North Saskatchewan and Ram Rivers Bull Trout Spawning Stock Assessment, Alberta, 2007 - 2009

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EXECUTIVE SUMMARY

Bull Trout (*Salvelinus confluentus*), Alberta's provincial fish and a native sport species, have declined significantly in abundance and distribution throughout Alberta. Despite being a priority species for management, critical Bull Trout habitats and migratory behavior of the species in the North Saskatchewan River drainage is relatively unknown. Our study area included the North Saskatchewan River from the Bighorn Dam downstream to the community of Rocky Mountain House, as well as along the lower reaches of the Bighorn, Clearwater and Ram rivers. In a 2007 pilot study we confirmed angler reports of large, migratory Bull Trout using Fall Creek, a Ram River tributary, to spawn. Following this, our study objectives were to determine the timing, magnitude and location of Bull Trout spawning in Fall Creek. Additional objectives included ascertaining the overwintering location(s) of the stock, assessing the use of Fall Creek by juvenile Bull Trout and examining the relatedness of the stock to putative migratory stocks in the Bighorn, North Saskatchewan and Ram rivers.

We used a combination of migration trapping, redd surveys, telemetry, abundance estimation and genetic techniques to achieve our study objectives. We operated a fish fence and trap at the mouth of Fall Creek to capture out-migrating Bull Trout. We performed redd surveys on the length of Fall Creek that is available to migrants. A total of 27 migrants captured in the Fall Creek fish trap were implanted with radio-transmitters and manually relocated monthly using a rotary wing aircraft. We electrofished nine 250-m sites systematically distributed along Fall Creek and modeled abundance of juvenile (70-300 mm fork length; FL) Bull Trout in the stream. In addition to our catch at the trap, angling and electrofishing gear was used to capture Bull Trout ≥200 mm FL for collection of tissue samples (adipose fin clip) for microsatellite DNA analysis.

Bull Trout spawning activity in Fall Creek peaked around the third week of September and was essentially complete by the first week of October. We observed 30, 55 and 58 Bull Trout redds in Fall Creek in 2007, 2008 and 2009, respectively. The majority of redds (≥85%) were consistently observed in the uppermost 1.5 km of stream that is available to migrating fish. The 25 fish consistently located using telemetry gear moved directly to overwintering locations in the Clearwater (n=2), North Saskatchewan (n=7) and Ram (n=13) rivers, or their confluence (n=3). Overall the distance fish migrated was relatively short (2-74 km) and movement over the winter months (November to March) was minimal (0-3 km).

We estimated that 3,981 (95% CI=1,331-13,206) juvenile Bull Trout inhabit Fall Creek. Size distribution ranged from 41-680 mm FL and most likely included young-of-the-year, juvenile and adult fish. Tissue samples collected from Bull Trout in Fall Creek and the lower Ram River were sufficient (n>30) for population-level analysis of genetic diversity and divergence. Samples obtained from these streams were significantly different from one another genetically ($\Theta=0.038$, $P<0.001$) indicating to a large extent that these are demographically independent populations. Of these populations only one fish could be excluded from the Fall Creek population and it was inferred to be an immigrant from the lower Ram River population, indicating a high level of spawning site fidelity. Despite considerable effort, Bull Trout catch rates in the Bighorn and North Saskatchewan rivers were very low and only 8 (includes fish < 200 mm FL) and 6 tissue samples were obtained from these streams, respectively.

Study results clearly indicate that Fall Creek is a key spawning and rearing stream for Bull Trout in the North Saskatchewan River drainage. Industrial and recreational activities are pervasive throughout much of the Fall Creek watershed. While it is unclear what impact these activities have had on the population, it is clear that the opportunity for future negative impacts is considerable and continued monitoring of the Bull Trout population is advised. Based on the results of our tissue sampling effort it appears that Bull Trout may be less abundant and more restricted in distribution in the study area than is commonly assumed although a more comprehensive evaluation is necessary to confirm this. Overwintering habitat in the North Saskatchewan River upstream of the mouth of the Ram River is limited by shallow water and anchor ice but increases downstream toward Rocky Mountain House. As a broad diversity of factors limit the maintenance and recovery of Bull Trout within the study area, basic life history and habitat-use information collected during studies like this is essential for the sound management of the species.

Key words: Alberta, Bull Trout, Fall Creek, North Saskatchewan River, Ram River, spawning

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1.0 INTRODUCTION

1.1 General introduction

Bull Trout (*Salvelinus confluentus*), Alberta's provincial fish and a native sport species, have declined significantly in abundance and distribution throughout Alberta; 81% of core areas (38 of 47) currently containing Bull Trout are considered at risk of extirpation (Alberta Sustainable Resource Development (ASRD) In prep.). One such core area at risk is the Middle North Saskatchewan River, and its tributaries, from the Bighorn Dam downstream to the mouth of the Clearwater River near the community of Rocky Mountain House. Despite being a priority species for management, critical Bull Trout habitat and its migratory behavior within much of this core area remains unknown (ASRD 2008). Along with the river itself, two of the North Saskatchewan River's largest tributaries, the Ram and Bighorn rivers, are thought to contain large presumably migratory Bull Trout. Other tributaries in the area are known to contain Bull Trout, however they are considered less likely to support a migratory population. Anglers also reported catching large Bull Trout in the autumn in Fall Creek, a Ram River tributary.

Industrial and recreational activities are pervasive throughout much of the core area but activity in the Fall Creek drainage is particularly intense. Off-highway vehicle (OHV) use, forestry, oil and gas extraction and cattle grazing all occur within the drainage and have the potential to negatively impact Bull Trout populations with spawning areas particularly susceptible to impacts (ASRD and Alberta Conservation Association (ACA) 2009). In a 2007 pilot study, we confirmed the use of Fall Creek by migratory Bull Trout for spawning. We expanded our study in 2008 and 2009 to identify the stream of origin of these fish and the timing, magnitude and location of the spawning run using a combination of telemetry and genetic techniques. In addition, we sought to identify the overwintering location(s) of the stock and to assess the use of Fall Creek by juvenile Bull Trout. The basic habitat use and life history information collected over the course of our study is critical to the informed management of Bull Trout in this core area.

1.2 Study objectives

1. Determine the timing, magnitude and location of Bull Trout spawning in the Fall Creek drainage.
2. Determine overwintering location(s) of the Fall Creek Bull Trout spawning stock.
3. Assess the abundance and spatial distribution of juvenile Bull Trout within Fall Creek.
4. Determine the relatedness of the Fall Creek Bull Trout spawning stock to putative migratory stocks in the Bighorn, North Saskatchewan and Ram rivers.

2.0 STUDY AREA

Our study area encompassed the North Saskatchewan River, and its larger tributaries, from the Bighorn Dam downstream to Rocky Mountain House (Figure 1). This reach of the North Saskatchewan River is approximately 130 km in length. Upstream of its passage through the Brazeau Mountain Range (locally known as the "Brazeau Gap") the river flows through a broad alluvial valley and braids considerably, while the remaining 90 km downstream of the Brazeau Gap is confined to a single channel for most of its length. River substrates are primarily cobble, gravel and boulder, often embedded in sand and silt (ASRD 2008).

Within the study area both the Bighorn and Ram rivers and on a smaller scale, Fall Creek, are characterized by boulder and cobble substrates, and sections of exposed bedrock, resulting in numerous cascade-plunge pool complexes and deep valleys. Upslope soils are highly unstable and consequently clarity of these streams during the open-water season is typically poor except in early spring before freshet, and late summer/early autumn during periods of low precipitation. Flows of both the Ram River and Fall Creek are moderated by considerable groundwater input, often highly flocculated, which smell strongly of sulfur. All three streams contain natural barriers to fish passage and their headwaters were historically fishless. Crescent Falls, the uppermost of a series of falls that are a barrier to fish passage, is located 10.5 km upstream of the mouth of the Bighorn River. The waterfall barrier on the Ram River is

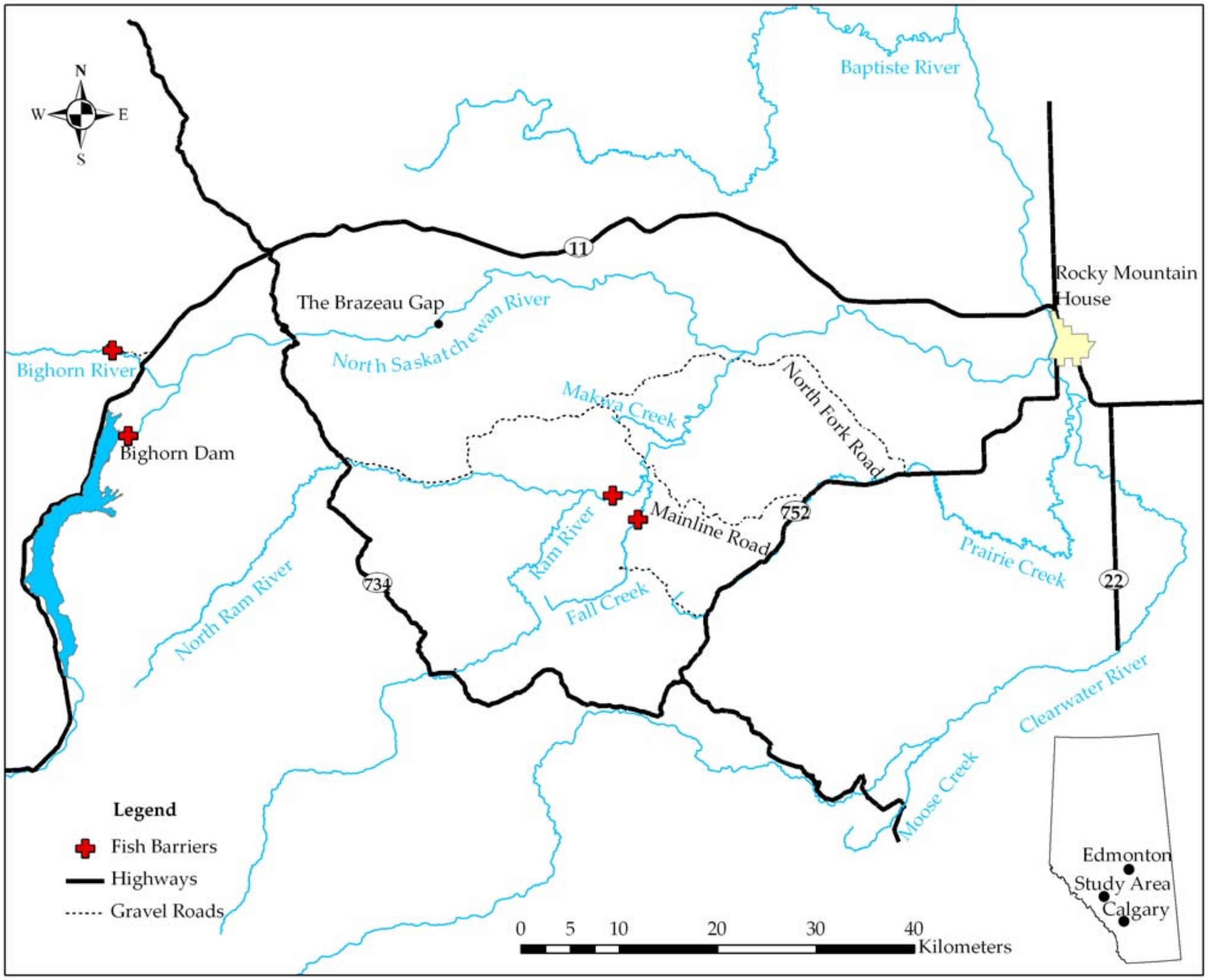

Figure 1. Location of the North Saskatchewan and Ram rivers Bull Trout spawning stock assessment study area in Alberta, 2007 to 2009.

31 km upstream of the mouth and the waterfall barrier on Fall Creek is 7.5 km upstream of its confluence with the Ram River. These waterfall barriers along with the Bighorn Dam comprise the upstream boundaries of our study area.

Following preliminary results of our telemetry work in October, 2008 we expanded the study area in November, 2008 to include the lower portion of the Clearwater River drainage and the North Saskatchewan River downstream of Rocky Mountain House. Habitat use and migratory behavior of Bull Trout in the headwaters of the Clearwater River is well documented (Rhude and Rhem 1995) although the origin of Bull Trout occasionally caught near its confluence with the North Saskatchewan River is less clear. Based on what limited information was available, we chose the mouth of Moose Creek and the bridged crossing of Secondary Highway 752 over Prairie Creek (a Clearwater River tributary) as upstream boundaries within this drainage. We also extended relocation flights downstream on the North Saskatchewan River to the mouth of the Baptiste River. In total approximately 340 km of the Bighorn, Clearwater, North Saskatchewan and Ram rivers, Fall and Prairie creeks were included in our study area. Geographic coordinates for these boundaries are contained in Appendix 1.

The entire study area occurs within the Foothills Natural Region. The region is characterized by its expansive deciduous or mixedwood forests at lower elevations, conifer stands at higher elevations, relatively high annual precipitation, variable topography and diverse habitats. Water bodies occupy less than one percent of the total area within the region (Natural Regions Committee 2006). Topography of the Ram River subwatershed, in which nearly the entire study area is contained, is characterized by strong, rolling ridges of shale and sandstone. The economic base of the region consists of oil and gas, forestry, agriculture and tourism. Nearly all the subwatershed (99%) lies in a Forestry Management Unit and a relatively high percentage (1.6%) of the subwatershed has been affected by linear development (North Saskatchewan Watershed Alliance 2005).

The North Saskatchewan River within the study area supports at least seven species of non-sport fish including Longnose Sucker (*Catostomus catostomus*), White Sucker (*Catostomus commersoni*), Mountain Sucker (*Catostomus platyrhynchus*), Longnose Dace (*Rhinichthys cataractae*), Lake Chub (*Couesius plumbeus*), Spoonhead Sculpin (*Cottus ricei*) and Emerald Shiner (*Notropis atherninoides*) and three native species of sport fish in addition to Bull Trout including Mountain Whitefish (*Prosopium williamsoni*), Walleye (*Sander vitreus*) and Burbot (*Lota lota*). Naturalized populations of Brown Trout (*Salmo trutta*), Cutthroat Trout (*Oncorhynchus clarki*), Rainbow Trout (*Oncorhynchus mykiss*) and Brook Trout (*Salvelinus fontinalis*) also occur in the area (ASRD 2008).

3.0 MATERIALS AND METHODS

We used a combination of migration trapping, redd surveys, telemetry, abundance estimation and genetic techniques to achieve our study objectives.

3.1 Fish capture

We captured fish using angling, electrofishing and trap-netting gear. Sampling occurred at various locations throughout the study area from April to October, 2007 to 2009 but we focused on the early-spring and late-summer periods when water clarity was best. Angling gear included spinning rods with crankbaits, spinners and jigs with barbed, baited hooks. The North Saskatchewan River was electrofished using both raft (2008 and 2009) and jet boat (2007) mounted electrofishers moving downstream. The raft electrofisher was equipped with a ring-style anode and the jet boat with two front-mounted booms with dropper-style anode arrays. Typical electrofisher settings ranged from 50 to 1000 V and 60 Hz with a 1 to 5 ms pulsewidth, generating 2.0 to 4.5 A. Run time (seconds) was recorded with a stopwatch in 2007. A backpack electrofisher was used to sample Fall Creek (2008) and the Bighorn River (2009).

In 2008, we installed and operated a conduit fish fence and trap on Fall Creek approximately 80 m upstream of the mouth of the creek to capture post-spawn Bull Trout migrating out of the creek. The trap was operational from 2 September to 8 October and consisted of fence wings flanking a box trap similar to that described by Hvenegaard and Thera (2001). The trap was constructed to capture fish moving upstream and acted as a barrier to downstream fish movement. We checked and cleaned debris from the fence and trap daily. Downstream migrants typically staged in pools and near woody debris immediately above the trap. We dip netted, seined, angled or electrofished (in that order of preference) fish staging above the trap. Fish were released either upstream or downstream of the trap, according to their direction of travel. The trap was removed after we failed to observe Bull Trout for three consecutive days. Before removal, we electrofished the pools immediately upstream of the trap and visually inspected pools within a 1-km reach above the trap to ensure that no Bull Trout were staging in the area.

All fish caught were identified to species according to Nelson and Paetz (1992) and fork length (FL; mm) was measured. Fish weights (g) were measured opportunistically as many sampling locations were accessible only by foot limiting the amount of gear we could carry. All Bull Trout ≥300 mm FL were tagged with a T-bar anchor tag that was colour-coded to the reach where the fish was originally captured (Bighorn River=orange, Fall Creek=white, North Saskatchewan River=yellow, lower Ram River (below the mouth of Fall Creek)=red, upper Ram River (upstream of the mouth of Fall Creek)=blue).

In 2007, we tagged Bull Trout throughout the study area and then assessed their occurrence in the Fall Creek spawning run. In 2008 and 2009, we expanded our effort to include the collection of tissue samples for genetic analysis in addition to tagging. The tissue sample was an adipose fin clip taken from all Bull Trout ≥200mm FL; smaller size Bull Trout were included in our sample from the Bighorn River as capture rates were very low. Samples were preserved in 5 ml of anhydrous ethyl alcohol in vials. Effort to capture Bull Trout was focused on pool and run habitats within the study area and targeted larger Bull Trout.

3.2 Redd surveys

We conducted redd surveys on Fall Creek in September and October, 2007 to 2009. All 7.5 km of stream accessible to fish migrating from the Ram River were surveyed. We visited the creek multiple times in 2007 (September 18-19; October 3-4) and 2008 (September 4-7; September 15-21; September 30-October 2) to assess the timing of Bull Trout spawning activity and redd life (i.e. the length of time redds remain visible; Gallagher et al. 2007). In 2009, we surveyed the creek October 6 to 7. Surveys were conducted by two observers on opposite banks who recorded the number of redds, their location, and the number and species of fish observed in the reach. Deeper pools within the reach were snorkeled in 2007 and 2008 to confirm the accuracy of our bank observations. Redds were categorized as "definite" or "probable" according to criteria outlined in Bonar et al. (1997). The location of each redd or cluster of redds was identified using a handheld Global Positioning System (GPS). In 2008 we uniquely marked each redd location with flagging tape for relocation during subsequent surveys.

3.3 Telemetry

In 2008, we surgically implanted 27 of the 75 downstream migrants captured in the Fall Creek fish trap with Lotek MCFT-3EM coded telemetry transmitters (frequencies 149.58Hz, 150.28Hz, 150.64Hz). Effort was made to ensure implanted fish were representative of the spawning run. Surgeries were distributed across the trapping season (September 17-29) and mean (±SD) fork length of implanted fish (570±82 mm; range 420-730 mm) did not differ markedly from the remainder of the catch (578±82 mm; range 376-757) although female fish were overrepresented in our sample relative to their composition of the total catch (44% and 29% respectively). Our transmitters weighed 8.9 g (in air) and represented a low percentage of each implanted fish's body weight (0.60±0.25 %; mean±SD) (Brown et al. 1999). Transmitters had a typical battery life of 336 days.

Prior to surgery, we anesthetized fish with clove oil (~25 ml/L) and surgical tools and the transmitters were disinfected in a dilute Betadine solution, and then rinsed with a saline solution. After swabbing the area with Betadine, an approximately 2-cm incision was made lateral to the midline of the fish and anterior of the pelvic girdle on the ventral side. We used a large-bore needle and grooved aluminum guide to create a lateral antenna exit hole through the body wall near the pelvic fins. To close incisions we used 4 to 5 sutures using 3-0 silk suture material. Fish were allowed to recover in a flow-through pen post surgery until upright and swimming. Once recovered, we released fish into a backwater area of the Ram River at the mouth of Fall Creek. A single fish died during surgery as a result of handling stress.

We manually relocated implanted Bull Trout using rotary wing aircraft fitted with a four-element Yagi-style antenna connected to a Lotek SRX-400 programmable receiver. Relocation flights occurred monthly from October 2008 to April 2009; we typically flew

80 m above the stream surface at a speed of 90 km/h. Precision and accuracy of our relocations, as determined through blind relocations of a transmitter placed along the flight path, was sufficient for the purposes of our study (138±110 m; mean±SD, n=6).

Over the course of our October and November, 2008 flights we flew the length of all our focal streams within the study area (i.e. Bighorn, North Saskatchewan, Ram and Clearwater rivers, Fall and Prairie creeks) relocating 25 of 27 fish. For the remainder of the study our typical flight plan included the North Saskatchewan River from Rocky Mountain House to the Brazeau Gap, the Ram River from its mouth to the waterfall barrier and the Clearwater River from its confluence to the mouth of Prairie Creek. Supplementary relocations were occasionally made from the ground. All fish locations were identified using a handheld GPS.

To gather more detailed Bull Trout movement information we placed Lotek SRX-400 fixed station data loggers along the Ram River at the North Fork and Mainline road crossings (Figure 1). Data logger receivers were powered by two 12-volt, deep-cycle marine batteries operating in series and equipped with a single four-element Yagi-style antenna set perpendicular to the river. This antenna arrangement only allowed us to detect fish travelling past the data logger, not their direction of travel. Data logger settings were adjusted to ensure transmitter detection within 100 m of the logger. The data loggers operated continuously from 26 September, 2008 to 28 May, 2009 (North Fork) and 2 April, 2009 to 29 May, 2009 (Mainline). Data loggers were checked approximately every three weeks during operation. When assessing Bull Trout overwintering habitat use within the study area, we defined winter as the period from November to March during which base flow conditions prevail, water temperatures are near 0˚C and stream reaches not influenced by groundwater are typically ice covered.

3.4 Fall Creek juvenile abundance and spatial distribution

We electrofished nine 250-m sites (2.25 km total) systematically distributed along Fall Creek, downstream of the waterfall barrier from July 29 to 31, 2008. Site length was based upon recommendations made in Fitzsimmons and Rodtka (2008). We electrofished working upstream and recorded effort (seconds), measured wetted and rooted stream width, and maximum stream depth (±0.1 m) at transects spaced every 50 m within each 250-m site (Appendix 2). Juvenile Bull Trout were defined as fish 70 to 300 mm FL (ASRD and ACA 2009).

To estimate juvenile Bull Trout abundance and distribution we used a model outlined by Paul and Dormer (2005). The model adjusts observed catch data at each site by incorporating uncertainty in capture efficiency and fish captures given a constant capture efficiency using the beta and negative binomial distributions, respectively. A generalized additive model is then used to estimate the abundance of fish incrementally (250 m in this case) along the stream length. We repeated this process 10,000 times to calculate 95% confidence limits around means. Backpack electrofishing capture efficiency estimates reported for similar work on Bull trout in the Waiparous Creek (Fitzsimmons 2008a) and Canyon Creek (Fitzsimmons 2008b) drainages were used to parameterize the beta distribution (Appendix 3). All modeling was performed using the R software program (R Development Core Team 2005). For a more detailed description of the model see Fitzsimmons (2008a, 2008b).

3.5 Microsatellite DNA analysis

We sent tissue samples from the Bighorn River (n=8), Fall Creek (n=50), North Saskatchewan (n=6), and lower (n=41) and upper (n=2) Ram rivers to Eric B. Taylor's laboratory at the University of British Columbia for microsatellite DNA analysis. Nine microsatellite loci (*Sfo*18, *Sco*102, 105, 106, 215, 216, 220, *Smm*22 and *Omm*1128) derived from *Salvelinus fontinalis* (*Sfo*), *S. confluentus* (*Sco*), *S. malma* (*Smm*) and *Oncorhynchus mykiss* (*Omm*) genomic libraries (DeHaan and Arden 2006; Warnock et al. 2009) were chosen for analysis based on clarity of resolution and degree of polymorphisim (Taylor 2010). Polymerase chain reactions were carried out with dye-labeled primers in 10 μl volumes of 10 mM Tris-HCL (pH 8.3), 1.5 mM $MgCl_2$, 0.8 mM dNTP's and 0.1 units of *Taq* polymerase in MJ PTC 100 and 200 thermocyclers using cycling parameters outlined in Warnock et al. (2009). Polymerase chain reaction products were visualized using a Beckman-Coulter CEQ 8000 automated genotyper (Taylor 2010).

The Fall Creek and lower Ram River samples sizes (n>30) were large enough to conduct tests for deviation from Hardy-Weinberg equilibrium, genotypic linkage disequilibrium and population differentiation using GENEPOP version 3.3 (Raymond and Rousset

2001). Basic descriptive statistics of all samples were compiled using FSTAT version 2.9 (Goudet 2001). Tests of inter-population migration and of the null hypothesis that individuals were actually born in the populations from which they were sampled were performed using the program GENECLASS (Piry et al. 2004). For a more detailed description of the methods used for the microsatellite DNA analysis component of our study and study results see Taylor (2010).

3.6 Stream temperature and flow monitoring

During the open water season from 2007 to 2009 we collected stream temperature (˚C) data using two temperature data loggers located in the Ram River at the North Fork Bridge and near the mouth of Fall Creek. Data loggers measured water temperature every 1.5 to 2.5 h and the period over which our monitoring occurred varied from year-to-year depending upon high water conditions. We summarized stream discharge (m^3/s) data (2007-2009) from the Water Survey of Canada hydrometric station No. 05DC006 located near the mouth of the Ram River near the North Fork Bridge. Water temperature and discharge data are presented in Appendix 4 and 5 respectively.

3.7 Data management

All fish and habitat data was entered into the Alberta Sustainable Resource Development Fisheries Wildlife Management Information System (FWMIS), Project ID 7963. We plotted raw Bull Trout length-weight data to visually assess these data for outliers. Outliers were checked against the original datasheets for accuracy and a single outlier from our catch at the fish fence and trap was removed. Bull Trout length-weight data were $\log_{10}$-transformed and summarized using linear regression analyses (Pope and Kruse 2007). Unless stated otherwise, statistical analyses were performed using JMP statistical software (JMP 2005). Geographic information was analyzed using ArcGIS 9.2 software (ESRI 2006) and the Government of Alberta Resource Management Information Branch 2005 data layers. Water temperature, discharge and length-weight data are presented for comparison to future studies.

4.0 RESULTS

4.1 Fish capture

We captured 11 species consisting of Mountain Whitefish (n=267), Bull Trout (n=152 including 35 recaptures), Cutthroat Trout (n=112), Longnose Sucker (n=34), Brown Trout (n=15), Longnose Dace (n=9), Lake Trout (*Salvelinus namaycush*; n=5), Mountain Sucker (n=5), White Sucker (n=5), Brook Trout (n=1) and Walleye (n=1) while both electrofishing the Bighorn and North Saskatchewan rivers and angling throughout the study area. Our highest Bull Trout catch rates were in Fall Creek, where we typically targeted the spawning run, followed by the Ram River which were still well above catch rates in the North Saskatchewan and Bighorn rivers (Table 1). By 2009, 35% of our catch from the Ram River were fish we had previously tagged. Electrofishing and angling the North Saskatchewan and Bighorn rivers produced few Bull Trout and we suspect abundances in these rivers is quite low.

Table 1. Total effort, Bull Trout (BLTR) catch and mean catch-per-unit-effort (CUE) using electrofishing (fish/100 s) and angling (fish/h) gear in the North Saskatchewan River drainage, April to October 2007 to 2009. Electrofishing effort in 2007 was measured with a stopwatch. Values in brackets represent recaptures.

		2007			2008			2009		
Stream	Capture method	Total effort	Total BLTR	CUE (±SD)	Total effort	Total BLTR	CUE (±SD)	Total effort	Total BLTR	CUE (±SD)
Bighorn River	Electrofishing	—	—	—	—	—	—	1643	6	0.40
	Angling	—	—	—	5.2	2	0.4	4.3	0	0
Fall Creek	Angling	14.2	38 (7)	2.0 ± 2.7	10.7	23 (4)	1.4 ± 1.3	—	—	—
North Saskatchewan River	Electrofishing	5524	3	0.04 ± 0.05	—	—	—	5946	1	0.01 ± 0.02
	Angling	4.4	1	0.1 ± 0.2	43.3	5 (1)	0.1 ± 0.3	2.3	1	0.8 ± 1.1
Lower Ram River	Angling	19.1	13	0.8 ± 0.5	20.9	20 (7)	1.0 ± 1.4	22.9	32 (11)	1.1 ± 1.1
Upper Ram River	Angling	—	—	—	5.4	5 (1)	1.0 ± 0.9	11.0	2 (1)	0.3 ± 0.4

4.2 Redd surveys and telemetry

4.2.1 Timing, magnitude and location of Bull Trout spawning in Fall Creek

A single implanted Bull Trout was relocated in Fall Creek in April 2009 after having spent the winter in the Ram River. Migratory Bull Trout were captured throughout the creek by late July, and fish were congregated in a large plunge pool below the barrier waterfall by mid-August. Only one fish was captured attempting to move upstream of the fish trap which was in place 2 September to 8 October. Bull Trout spawning activity (i.e. redd excavation, courtship behavior, etc.) in Fall Creek peaked around the third week of September and was essentially complete by the first week of October. Female fish left the stream slightly earlier than males (Figure 2). Our greatest single-day catch of Bull Trout at the trap occurred 22 September (n=10) and coincided with turbid water conditions and decreasing water temperature. The last downstream migrating Bull Trout captured at the trap was caught on 5 October (Figure 2).

We observed 30, 55 and 58 Bull Trout redds in Fall Creek in 2007, 2008 and 2009 respectively. In total, 75 individual Bull Trout were captured at the trap in 2008 (Table 2), resulting in a Bull Trout per redd ratio of 1.4:1. Assuming this ratio is representative of the population during the period of our study and measured without error, 42 and 81 Bull Trout spawned in the stream in 2007 and 2009, respectively.

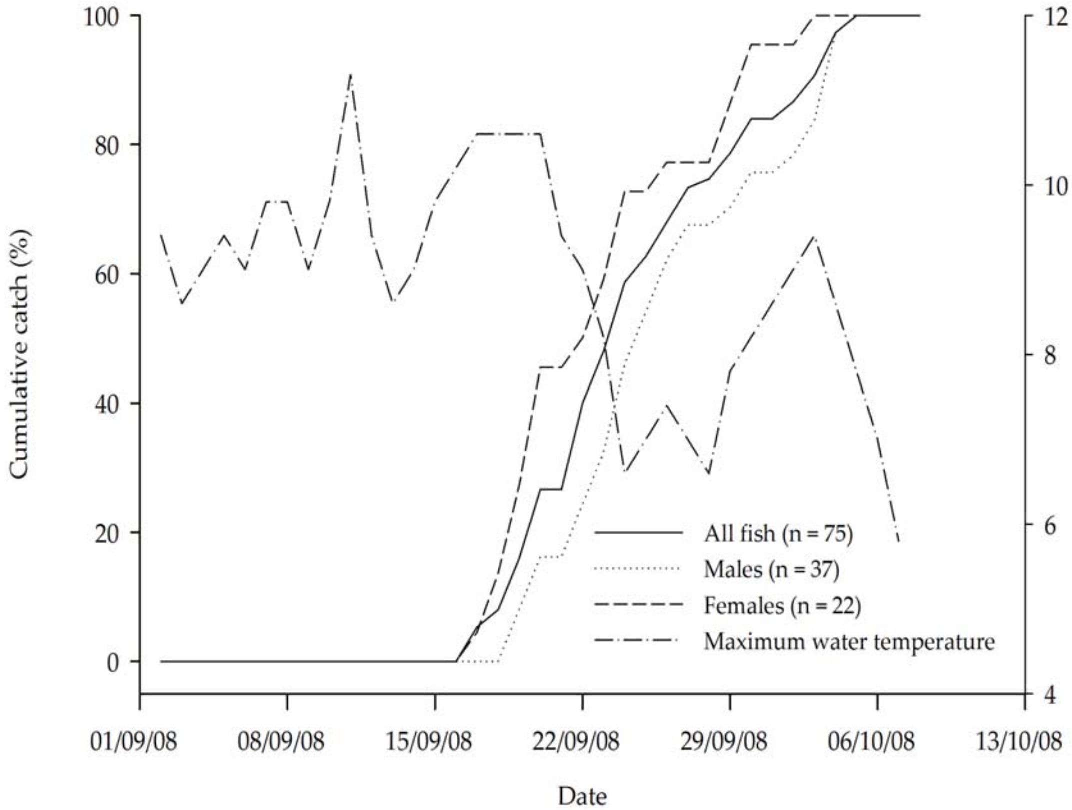

Figure 2. Cumulative catch of downstream Bull Trout migrants and daily maximum water temperature at the Fall Creek trap.

Table 2. Fork length and weight of downstream Bull Trout migrants at the Fall Creek trap, 2 September to 8 October, 2008.

Sex	n	Fork length (mm)		Weight (g)	
		Mean (±SD)	Range	Mean (±SD)	Range
Males[a]	37	577 ± 89	376 — 755	1952 ± 799	535 — 3680
Females[b]	22	571 ± 85	420 — 737	1692 ± 777	655 — 3500
Unknown	15	575 ± 86	453 — 757	1637 ± 727	745 — 3230

[a]Log_{10} Weight= -4.7798 + 2.9128 Log_{10} Fork length; r^2=0.98
[b]Log_{10} Weight= -4.8659 + 2.9261 Log_{10} Fork length; r^2=0.96

Although we observed Bull Trout spawning throughout the stream (Figure 3), 87% (n=26), 85% (n=47) and 97% (n=56) of the 2007, 2008 and 2009 redds, respectively were observed in the uppermost 1.5 km of stream that was accessible to Bull Trout (i.e. stream kilometers 6.0-7.5). Redd life exceeded the period of our survey every year and redds were typically categorized as "definite" with only 10, 7 and 6 "probable" redds being identified in the 2007, 2008 and 2009 surveys, respectively.

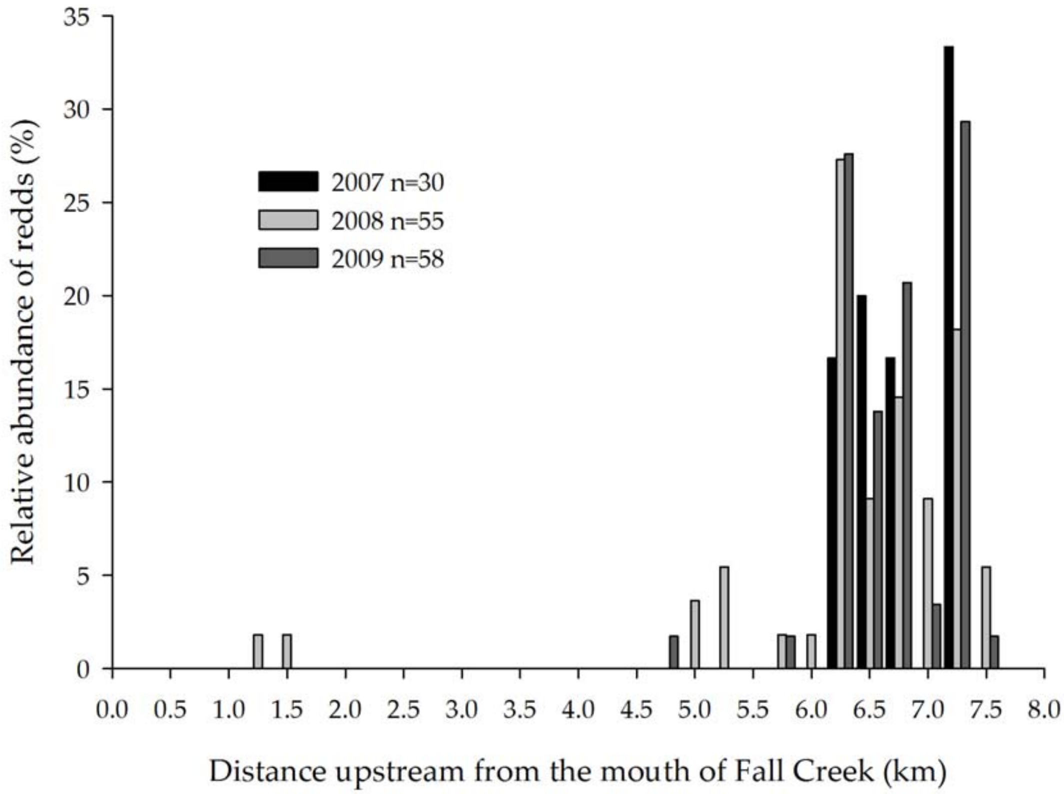

Figure 3. Relative abundance and location of Bull Trout redds in Fall Creek, 2007 to 2009. The mouth of Fall Creek is located at 0 km and the upstream barrier waterfall at 7.5 km. Four redds (not shown) were observed between the mouth of Fall Creek and kilometer 3.75 in 2007 but their exact location was not noted.

4.2.2 Overwintering locations of Bull Trout

The 25 fish that we consistently relocated over the five winter months moved directly from Fall Creek to overwintering locations in the Clearwater (n=2), North Saskatchewan (n=7) and Ram (n=13) rivers, or their confluence (n=3) (Figure 4). Migration out of the Ram River appears to have been very rapid. The fixed station data logger at the mouth of the river recorded only one fish leaving the watershed after it was operational. This fish travelled the 24 km from the mouth of Fall Creek to the mouth of the Ram River the day following surgery. The remainder of fish not detected leaving the Ram River but subsequently relocated in the North Saskatchewan or Clearwater rivers had likely left the drainage in the nine days between the start of surgeries and data logger installation.

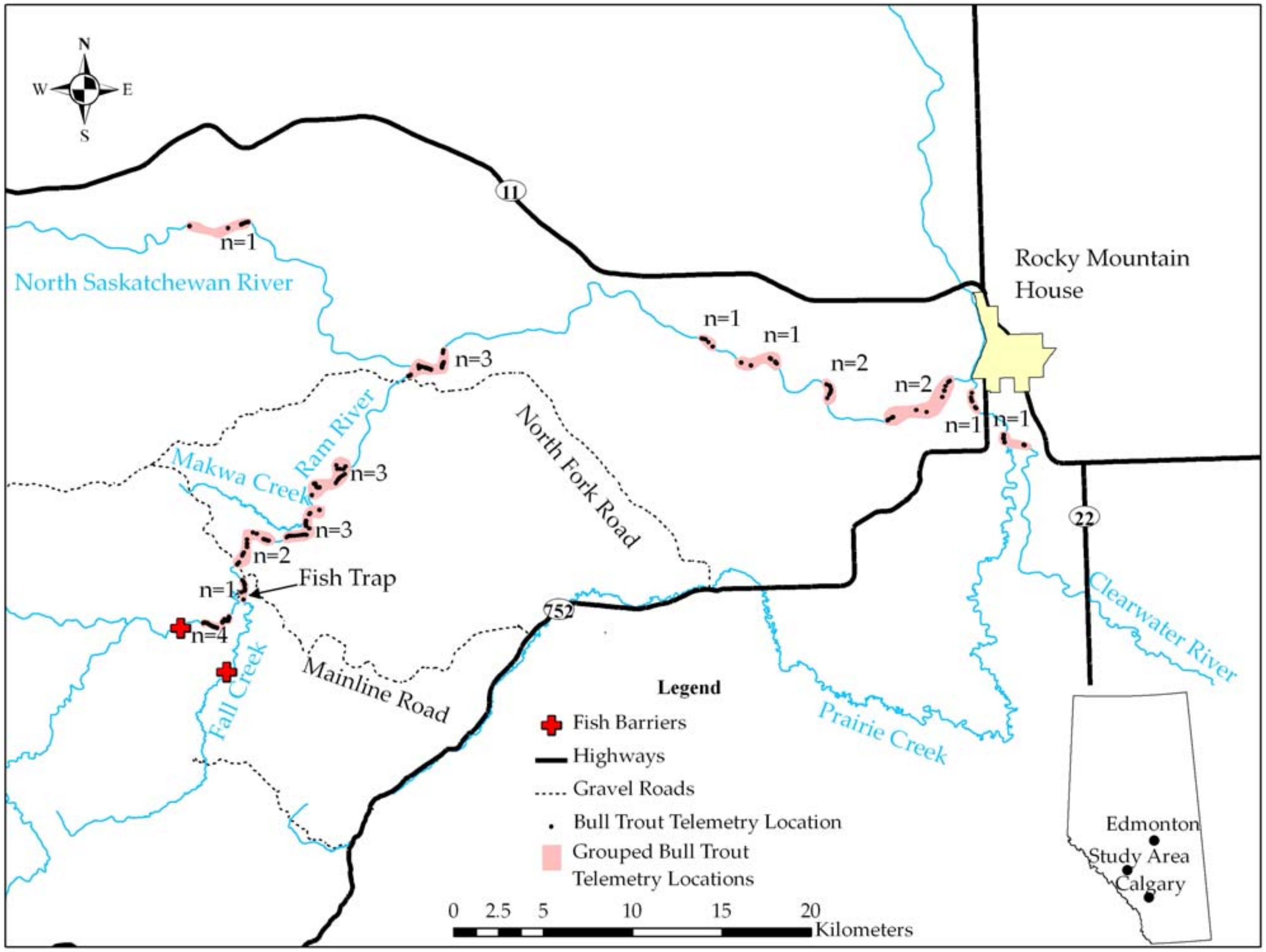

Figure 4. Overwintering locations of 25 Bull Trout in the North Saskatchewan River drainage, Alberta. Bull Trout were initially implanted in Fall Creek and tracked monthly over the winter (November 2008 - March 2009) using radio-telemetry.

Overall the distance fish migrated was relatively short, movement over the winter months was minimal and no clear differences between males and females were apparent (Table 3). Appendix 6 contains a summary of fish recapture and movement data of all Bull Trout located or captured three or more times over the course of the study.

Table 3. Comparison of maximum migration distance (October 2008 - April 2009) and monthly winter movement (November 2008 - March 2009) of Bull Trout in the North Saskatchewan River drainage, Alberta.

Sex	n	Migration (km)		Monthly winter movement (km)	
		Mean (±SD)	Range	Mean (±SD)	Range
Males	7	23.1 ± 21.9	3 — 57	1.0 ± 0.8	0 — 2
Females	11	33.5 ± 28.2	2 — 74	1.4 ± 0.7	1 — 3
Unknown	7	27.0 ± 24.8	3 — 63	1.0 ± 0.8	0 — 2

4.3 Juvenile Bull Trout abundance and spatial distribution in Fall Creek

We captured 298 Bull Trout during the electrofishing survey of Fall Creek in 2008 (Bull Trout catch summarized in Appendix 7). We estimate 3,981 (95% CI=1,331-13,206) juvenile Bull Trout inhabit the 7.5 km of Fall Creek below the barrier waterfall. Juvenile Bull Trout were distributed throughout the stream but were most abundant in the upper reaches (Figure 5). Overall, the Bull Trout catch included fish ranging in size from 41 to 680 mm FL (122±80 mm; mean±SD) (Figure 6) and most likely included young-of-the-year, juvenile and adult fish.

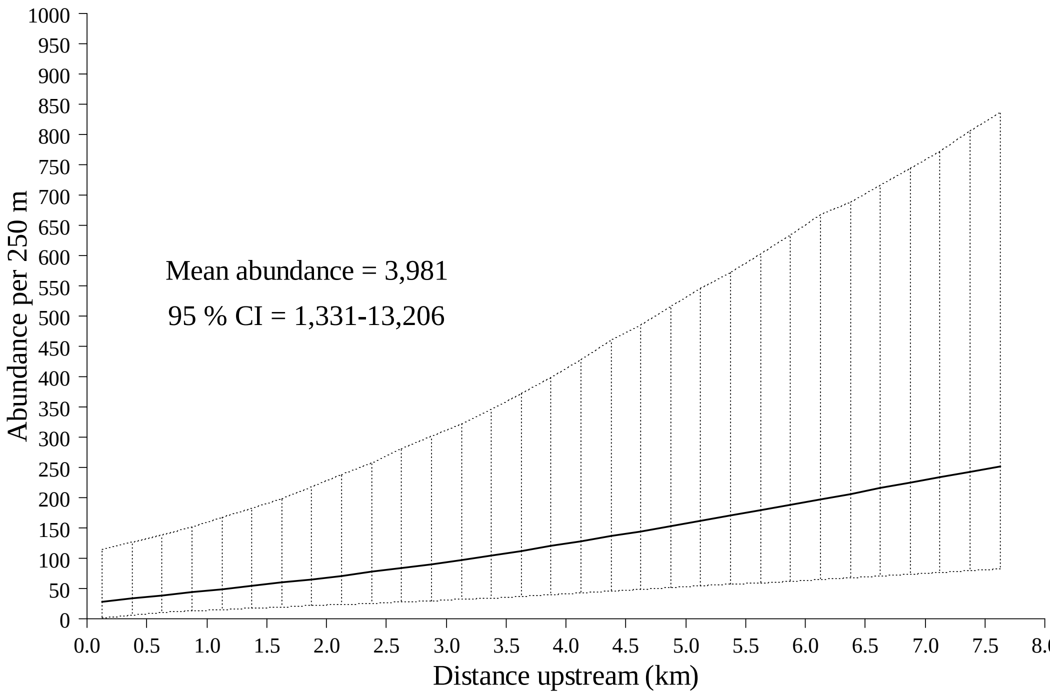

Figure 5. Estimated abundance and spatial distribution (250 m increments) of juvenile Bull Trout (70-300 mm FL) in Fall Creek, 2008. Mean and 95% CI (10,000 model runs) of the 250-m sections is presented.

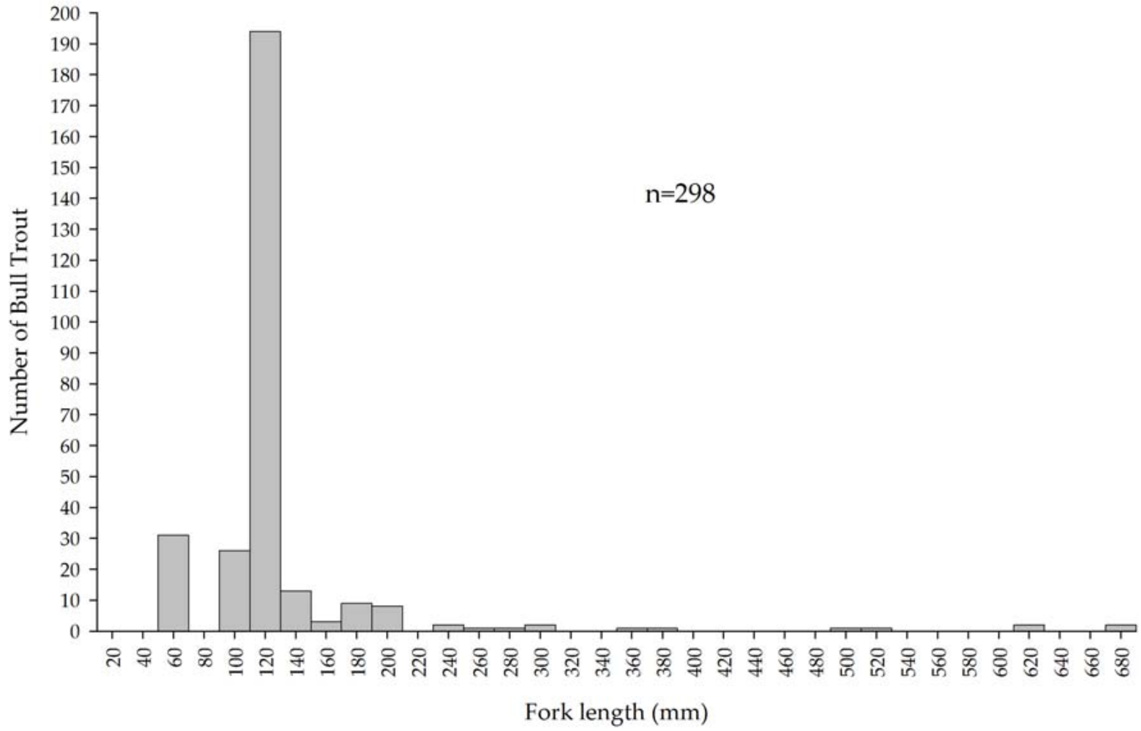

Figure 6. Length-frequency distribution of Bull Trout captured while electrofishing, Fall Creek, 2008.

4.4 Microsatellite DNA analysis

Only our tissue collections from Fall Creek and the lower Ram River produced sample sizes sufficient (n>30) for population-level analysis of genetic diversity and divergence. In these two populations, the average number of alleles per locus were between 7 and 9 and heterozygosity was approximately 0.62 (Table 4) which is typical of Bull Trout assayed at the same loci in other geographic areas. Samples from the lower Ram River and Fall Creek were significantly different from one another genetically (Θ=0.038, $P<0.001$) indicating to a large extent that these are demographically independent populations. Of these populations, only one fish could be excluded from the Fall Creek population. This fish was inferred to be an immigrant from the lower Ram River population indicating a high level of spawning site fidelity. Genetic characterization of the other rivers was limited by low sample sizes.

Table 4. Results of microsatellite DNA analysis of Bull Trout tissue samples. N_A = average number of alleles across loci, H_E = average expected heterozygosity, N_{EX1}/N_{EX2} = number of fish excluded as being from the same genetic population as the sample locality (0.001/0.1 confidence level respectively), and the probable origin of these fish (0.1 confidence level). Table adapted from Taylor (2010).

Sample Area	n	N_A	H_E	N_{EX1}	N_{EX2}	Probable origin[a]
Bighorn River	8	—	—	3	3	NSR, FC, CR
Fall Creek	50	9.67	0.649	1	1	LRR,
North Saskatchewan River	6	—	—	2	3	LRR, CR
Lower Ram River	41	7.33	0.619	0	0	—
Upper Ram River	2	—	—	2	2	LRR, NSR

[a]NSR = North Saskatchewan River, FC = Fall Creek, CR = Clearwater River (Rodtka unpublished data), LRR = Lower Ram River

5.0 DISCUSSION

Our study clearly indicates that Fall Creek is a key spawning and rearing stream for Bull Trout in the North Saskatchewan and Ram River drainages. Over the course of our study we observed industrial and recreational activities which have the potential to negatively impact the Fall Creek Bull Trout spawning population. Road building, watercourse crossing and land clearing activities associated with the forestry and petroleum sectors can all lead to increased stream sedimentation which in turn can reduce survival of incubating Bull Trout eggs (ASRD and ACA 2009). Cattle grazing, which may also lead to degradation of riparian areas and increased sedimentation (Belsky et al. 1999), occurs in the watershed as well. Industrial development has increased access to this area which is popular with recreationalists, particularly OHV users. The Fall Creek Trail follows the stream valley for much of its length, crossing or travelling along the streambed repeatedly, including eight crossings in the area most frequented by spawning Bull Trout. During fieldwork, evidence of OHV use upstream was observed in the form of visible silt plumes. As well, we found evidence of OHV's being driven over redds.

Adult fish also appeared vulnerable. Spawning often occurred at or near trail crossings and these large fish were conspicuous in the relatively shallow waters where they congregated. Although our study was not designed to rigorously determine the start of Bull Trout migration into Fall Creek, it appears that at least some migratory adults spend a relatively long time in the stream. Alberta Bull Trout populations typically begin migrating between late May and August (ASRD and ACA 2009) but we relocated a migrant in Fall Creek in April. We also suspect a portion of the population spawns in consecutive years as we observed two implanted fish spawning in the stream during the 2009 redd survey. Given the lack of historical information on Bull Trout abundance in this area we are unable to assess what impact industrial and recreational activities have had on the Fall Creek spawning population however, what is clear is that the opportunity for future negative impacts is considerable.

Although the limitations of redd surveys for the monitoring of Bull Trout stocks have been well documented (Maxell 1999; Dunham et al. 2001; Al-Chokhachy et al. 2005) this technique may be worth considering for Fall Creek. Water conditions typical of Fall Creek in the autumn, i.e. low, clear water, make observation of Bull Trout redds and adults straightforward. Both the location and timing of Bull Trout spawning activity in the stream is relatively discrete, and the Fall Creek spawning stock appears to be genetically distinct from other stocks in the area. The entire reach accessible to Bull Trout can be surveyed by a two-person crew in two days and the upper reach, where the vast majority of spawning was concentrated, can be surveyed in a single day.

Validation of the Bull Trout per redd ratio we report is recommended if future extrapolation of redd numbers to adult abundance is being considered. The Bull Trout per redd ratio of 1.4:1 we observed is relatively low. In a survey of five similar studies in the Columbia River drainage Al-Chokhachy et al. (2005) found a mean ratio of 2.7 fish per redd (range 1.2-4.3). We suspect our estimates of the abundance of spawning fish in Fall Creek in 2007 and 2009 based on extrapolation of the ratio we observed in 2008 are conservative. We observed 32 Bull Trout during the September 18 to 19 redd survey in 2007 and are reasonably confident in our identification of individual fish. It seems unlikely that we detected over three-quarters of the population during a single, shore-based survey. Based on our limited sampling we cannot unequivocally state that spawning of resident fish, removal of the fish fence and trap before all migratory fish had left the stream and/or the counting of "test" redds (Gallagher et al. 2007) did not bias our results. However, evaluation of these potential biases is possible and, along with an estimate of inter-observer variability in redd identification, would provide the basis for a cost-effective, longer-term monitoring program. Even in the absence of these data we see value in a continuation of redd survey work for a broad assessment of adult abundance given the importance and vulnerability of the spawning population of Fall Creek.

Our identification of another spawning population of Bull Trout in the Ram River drainage through microsatellite DNA analysis highlights the value of this method for studies such as ours, particularly when paired with more traditional approaches such as migration trapping and/or telemetry. The spawning location(s) of this population is currently a matter of speculation. Many areas of groundwater discharge to the Ram River were observed within the study area, particularly upstream of the mouth of Fall Creek, and we suspect at least some spawning occurs in the river. Other tributaries to the Ram River lacked suitable flow conditions for passage of larger fish and we observed a pair of Bull Trout digging a redd in the Ram River at the mouth of Fall Creek in 2008, although this could have been an artifact of trap avoidance behavior. Identification of all the Bull Trout spawning locations in the Ram River drainage would be valuable as this drainage is an important source of Bull Trout migrants for the Middle North Saskatchewan core area.

Drawing largely from anecdotal evidence and angler reports we assumed that the North Saskatchewan, Bighorn and Ram rivers all supported, at least seasonally, appreciable numbers of adult Bull Trout. Despite considerable targeted sampling effort in the North Saskatchewan and Bighorn rivers we failed to capture more than a handful of larger Bull Trout. Based on the results of our tissue sampling efforts in these rivers, it appears that only the Ram River contains more than a remnant population. We suspect many recent angler reports of Bull Trout capture immediately below the Bighorn Dam are actually misidentified Lake Trout which have flourished in the reservoir since its creation in the 1970s (ASRD fisheries files, Rocky Mountain House) and were readily caught below the dam during our study. Based on our observations we believe that Bull Trout may be less abundant and more restricted in distribution within the Middle

North Saskatchewan River core area than is commonly assumed, although a more comprehensive evaluation is necessary to confirm this.

Although we failed to find evidence for a strong migratory Bull Trout spawning population in the Bighorn River we did observe a small number of large Bull Trout, presumed migrants, including a pair on a redd, during one of our autumn tissue collection efforts. We believe further investigation of this river is warranted. In general, overwintering habitat in the North Saskatchewan River between the Bighorn Dam and the mouth of the Ram River appears very limited. Apart from the occasional deep pool, particularly in the Brazeau Gap area, this reach consists primarily of shallow run and riffle habitat. We also observed extensive formations of anchor ice in the reach during winter telemetry flights. Overwintering habitat, mostly in the form of deeper runs, increased downstream of the mouth of the Ram River

The Middle North Saskatchewan River core area is a microcosm of the factors implicated in the decline of Bull Trout across the eastern slopes of Alberta. Migratory barriers, notably the Bighorn Dam but also the relatively high number of cutlines, roads and pipeline right-of-ways in the subsubwatershed (North Saskatchewan Watershed Alliance 2005) have degraded and fragmented stream habitats, while competitive non-native Brown Trout and Brook Trout are naturalized throughout much of the area. Straddling Highway 11, a major travel corridor to the Rocky Mountains, the area is also popular with recreational users. Nearly one million person-night stays in camps or trailer parks were recorded in the area in 2008 (Government of Alberta 2010) and the ES 2 Fisheries Management Zone, within which the core area is contained, received an estimated 8% (approximately 213,000 days fished) of the total provincial sportfishing effort in 2005 (Park 2007). Given these pressures, life history strategy, population abundance, and habitat-use information are essential for Bull Trout management in the area, providing the foundation upon which mitigation and conservation measures may be built. These measures will likely be necessary for maintenance and recovery of the Middle North Saskatchewan River core area's Bull Trout population.

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7.0 APPENDICES

Appendix 1. Geographic coordinates (UTM NAD 83, Zone 11) of the Bull Trout spawning stock assessment study area boundaries, Alberta, 2007 to 2009.

Barriers or limits of study area	UTM Easting	UTM Northing
Bighorn Dam, North Saskatchewan River	546140	5795502
Bighorn River falls	544553	5804230
Fall Creek falls	597942	5786975
Lower limit of North Saskatchewan River	630229	5838112
Ram River falls	595369	5789443
Upper limit of Clearwater River	628417	5764652
Upper limit of Prairie Creek	627814	5791693

Appendix 2. Summary of electrofishing sites on Fall Creek, Alberta, 2008. Geographic coordinates are UTM, NAD 83, Zone 11.

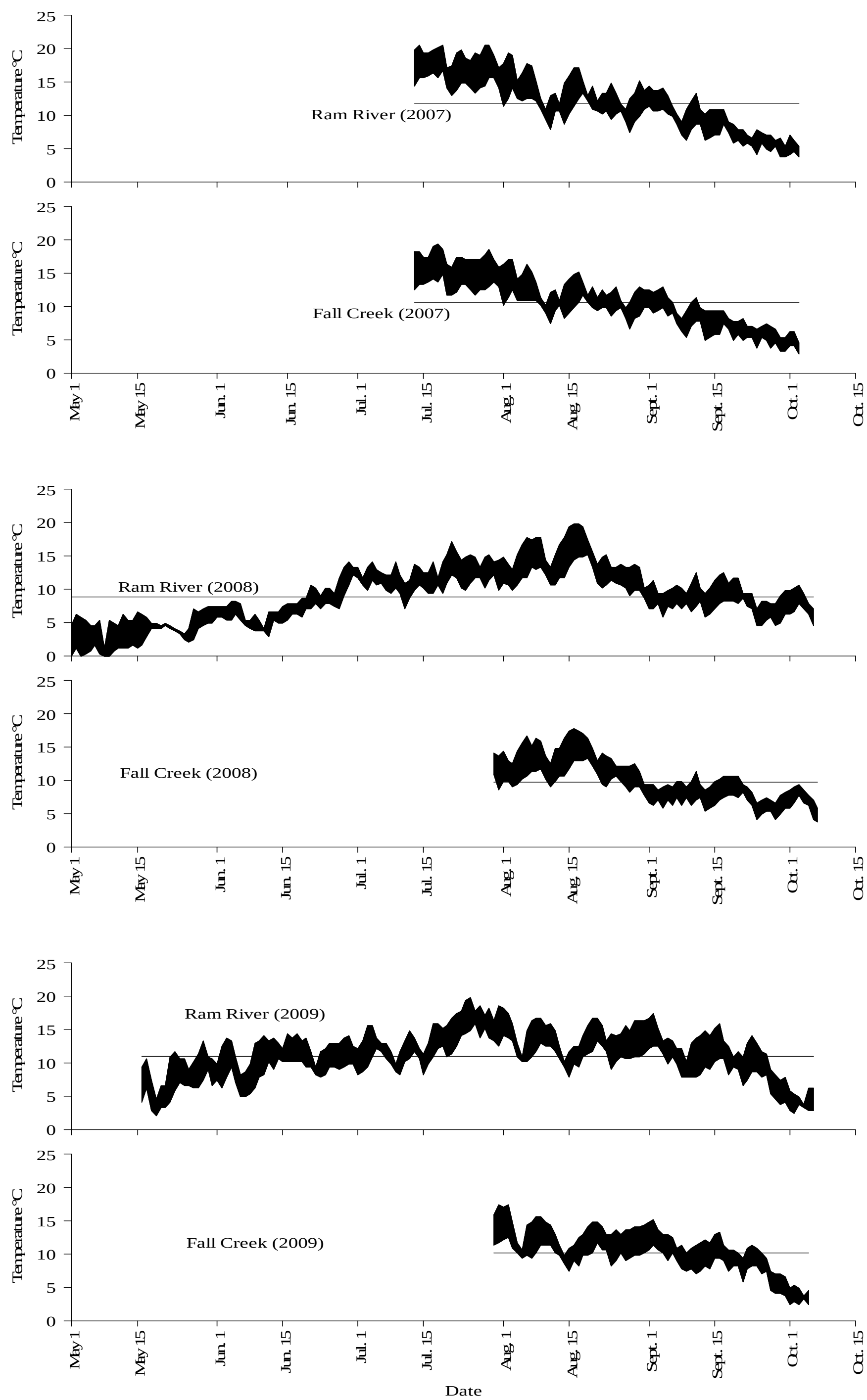
Location ID	Date	UTM Easting	UTM Northing	Water Temp. (°C)	Mean wetted width (m)	Mean rooted width (m)	Mean maximum depth (m)
F-3	30-July	598916	5791048	11	9.33 ± 2.92	37.35 ± 13.27	0.32 ± 0.08
F-6	30-July	599268	5790758	12	8.55 ± 2.45	19.80 ± 6.21	0.49 ± 0.32
F-9	30-July	599260	5790343	12	8.75 ± 2.45	18.67 ± 6.21	0.50 ± 0.24
F-12	29-July	599083	5789857	10	9.03 ± 1.59	20.17 ± 9.31	0.40 ± 0.14
F-15	29-July	599060	5789528	12	10.35 ± 2.81	38.23 ± 16.95	0.38 ± 0.14
F-18	29-July	598831	5789117	14	9.03 ± 2.63	26.48 ± 8.83	0.35 ± 0.10
F-21	31-July	598620	5788497	9	9.47 ± 2.33	24.15 ± 5.93	0.49 ± 0.40
F-24	31-July	598406	5788123	11	10.80 ± 7.13	18.85 ± 6.38	0.41 ± 0.14
F-27	31-July	598372	5787476	13	8.97 ± 2.40	15.98 ± 2.32	0.50 ± 0.16

Appendix 3. Bull Trout backpack electrofishing capture efficiencies used to calculate abundance of juvenile Bull Trout in Fall Creek, Alberta, 2008. All population estimates were conducted using capture-mark-recapture.

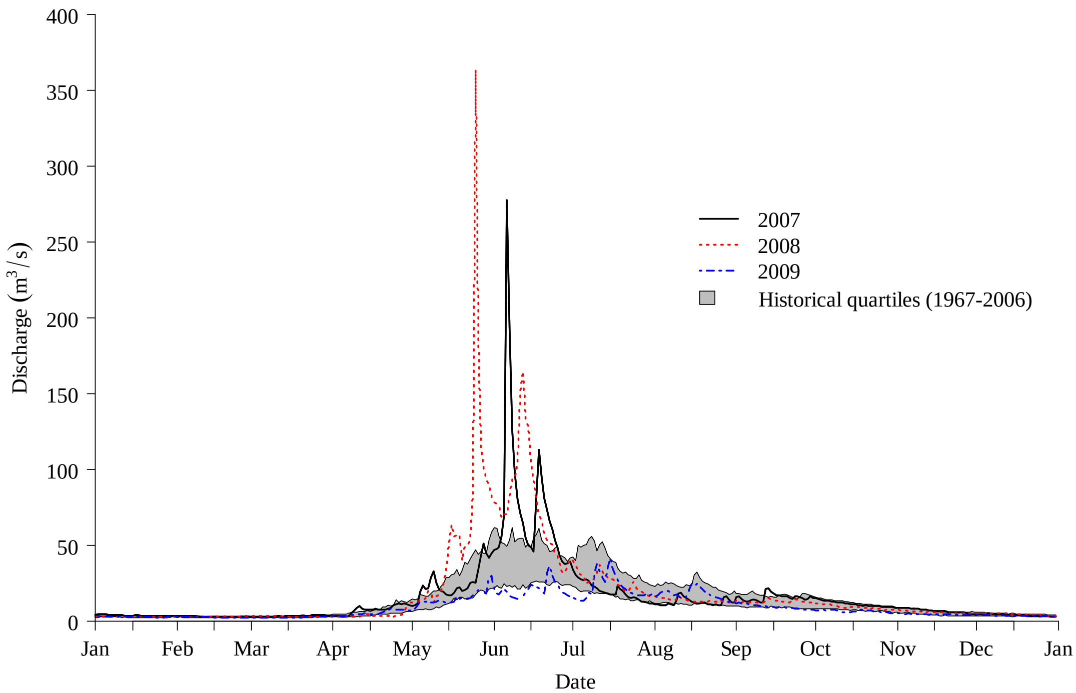
Population estimate site	Bull Trout capture efficiency
Canyon Creek[a]	0.5366
Unnamed Creek (Canyon Creek)[a]	0.3244
Unnamed Creek (Waiparous Creek)[b]	0.2016
Mean q	0.3542
Beta distribution 95% CI	0.075 – 0.711

[a] Summarized in Monitoring bull trout and cutthroat trout populations in Canyon and Prairie creek drainages, Elbow River, Alberta, 2005 (Fitzsimmons 2008b).
[b] Summarized in Assessment of trout abundance and distribution in the Waiparous Creek drainage, Alberta, 2006 (Fitzsimmons 2008a).

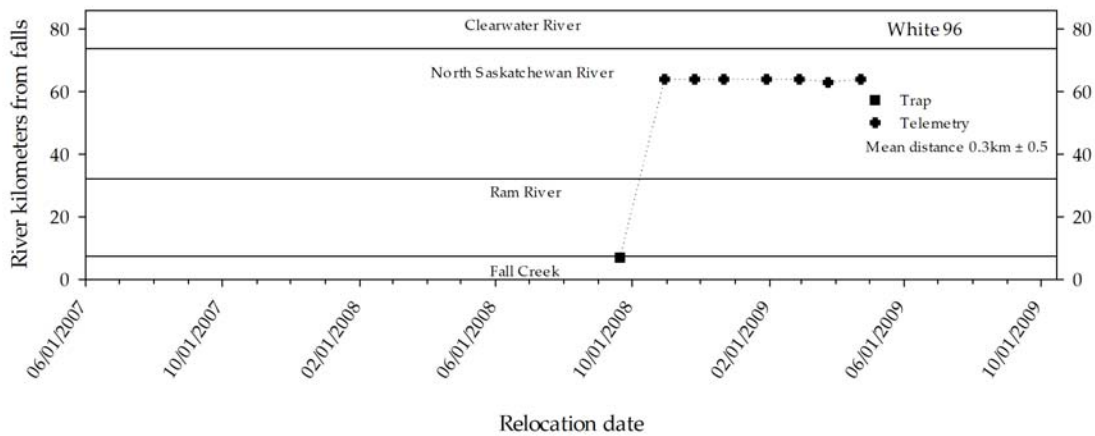
Appendix 4. Maximum, minimum and seasonal mean (horizontal line) water temperature during the open water season of Ram River and Fall Creek, Alberta, 2007 to 2009.

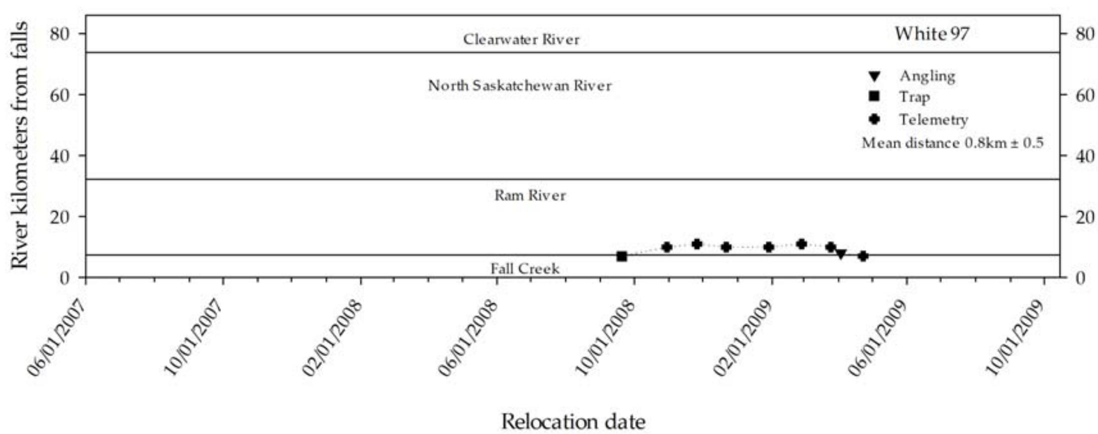


Appendix 5. Water discharge measured at Water Survey Canada hydrometric station No. 05DC006 near the mouth of the Ram River, Alberta.



Appendix 6. Summary of relocations by method for Bull Trout located or captured three or more times during the North Saskatchewan and Ram rivers Bull Trout spawning stock assessment, 2007 to 2009. Kilometre 0 on the y-axis is located at the waterfall barrier on Fall Creek. The mouth of Fall Creek is located at kilometre 7.5, the mouths of the Ram and Clearwater rivers are located at kilometres 32 and 74 respectively. Mean distance (±SD) moved between telemetry relocations during the winter months (November-March) is reported for implanted fish only.





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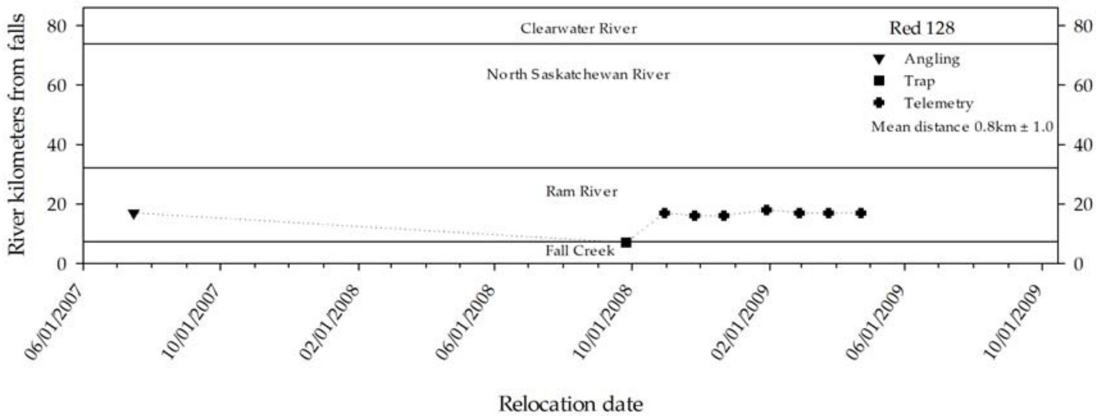

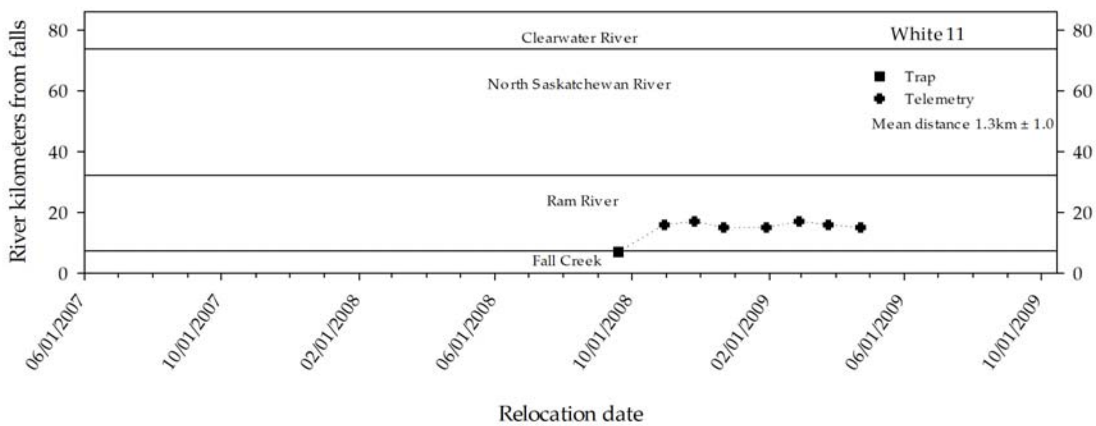

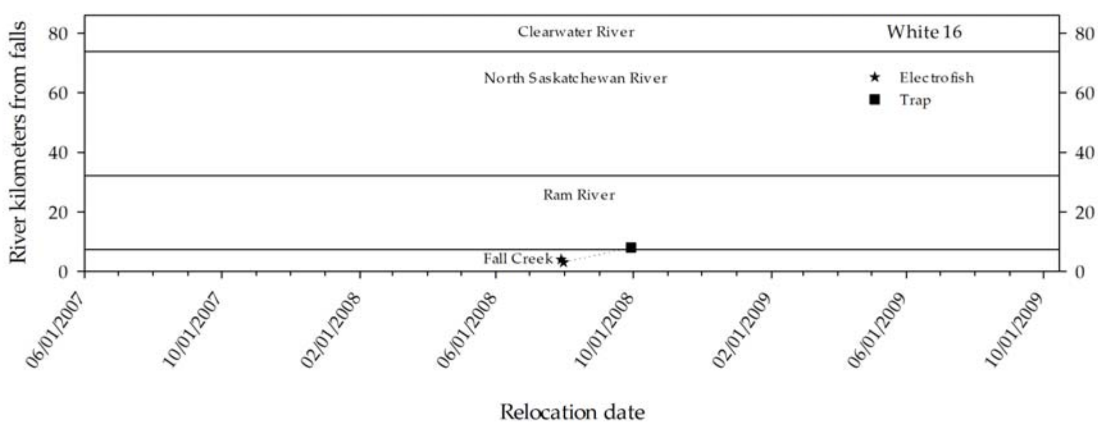

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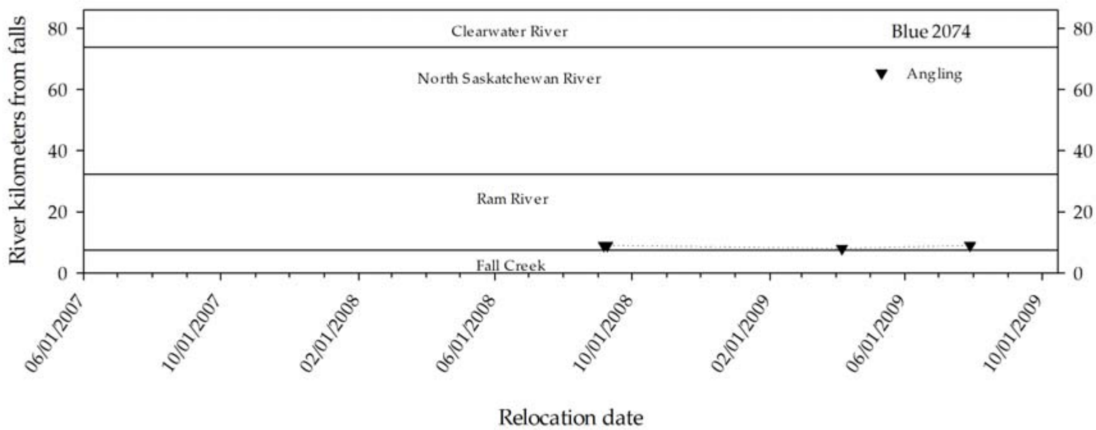

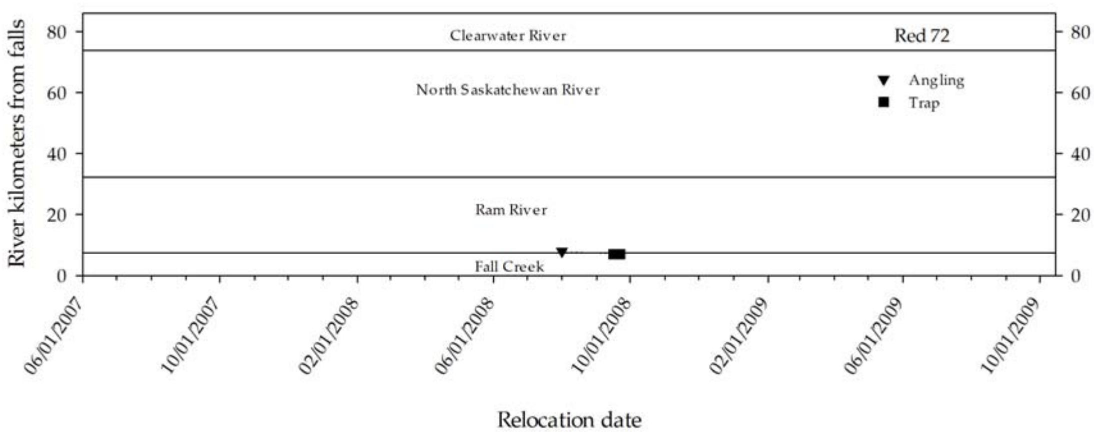

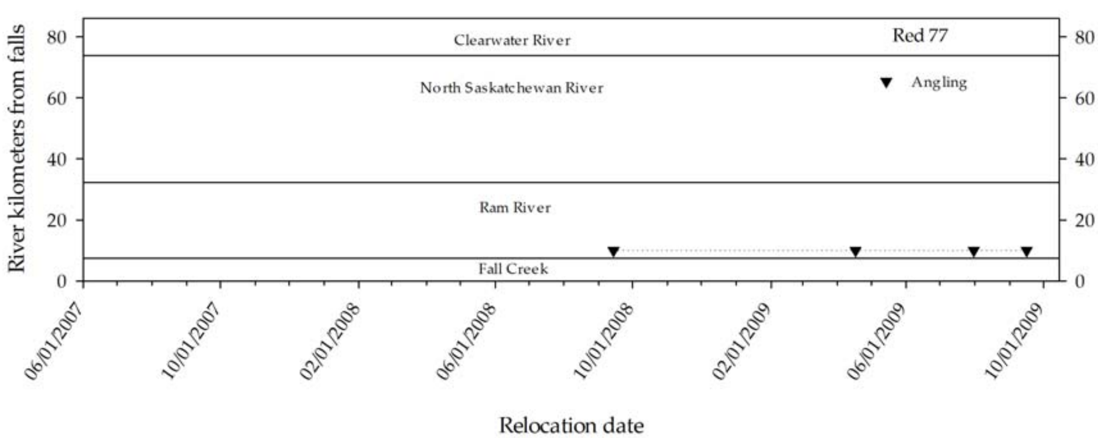

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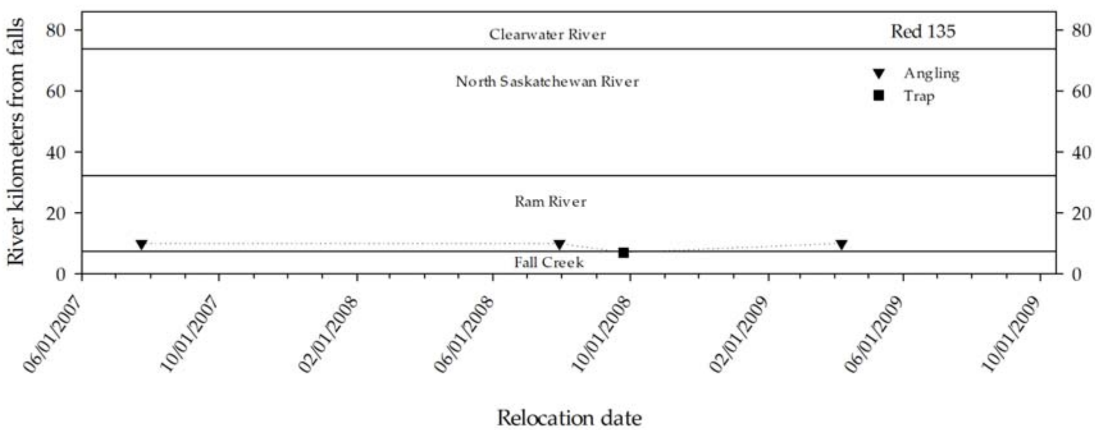

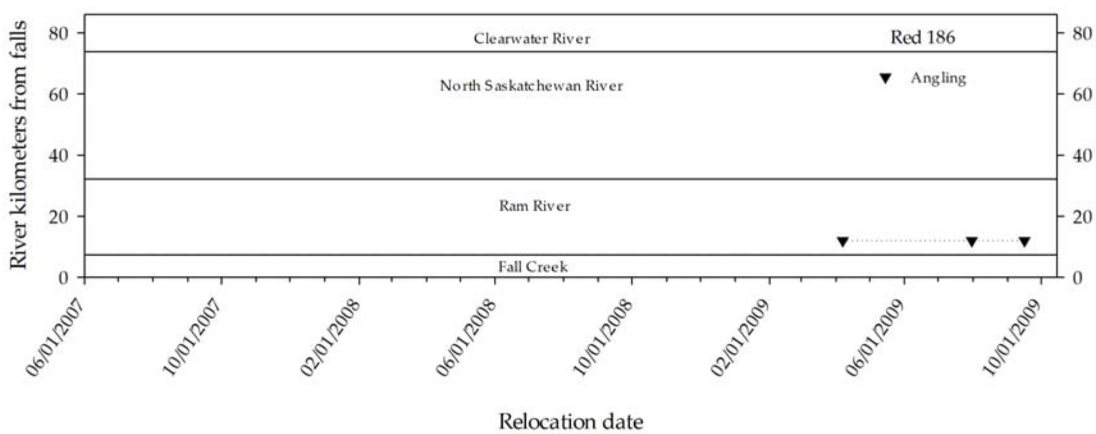

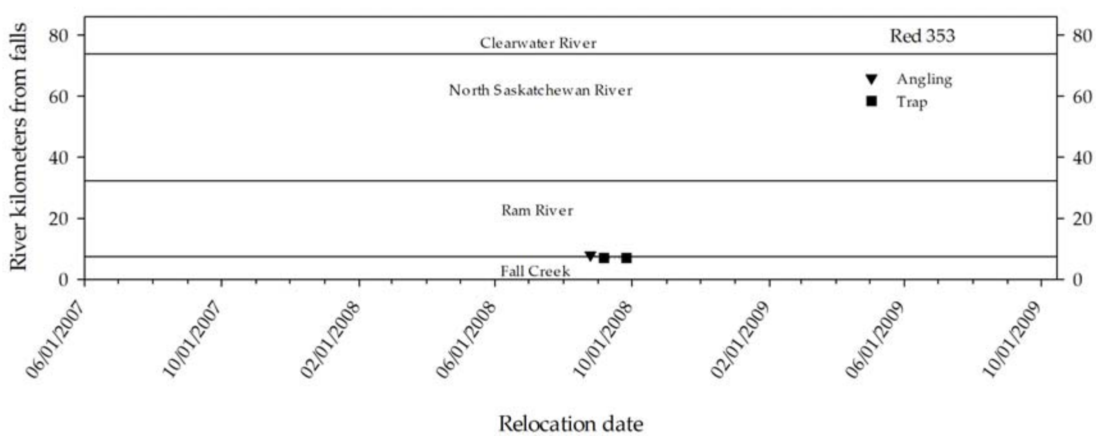

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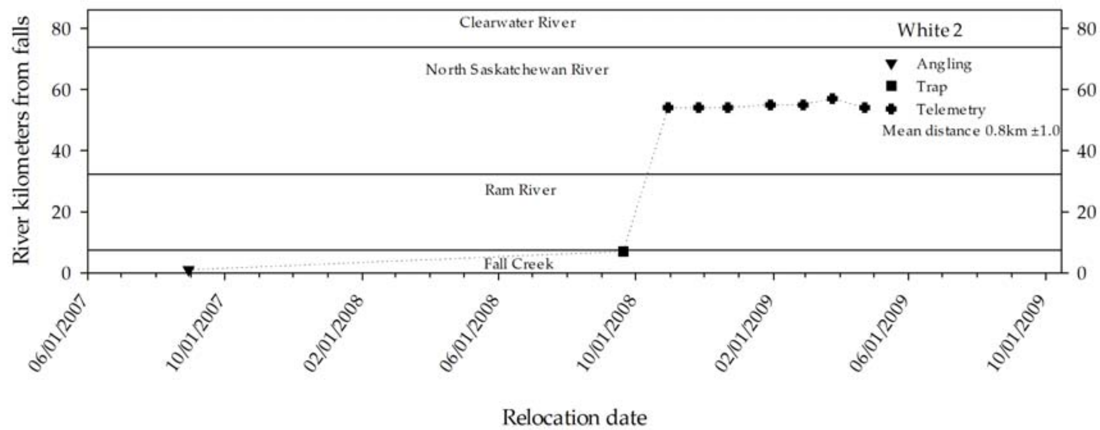

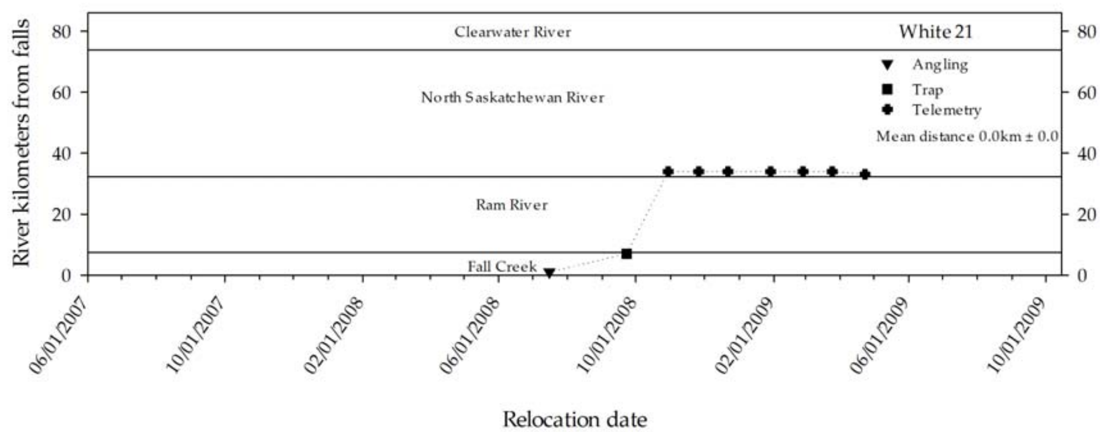

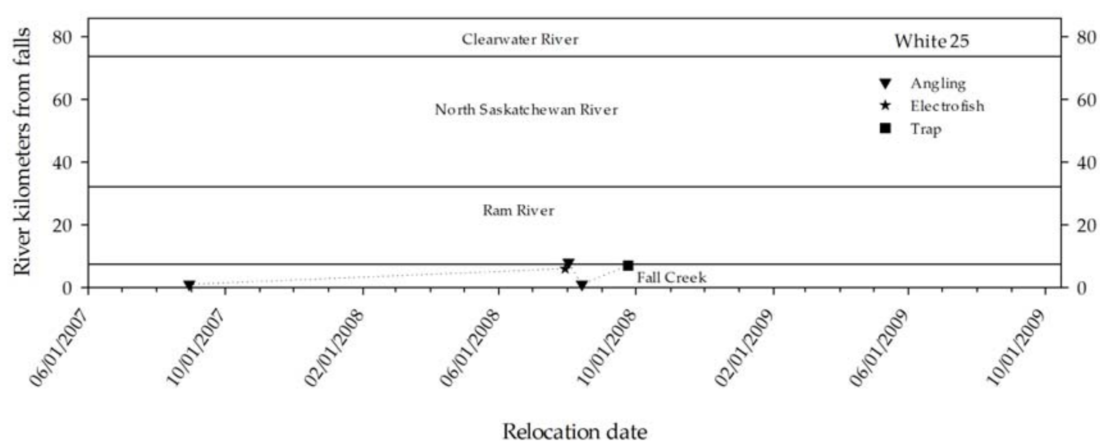

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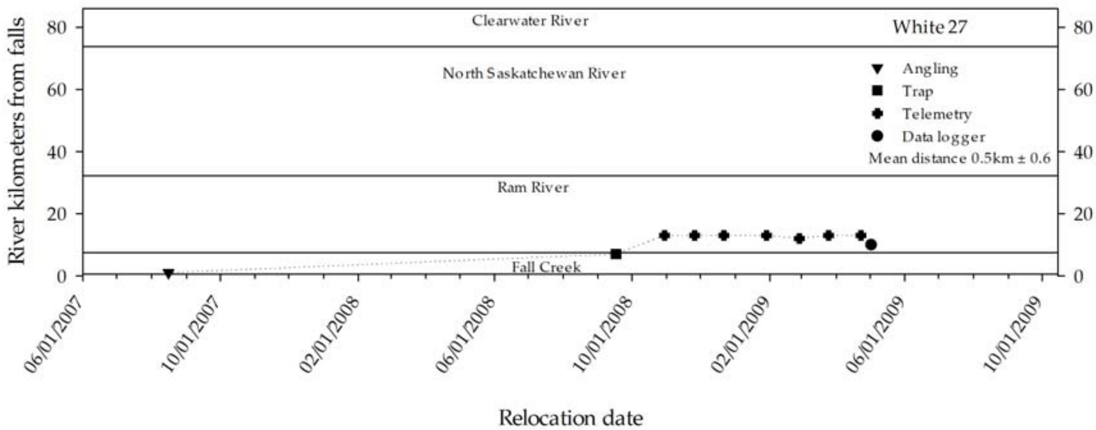

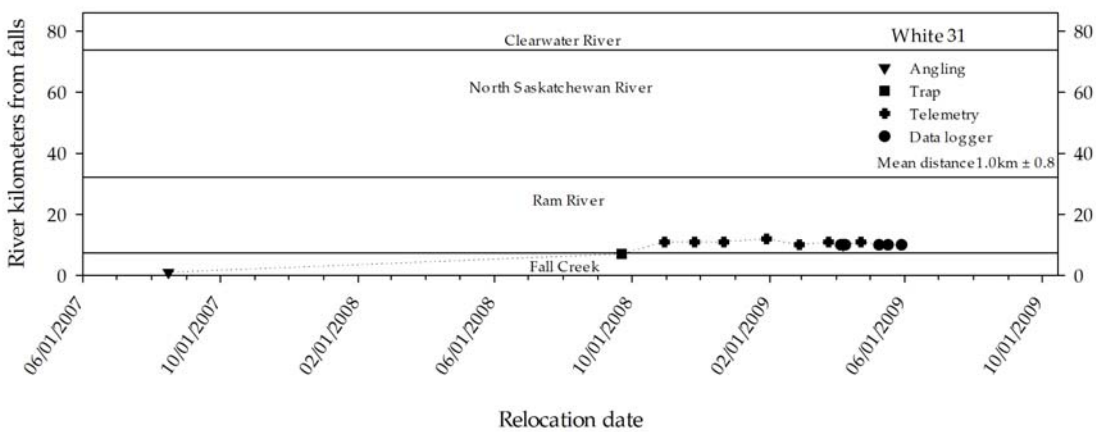

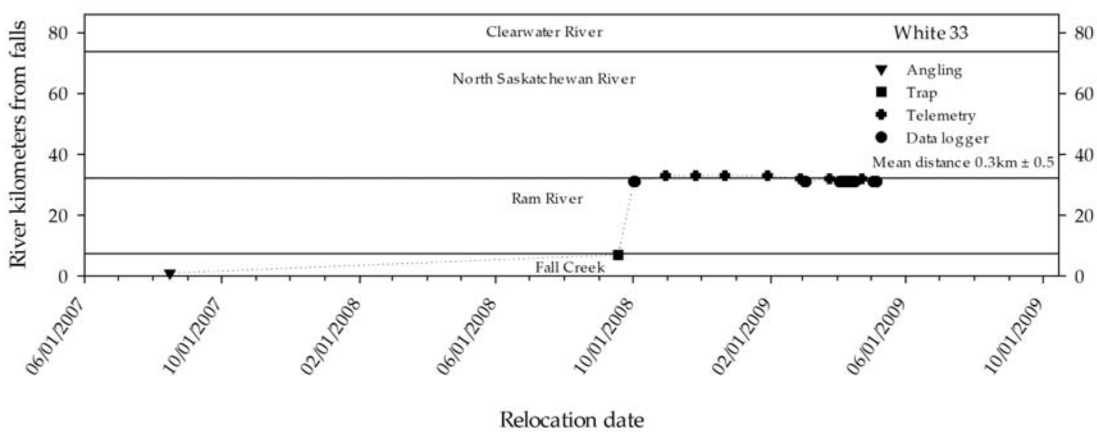

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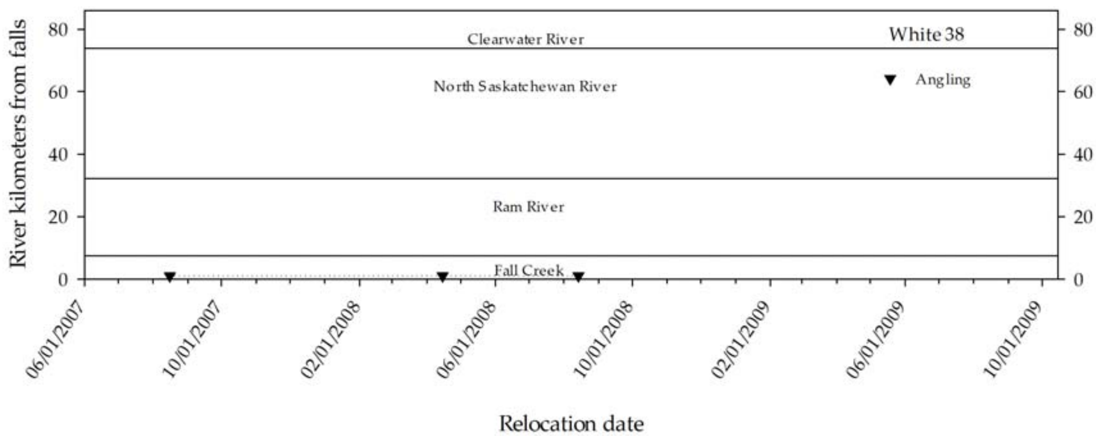

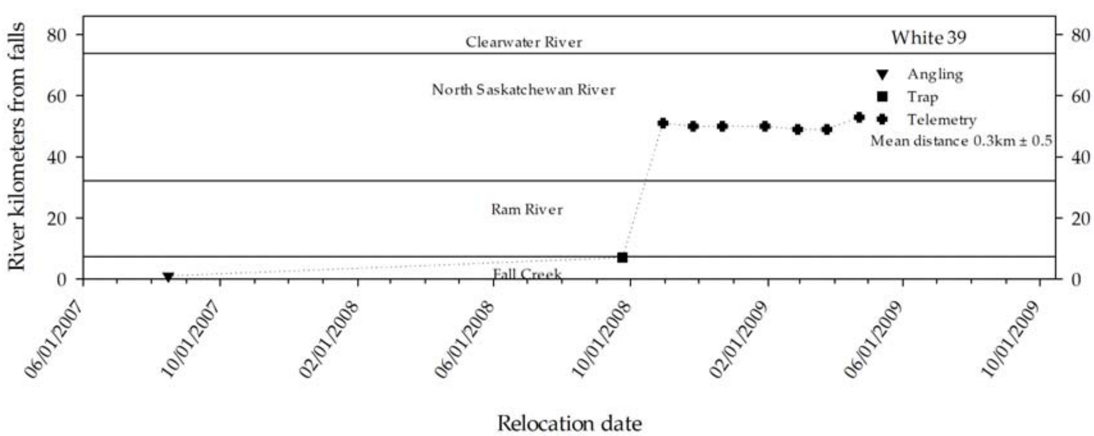

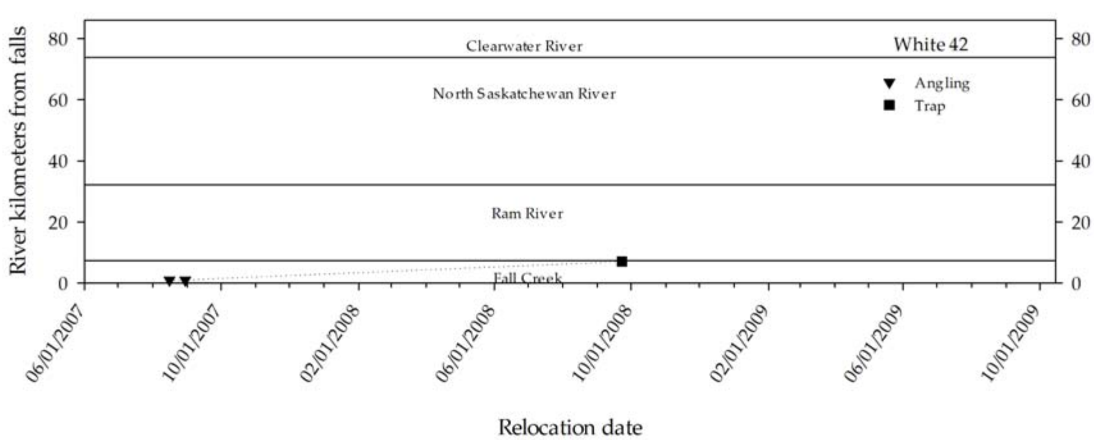

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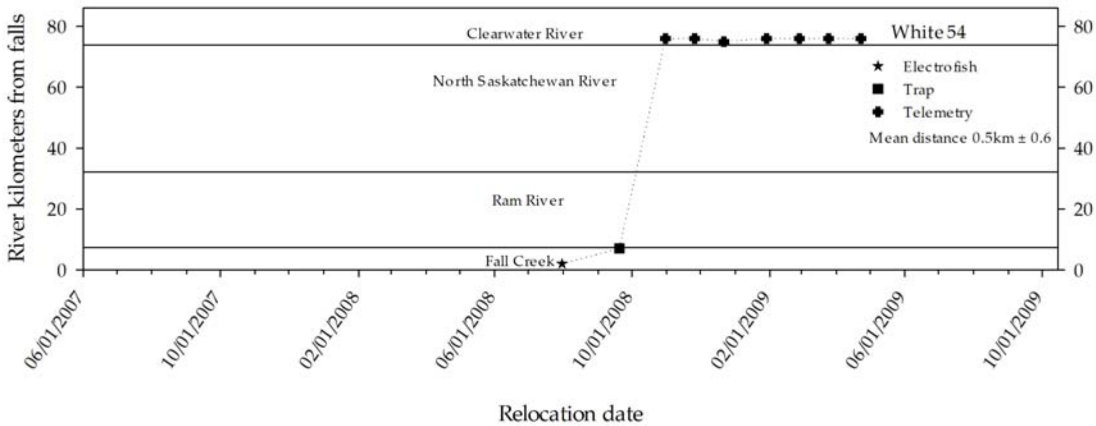

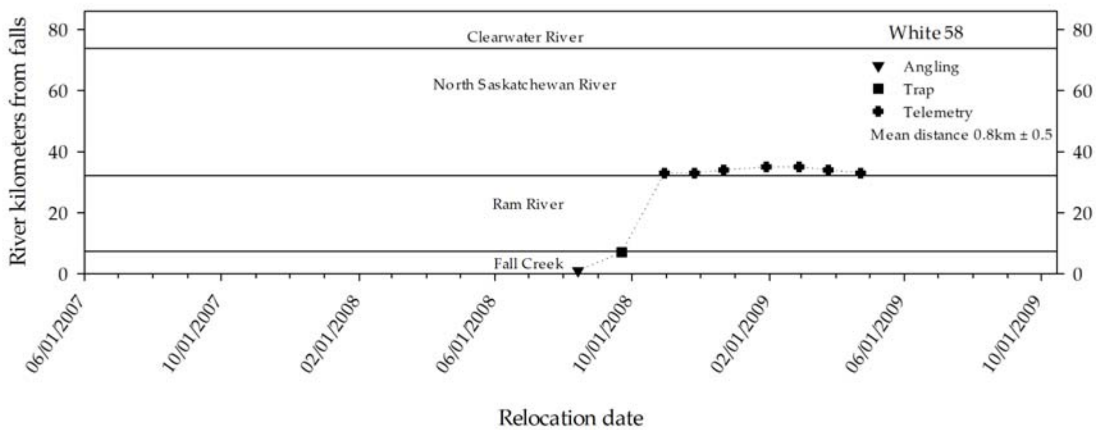

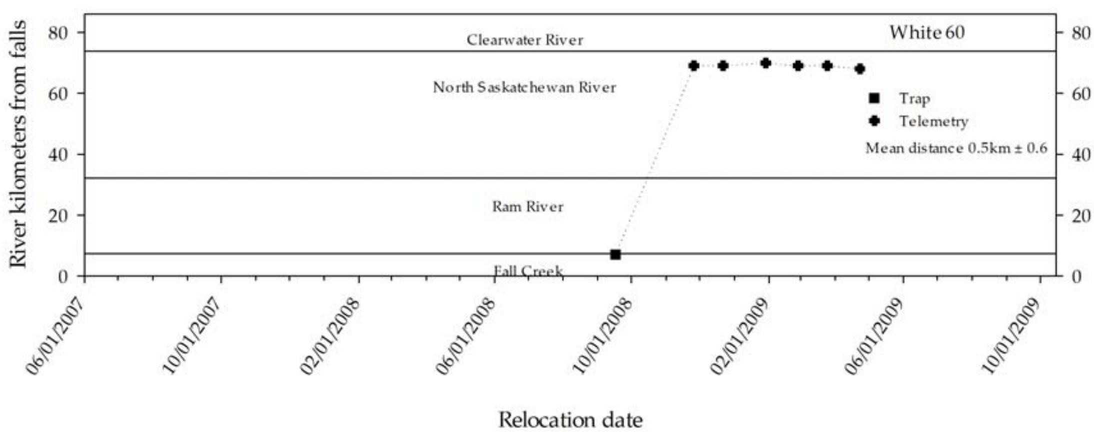

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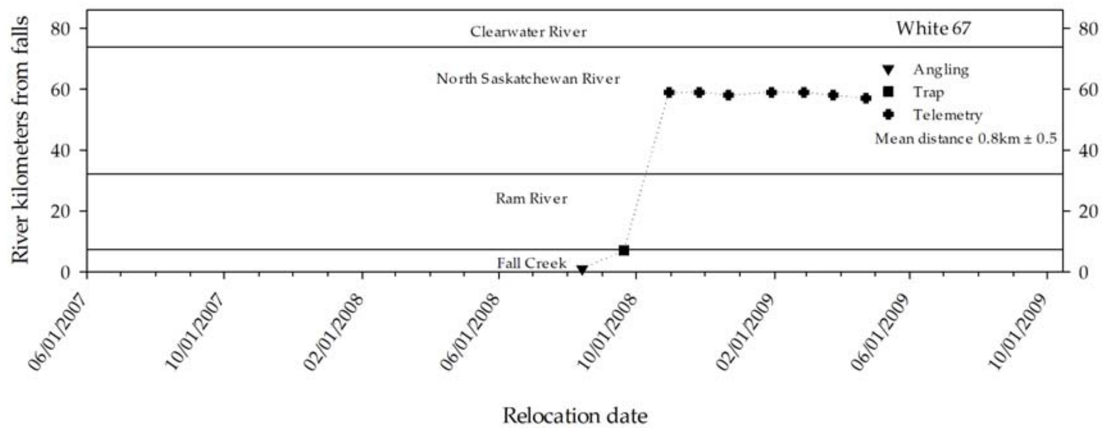

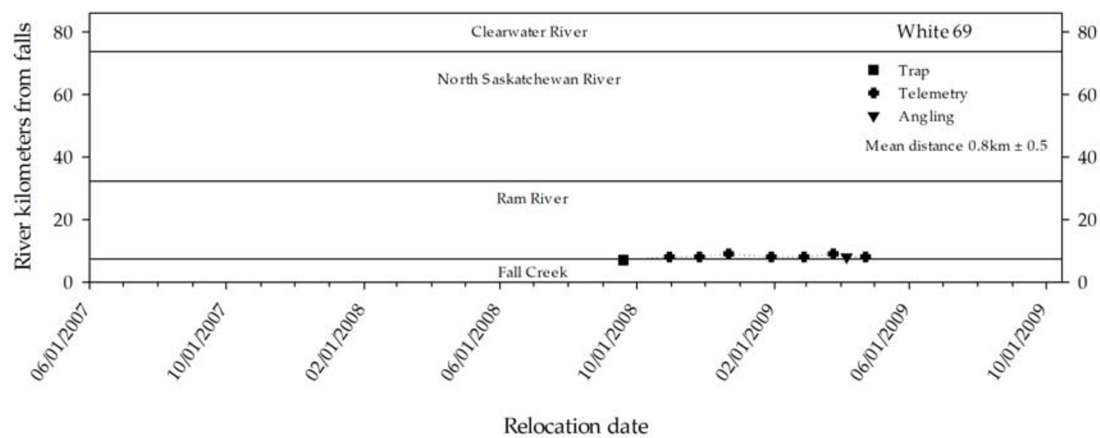

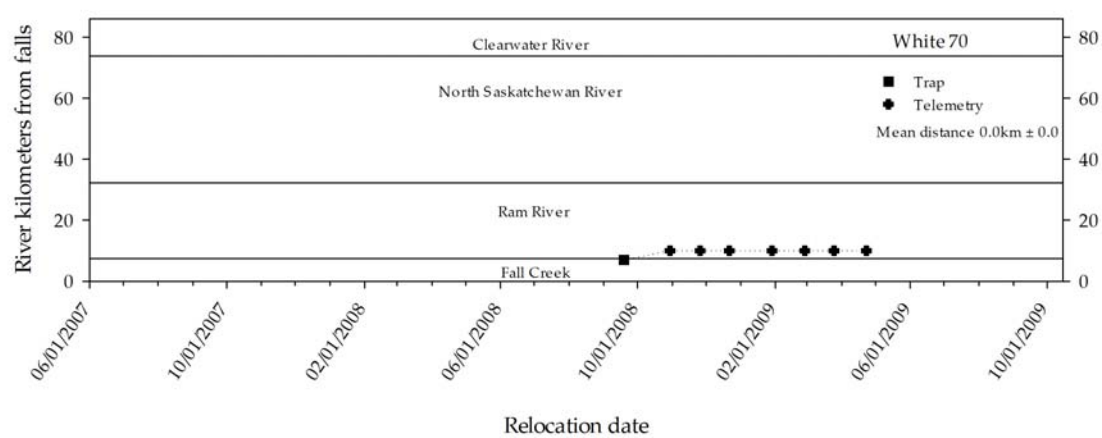

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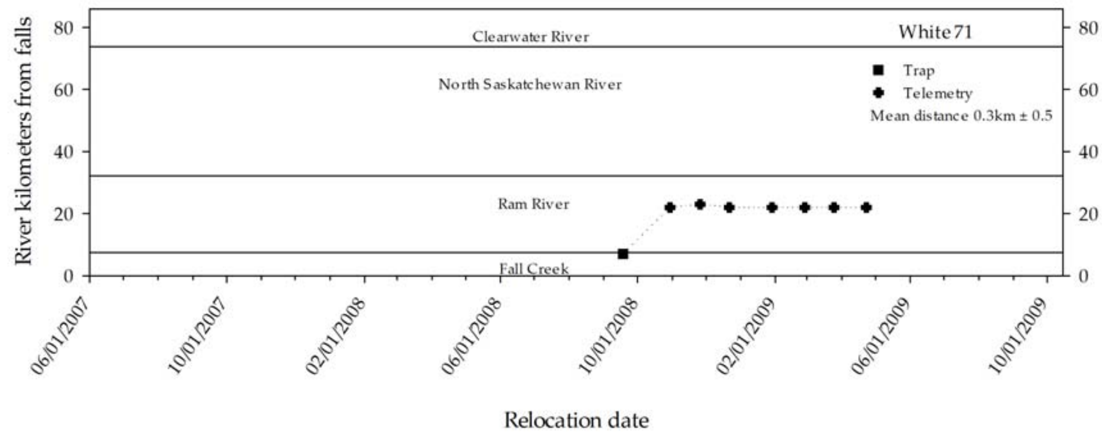

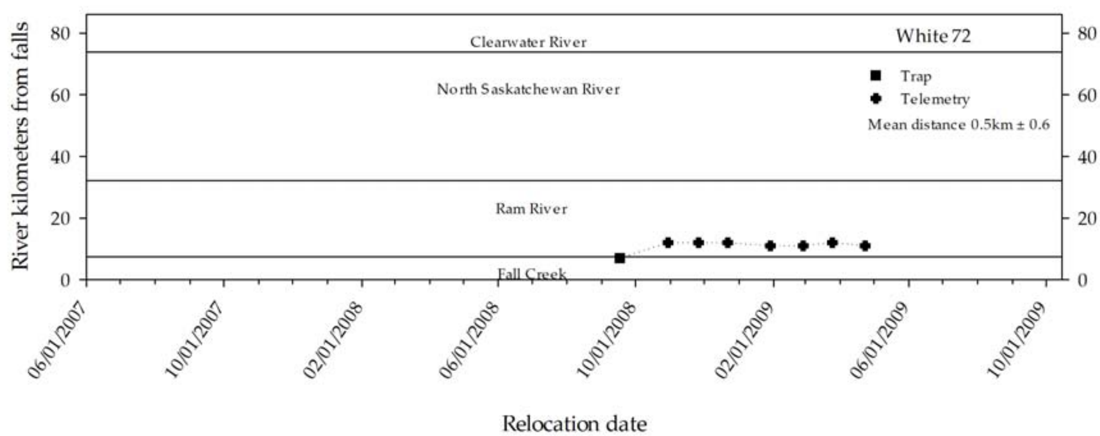

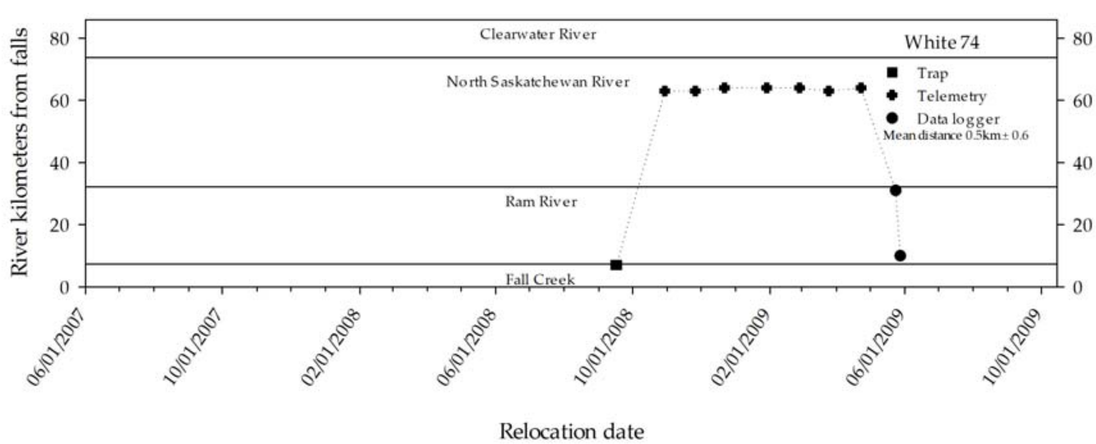

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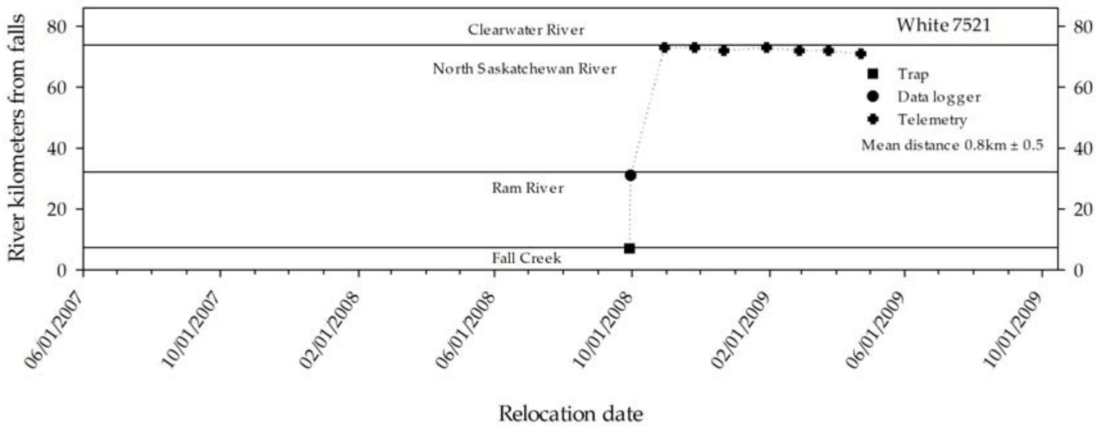

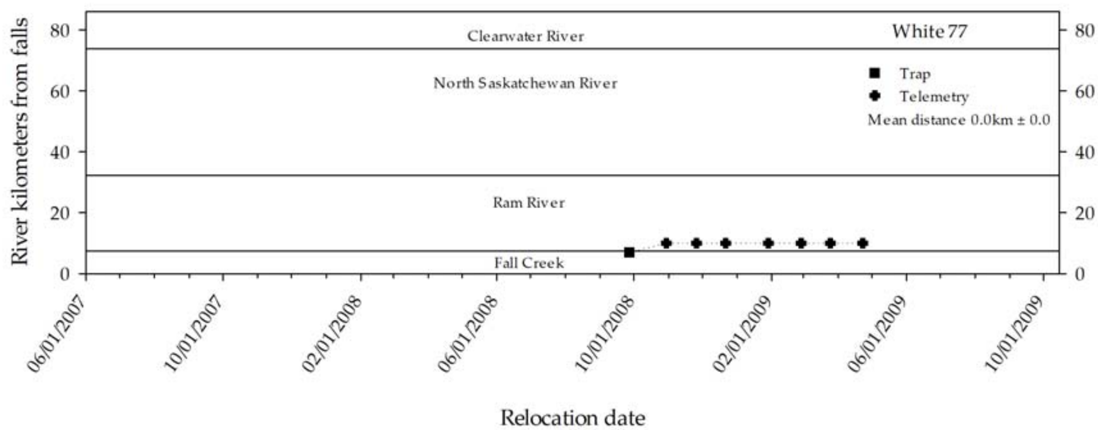

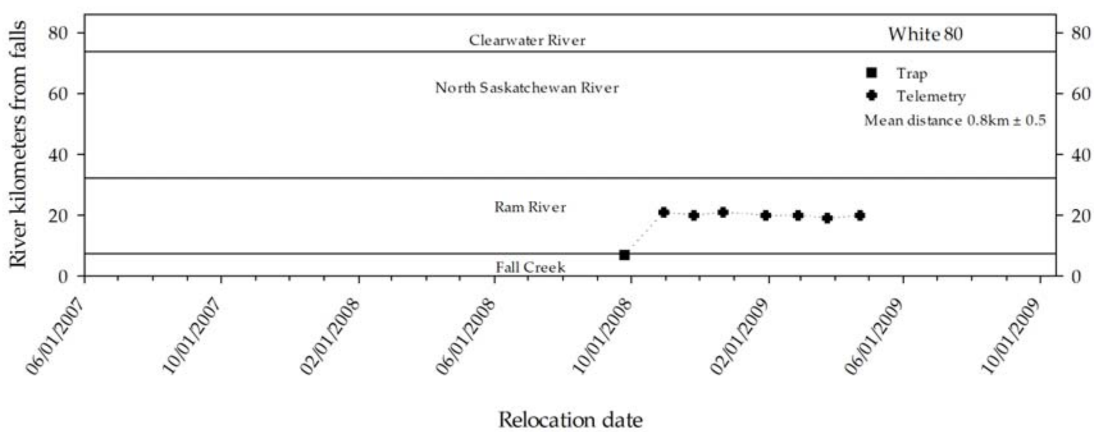

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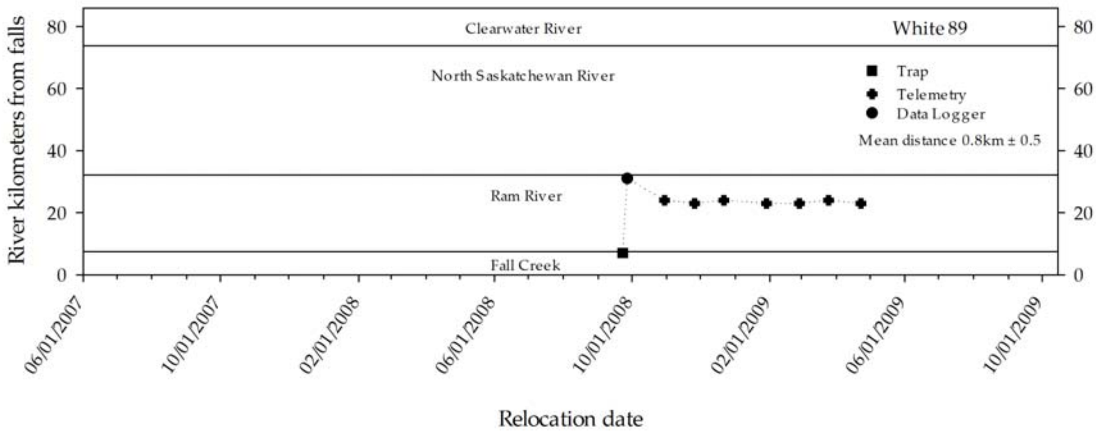

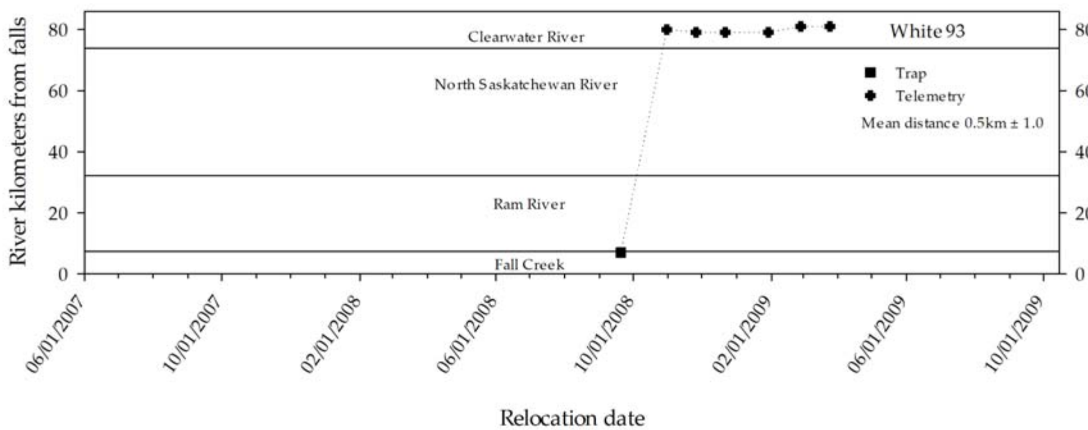

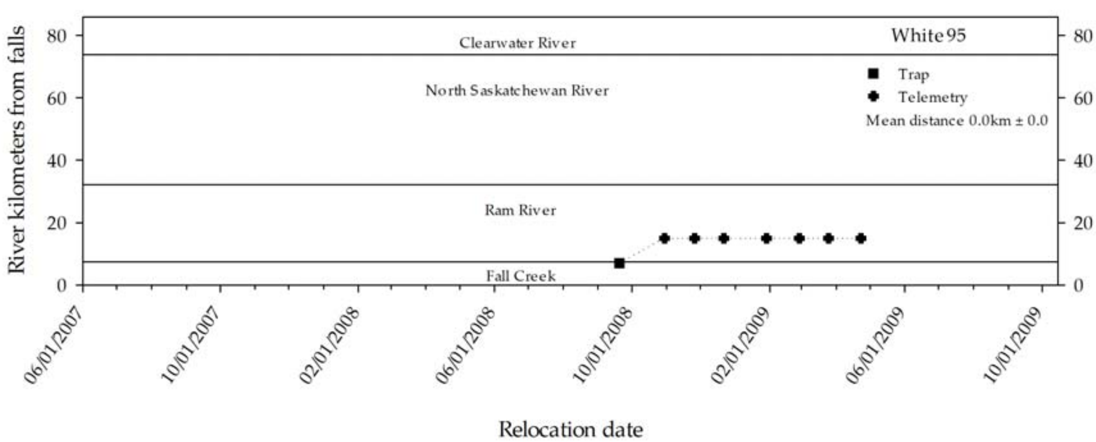

Appendix 7. Summary of backpack electrofishing information for the Bull Trout catch, Fall Creek, Alberta, 2008. Length-weight relationship of the combined Bull Trout catch is Log_{10} Wt = -4.773179 + 2.90023 Log_{10} FL (n=258, r^2=0.97).

Location ID	Effort (s)	Mean fork length (mm) ± SD (n)	Fork length range	Mean weight (g) ± SD (n)	Weight range	Catch/ 100 s
F-3	1206	101 ± 15 (17)	491–19	12.4 ± 2.0 (16)	9.4 – 16.5	1.4
F-6	990	118 ± 34 (15)	95 – 225	21.0 ± 25.7 (15)	10.2 – 110.1	1.5
F-9	856	131 ± 126 (17)	45 – 606	14.1 ± 11.2 (14)	7.8 – 52.3	2.0
F-12	1121	139 ± 97 (8)	100 – 378	12.0 ± 1.0 (7)	10.5 – 13.1	0.7
F-15	1464	135 ± 94 (41)	52 – 680	25.1 ± 29.8 (38)	7.7 – 151.7	2.8
F-18	966	132 ± 109 (33)	47 – 680	29.4 ± 75.6 (30)	9.8 – 424.0	3.4
F-21	1011	121 ± 90 (35)	45 – 615	16.7 ± 12.2 (30)	9.8 – 64.9	3.6
F-24	1189	117 ± 61 (65)	47 – 510	22.3 ± 32.5 (56)	10.5 – 248.1	5.5
F-27	1279	117 ± 65 (67)	41 – 488	28.7 ± 40.7 (52)	9.3 – 249.0	5.2

The Alberta Conservation Association acknowledges the following partner for their generous support of this project

Government of Alberta
Sustainable Resource Development

Forest Resource Improvement Association of Alberta (FRIAA)

Alberta stream watch

Alberta Conservation Association