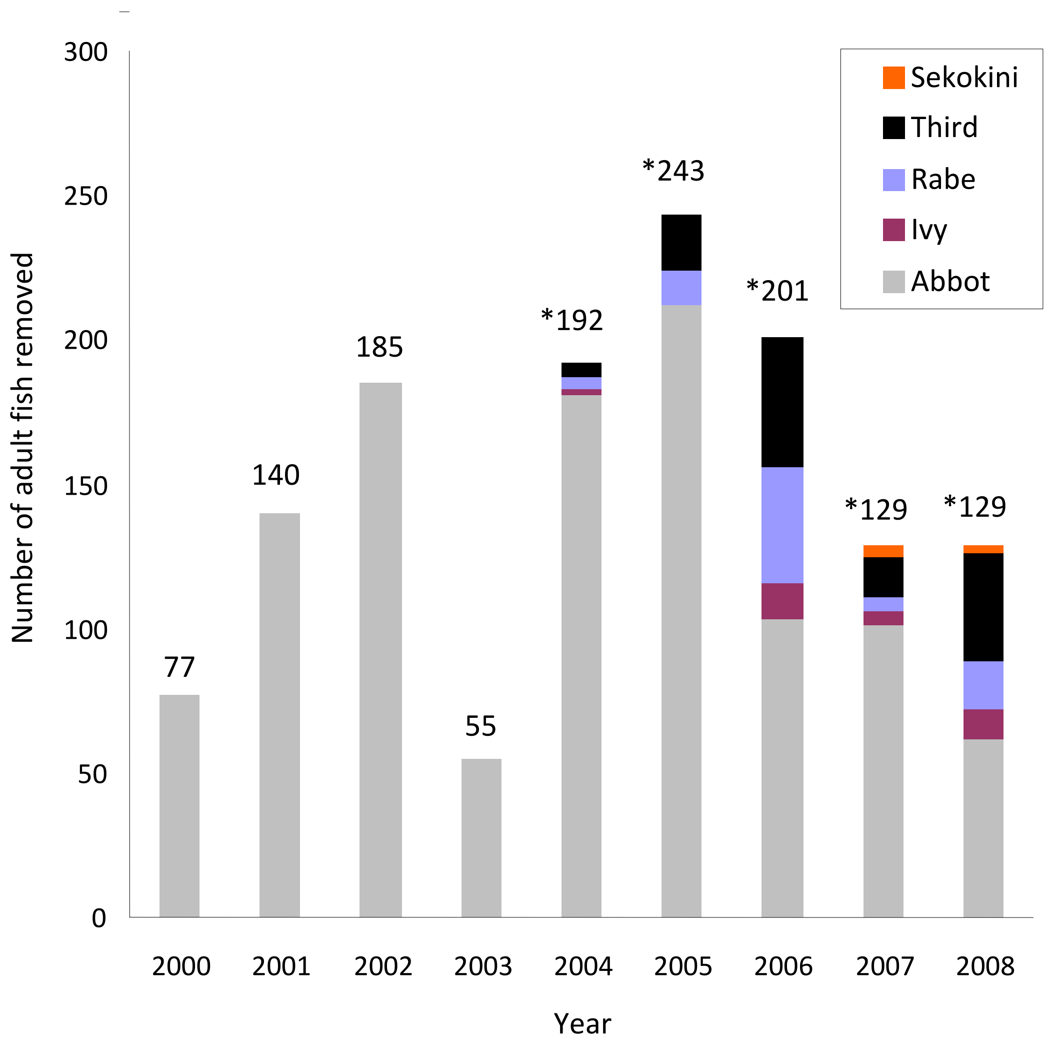


Figure 7. Numbers of adult rainbow trout and hybrids (rainbow trout x westslope cutthroat trout) removed from North Fork and Mainstem Flathead River tributaries by electrofishing and trapping from 2000 to 2008. Asterisks denote years with increased electrofishing effort.

Table 4. Number of adult rainbow trout and hybrid fish removed from tributary mouths in the Flathead River system by electrofishing and trapping from 2000 through 2008. EF denotes electrofishing.

	Creek						
Year	Abbot		Third	Ivy	Sekokini	Rabe	
	Trap	EF	EF	EF	EF	EF	Total
2000	77	--	--	--	--	--	77
2001	140	--	--	--	--	--	140
2002	74	114	--	--	--	--	188
2003	12	43	--	--	--	--	55
2004	157	11	--	--	--	--	168
2005	129	77	--	--	--	30	236
2006	84	20	46	13	--	40	203
2007	80	14	12	5	4	4	119
2008	46	25	33	10	3	16	133
	799	304	91	28	7	90	1319

Langford and Cyclone creeks

Introduction and Methods

Bi-directional migrant traps were deployed and monitored in Langford and Cyclone creeks, tributaries to the North Fork Flathead River, for collection of spawning hybrids (westslope cutthroat trout x rainbow trout) and downstream juvenile migrants during spring and summer of 2008. This effort built upon an investigation of hybrid fitness and movement initiated in 2003 (Muhlfeld et al. 2009).

The Langford upstream trap was fished continuously from 31 March to 10 July (101 d) and the Cyclone upstream trap was fished from 4 June to 21 July (47 d). The Langford downstream trap was fished from 14 May to 6 August (84 d) and the Cyclone downstream trap was run from 16 June to 6 August (51 d). Trap installation was delayed by about 30 days relative to previous years because of late season snow conditions and resulting stream access restriction.

Total length (mm), scales for age and growth determination, and fin clips for genetic analyses were taken from all fish. Additionally, passive integrated transponder (PIT) tags were inserted into the body cavity using a sterilized 12-gauge hypodermic needle. PIT tag monitoring stations were operated at each stream mouth to record adult movement and juvenile emigration. A detailed description of PIT tag station methodology can be found in Muhlfeld et al. (2004). Mean daily temperatures were recorded with thermographs and water level was noted during each trap check (at least twice weekly).

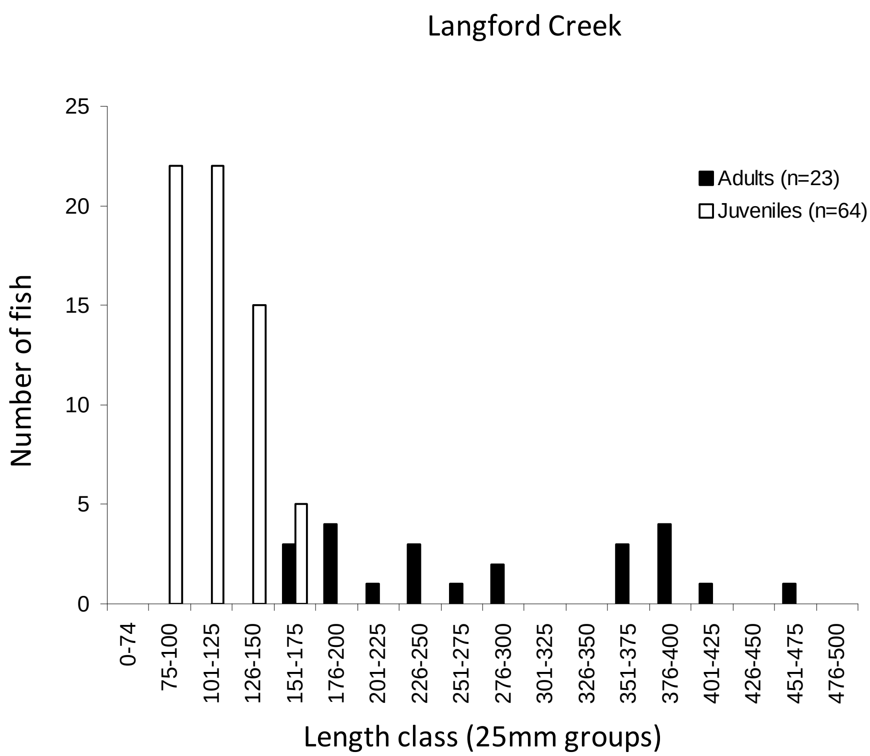
Results and Discussion

One previously-marked adult and 23 unmarked adult spawners were captured in Langford Creek between 8 April and 26 June 2008 (median date = 12 May). Average total length was 286 mm (range = 163–475 mm). Sixty-four out-migrating juveniles were sampled in the downstream trap between 17 May and 19 July 2008 (median date = 9 June). Mean total length was 115 mm (range = 85–175 mm) (Figure 8).

The upstream trap in Cyclone Creek caught 17 unmarked spawners between 5 June and 25 June 2008 (median date = 14 June). Average total length was 221 mm with a range of 172–392 mm. A total of 32 juveniles were captured in the downstream trap between 18 June and 17 July (median date = 1 July). Mean total length was 168 mm (range = 87–205 mm) (Figure 8). However, spring run-off was relatively late in 2008, hampering access to Cyclone Creek and delaying trap installation. Thus, both upstream and downstream trapping efforts most likely missed some of the fish migrations and should only be considered a partial sample of the entire run.

Adult *Onc. spp.* entered Langford Creek on the ascending limb of the hydrograph toward peak discharge whereas they entered Cyclone Creek after peak discharge (Figure 9). Adults entered Langford Creek beginning 8 April and Cyclone Creek beginning 5 June 2008. The majority of Cyclone Creek fish also spawned later in the season than those using Langford Creek.

As reported previously (Steed et al. 2008), juvenile fish emigration from Langford and Cyclone creeks ranged from peak stream discharge through the descending limb of the hydrograph. The emigration run in Langford Creek began 17 May and in Cyclone Creek on 18 June 2008. Juvenile fish in Langford Creek emigrated as water temperatures reached 7^{o}C and continued through 17 July as temperatures reached as high as 11^{o}C (Figure 10). Cyclone Creek juveniles began emigrating as water temperatures reached 10^{o}C and continued through 6 August with the majority of the fish emigrating in late June and early July as temperatures reached 14^{o}C (Figure 10).



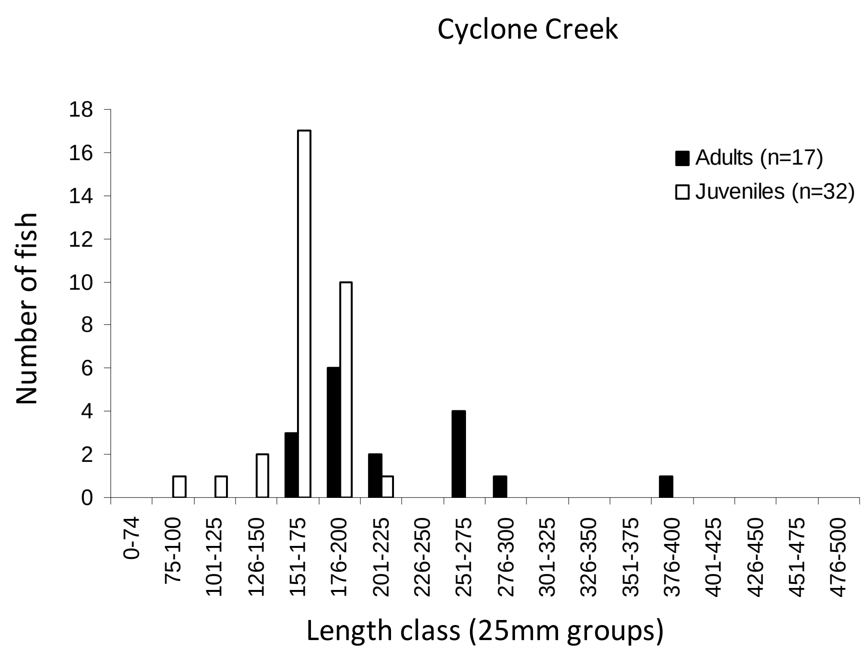


Figure 8. Length frequency distributions of adult and juvenile fish captured in migrant traps in Langford and Cyclone creeks, respectively, in 2008.

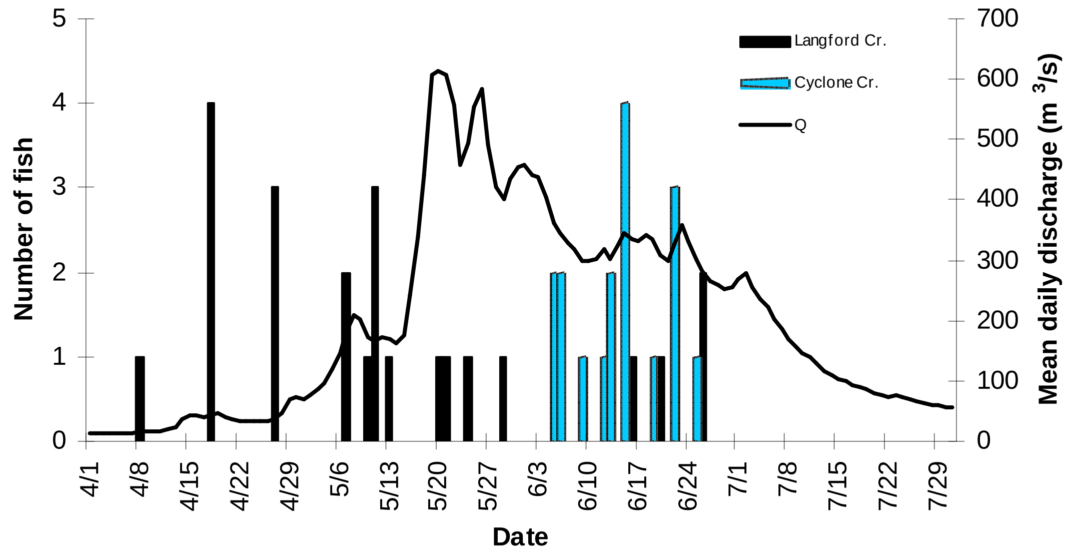


Figure 9. Number of adult *Onc. spp*. captured in migrant traps in Langford and Cyclone creeks corresponding to mean daily discharge at the North Fork Flathead River USGS gauging station in 2008.

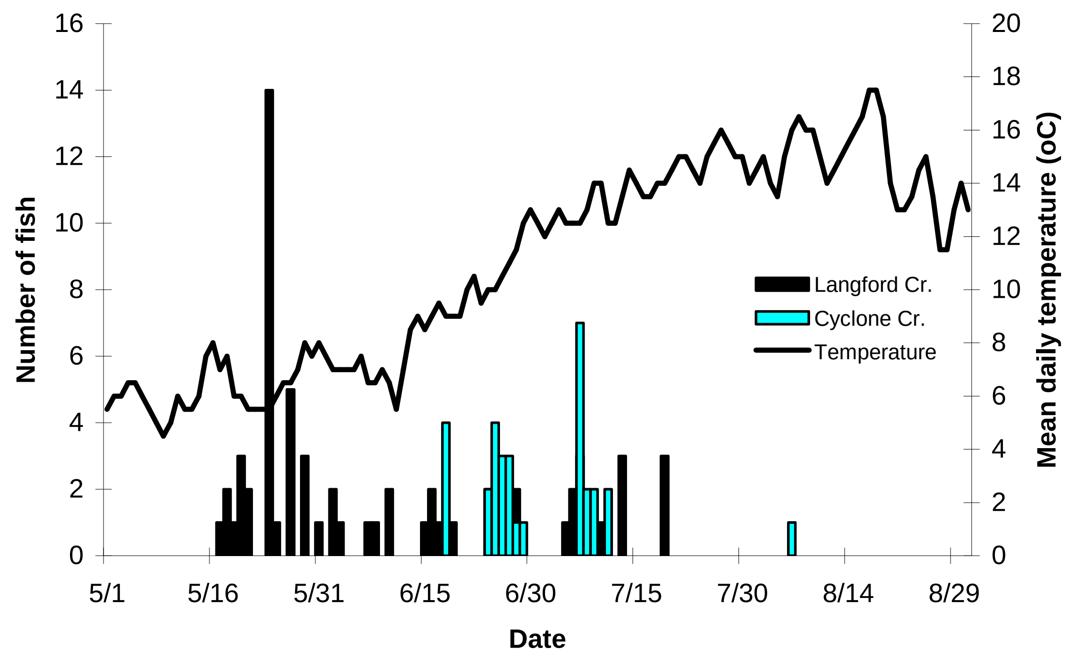


Figure 10. Number of juvenile *Onc. spp*.captured in migrant traps in Langford and Cyclone creeks corresponding to mean daily temperature at the North Fork Flathead River USGS gauging station in 2008.

Taylor's Outflow

The Taylor's Creek (a.k.a., Taylor's Outflow) fish barrier has been in continuous operation since its construction in June 2006. This spring creek enters the Mainstem Flathead River in Columbia Falls, Montana. It had been providing suitable spawning habitat in close proximity to over-wintering populations of both WCT and hybrids. The barrier design incorporates a trap box to catch fish attempting to ascend the stream. No fish were caught in the barrier trap box during spring 2008. Although fish may be avoiding the barrier or escaping the trap box, this barrier is helping to limit hybrid fish production in the Flathead drainage and will continue to be operated into the future.

MOVEMENT AND SURVIVAL OF SUB-ADULT WESTSLOPE CUTTHROAT TROUT, BULL TROUT, AND MOUNTAIN WHITEFISH IN THE MAINSTEM FLATHEAD RIVER

Introduction and Methods

In spring 2008 field crews used radio telemetry to monitor movements of juvenile westslope cutthroat trout (WCT), bull trout (BULL), and mountain whitefish (MWF). Fish were captured in the Mainstem Flathead River by boat electrofishing and hoop netting, implanted with radio transmitters, and released near capture locations. Three sizes of Lotek transmitters (nano tags) were used on the 150.740 MHZ frequency (Table 5).

Table 5. Types, weights, and life spans of transmitters used in sub-adult westslope cutthroat trout, bull trout, and mountain whitefish in the Mainstem Flathead River system in 2008.

Tag type	Weight in air (g)	Life of tag (d)
NTC4-2L (small)	2.1	163
NTC-6-1 (medium)	2.8	232
NTC-6-2 (large)	4.5	441

Each fish was located by jet boat or by truck 1 to 2 times per week using a Lotek SRX 400 model receiver and either an omni directional whip antenna or three element directional Yagi antenna. Ground stations were used in five locations throughout the Flathead River to continuously monitor fish movements (Figure 11). These stations consist of a Lotek data-logging receiver equipped with a three element directional Yagi antenna. Aerial surveys were performed to locate fish undetectable by boat or truck. A GPS point was taken at each fish location.

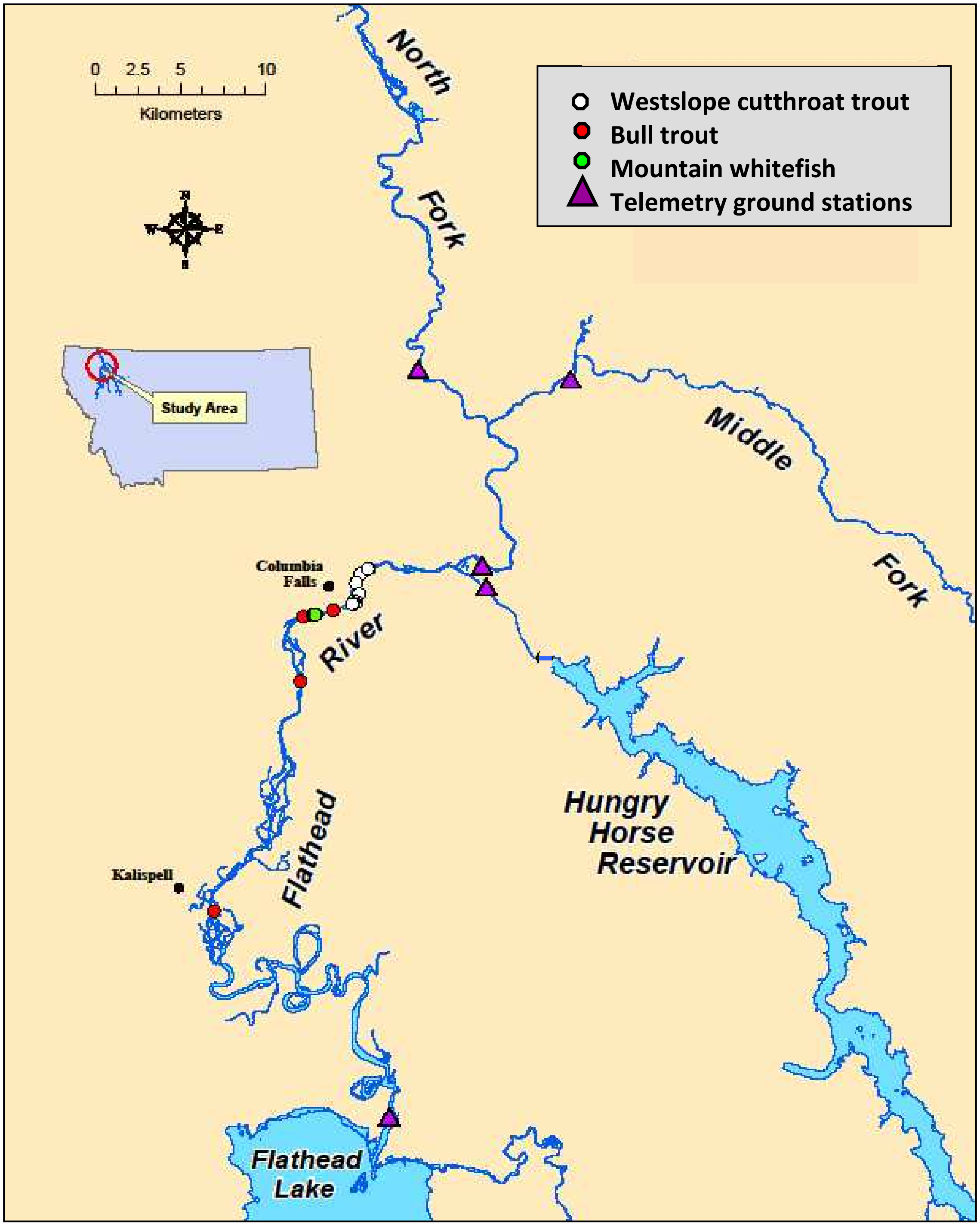


Figure 11. Release locations for sub-adult westslope cutthroat trout, bull trout, and mountain whitefish inserted with radio telemetry tags in 2008.

Results and Discussion

Westslope cutthroat trout

Ten WCT were tagged in 2007 using 7 small and 3 medium nano tags (Table 6). The average tag weight to body weight ratio was 1.7% (range 1.3-2.3%). Mean total length was 252 mm (range = 233-285 mm). Of the 7 fish that received the small nano tags, 4 were located for about 1 month and subsequently lost. One fish was never located after being tagged. These lost fish either moved into deepwater where radio reception is poor, the radio tags died prematurely, or the fish died and/or was removed from the system. Of the 6 WCT that were relocated for several months, 3 moved downstream into the lower lake-influenced section of the river and resided in deep holes, 1 moved downstream into Flathead Lake, and 2 fish moved upstream or remained near their tagging location.

Bull trout

Ten BULL were tagged in 2007 using 7 large tags, 2 medium tags, and 1 small tag (Table 6). Fish were captured using baited hoop nets or boat electrofishing. Average tag weight to body weight ratio was 1.4% (range 0.9-1.9%). Mean total length was 333 mm (range = 245-384 mm). Two BULL were never relocated after tagging. One tag was found onshore just above the lake-influenced section of the Flathead River in January 2009; an exact location on this transmitter had not been determined since September 2008. This fish may have been predated upon because it was found onshore with the tag antenna missing. Four BULL moved either up or downstream in the main river or stayed near their release location. One BULL was only found for 1 month and lost whereas the remaining 2 BULL radios continued to be tracked as of May 2009.

Mountain whitefish

Ten MWF were caught during boat electrofishing and tagged in 2007 using 3 large tags, 5 medium tags, and 2 small tags (Table 6). Average tag weight to body weight ratio was 1.5% (range 1.0-1.8%). Mean total length was 306 mm (range = 224-394 mm). One radio was found on-shore in January 2009; this fish most likely died sometime during the previous summer. Three MWF were only located a few times after tagging and were subsequently lost. Two MWF moved down into the lake-influenced lower river whereas 4 fish moved either up or downstream and subsequently returning close to their tagging location. One of these large radios continued to be tracked as of May 2009. This fish has resided in a backwater (sometimes under ice) in the Mainstem Flathead River.

Table 6. Movement and other descriptive data for sub-adult bull trout (BULL), mountain whitefish (MWF), and westslope cutthroat trout (WCT) tracked by radio telemetry in the Flathead River system during 2008. Standard deviations are shown in parentheses. Data was not used for fish with < 2 relocations.

Species	Tag air weight (g)	Number of fish tagged	Average number of relocations	Average distance moved (km)
BULL	2.8	2	24.5 (3.5)	9.0 (7.2)
BULL	4.5	6	20.5 (10.0)	16.5 (16.1)
MWF	2.1	2	8.5 (6.4)	18.0 (6.6)
MWF	2.8	4	11.0 (6.2)	16.4 (5.0)
MWF	4.5	3	17.0 (13.0)	44.8 (26.0)
WCT	2.1	5	14.6 (7.4)	18.4 (17.7)
WCT	2.8	3	13.3 (4.0)	57.0 (15.3)

It is important to note that because the numbers of relocations were not identical across all fish, comparisons of total distances moved are biased (i.e., likely underestimated for fish with relatively few relocations). However, WCT with medium tags moved substantially more, on average, than MWF or BULL with same size tags (Table 6). BULL with large tags moved relatively less than MWF; though small-tagged MWF and WCT moved comparable distances (Table 6).

BULL TROUT SURVIVAL: JUVENILE EMIGRATION TO ADULT RETURN

Trail Creek

Introduction and Methods

Life history characteristics of bull trout in the Flathead River system have been investigated since 1953 (Block 1955; Hanzel 1976), yet information gaps remain because of the species' migratory nature, basin-wide and micro-scale changes in habitat availability from land and hydropower management practices, non-native species introductions, and more recently, climate change. Only the migratory bull trout life history form has been documented in the Flathead River system (Weaver et al. 2006), with 52% of all spawning occurring in North Fork tributaries (Weaver 2008). Juvenile bull trout abundances and adult redd counts in tributary streams have been documented since 1980 (Weaver et al. 2006). However, survival during the three to five years between juvenile emigration and adult return (Fraley and Shepard 1989) is a poorly understood period of adfluvial bull trout life history. Therefore, a multi-year study was initiated in 2005 to estimate survival of juvenile bull trout to adulthood in Trail Creek, a tributary to the North Fork Flathead River. This research will continue through at least 2013 to capture one complete bull trout life cycle (Fraley and Shepard 1989).

Survival of bull trout in the Trail Creek drainage from juvenile emigration to adult return was investigated through the use of passive integrated transponder (PIT) tag technology. In 2005, an experimental "crump weir" multiple-antenna system was installed relatively low in the Trail Creek drainage to enumerate emigrating juvenile bull trout implanted with PIT tags. This system was used from October 2005 through September 2008 and was originally employed to increase tag detection by causing fish to pass closer to the antenna than would a flat-panel design. However, tag detection was compromised because of increased antenna noise levels (interference) associated with 2006 spring flows (Muhlfeld et al. 2007). In September 2008, Biomark Inc. (Boise, ID) was contracted to replace the crump weir design with new "flat plate" antennas that are installed flush with the stream bed, minimizing flow disturbance and associated antenna noise (Figure 12).

Figure 12. Flat plate antenna (Biomark Inc.) installed in Trail Creek, September 2008.

Based adult bull trout return rates in a comparable system (Downs et al. 2006), about 300 juveniles have been implanted with PIT tags annually since 2005. This effort was estimated as the minimum number of tagged fish required to produce adult return rates ranging from 9-15% (Downs et al. 2006). Juveniles were sampled in October and November of each year using backpack electrofishers over a 4 km section of Trail Creek, extending no closer than 1 km above the PIT tag detection system. Fish were abdominally implanted with a unique PIT tag and the adipose fin was clipped for tag loss verification in the event of recapture. A total of 975 juvenile fish were marked from 2005 through 2008. Total length ranged from 79 to 277 mm (mean = 129 mm).

Results and Discussion

A total of 60 fish were detected emigrating from Trail Creek in 2007 and 2008. However, antenna interference associated with the crump weir design likely led to an underestimation of emigrating juveniles prior to its replacement. As observed in other systems (Downs et al. 2006), juvenile bull trout predominantly emigrated in spring just prior to and during the spring freshet and in the fall during rain events in October and November (Figure 13). Fraley and Shepard (1989) did not observe this spring and fall pulse; however, their sampling was limited to post-freshet (June) and early fall (October) and thus did not capture all emigration during these periods.

The Peterson method was employed to establish length-at-age relationships using length frequency data (Devries and Frie 1996; Figure 14). This technique allowed individual age assignment at marking and subsequent determination of age at emigration using the PIT tag weir. Bull trout in Trail Creek generally emigrated at ages 2 and 3, with a few individuals leaving at ages 1 and 4 (Table 7). This study will continue through 2015 to capture a complete bull trout life cycle. It will also be replicated in a second North Fork Flathead River drainage (Big Creek) starting in 2009.

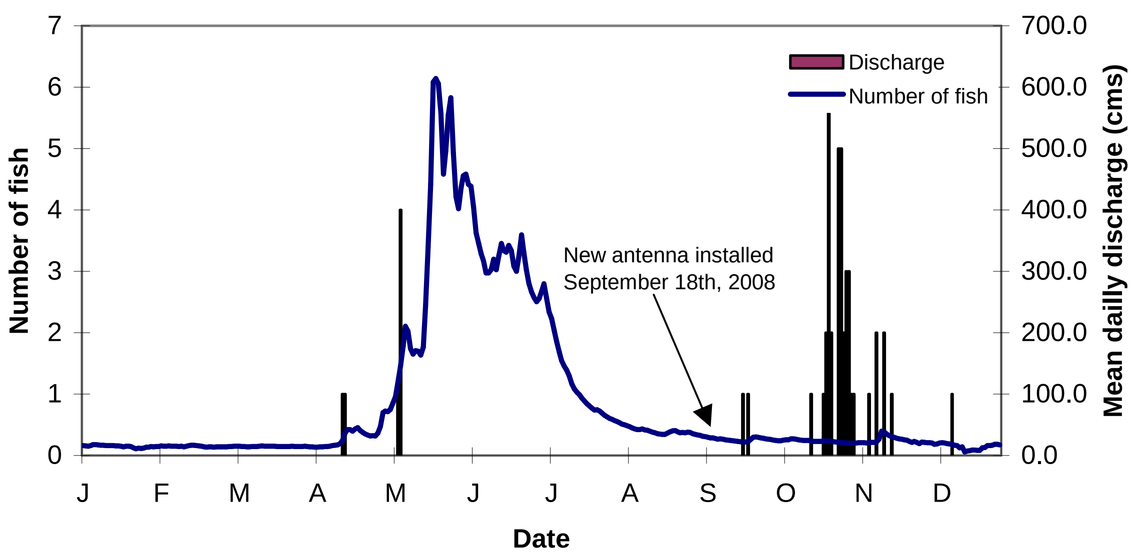


Figure 13. Number of marked fish detected at the PIT tag monitoring weir on Trail Creek in 2008.

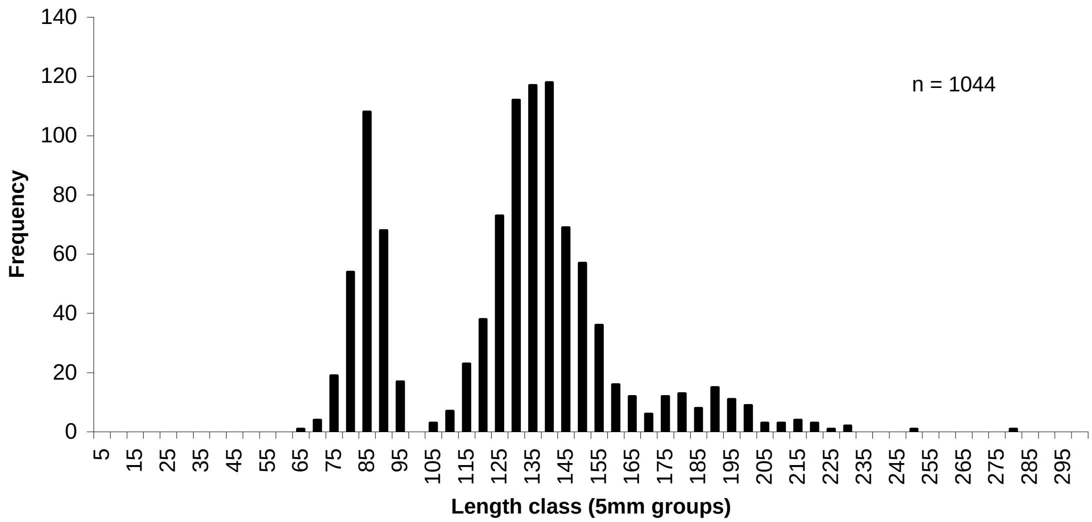


Figure 14. Length frequency distribution of juvenile bull trout sampled in Trail Creek in October and November 2005-2008.

Table 7. Lengths-at-age and ages at emigration for juvenile bull trout recorded at the PIT tag detection system in Trail Creek, 2007 and 2008. Lengths-at-age were determined using the Peterson method with length frequency data.

Length-at-age		Number of fish emigrated	
Age Class	Length range (mm)	2007	2008
1+	65-100	0	1
2+	101-170	1	32
3+	171-204	9	11
4+	205-235	2	3

PILOT POPULATION MONITORING OF MOUNTAIN WHITEFISH IN THE MAINSTEM FLATHEAD RIVER

Introduction and Methods

Mountain whitefish (*Prosopium williamsoni*)(MWF) are putatively the most abundant native species within the Flathead River system (McMullin and Graham 1981), yet little is known of their localized life history, population demographics, or abundances. Investigating these characteristics can both enhance our understanding of the species while evaluating the influence of Hungry Horse Dam operation on health and survival. A pilot study was initiated in spring 2008 to determine the most effective implementation of a long-term population monitoring program for MWF. A study investigating the spatio-temporal movement of sub-adult MWF was initiated in addition to the population estimation described below.

A multiple-census mark and recapture Schnabel estimate was attempted by electrofishing three reaches of the Mainstem Flathead River to determine abundance and movement of MWF, given adequate recaptures. Each reach was about 250 m long, consisted of un-braided and relatively simple habitat, and was separated by about 500 m from any other reach (Figure 15). Surveys were performed once per week beginning 20 March and ending 3 April (3 surveys total). Electrofishing began at nightfall and continued until two passes were completed on each bank (four passes total) per night, with two boats simultaneously surveying each bank. Electrofishing was performed from jet boats equipped with fixed-boom anodes. The Coffelt M22 unit used was operated to produce straight DC at 3 to 5 amperes in adherence to recent MFWP electrofishing policy dictating the use of straight DC or pulse rates $\leq$ 30 Hz when sampling waters with native fishes.

Passes began at the upstream boundary of each section and progressed downstream along each of the banks to the lower boundary. All MWF were netted, measured for total length (mm), weight (g), scale-sampled for age and growth analyses, genetic-sampled, and marked with a unique fin clip during the first two of three mark runs. Passive integrated transponder (PIT) tags were inserted into a subset of 30 fish from each pass (60 fish total/reach/night) to identify individual movement among reaches and to estimate annual survival. A subsample of otoliths were collected to validate scale-based age and growth analyses and to potentially investigate microchemical signatures to estimate river residence time and to identify natal streams.

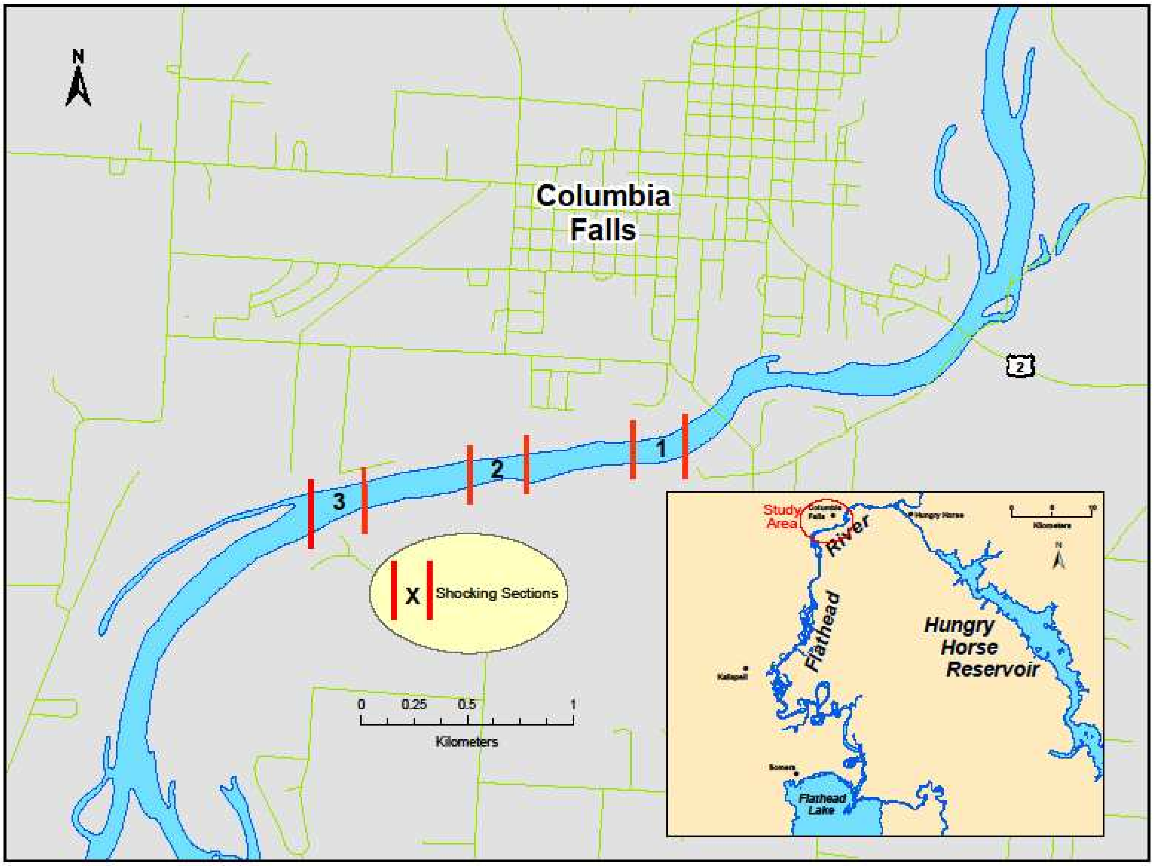


Figure 15. Mountain whitefish electrofishing survey reaches in Mainstem Flathead River, Montana, 2008.

Results and Discussion

Although a population estimate could not be calculated for the targeted portions of the Mainstem Flathead River because too few MWF were sampled during repeated sampling events (Table 8), useful information was gained from the effort (discussed below). Potential reasons for low capture and recapture rates include poor habitat in sample reaches (and thus low fish densities), targeting portions of the river channel where whitefish were not concentrated (i.e., margins), fish movement out of sample reaches after marking events, low conductivity and resulting low capture efficiency, and marking too few fish over relatively short sample reaches.

Table 8. Numbers of mountain whitefish sampled during a population estimate on the Mainstem Flathead River in spring 2008. *C* = total number of fish captured (including recaptures), *R* = number of recaptures.

Run	1			2			3		
Reach	1	2	3	1	2	3	1	2	3
C	52	51	27	38	34	23	40	18	21
R	N/A	N/A	N/A	0	1	0	0	1	0

Run 1 = 3/20/08
Run 2 = 3/27/08
Run 3 = 4/3/08

Several age classes dominated the MWF sample, though ages 8+ fish were likely handled (Figure 16; McMullin and Graham 1981). Ages 1, 2 and 4 were most commonly detected, comparable to observations of McMullin and Graham (1981). Although scales were collected for age and growth verification, age was estimated by length frequency in this report.

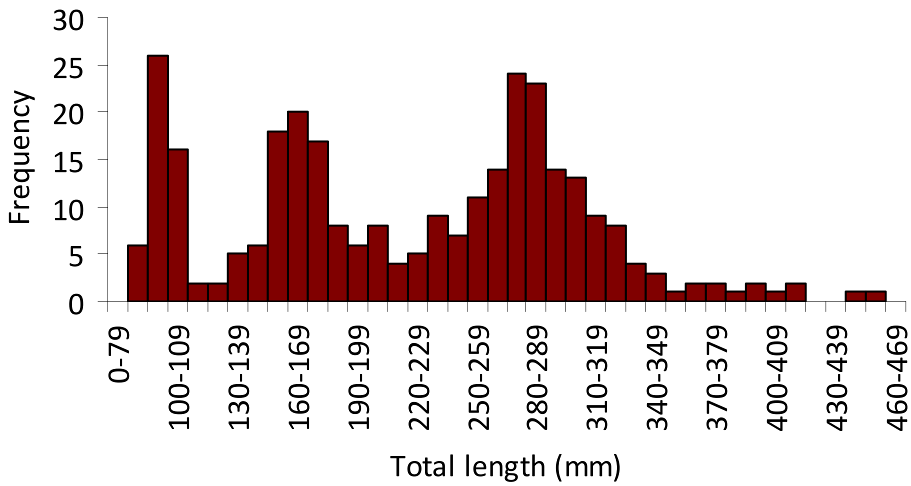


Figure 16. Length frequencies of mountain whitefish sampled in the Mainstem Flathead River during spring 2008.

Determining spatio-temporal site fidelity was one goal of this estimate. Although this could not be fully quantified from the data collected, results indicate that either strong, small-scale (i.e., < 2 km) site fidelity does not exist in most fish during this relatively short temporal window (i.e., 2 weeks) in the main river channel in early spring, electrofishing and handling adversely affects fish behavior (resulting in uncharacteristic movement up or downstream) or a combination of these variables. MWF in the Peace River, British Columbia displayed a wide range of spring and summer movement patterns, with over half (65%) demonstrating no net movement whereas 8% of fish sampled moved 20-77 km (Pattenden et al. 1991). Substantial and rapid upstream movement was documented in the North Fork Clearwater River in Idaho after tagging, with individuals moving between 66-80 km within 2-3 months of initial capture (Pettit and Wallace 1975). However, strong annual site fidelity was detected in about one-third of fish tagged in a tributary of this system, with many fish found in the pool of original capture (Pettit and Wallace 1975).

Alternative approaches to abundance estimation will include, 1) sampling a longer, contiguous stretch of river to mark a greater number of MWF, 2) shifting sampling dates to optimize capture efficiency and probability (e.g., closer to peak flows when MWF congregate along river banks and conductivity is increased), or 3) sample tributaries throughout the Flathead system using snorkeling or hook-and-line methodologies. Additionally, effective population size (N_e) will also be investigated using genetic data collected both above and below Hungry Horse Dam, building upon existing regional analyses (Whiteley et al. 2004).

HABITAT RESTORATION

South Fork Coal Creek

Introduction and Methods

The Coal Creek watershed, a tributary to the North Fork Flathead River, provides critical habitat for native fishes. It is an important spawning tributary for fluvial bull trout, a species listed as Threatened under the federal Endangered Species Act (USFWS 1998) and an important rearing area for juvenile westslope cutthroat trout and bull trout (Fraley and Shepard 1989; Deleray et al. 1999). In an effort to quantify bull trout populations, annual and basin-wide redd counts have been conducted since the early 1980s (Weaver et al. 2006). These redd counts have indicated declines in the Coal Creek bull trout population. Although dozens of redds were observed in South Fork Coal Creek (SFCC) during the 1980s counts since 1997 have dropped to single digits (Weaver et al. 2006). Montana Fish, Wildlife & Parks (FWP), in cooperation with the Flathead National Forest (FNF), conducted a stream survey to identify sediment sources, bank instability, and potential restoration actions in the Coal Creek watershed in 1988 and 2003 (Weaver et al. 2004). The investigation concluded that there were highly unstable channel areas in each of the three major forks of the drainage (Weaver et al. 2004). For example, logging throughout the riparian area in the 1950s and 1960s and direct channelization from heavy equipment use changed aquatic habitat in some areas of the South Fork of Coal Creek. Large wood was lost in the channel as well as along the banks, resulting in a more simplified channel. FNF and FWP field crews documented coarser substrate, fewer pools, and less frequent large woody debris. These conditions could be inhibiting the short and long-term viability of native bull trout. For more details on channel surveys see Weaver (1989) and Weaver et al. (2004).

The 2003 survey provided an overview of channel conditions and attempted to compare 2003 conditions to the 1988 report prepared by FWP. Reach 3, the focus of this project, was surveyed from Whitefish Divide downstream to the confluence of SFCC and the main stem Coal Creek. For detailed information and surveyors' notes see Weaver et al. (2004).

FWP, in contractual conjunction with River Design Group, Inc. (RDG), enhanced approximately 2100 ft of channel in the SFCC. Project construction was completed during summer and fall 2008. The primary goal of this project was to restore LWD assemblages that resembled natural habitat arrays found in the upstream reference reaches to benefit adult and juvenile native fishes. Objectives of this habitat enhancement project included reestablishing large woody debris aggregates, channel spanning logs, and single log veins which would: 1) Increase pool habitat frequency for resting and rearing juvenile and adult fishes; 2) increase the distribution of spawning substrate for adult bull trout; 3) increase pool habitat diversity; 4) increase channel roughness; and 5) increase LWD retention. These objectives and goal were established by FWP and the FNF. See River Design Group, Inc. (2007) to review project recommendations and design report.

Phase 1 – Preparation and Construction

Several subcontractors were used to carry out the objectives and goal of the project. The consulting company (RDG) was present throughout the preparation and construction phases and was key in coordinating on-the-ground log placement and structure design.

The first step was to designate which trees from the Sun Dog Fire (a 2006 burn adjacent to the project site) would be used. FWP field crews spent several days flagging 90 to 100 down dead or standing dead trees throughout the Sun Dog Fire burn area. Tree dbh ranged from 17-30 in, lengths ranged from 25-50 ft, and root wad spans ranged from 4-6 ft. Specific key piece dimension equations and calculated dimensions based on SFCC channel morphology can be found in River Design Group, Inc. (2007). A sawyer crew of 2 people worked five days removing trees on top of key pieces, cutting trees to specified lengths, and falling standing trees to prepare wood for helicopter transport.

Following tree preparation, the project area was walked and 25 sites were designated for structures. A Chinook helicopter equipped with a hydraulic claw (Columbia Helicopters, Inc.) was used to import approximately 63 root wads with stems and approximately 45 stems (with no root wads) into the project reach (Table 9; Figures 19-21). The helicopter lifted up to 6000 lbs per load, importing all wood from the donor site to 25 separate stream locations in 5 hours. Depending on sites, the helicopter was able to place trees directly in the creek or stockpile logs on the bank. After all wood was imported, a spider backhoe rearranged pieces in the stream channel over the course of 10 days (Figures 22-24). Existing wood in the channel and a few green trees near site locations were also incorporated into the structures. Both the helicopter and spider backhoe were chosen to minimize impacts to the riparian area.

Phase 2 - Project Monitoring

A monitoring plan was established and will be implemented by FWP (River Design Group, Inc. 2007). An as-built survey was completed during October-November 2008. Year 1, year 3, and year 5 surveys will be completed to compare changes in pool and riffle frequencies, channel profile, substrate size, and structure stability. Two reaches were established in the project area for monitoring. The first reach (Reach #1) is approximately 330 ft long and has 5 structures and 4 cross sections throughout. The second reach (Reach #2) is approximately 910 ft long and has 6 structures and 3 cross sections. Reach #2 was extended due to a recent (fall 2008) beaver dam.

Structure stability

Each piece of LWD from sites 11-17 and sites 20-25 was tagged with a numbered metal tag and a diagram was drawn depicting locations of wood within each structure as well as wood type (green tree, dead tree, with or without rootwads). Photo documentation was also taken at each site (Figures 19-24).

LWD influence on channel morphology

A longitudinal profile was surveyed through each monitoring reach with a laser level. Figure 17 displays the 2008 channel profile for Reach 1 and Figure 18 displays the channel profile for Reach 2. Cross sections and some LWD sites are also shown.

Substrate composition

Sampling of the channel substrate was completed immediately downstream of each cross section, producing 7 pebble counts throughout the two reference reaches. Follow-up surveys during post-implementation years 1, 3 and 5 will determine if project objectives were met, including increased detainment of gravel required by spawning bull trout.

Phase 3 -Fisheries monitoring

Fish population estimates for bull trout and westslope cutthroat trout were completed in the project reaches as well as downstream of the project reach (Tables 10 and 11; Figures 25 and 26). The annual fish population estimates (index section downstream of project area) has been sampled since 1985 (with the exception of 1986). Population estimates within the project reach were conducted annually for 2 years prior to construction.

Table 9. South Fork Coal Creek structure characteristics. Actual installed wood as per project conclusion 8/14/08. Table adapted from River Design Group, Inc. (2007).

		Imported wood		Harvested green		Existing wood		Imported: design versus actual	
Site ID	Structure type	Rootfans	Stems	Rootfans	Stems	Rootfans	Stems	Rootfans	Stems
Site 1A	Channel Spanner	3	1	0	0	0	0	0	0
Site 1B	LWD Aggregate	3	3	0	0	0	0	1	2
Site 1C	LWD Aggregate	4	1	0	0	0	1	1	0
Site 2	LWD Aggregate	3	1	0	0	5	7	-1	0
Site 3	Channel Constrictor	1	2	0	0	2	6	-1	1
Site 4	LWD Aggregate	2	0	0	0	3	2	-1	-1
Site 5	LWD Aggregate	1	2	0	0	1	2	-2	1
Site 6	LWD Aggregate	1	2	1	0	0	1	-2	1
Site 7	LWD Aggregate	2	2	0	0	0	1	-1	1
Site 8	LWD Aggregate	3	2	0	0	4	5	0	1
Site 9	LWD Aggregate	1	1	0	0	2	2	-2	0
Site 10	Channel Spanner	0	2	1	0	0	0	-2	1
Site 11	LWD Aggregate	4	4	1	0	0	0	1	3
Site 12	Log Step 1	2	1	1	0	1	0	0	0
Site 13	Log Step 2	2	3	0	0	0	1	0	2
Site 14	Channel Spanner	2	1	0	0	0	1	0	0
Site 15	Channel Spanner	3	1	0	0	2	1	1	0
Site 16	LWD Aggregate	4	1	0	0	2	4	0	0

Table 9.—continued.

Site ID	Structure type	Imported wood		Harvested green		Existing wood		Imported: design versus actual	
		Rootfans	Stems	Rootfans	Stems	Rootfans	Stems	Rootfans	Stems
Site 17	LWD Aggregate	3	2	0	0	1	0	-1	1
Site 18	Channel Spanner	2	1	0	0	0	3	0	0
Site 19	Log Step 3	2	3	0	0	0	0	0	1
Site 20	Log Step 4	3	2	0	0	0	0	-1	0
Site 21	LWD Aggregate	3	1	1	0	0	0	0	0
Site 22	LWD Aggregate	3	0	0	0	0	0	0	-1
Site 23	LWD Aggregate	2	2	1	0	1	0	-1	1
Site 24	LWD Aggregate	2	2	0	0	1	0	0	1
Site 25	LWD Aggregate	2	2	0	0	0	1	0	2
Total		63	45	6	0	25	38	-11	17

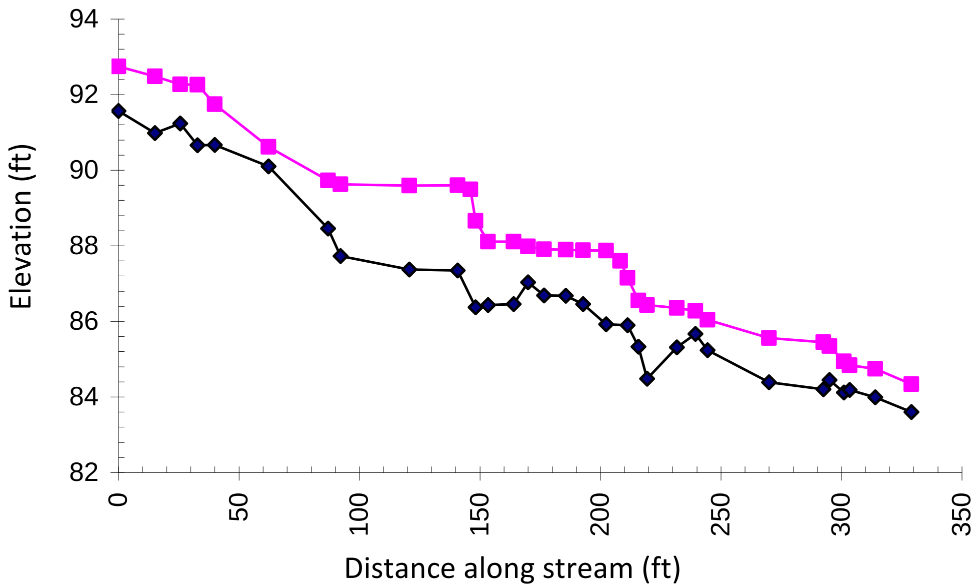


Figure 17. Longitudinal profile in Reach 1 of South Fork Coal Creek restoration project. Black diamonds represent channel thalweg and pink squares represent water surface measurements.

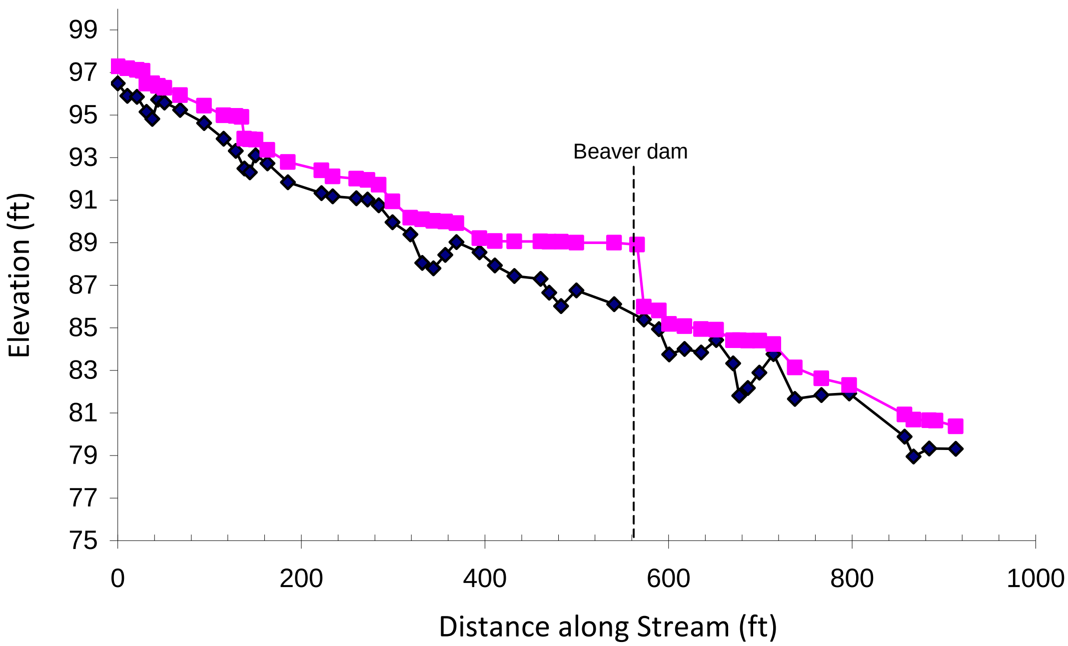


Figure 18. Longitudinal profile in Reach 2 of South Fork Coal Creek restoration project. Black diamonds represent channel thalweg and pink squares represent water surface measurements.

Figure 19. Chinook helicopter hoisting tree from Sun Dog burn area into South Fork Coal Creek restoration project zone during summer 2008.

Figure 20. Helicopter placing tree at restoration site location on South Fork Coal Creek in summer 2008.

Figure 21. Trees placed in South Fork Coal Creek by helicopter for habitat restoration in summer 2008.

Figure 22. Downstream view of pool created by channel-spanning log in South Fork Coal Creek during summer 2008.

Figure 23. Channel spanner/step pool created by channel-spanning log in South Fork Coal Creek during summer 2008.

Figure 24. Spider backhoe creating large woody debris aggregate in South Fork Coal Creek during summer 2008.

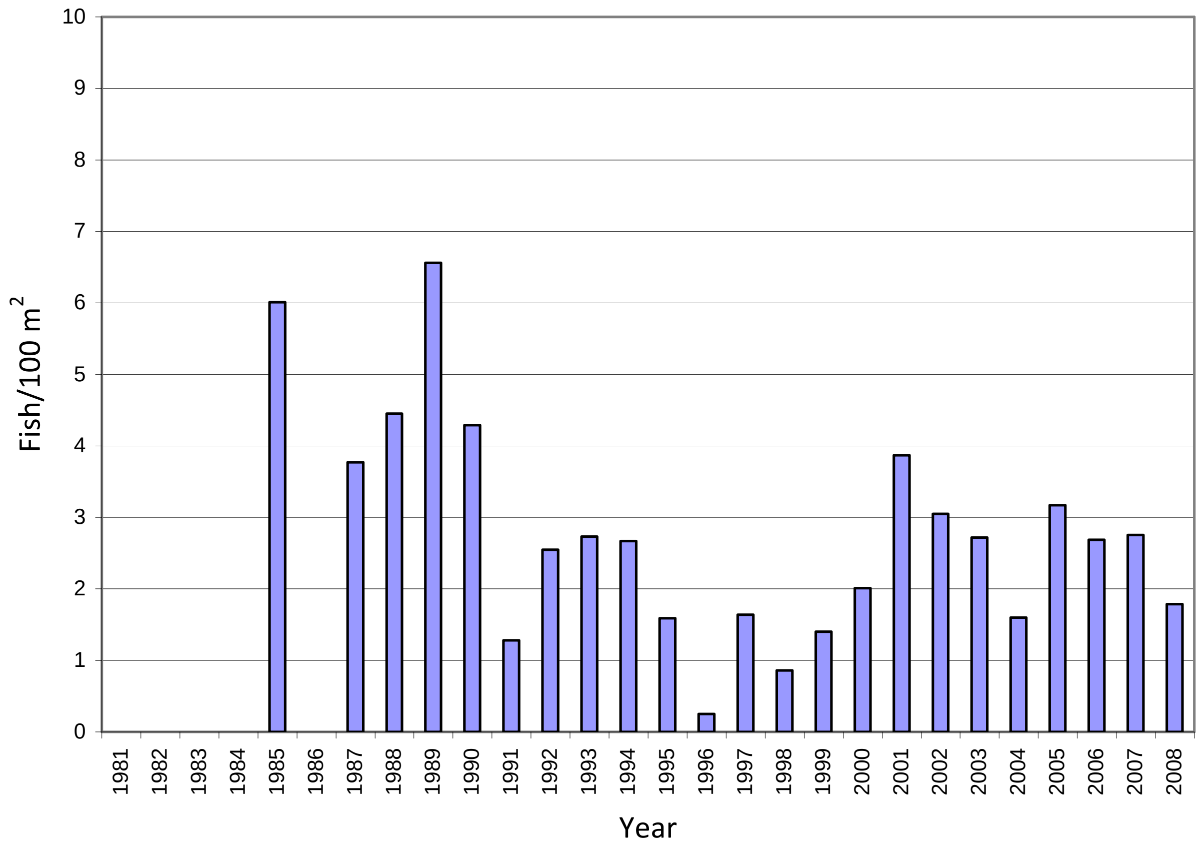


Figure 25. Westslope cutthroat trout densities in the annual electrofishing index section of the South Fork Coal Creek (Weaver et al. 2006). The index section is located downstream of reaches restored in 2008.

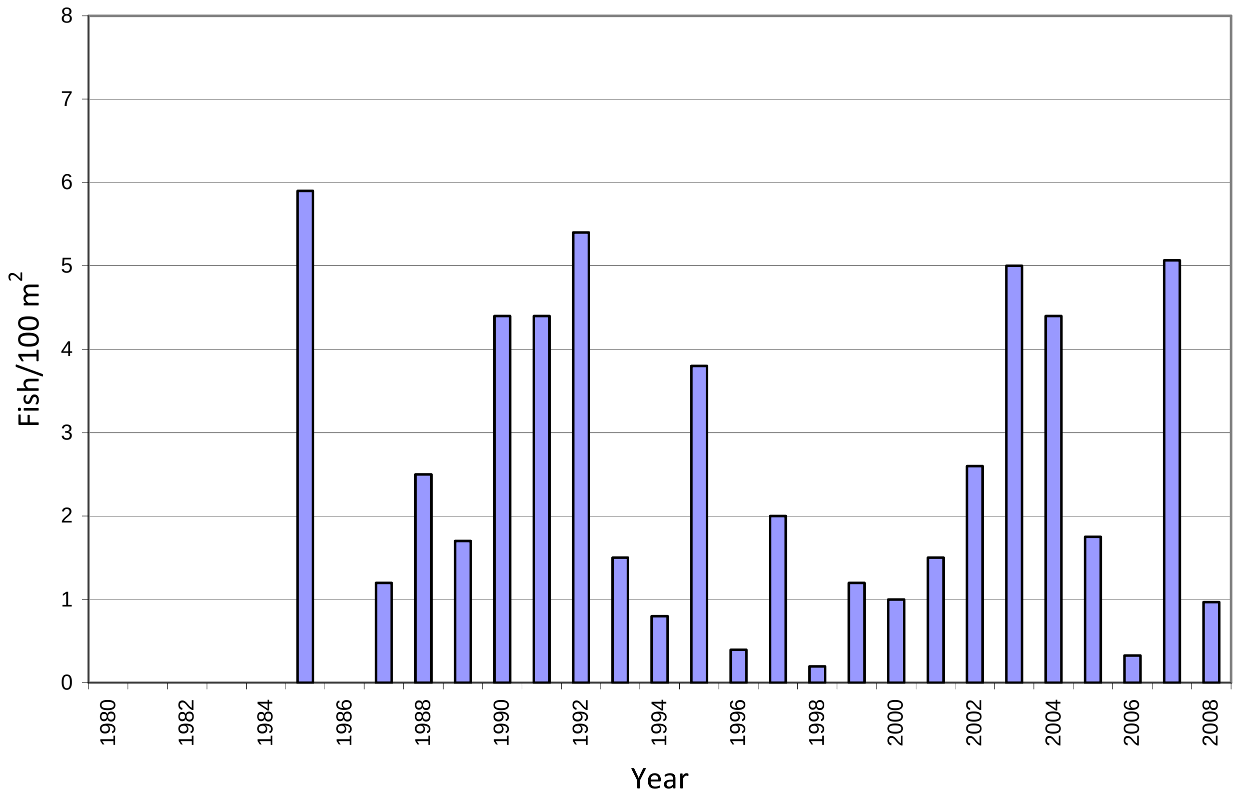


Figure 26. Bull trout densities in the annual electrofishing index section of South Fork Coal Creek (Weaver et al. 2006). The index section is located downstream of reaches restored in 2008.

Table 10. Westslope cutthroat trout population estimates on South Fork Coal Creek in the section restored in summer 2008.

Year	Number of fish caught	Mean length (mm)	SD	Estimated abundance	95% CI	Estimated number of fish/100 m^2
2007	19	168	45	19	(17, 21)	2
2008	29	166	30	30	(26, 34)	3

Table 11. Bull trout population estimates on South Fork Coal Creek in the section restored in summer 2008.

Year	Number of fish caught	Mean length (mm)	SD	Estimated abundance	95% CI	Estimated number of fish/100 m^2
2007	38	130	26	42	(33, 51)	4
2008	15	180	41	15	(12, 18)	1

Literature Cited

Allendorf, F. W., and R. F. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species: the cutthroat trout. Conservation Biology 2:170-184.

Block, D. G. 1955. Trout migration and spawning studies on the North Fork drainage of the Flathead River. University of Montana, Missoula, Montana. M.S. Thesis.

Deleray, M., L. Knotek, S. Rumsey, and T. Weaver. 1999. Flathead Lake and river fisheries status report. DJ Report No. F-78-R-1 through 5. Montana Department of Fish, Wildlife and Parks, Kalispell.

Devries, D.R., and R.V. Frie. 1996. Determination of age and growth. Pages 483-512 *in* Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Downs, C. C., D. Horan, E. Morgan-Harris, R. Jakubowski. 2006. Spawning demographics and juvenile dispersal of an adfluvial bull trout population in Trestle Creek, Idaho. North American Journal of Fisheries Management 26:190-200.

Fraley, J.J., and B.B. Shepard. 1989. Life history ecology and population status of migratory bull trout (Salvelinus confluentus) in the Flathead Lake and River System, Montana. Northwest Science 63:133-143.

Hanzel, D. A. 1976. The seasonal, area, and depth distribution of cutthroat trout and Dolly Varden in Flathead Lake. Job Performance Report, Project No. F-33-F-10, Job I-a. Montana Department of Fish, Wildlife & Parks, Kalispell, Montana.

Hitt, N. P., C. A. Frissell, C. C. Muhlfeld, and F. W. Allendorf. 2003. Spread of hybridization between native westslope cutthroat trout, *Oncorhynchus clarki lewisi*, and nonnative rainbow trout, *Oncorhynchus mykiss*. Canadian Journal of Fisheries and Aquatic Sciences 60:1440-1451.

Liknes, G.A. and P.J. Graham. 1988. Westslope cutthroat trout in Montana: life history, status and management. Pages 53-60 *in* R.E. Gresswell, editor. Status and management of cutthroat trout. American Fisheries Society, Symposium 4, Bethesda, Maryland.

McMullin, S.L., and P.J. Graham. 1981. The impact of Hungry Horse Dam on the kokanee fishery of the Flathead River. Montana Fish, Wildlife and Park, Kalispell, Montana.

Muhlfeld, C.C., S.Glutting, R. Hunt, D. Daniels, M. Boyer, J. Wachsmuth, and B. Marotz. 2003. Hungry Horse Mitigation Program, 2002 Annual Progress Report: Investigations of the Flathead River Native Species Project. BPA Project Number 199101903.

Muhlfeld, C.C., S.Glutting, R. Hunt, D. Daniels, M. Boyer, J. Wachsmuth, and B. Marotz. 2004. Hungry Horse Mitigation Program, 2003 Annual Progress Report: Investigations of the Flathead River Native Species Project. BPA Project Number 199101903.

Muhlfeld, C.C., S.Glutting, R. Hunt, D. Daniels, M. Boyer, J. Wachsmuth, and B. Marotz. 2007. Hungry Horse Mitigation Program, 2005-2006 Annual Progress Report: Investigations of the Flathead River Native Species Project. BPA Project Number 199101903.

Muhlfeld, C.C., S.T. Kalinowski, T.E. McMahon, M.L. Taper, S. Painter, R.F. Leary, and F.W. Allendorf. 2009. Hybridization rapidly reduces fitness of a native trout in the wild. Biology Letters, 3/18/09 (doi:10.1098/rsbl.2009.0033).

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, Number 191.

River Design Group, Inc. 2007. South Fork Coal Creek fish habitat restoration project Report, Whitefish, Montana.

Pattenden, R., C. McLeod, and G. Ash. 1991. Peace River Site C hydroelectric development, pre-construction fisheries studies; fish movements and population status. 1990 studies interim final report. Submitted to B.C. Hydro by R. L. & L. Environmental Services Ltd., Edmonton, Alberta.

Pettit, S.W., and R.L. Wallace. 1975. Age, growth, and movement of mountain whitefish, *Prosopium williamsoni* (Girard), in the North Fork Clearwater River, Idaho. Transactions of the American Fisheries Society 1: 68-76.

Shepard, B.B., K.L. Pratt, and P.J. Graham. 1984. Life histories of westslope cutthroat trout and bull trout in the upper Flathead River Basin, Montana. Montana Department of Fish, Wildlife and Parks, Helena.

Steed, A., R. Hunt, D. Belcer, and S. Glutting. 2008. Investigations of the Hungry Horse Mitigation Program, 2006-2007 Annual Report. BPA Project number 199101903.

U.S. Fish and Wildlife Service. 1998. Endangered and threatened wildlife and plants; determination of threatened status for the Klamath River and Columbia River distinct population segments of bull trout. Federal Register 63:31647-31674.

Weaver, T., J. Cavigli, and M. Deleray 2004. Coal Creek Channel Survey Preliminary Overview 2003. Montana Department of Fish, Wildlife and Parks, Kalispell Montana.

Weaver, T., M. Deleray, and S. Rumsey 2006. Flathead Lake and river system fisheries status report. Montana Department of Fish, Wildlife & Parks, Kalispell.

Weaver, T. 2008. Flathead Basin bull trout redd counts: TW-004-08. Montana Fish, Wildlife and Parks, Kalispell, Montana.

Whiteley, A.R., P. Spruell, F.W. Allendorf. 2004. Ecological and life history characteristics predict population genetic divergence of two salmonids in the same landscape. Molecular Ecology (13) 3675–3688.