Distribution and Abundance of the Migratory Bull Trout Population in the Castle River Drainage, 2011 – 2014

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EXECUTIVE SUMMARY

The Castle River bull trout population is one of 38 populations in Alberta identified as at *High Risk* as a result of the effects from anthropogenic activities in the drainage. Factors affecting the Castle bull trout population include habitat degradation, fragmentation, migration barriers, illegal harvest, and the introduction of non-native fish species. The increase in industrial, recreational and agricultural activities is posing great risk to fisheries in the Castle River drainage.

Few studies have been completed on the Castle River drainage bull trout population, and managers are challenged with making decisions using insufficient data. Alberta Conservation Association completed a four-year (2011 – 2014) migratory bull trout population and spawning assessment in the Castle River drainage to collect data to supplement existing data and help conserve the species. The objectives of the study were to determine the abundance of the migratory bull trout population in each major spawning stream and to document the distribution of bull trout spawning areas throughout the drainage.

Post-spawn bull trout were captured with fish traps installed in the fall season in four major spawning tributaries throughout the drainage: Mill Creek and South Castle, Carbondale and West Castle rivers. Adult bull trout (≥300 mm fork length) were individually marked using passive internal radio frequency transponder tags to identify recapture events. We supplemented the number of tagged fish by angling. Spawning surveys were conducted in all bull trout spawning streams throughout the drainage. We enumerated redds and assessed spawning habitat in all spawning areas.

Between 2011 and 2014, 459 bull trout were captured in the drainage, with fish catch being highest in Carbondale River (n = 185) followed by South Castle River (n = 149) and Mill Creek (n = 109); we experienced the lowest catch rates in the West Castle and Castle rivers.

Fish size and recapture data indicate that bull trout populations in the Carbondale and South Castle rivers and in Mill Creek are primarily migratory. These data also suggest that resident components are present in the South Castle River and Mill Creek populations. Our data suggest the West Castle bull trout population primarily consists of resident fish and may include a small component of migratory fish. Our recapture data highlight that migratory fish exhibit strong stream fidelity as most of the tagged fish were recaptured in the same stream as their initial capture. Recapture data also revealed migratory behaviours between different streams inside and even outside the Castle River drainage. Fish from Carbondale River were documented to have the most widespread migratory tendencies. We detected instances of trap avoidance behaviour and calculated the annual migratory bull trout population in the main spawning area in upper Mill Creek.

We documented 68 km of active bull trout spawning habitat throughout the drainage. South Castle River was found to be the most extensive spawning stream in the entire study area. We identified three primary spawning streams in the Carbondale River sub-drainage. All spawning areas were influenced by groundwater. Most of the major spawning areas were immediately downstream of seasonal subsurface stream flow breaks. The remaining subsidiary spawning areas were influenced by bank seeps and other types of stream upwellings.

Key words: angling, bull trout, Carbondale River, Castle River drainage, Mill Creek, South Castle River, West Castle River, passive internal radio frequency transponder tags, recapture, redd, spawning survey, trap.

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1.0 INTRODUCTION

Of the 50 bull trout (*Salvelinus confluentus*) populations in Alberta, 38 populations are classified as at *High Risk* of extirpation; at least three populations are extirpated (Alberta Sustainable Resource Development [ASRD] and Alberta Conservation Association [ACA] 2009). Factors affecting these populations include habitat degradation and fragmentation, introduction of non-native fish species, overharvest, and migration barriers (ASRD and ACA 2009; Alberta Environment and Sustainable Resource Development [ESRD] 2014a). In southwestern Alberta drainages, including the Castle River drainage, bull trout distribution has been reduced to approximately 31% of its historical range (Fitch 1997). Current populations, all of which are *At Risk* of extirpation, exist only in headwater stream systems.

Linear density is often used to assess the level of land-use disturbance in a watershed. Ripley et al. (2005) determined an increase in resource development (road density and percent forest harvest) in stream basins profoundly impacts bull trout populations and habitat; linear feature densities greater than 0.2 km/km^2 inversely affects bull trout populations. Currently, over 1,283 km of linear features exist in the Castle River Forest Land Use Zone (FLUZ), which equates to a *High Risk* linear disturbance density of 1.3 km/km^2 (Lee and Hanneman 2011). This level of watershed disturbance is negatively impacting Castle River bull trout habitat and their survival. Given the high level of development in the Castle River drainage (Lee and Hanneman 2011), an updated estimate of bull trout population density and structure would provide better guidance for managing this species.

Alberta bull trout exhibit three life history strategies: resident, fluvial and adfluvial (ASRD and ACA 2009). Fluvial and adfluvial are both migratory life history strategies in which adult fish migrate upstream to spawn in headwater streams; fluvial fish overwinter in larger, higher-order streams lower in the drainage, whereas adfluvial fish overwinter in lakes and reservoirs. Resident fish do not migrate, and spawning occurs in the same stream as they reside. Resident fish are typically smaller in size (<300 mm fork length, FL) and inhabit smaller, low-productivity headwater streams, whereas migratory fish grow much larger (≥400 mm FL) because they reside in more productive systems lower in the watershed (Rieman and McIntyre 1993; Berry 1994). Migrant fish enhance genetic exchange between populations, increasing genetic heterogeneity and thus reducing the risk of inbreeding. As an apex predator, the migratory form is highly successful, and where migratory and resident populations coexist, the migratory life history form is dominant (Whitesel et al. 2004; Fredenberg et al. 2005).

Warnock (2008) documented three bull trout populations in the Castle River drainage in Mill Creek, Carbondale River and West Castle River. Migratory, fluvial and adfluvial bull trout were identified in all three populations; however, the West Castle population was comprised primarily of residents with a small component of migrants (Warnock 2008). The abundance and distribution of these migratory populations have never been thoroughly assessed, and given the high level of development in the drainage, there is uncertainty to what degree these populations are affected.

Fish traps are a common capture method used to estimate abundance of bull trout populations in spawning streams throughout northwestern North America (RL&L 1992; Kelly Ringel and DeLaVergne 2008; Starcevich et al. 2012). These estimates assume that fish have equal catchability and do not avoid traps. Trap avoidance would introduce a sampling bias and result in inaccurate estimates of the fish population. Little documentation exists on whether bull trout exhibit trap avoidance; therefore, further investigation into this behaviour will improve accuracy of population estimates.

We conducted a multi-year assessment of the bull trout population and spawning habitat in the Castle River drainage to update the status of existing populations. Specifically, we determined abundance of the migratory bull trout populations and the distribution of spawning habitat throughout the drainage, which can be used to assess potential land-use impacts on the drainage. The main objectives of our study were to:

- estimate the relative abundance of migratory bull trout populations in spawning streams in the Castle River drainage: Mill Creek and South Castle, West Castle and Carbondale rivers
- document the current distribution of bull trout spawning locations throughout the Castle River drainage
- determine if trap avoidance behaviour is present in post-spawn bull trout

2.0 STUDY AREA

The Castle River drainage is one of five tertiary headwater watersheds in the Oldman River basin situated in the east slopes of southern Alberta's Rocky Mountains (Figure 1). The drainage area comprises only 4% of the Oldman River basin, but because of its high annual precipitation, it supplies 30% of the entire water flow in the basin (Lee and Hanneman 2011). The Castle River drainage is comprised of the Rocky Mountain and Foothills natural regions, which are dominated by montane sub-region with sub-alpine and alpine sub-regions in the upper elevations. The drainage contains a diverse ecosystem with many sensitive flora and fauna species and several at risk species (McLeod 2007).

The community of Pincher Creek is located adjacent to the drainage, approximately 225 km south of Calgary. Most of the upper drainage is encompassed by the Castle River FLUZ, and most headwater streams are situated in the Castle Wilderness Area. Land use in the drainage includes forestry, oil and gas development, livestock grazing, motorized vehicle use, random-access camping, hunting, angling, and a commercial ski resort. Human activities are increasing in the drainage, and development of these activities has resulted in widespread disturbance throughout the drainage.

Within the drainage, four major tributaries flow into the Castle River: Carbondale River, West Castle River, South Castle River and Mill Creek. All of the latter three tributaries and the upper half of Mill Creek are encompassed in the FLUZ.

Most streams in the drainage support cold-water sport fish species, including Westslope cutthroat trout (*Onchorhyncus clarkii lewisi*), bull trout, rainbow trout (*Onchorhyncus mykiss*) and mountain whitefish (*Prosopium williamsoni*). These cold-water trout streams are renowned angling destinations (ESRD 2014b). Brook trout (*Salvelinus fontinalis*) and various sucker species (*Catostomus* spp.) are also common throughout the lower drainage.

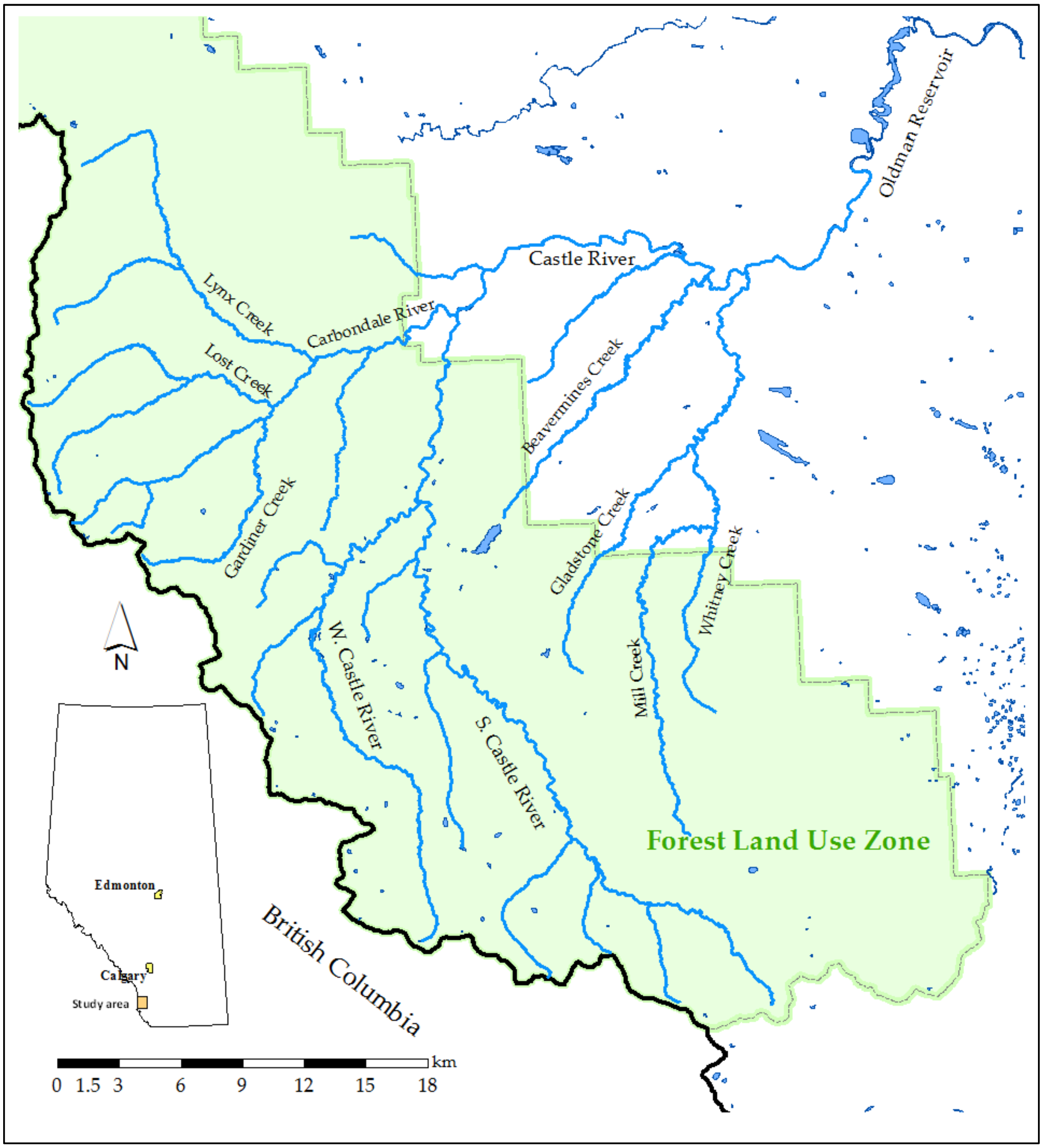

Figure 1. Castle River bull trout population assessment study area, 2011 – 2014.

3.0 MATERIALS AND METHODS

3.1 Fish capture

To estimate migratory bull trout abundance for each population, we installed directional conduit fish traps in the South Castle, West Castle and Carbondale rivers, and in Mill Creek. Traps were installed annually by the last week in August for four years (2011 – 2014) and removed when spawning was complete, during the last week of October. Traps were installed near the mouths of Mill Creek, South Castle River and West Castle River, and mid-reach in Carbondale River (Figure 2).

Each trap consisted of a trap box, placed perpendicular to the thalwag, near the middle of the stream channel, and deflection wings attached to each side of the box extended upstream at an approximate 35° angle to the adjacent bank (Hvenegaard and Thera 2001). Each trap created a stream-wide fish barrier that led downstream migrating fish into the entrance of the holding box. Fish traps were checked daily; before checking traps we used dip nets to catch blocked fish on the downstream end of the trap. Once the downstream end was clear of fish, we removed fish from the trap box.

The 2011 Mill Creek data suggested both resident and migratory fish existed in the population, which prompted us to investigate further by modifying the study's design. Starting in 2012, we moved the trap from the 2011 location closer to the mouth (lower trap) and added a second trap near the headwaters (upper trap). The upper trap was installed in mid-September to allow fish to move to spawning areas upstream of the trap. Fish captured in both traps were considered migratory, and fish captured only in the headwaters trap were considered residents. Detailed trap location information is summarized in Appendix 1. We discontinued trapping in West Castle River in 2013 because of low catches in 2011 and 2012. Traps were typically operational throughout the spawning season (September to October); however, unseasonably high stream flows and vandalism did result in occasional trap malfunction; Appendix 2 provides details on fish trap operation during our study.

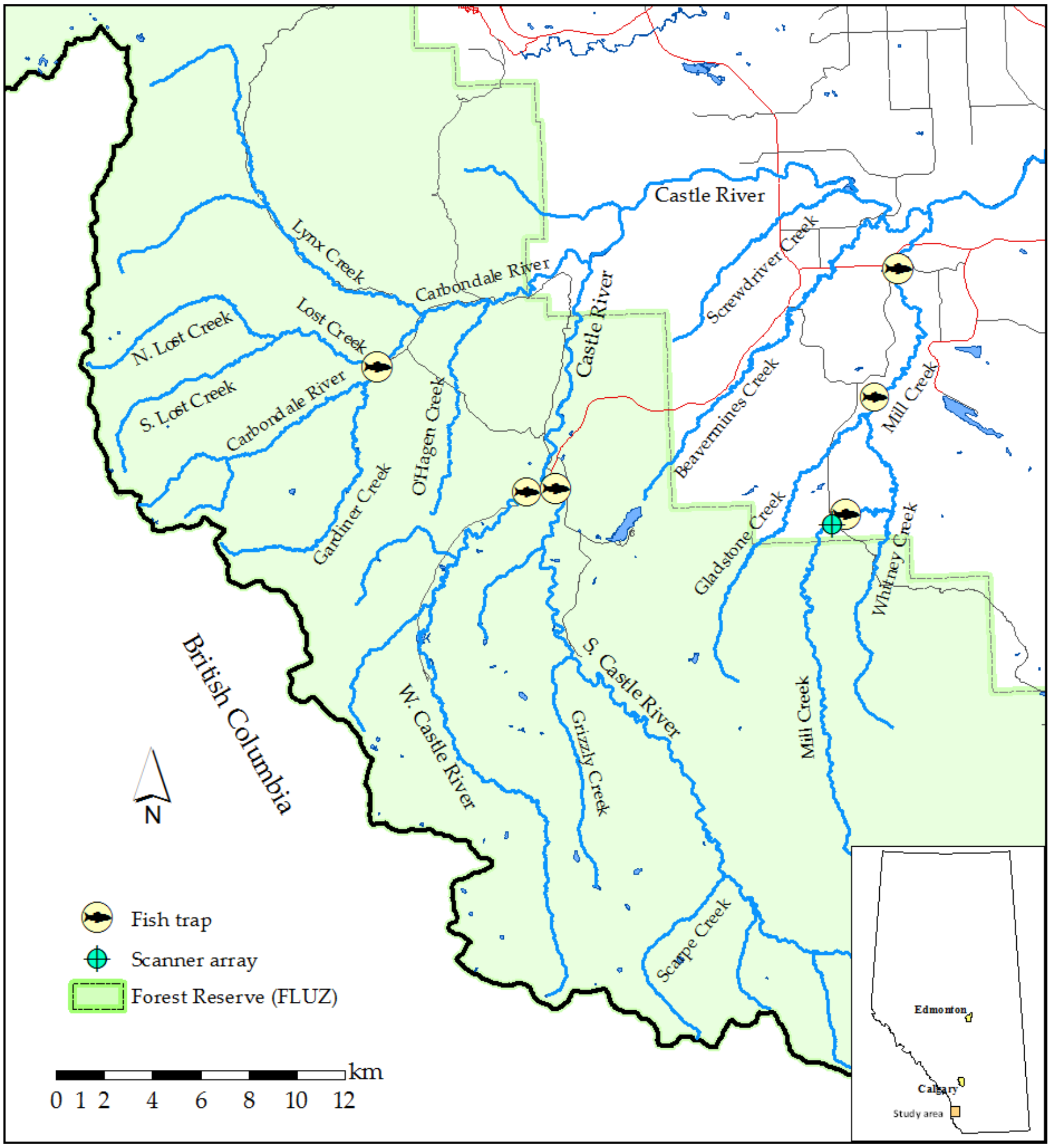

Figure 2. Locations of fish traps and transponder scanner arrays in the Castle River drainage, 2011 – 2014.

All captured fish were placed in a live-well before processing. We measured fish weight (g), FL (mm) and total length (mm), and marked fish with an upper caudal fin clip to identify recaptured fish.

To limit fish stress and injury and to ease fish handling, we anaesthetized each bull trout individually by immersing it in a clove oil solution bath (10 drops clove oil/10 mL anhydrous ethanol/10 L water) for 120 to 180 seconds. Adult bull trout (≥300 mm) were tagged with a passive integrated transponder (PIT) tag (FDX – 134.2 kHz – 12.5 mm) to track recaptured fish. Tags were injected into the musculature of the fish at the base of the dorsal fin using a sterilized 12-gauge needle; before tagging, we scanned each fish with a hand-held scanner (Biomark 601 Reader) to ensure it had not been previously tagged. The caudal fin mark on each tagged fish was used to assess tag retention. Although fin regeneration was observed on recaptured fish, the regeneration was obvious and we re-clipped fish to ensure future detection.

After tagging, we determined fish gender by gently stripping the abdomen for milt or eggs; fish failing to produce reproductive material were categorized as unknown gender. After sampling, we revived fish and returned them to the stream according to their direction of travel.

To assess the relationship between water temperature and the timing of post-spawn migration, we installed HOBO (Onset) temperature data loggers in the stream, alongside each trap. We also fished opportunistically in spawning streams during the summer and fall months to increase the total number of tagged bull trout in our study. We waded in sections of streams and angled bull trout with spin cast gear and hardware.

Complementary bull trout tagging data was available from the Castle River cutthroat population stock assessment (Blackburn 2010), the Crowsnest River drainage sport fish population assessment (Blackburn 2011), and the upper Oldman River drainage bull trout population assessment (Hurkett et al. 2011).

3.2 Population estimate and trap avoidance

The headwaters portion of Mill Creek, between the upper trap and the subsurface water barrier, was selected to assess trap avoidance behaviour and estimate abundance of the annual migratory spawning population. This reach was selected because it is a primary spawning area that provides insufficient overwintering habitat and would likely trigger post-spawn fish to travel downstream to more suitable overwintering habitat and encounter the trap.

Beginning in 2012, one week before annual trap installation, we set up a multiplexing transceiver scanner array in Mill Creek to supplement data for mark-recapture abundance estimates as well as to assess trap avoidance behaviour. The scanning unit was installed 200 m upstream of the upper trap in Mill Creek (11U 705162 5472676) (Figure 2). We used a Biomark Multiplexing Transceiver System (IS1001-MTS), configured as a directional scanning station. This system was comprised of two 20-foot antennae, each hard-wired into an independent control box, four sealed 12 V deep-cycle batteries, and two 100-foot cables. The antennae were embedded in the stream substrate and anchored using cabled dead-man anchors. Antennae were spaced approximately 10 m apart to reduce radio signal interference between them. Data collected during each scanning event included tag number, time and date. To limit data loss, scanned data were uploaded every two days, when batteries were replaced. The scanner system was removed at the end of each season during the last week of October.

Trap avoidance behavior

We used the direction of fish movement to determine trap avoidance behaviour. Direction of movement was determined using the time lapse between fish scans from the two antennae (Appendix 3). Fish identified by scanners as moving downstream but not captured in the trap were considered to have avoided the trap.

Population estimate

We used the Chapman estimator to estimate the number of migratory spawning bull trout in Mill Creek upstream of the upper trap (Hayes et al. 2007):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1$$

Marked fish (M) included fish caught and marked in our study period, or those marked in previous studies, that were captured upstream of the trap by dip net or angling, or that were scanned (upstream direction). Captured fish (C) included all fish captured in the trap, dip netted immediately upstream of the trap, or scanned moving downstream. Recaptured fish (R) included all fish captured or scanned a subsequent time following their initial capture. Variance of the estimator was approximated using:

$$V(\hat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(C+1)(C+2)} - 1$$

We used three years (2012 – 2014) of mark-recapture data to estimate the migratory spawning population in each spawning season.

3.3 Redd count surveys

We conducted redd count surveys in bull trout spawning streams throughout the Castle River drainage. Surveys consisted of hiking up the stream to assess bull trout habitat and count redds. All prospective spawning streams were broken into 2,000 m transects, and each transect was prioritized to ensure we documented all spawning activities (Figure 3). Priority of each transect was based on past redd count data collected from this study and by the Alberta Government in the late 1990s (summarized in Gerrand and MacCulloch 1995; Gerrand and Watmough 1996, 1999; Gerrand and DeRosa 1997).

Transects where redds were historically documented were ranked highest (Priority 1) and surveyed at least two times throughout the season to ensure we enumerated all redds. Priority 2 transects were adjacent to priority one transects, both upstream and downstream. Priority 3 transects were suspected spawning reaches with suitable spawning habitat but where redd surveys were never completed. If a redd was discovered in a Priority 2 or 3 transect, the transect would be reprioritized to Priority 1 and resurveyed. All Priority 1 transects were surveyed every year, even if redds were not identified in previous years.

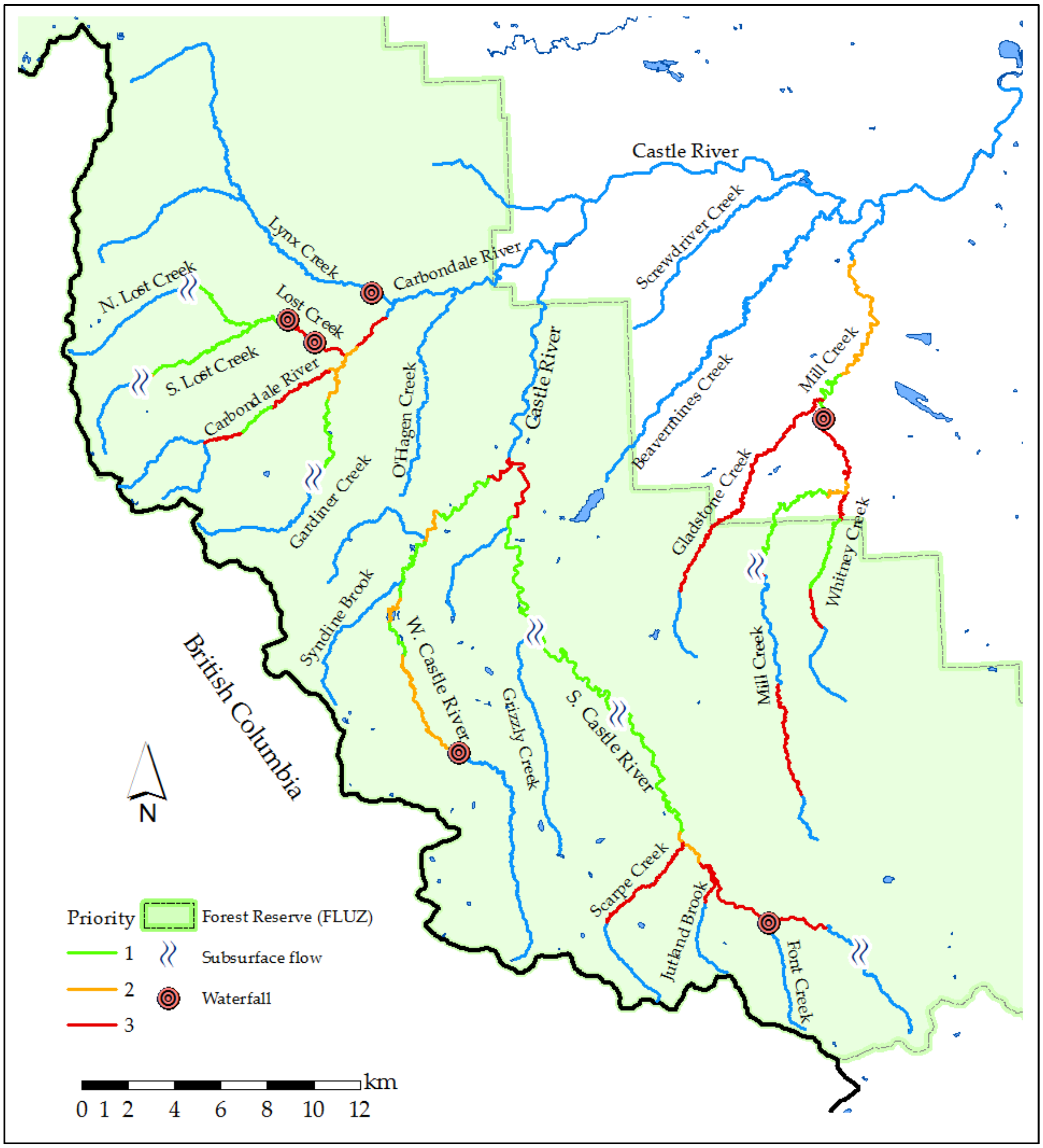

Figure 3. Priority of spawning survey transects and locations of fish barriers (subsurface flow and waterfalls) in the Castle River drainage.

If fish barriers were observed, such as waterfalls or subsurface flow reach breaks, we assessed fish passage potential and spawning habitat quality upstream of the barrier. We classified waterfalls as a permanent or seasonal fish barrier based on the barrier height and assessed fish passage potential at different stream flows; a seasonal barrier would be passable only in high flows. Vertical waterfalls greater than 3 m were identified as permanent fish barriers. If the upstream section was unsuitable for spawning, we disregarded this section from our study. Data collected during redd surveys included geographic location (Universal Transverse Mercator [UTM] – derived from Global Positioning System [GPS]), redd length and width (cm), pit depth (cm), instream location, substrate composition, cover and stream type. Appendix 4 summarizes all spawning habitat categories assessed during our study. We did not conduct redd counts in South Lost Creek in 2013 because of unseasonably high stream flows, and in 2014, we surveyed redds only once early in the spawning season because of time constraints.

4.0 RESULTS

4.1 Distribution and abundance

We captured a total of 459 adult bull trout (≥300 mm FL) in streams throughout the Castle drainage between 2011 and 2014, of which 185 fish were from the Carbondale drainage, 149 from South Castle River, 109 from Mill Creek, 9 from Castle River and 7 from West Castle River (Figure 4 and Table 1).

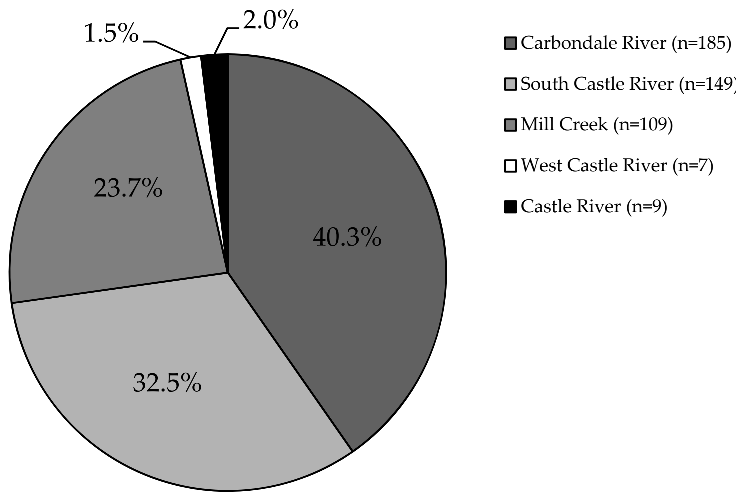

Figure 4. Distribution of bull trout captured and tagged in the Castle River drainage, 2011 – 2014 (n = 459).

Table 1. Number of bull trout captured and tagged using various methods in the Castle River drainage, 2011 – 2014.

Capture method	2011	2012	2013	2014
Trap	175	86	38	118
Angling	9	17	12	4
Total	184	103	50	122

Overall, bull trout abundance was highest in Carbondale River and South Castle River (Figure 5) and lowest in West Castle River (2011 and 2012). In general, catches were highest in 2011 and 2014, and lowest in 2013; low 2013 catch rates were attributed to unseasonable high stream flows that blew out traps in the Carbondale and South Castle rivers and lower Mill Creek. Declining catch rates in Mill Creek might also be attributed to trap malfunction; we found a hole in the upper trap in 2013 and a suspected hole in the same trap in 2014.

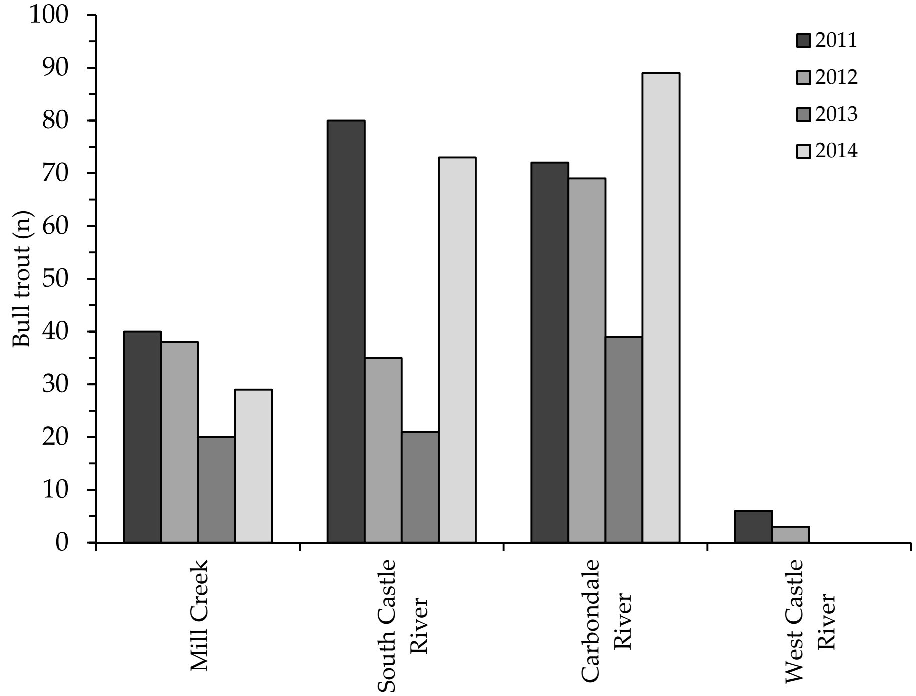

Figure 5. Bull trout trap abundance at spawning streams in the Castle River drainage, 2011 – 2014. Traps were not installed in West Castle River in 2013 and 2014 because of low catches in previous years.

Mean FL of bull trout ranged from 542 to 587 mm in Carbondale River and from 553 to 620 mm in South Castle River; we captured a higher number of large fish in South Castle River than Carbondale River and Mill Creek (Table 2 and Appendices 5 to 7). Mean FL varied between trap locations in Mill Creek, ranging from 381 to 536 mm for the lower trap and 549 to 581 mm for the upper trap. Both length ranges suggest the population is migratory; however, we captured a greater number of smaller fish (<300 mm FL) in the lower trap than the upper trap, which may have been adult residents and/or sub-adult migrants. The few bull trout captured in West Castle River were all greater than 400 mm (FL) indicating presence of migratory fish.

Table 2. Size of bull trout caught in fish traps in the Castle River drainage, 2011 - 2014.

Waterbody	Year	Fork length (mm)		n
		Mean (± SD)	Range	
Mill Creek	2011	539.7 (± 85.0)	365 – 698	40
	2012	552.0 (± 92.4)	284 – 702	38
	2013	538.4 (± 124.5)	145 – 729	20
	2014	450.0 (± 127.9)	290 – 735	29
South Castle River	2011	570.3 (± 82.6)	444 – 808	80
	2012	619.9 (± 105.8)	460 – 821	35
	2013	553.1 (± 93.2)	339 – 724	21
	2014	584.3 (± 99.7)	397 – 861	73
Carbondale River	2011	578.7 (± 89.2)	370 – 780	72
	2012	575.2 (± 95.6)	986 – 783	69
	2013	587.1 (± 114.7)	406 – 830	39
	2014	541.9 (± 111.5)	250 – 807	89
West Castle River	2011	583.7 (± 65.5)	489 – 656	6
	2012	589.8 (± 67.8)	521 – 664	3
	2013	–	–	–
	2014	–	–	–

Recapture rates of bull trout ranged between 4% and 54% over the study period. Generally, the lowest recapture rates in all streams occurred during the first year of trapping in 2011, most of these fish were marked in previous studies (Blackburn 2010, 2011; Hurkett et al. 2011) (Table 3); overall, recapture rates were highest in all streams in 2013. Recapture rates in South Castle River and Carbondale River were relatively high (≥28%) from 2012 to 2014. Mill Creek recapture rates, combining fish caught in both the upper and lower traps, were similar throughout the study. Recapture rates were low for fish travelling downstream from the upper Mill Creek trap to the lower trap in the same year.

Table 3. Recapture rates of tagged bull trout captured in fish traps in the Castle River drainage, 2011 – 2014.

Waterbody	Year	Fish tagged	Fish recaptured	Total catch	Recapture rate (%)
Mill Creek	2011	36	4	40	10
	2012	26	12	38	32
	2013	13	7	20	35
	2014	19	10	29	34
South Castle River	2011	66	14	80	18
	2012	24	11	35	31
	2013	11	10	21	48
	2014	52	21	73	29
Carbondale River	2011	69	3	72	4
	2012	49	20	69	29
	2013	18	21	39	54
	2014	55	34	89	38
West Castle River	2011	4	2	6	33
	2012	3	0	3	0

Recapture data showed that most recapture events occurred in the same stream where the fish was initially captured (Table 4). Our data permitted us to identify migratory patterns of individuals between streams within the Castle River drainage. Several bull trout initially captured in South Castle River were recaptured in Mill Creek, Carbondale River and West Castle River. Similarly, fish marked in Carbondale River were recaptured in Mill Creek, South Castle River and West Castle River. Bull trout from Mill Creek were also recaptured in South Castle River and Carbondale River.

Table 4. Castle River migratory bull trout movements based on multiple capture locations, 2011 – 2014 (n = 459). Fish marked in streams outside of the drainage were initially captured in previous projects.

Marking location	Recapture location						
	Mill Creek	South Castle River	Carbondale River	West Castle River	Castle River	Lost Creek	Crowsnest River
Mill Creek	101	1	2	–	3	(1)	–
South Castle River	3	136	1	2 (2)	–	–	2
Carbondale River	1	2	176	(2)	–	–	4
West Castle River	–	–	3	4	–	–	–
Lost Creek	–	1	1	–	–	–	–
Crowsnest River	1	4	–	–	–	(1)	–
Castle River	2	4	1	–	2	–	–
Oldman River	–	1	1	–	–	–	–

( ) fish captured in multiple streams and tallied at a different recapture location

Spawning behaviour for most bull trout was undetermined because most individuals were captured only once over the duration of the study. Bull trout that spawned in consecutive years (range 2 to 4 years) were more prevalent in Carbondale River than South Castle River and Mill Creek. Alternate-year spawning fish were most common in Mill Creek (Table 5).

Table 5. Spawning behaviour of bull trout in the Castle River drainage, 2011 – 2014.

Waterbody	No. of spawners	Fish expressing spawning behaviour (%)		
		Consecutive year	Alternate year	Undetermined
Carbondale River	194	23.2	7.2	69.6
South Castle River	167	9.6	12.0	78.4
Mill Creek	98	2.0	21.4	76.5

Overall, post-spawn migration occurred between mid-September and mid-October when water temperatures cooled to 6 ℃ to 8 ℃ (Appendices 8 to 12). Most bull trout captured in the lower trap of Mill Creek in early season (late-August to early-September), specifically in 2013 and 2014, were small adult or sub-adult fish (<300 mm) that were likely out-migrants exiting their rearing habitat.

Sex determination of post-spawn fish was inconsistent because most fish were spent and did not produce any reproductive material; this was more common in females than males. We were successful in assigning gender 38% to 73% of the time (Appendix 13). Overall, the proportion of confirmed males was greater than females, and males remained ripe later in the season compared to females.

Female bull trout were typically the first to migrate downstream as we captured many more females than males at the peak of post-spawn migration (Appendices 14 to 16). We observed a few male bull trout following post-spawn females, but most post-spawn male movements were gradual and occurred over a longer period.

4.2 Trap avoidance

Trap avoidance behaviour was variable following three years of data collection (Table 6). We observed little indication of trap avoidance behaviour in 2012 since only 15% (n = 4) of the scanned post-spawn fish were not captured in the upper trap. However, the number of scanned fish not trapped in the upper trap increased to 39% and 67% (n = 7 and 14) in 2013 and 2014, respectively.

Table 6. Trap avoidance comparison between trap catch and fish scanner array detections of tagged migratory bull trout (downstream direction) in Mill Creek, 2012 – 2014.

Year	Scanner direction	Fish scanned	Fish trapped	Fish scanned and trapped	Fish scanned and not trapped
2012	Upstream	1	2	0	1
	Downstream	26	31	22	4
	Undetermined	1	0	0	1
	Total	28	33	22	6
2013	Upstream	2	0	0	2
	Downstream	18	13	11	7
	Undetermined	0	0	0	0
	Total	20	13	11	9
2014	Upstream	5	2	2	3
	Downstream	21	8	7	14
	Undetermined	1	0	0	1
	Total	27	10	9	18

4.3 Mill Creek bull trout population estimate

We calculated the migratory spawning population in the upper reach of Mill Creek for three spawning seasons (2012 to 2014); estimates were identical in 2012 and 2013, and lower in 2014 (Table 7).

Table 7. Population estimates for the adult migratory bull trout population in upper Mill Creek, 2012 – 2014.

Year	Marked (M)	Captured (C)	Recaptured (R)	Population estimate	
				$\hat{N}$	95% CI
2012	41	33	31	45	42 – 48
2013	28	13	8	45	30 – 62
2014	29	10	8	37	30 – 45

4.4 Spawning

During four years of bull trout spawning surveys, we identified all active bull trout spawning areas in tributaries throughout the Castle River drainage. We documented a total of 68 km of spawning habitat in South Castle River, Mill Creek, the Carbondale River sub-drainage, and West Castle River (Appendix 17). Redd counts and spawning habitat varied slightly in each stream between years. In 2013, high stream flows prevented us from completing redd counts, and we observed existing redds had been scoured-out in previously surveyed spawning reaches (Table 8). In all four survey years, we observed several redds that were damaged by off-highway vehicle traffic in multiple spawning streams (Appendix 18).

Table 8. Redd count and stream distance surveyed in the Castle River drainage, 2011 – 2014.

Waterbody	Bull trout redd (n)				Survey distance (km)			
	2011	2012	2013[a]	2014	2011	2012	2013	2014
South Castle River	97	126	10	44	20	20	8	10
Mill Creek	66	81	7	72	8	12	8	8
Carbondale River drainage	90	121	33	68	20	18	10	14
West Castle River	26	9	7	13	10	2	2	2

[a] Incomplete spawning survey data in 2013 because of unseasonably high stream flows

South Castle River

South Castle River had the highest number of redds and the largest distribution of bull trout spawning habitat in the drainage. The highest density of redds occurred immediately downstream of a seasonal subsurface water barrier approximately 4 km upstream from the mouth of Grizzly Creek; the subsurface break varied in length from 500 to 1,000 m between years. A second spawning area was observed upstream of the groundwater break, approximately 1 km downstream from the mouth of Scarpe Creek (Figure 6); groundwater upwelling was observed in this section and is likely why the spawning area was active. A third spawning area, ranging from one to two redds, was documented each year in a tail-out of a pool immediately upstream of the South Castle trap.

Redd counts in South Castle River ranged between 44 and 126, excluding the incomplete 2013 count. Redd construction typically started at the beginning of the second week of September and continued until the first week of October. Generally, redds were common in run sections with coarse gravel substrate. Most redds were located in an open stream channel with no cover. Cover used by bull trout was under log jams, woody debris and overhanging vegetation. Spawning activity in a main spawning area was relocated to a new channel when the river re-channelized in 2012.

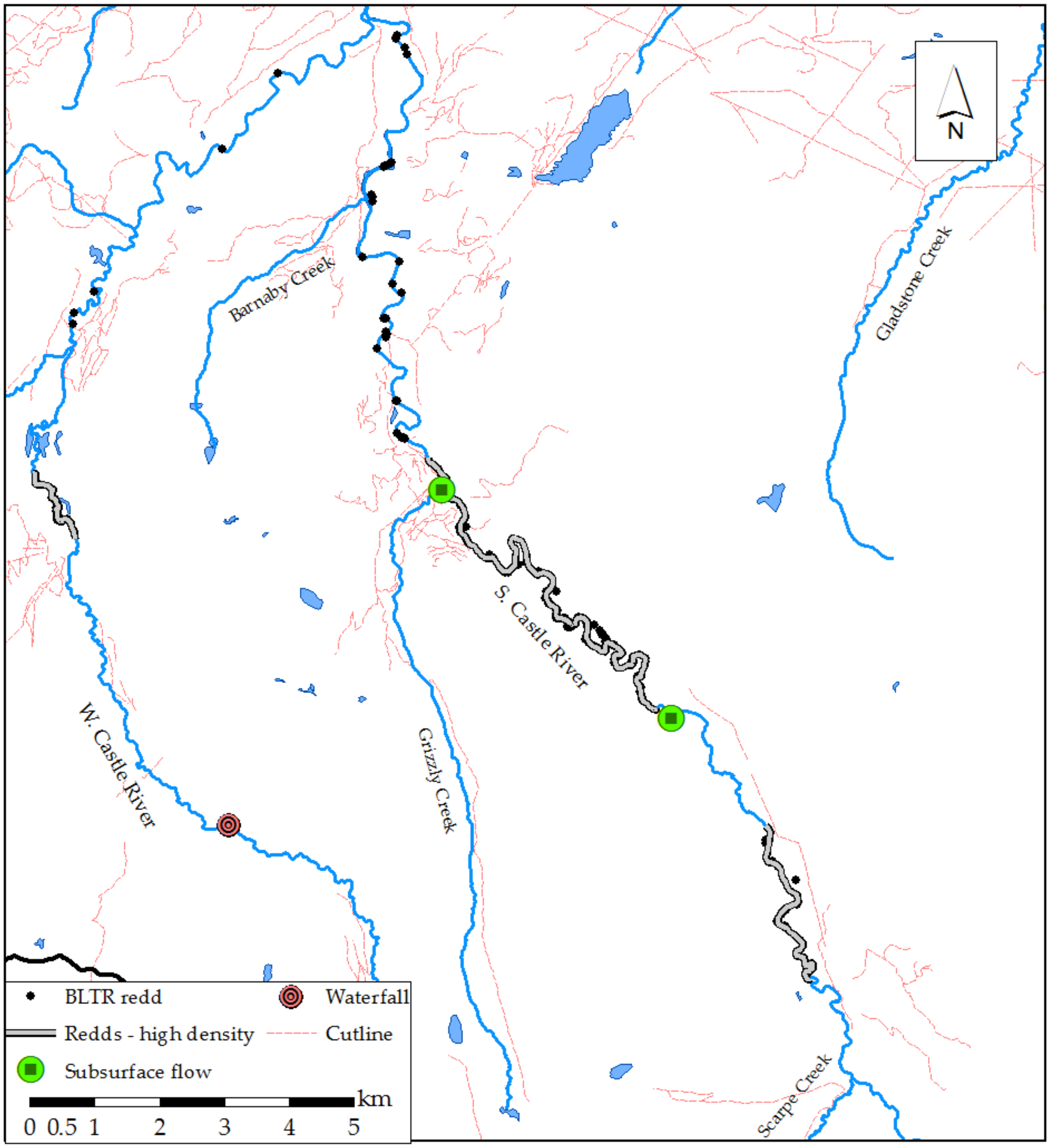

Figure 6. Bull trout spawning areas in South Castle River, 2011 – 2014.

Carbondale River drainage

We identified four main bull trout spawning areas in the Carbondale River sub-drainage, which includes Gardiner, North Lost, South Lost and Lost creeks; one redd was documented in Carbondale River upstream of the mouth of Gardiner Creek in 2012 (Figure 7).

Gardiner Creek had the highest number of redds of all four spawning areas in the Carbondale River sub-drainage. The spawning reach extended 2.5 km downstream from the seasonal subsurface water barrier, and most redds were concentrated in the upper half of this reach. Spawning habitat in Gardiner Creek was mostly in run sections with coarse gravel substrate. Cover was not typical as most redds were observed out in the open. Large woody debris was the prominent cover type for redds in Gardiner Creek. Redd construction began during the second week of September and ended by the second week of October.

North Lost and South Lost creeks were two other major spawning areas in the Carbondale sub-drainage. Spawning habitat was similar in both streams; redds were discovered in a confined stream channel, adjacent to dense forest and influenced by groundwater from subsurface channeling. Overall, we counted more redds in North Lost Creek than South Lost Creek. Redds in South Lost Creek were evenly distributed throughout the stream between the subsurface break and the confluence of North Lost Creek. Redds in North Lost Creek were concentrated in two spawning areas, immediately upstream of the mouth of the stream for 500 m and directly downstream of the subsurface water break. Redds were located in run type stream sections in coarse-size gravel and had no cover. Spawning began in these streams by the third week of September and ended before the third week of October.

Spawning activity was present in Lost Creek but to a lesser extent than the previous three spawning streams. We observed up to 14 redds in a small 500 m section of the stream downstream from the convergence of North and South Lost creeks and upstream of the lower canyon. Redds in this section were located in run-type stream sections with fine gravel substrate. Most redds were open and bare of cover. Spawning occurred between the third week of September and the second week of October.

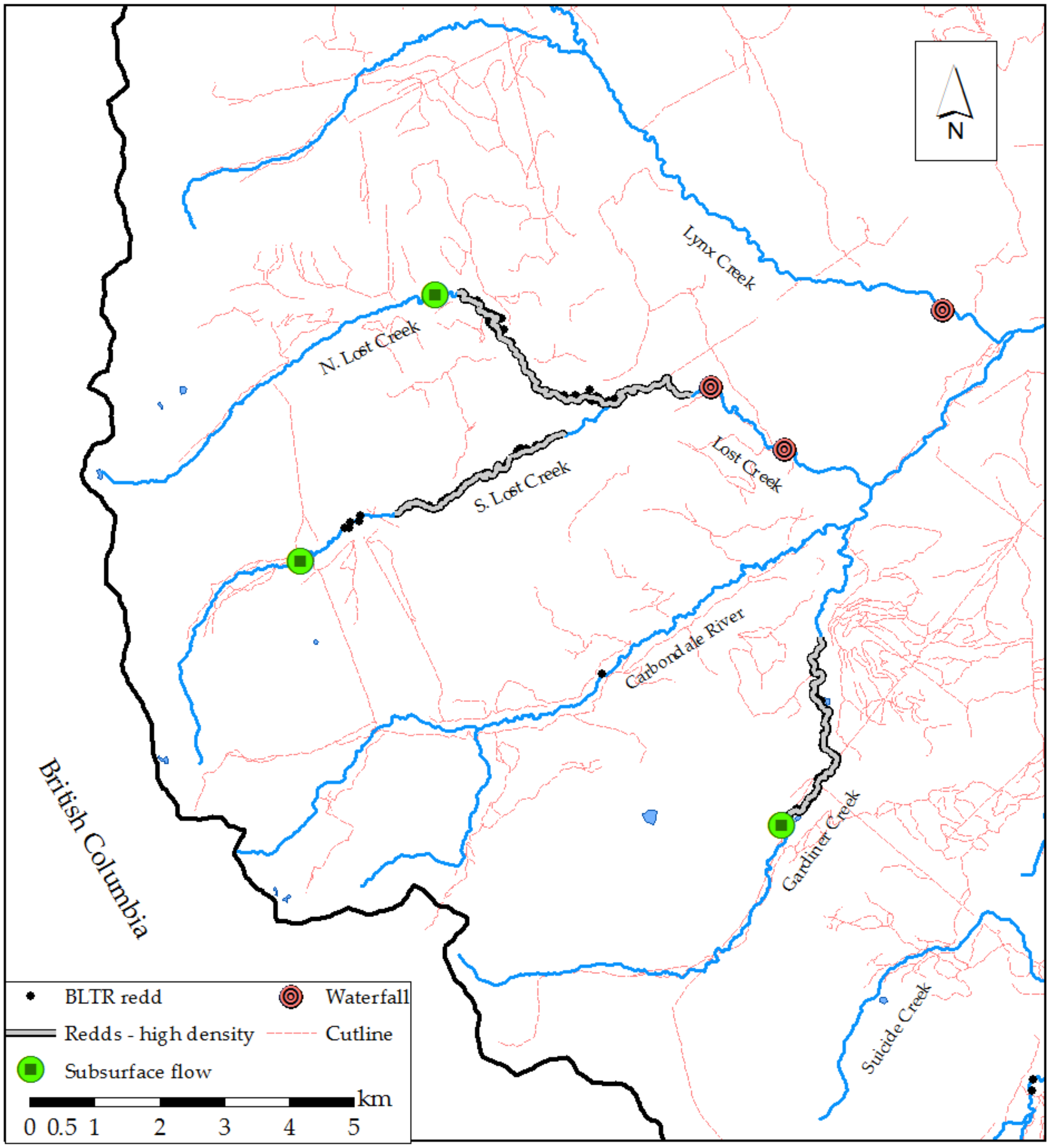

Figure 7. Bull trout spawning areas in the Carbondale River sub-drainage, 2011 - 2014.

Mill Creek drainage

We identified three spawning areas in Mill Creek (Figure 8). The upper most spawning area located upstream of the upper trap, documented by previous redd count studies (Gerrand and MacCulloch 1995; Gerrand and Watmough 1996, 1999; Gerrand and DeRosa 1997), had the highest density of redds over the four study years. This spawning reach extended 5 km downstream from a subsurface water barrier; subsurface flow varied between years from 300 to 2,000 m. A second spawning area, approximately 500 m in length, was located immediately downstream of the upper trap; it is likely that the spawning activity resulted from the presence of the trap. The third and lowest spawning area was located downstream of the Mill Creek waterfall; upstream and downstream of the mouth of Gladstone Creek. During the tail end of each post-spawn run, we observed one to two redds immediately upstream of the trap.

Spawning habitat was common in run-type stream sections with coarse gravel substrate and no cover. Cover used by spawning adults was under log jams or other woody debris and overhanging vegetation. Groundwater input appeared to influence spawning activity because most redds upstream of the trap were adjacent to stream bank seeps and other groundwater sources. Spawning started during mid-September and ended by mid-October.

We observed two redds in Whitney Creek in 2011. One redd was located in the upper reach, which was the same reach documented in previous redd count studies (Gerrand and MacCulloch 1995; Gerrand and Watmough 1996, 1999; Gerrand and DeRosa 1997), and the second redd was located downstream from the Shell road crossing.

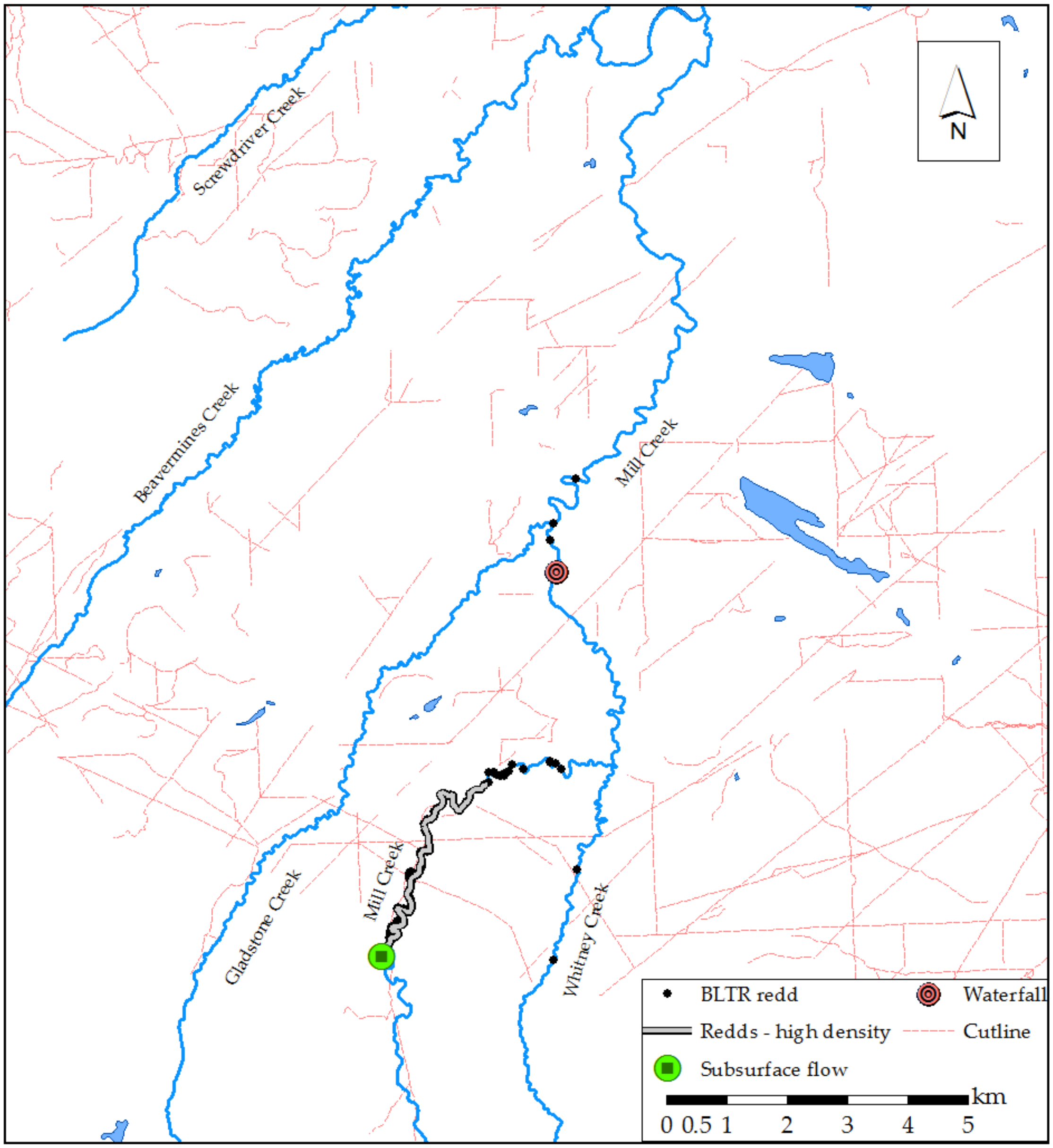

Figure 8. Bull trout spawning areas in the Mill Creek sub-drainage, 2011 – 2014.

West Castle River

We identified two main spawning areas in West Castle River (Figure 9). The main spawning area, approximately 2 km in length, was previously documented in the West Castle Wetlands Ecological Reserve in 2008 (Hurkett 2009). The lower reach was a smaller, 1 km reach that was seldom used by adult bull trout. Downstream of the lower spawning area, we observed individual redds intermittently throughout the stream in 2011 and 2012. Redd counts ranged between 10 and 26, and most redds were located in the West Castle Wetland Ecological Reserve; only a few redds were observed in the lower spawning area in 2011. Spawning habitat in West Castle River was primarily comprised of a run stream type with fine to coarse gravel substrate. Most redds were open and free of cover. Spawning began as early as mid-September, but most redds were not constructed until the last week of September; spawning ended by mid-October.

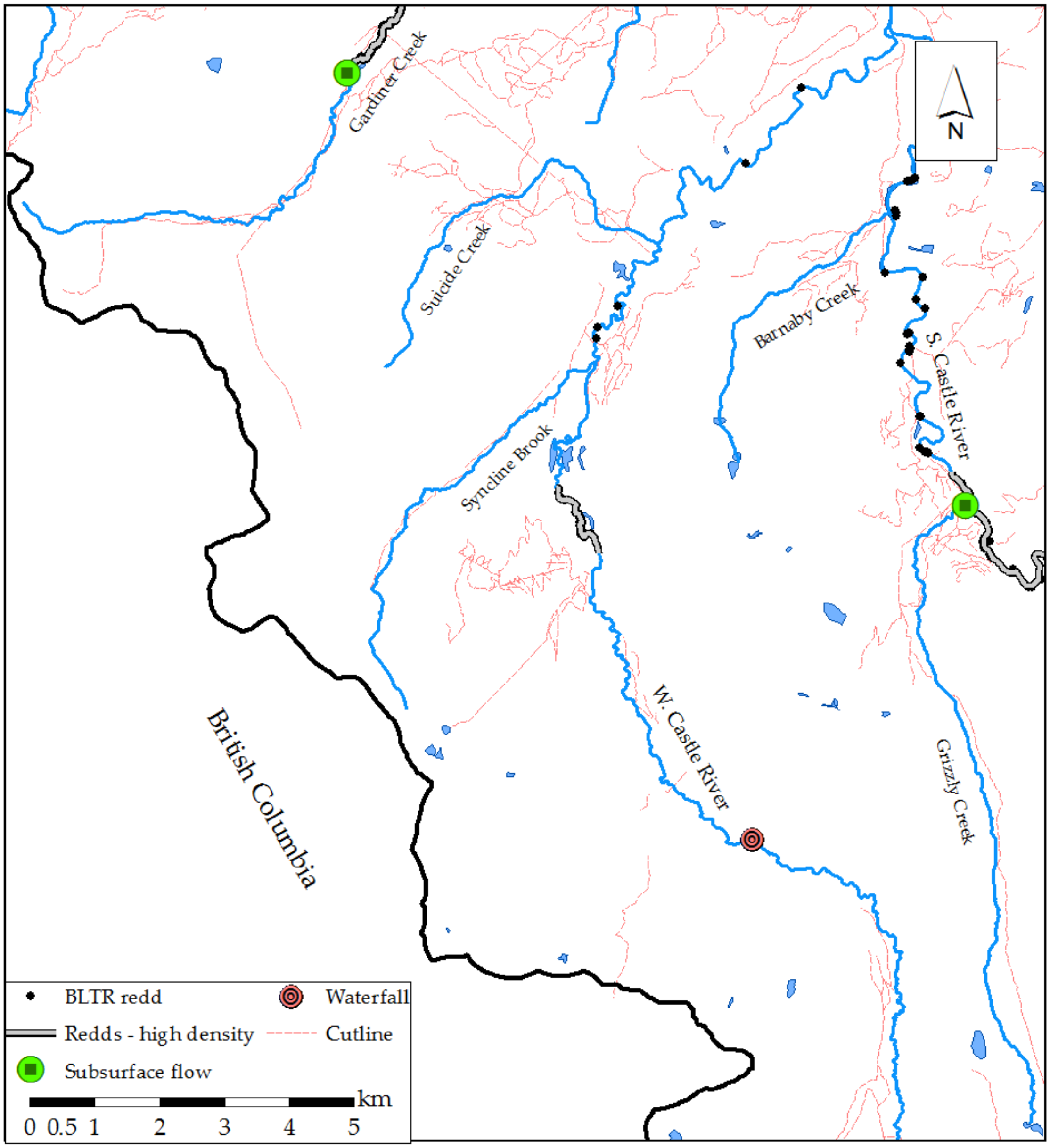

Figure 9. Bull trout spawning areas in West Castle River, 2011 – 2014.

5.0 DISCUSSION

Of the four spawning streams assessed, migratory bull trout were most abundant in Carbondale River, followed by South Castle River, Mill Creek and West Castle River. Catch declined following 2011 trapping efforts but rebounded in 2014. Low catch rates in 2013 were attributed to high water flows that blew out fish traps in Carbondale River, South Castle River and lower Mill Creek. In Mill Creek, this pattern might result from alternate-year spawning behaviour documented over the duration of the study, as the timing between recurring spawning events for fish varied by either two or three years, which would have affected annual spawning totals.

Based on our trapping results, it appears that three distinct migratory bull trout populations exist in the Castle River drainage. The Carbondale bull trout migratory population was the largest, followed by the South Castle and Mill Creek populations. Warnock (2008) identified Mill Creek bull trout as the largest migratory population in the drainage but included South Castle bull trout in the Mill Creek population.

The South Castle River trap catch was the second highest in the study. Our data suggest that South Castle bull trout are primarily migrants because we captured a high number of post-spawn fish greater than 400 mm. Our data also identified a resident component within the population because the total number of redds in any year exceeded the number of bull trout caught in the trap. This result suggests that fish reside in the stream year round as residents or perhaps they are migrants that stage in this habitat and gradually exit the stream before ice-up. We believe the spawning fish upstream of the sub-surface water break are residents because the barrier prohibits them from moving downstream after they have spawned. These fish likely overwinter in the larger pools found throughout the tail-outs of each stream bend. Fish spawning downstream of the barrier are likely migrants that are not impeded by the barrier during their post-spawn migration.

We captured the highest number of bull trout in the Carbondale River trap. Our data suggest that Carbondale River bull trout are migrants because we intercepted a high number of post-spawn fish greater than 400 mm; we did not detect resident fish during our study. We identified four primary spawning areas in four tributary streams:

Gardiner, North Lost, South Lost and Lost creeks. All streams are low-volume, high-gradient creeks with minimal overwintering habitat; Carbondale River also offers little overwintering habitat upstream of the mouth of Lost Creek. Post-spawn bull trout likely increase their winter survival by migrating downstream to more suitable overwintering habitat. We recaptured several Carbondale River fish in other streams both inside and outside the drainage, suggesting that the Carbondale River bull trout migration network is more extensive than those of the other populations. The most common migratory path was between Carbondale River and lower Crowsnest River as we recaptured four tagged individuals between the two streams.

Our catch data suggest that both resident and migratory fish are present in Mill Creek. Migrants were identified as fish captured in both the upper and lower traps in the same season or Mill Creek tagged fish recaptured in other streams. Residents were identified as smaller fish (<300 mm FL) or fish captured in just the upper trap. Based on fish size, we assumed all post-spawn fish entering the upper trap were migrants (>450 mm FL), but since only a few of these fish were recaptured in the lower trap, they were classified as residents; residents were also detected by total redd counts outnumbering fish catches. A canyon section between the upper and lower traps provides excellent overwintering habitat; we observed numerous large, deep pools that provide ideal winter refuge. It is likely that most of the post-spawn fish migrate downstream into the canyon to overwinter or perhaps delay their migration to other overwintering streams. The proximity of Mill Creek Falls may affect bull trout spawning behaviour. As water levels recede, the falls act as a seasonal fish barrier, which reduces the chance for fish passage. The lower spawning area documented downstream of the falls was likely used by migratory bull trout that could not pass the falls, or perhaps it was used by resident fish.

Warnock (2008) and RL&L (1992) speculated that the West Castle bull trout population was primarily a resident population with a small migratory component. Our data also support this claim because we only captured a total of 12 migratory-size bull trout in the trap; five of these fish were recaptured in South Castle River or Carbondale River in the same year. Interbasin migration identified between West Castle River and these other streams suggests that migrants captured in West Castle River likely originate from other populations. Spawning surveys strengthen support of a resident population since the number of redds identified upstream of the trap exceeded fish catches; redd development occurred late spawning season, after most fish passed through the trap. Our low catch in West Castle River in 2011 and 2012, interbasin migration movements, and presence of redds upstream of the trap strongly suggest that the West Castle bull trout population is resident or primarily resident with few migrants.

Our recapture data revealed that most spawning migrants expressed high fidelity to their natal streams because many tagged fish were recaptured in the same stream they were originally captured. Bull trout from this study and other tagging studies (Hurkett et al. 2011; Matt Coombs, ESRD, pers. comm.) enabled us to document an extensive migratory network between bull trout populations in the Castle River drainage and the Crowsnest River and upper Oldman River drainages. Several bull trout captured in either the Carbondale or South Castle rivers were either tagged or recaptured in Crowsnest River downstream of Lundbreck Falls; a single bull trout tagged in Mill Creek was also recaptured in Crowsnest River. Tagged individuals from the upper Oldman River drainage were recaptured in the Carbondale and South Castle rivers. This information provides a better understanding of the interactions between populations. Given the short-term capture period and limited capture techniques, our data provide a current snap shot of the Castle River drainage bull trout population, and it is likely that we did not fully document the entire migratory network.

We detected minimal trap avoidance behaviours in 2012 and higher trap avoidance behaviours in 2013 and 2014; we speculate that the increase likely resulted from a hole in the trap in 2013 and a suspected hole in 2014. Each year, several fish remained in the pool immediately upstream of the upper trap following the removal of the trap; an additional three bull trout showed signs of trap avoidance because they were scanned moving downstream, circumvented the upper trap, and were subsequently captured in the lower trap. It is uncertain if these fish were intentionally avoiding the trap; however, the consistency of this type of behaviour suggests that fish trapping is not entirely efficient in catching migratory bull trout.

Each year, bull trout were observed staging in pools immediately upstream of the trap in South Castle River and Carbondale River. In South Castle River, two to eight adult bull trout staged in a pool upstream of the trap in all four years. We had minimal success catching these individuals, but the fish that were captured were all males. When the South Castle trap washed out in 2013 and was temporarily non-functional, the same number of fish remained in the upstream pool when stream flows receded. If trap avoidance is not a factor, we speculate that these groups of fish are late-spawning fish, likely opportunistic males waiting to pair up with spawning females below the spawning habitat before they overwinter.

Spawning habitat types were similar among all streams. Most major spawning areas commonly occurred in low-gradient and floodplain sections influenced by groundwater; there were a few subsidiary spawning areas with a steeper gradient in canyon sections. With the exception of West Castle River, all major spawning areas were influenced by groundwater upwelling sources immediately downstream of subsurface water breaks. Other groundwater sources, such as bank seeps, influenced all other spawning areas. Spawning beds in most spawning areas consisted of fine to moderate-size gravel. Most redds throughout the study period were common in run stream-type reaches averaging approximately 30 cm in depth. Redd cover was not as common; however, when used, woody debris was the most common type of cover. South Castle River had the most extensive spawning habitat of all spawning streams in the drainage. The remaining spawning streams were localized in the upper stream reaches in areas with suitable spawning habitat. Erodible soil was minimal in these spawning areas as fine sediments have less erosion potential in low gradient streams (McIntosh and Laffan 2005).

The sedimentation/erosion potential based on linear disturbance in the South Castle River drainage was rated as low, and the Mill Creek, West Castle River and Carbondale River drainages were rated as moderate (Fiera Biological Consulting Ltd. 2014). We observed high levels of substrate embeddedness in spawning areas in North and South Lost creeks. The spawning beds in these two creeks were located in a confined channel adjacent to dense burnt forested stream banks (2003 Lost Creek fire) with high proportions of exposed erodible soil. Stream crossings in the spawning streams in the Carbondale sub-drainage were observed to have a large effect on stream sedimentation. The suspended sediment settled out on the substrate, covering redds downstream of the crossing for up to 150 m. These crossings were major point sources of fine sediment as the trails leading up to each crossing were channelized and susceptible to erosion.

We observed the transport of fine sediments via surface runoff entering the stream at each crossing point, which significantly increased stream turbidity and resulted in heavy accumulation of fine sediments over redds following moderate to high precipitation events.

Over the study period, we completed several spawning assessments in suspected bull trout spawning streams in the drainage. Several waterbodies were eliminated as spawning streams because of unsuitable spawning habitat or impassable fish barriers. Grizzly Creek, O'Hagan Creek, Jutland Brook and Syncline Brook were all discarded as migratory bull trout spawning streams because we observed significant subsurface water barriers at the mouth of each stream that prevent fish passage.

The upper reaches of South Castle River—upstream of Font Creek, Mill Creek and all of the spawning streams in the Carbondale River sub-drainage upstream of the subsurface water barriers—were eliminated as spawning streams because stream flows were not suitable for spawning. Lynx Creek and upper West Castle River both have significant waterfalls that prevent fish passage, and no bull trout exist upstream of the barriers (Blackburn 2010); we eliminated the lower reach of Lynx Creek as a spawning stream because the steep stream gradient and substrate dominated by boulders and bedrock were unsuitable spawning habitat. Font Creek, a small stream with a small waterfall near the mouth of the stream, offers very little spawning habitat.

We observed suitable spawning habitat in Scarpe Creek; however, a series of small waterfalls (>0.5 m) exist near the mouth, which could impede fish passage. We did not observe spawning activity in this stream. Gladstone Creek offers ideal spawning habitat, but we saw no spawning activity after a 6 km reach was surveyed upstream from the mouth of the stream. Our data suggest that these streams provide potential suitable spawning habitat but are not used by bull trout.

We did not observe evidence of hybridization with brook trout during the study. We captured one adult brook trout in Mill Creek in 2012 but did not document other brook trout or capture suspected hybrids for the remainder of the study. Brook trout are common throughout the Beaver Mines Creek sub-drainage, but it is evident that the species is not widespread throughout the Castle drainage.

This study is the first drainage-wide bull trout assessment in the Castle River drainage, which provides valuable information for future population monitoring. Bull trout and their spawning habitat remain widespread throughout the drainage. ESRD classified the Castle River bull trout population as being at *High Risk* of extirpation. Threats to Castle River bull trout are pervasive as the linear disturbance density in the Castle drainage greatly exceeds Ripley et al.'s (2005) 0.2 km/km^2 linear disturbance density threshold for bull trout. The density of linear disturbances is likely increasing as land-use activities continue to expand in the drainage, which could significantly impact Castle River bull trout as well as several other species in the drainage.

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7.0 APPENDICES

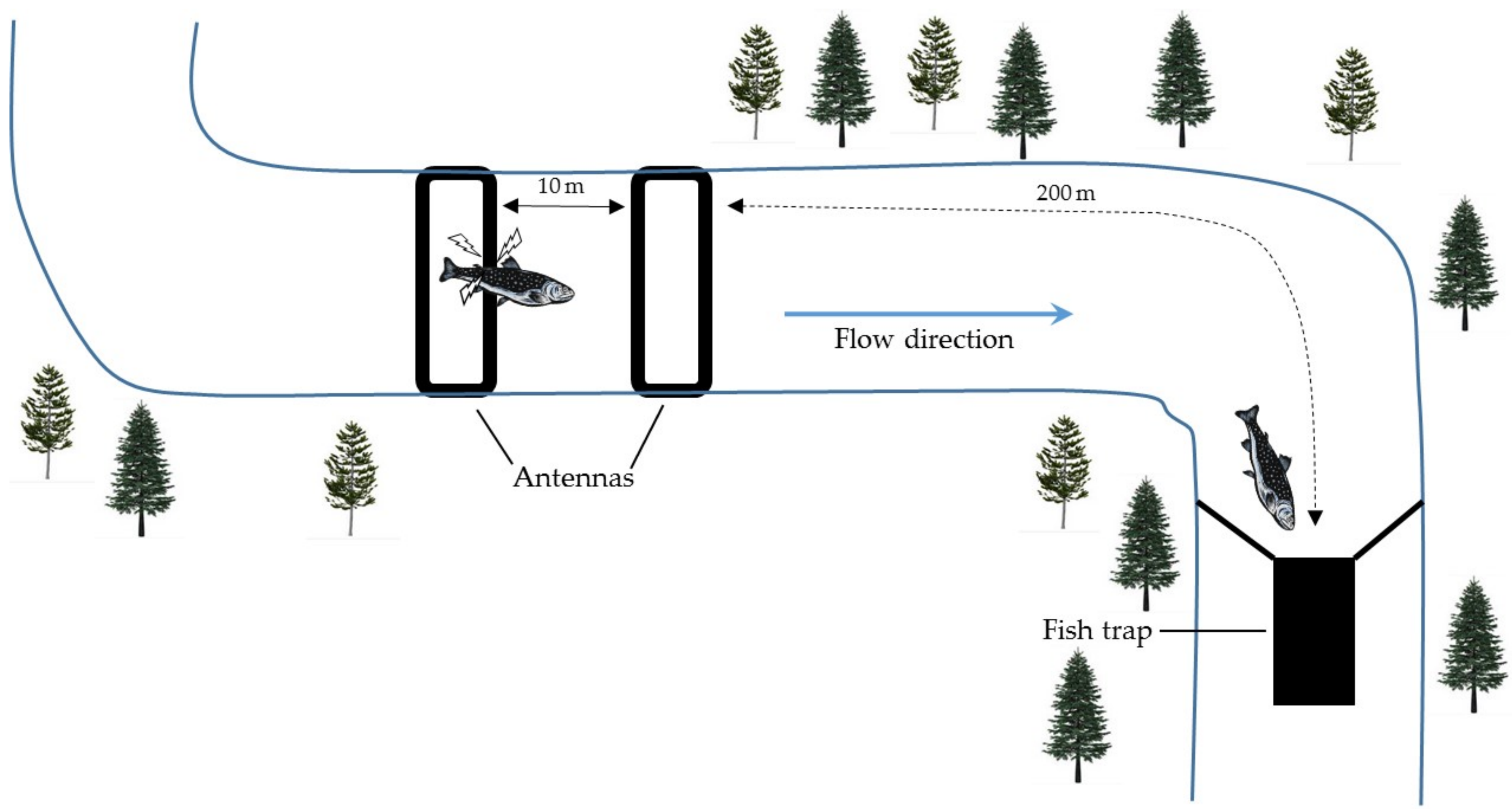
Appendix 1. Fish trap locations in the Castle River drainage, 2011 – 2014.

Waterbody	UTM		Description
	Easting	Northing	
South Castle River	693259	5474023	Installed at tail end of a large pool approximately 1.5 km downstream from the confluence of the South and West Castle rivers
Carbondale River	686133	5479125	Installed in a run/riffle stream section, approximately 800 m downstream from the mouth of Lost Creek
Upper Mill Creek	707649	5472875	Installed in a small pool at the base of a riffle, located approximately 14 km upstream from the stream's mouth
Lower Mill Creek	693259	5474023	Installed at the tail-out of a pool, approximately 4 km upstream of the confluence of Mill Creek and Castle River
Mill Creek (2011)	706574	5477676	Installed at the tail end of a pool approximately 1.5 km downstream from the mouth of Gladstone Creek
West Castle River	692130	5473670	Installed in a run section, immediately downstream of a riffle, approximately 2.2 km upstream of the confluence with South Castle River

Appendix 2. Fish trap deployment in the Castle River drainage, 2011 – 2014.

Year	Waterbody	Installation date, time	Removal date, time	Non-active days	Active days	Notes
2011	Lower Mill Creek	Aug. 22, 15:00	Oct. 31, 11:00	0	69	–
	South Castle River	Aug. 25, 17:30	Oct. 17, 16:00	0	52	–
	Carbondale River	Aug. 23, 15:00	Oct. 18, 12:30	0	55	–
	West Castle River	Aug. 24, 15:30	Oct. 16, 15:00	0	52	–
2012	Lower Mill Creek	Aug. 24, 16:00	Oct. 23, 14:00	0	59	–
	Upper Mill Creek	Sept. 17, 14:00	Oct. 22, 12:00	0	35	–
	South Castle River	Aug. 21, 17:00	Oct. 23, 10:00	1	61	Trap vandalized Oct. 10 – 11 (sections of conduit removed)
	Carbondale River	Aug. 22, 14:00	Oct. 22, 14:00	0	60	–
	West Castle River	Aug. 23, 15:00	Oct. 15, 14:00	0	52	–
2013	Lower Mill Creek	Aug. 20, 13:30	Oct. 17, 11:30	7	50	Pulled conduit Sept. 18 – 19 and Oct. 5 – 6 (high flows)
						Trap failure Sept. 29 – Oct. 1 (high water event)
	Upper Mill Creek	Sept. 9, 18:30	Oct. 17, 14:00	0	38	Hole observed in trap Sept. 22
	South Castle River	Aug. 21, 15:30	Oct. 18, 13:00	10	47	Trap failure Sept. 29 – Oct. 2 (high water event)
						Pulled conduit Oct. 2 – Oct. 8 (high flows)
	Carbondale River	Aug. 22, 14:00	Oct. 1, 15:00	0	38	Trap failure Sept. 29 – Oct. 1 (high water event)
2014	Lower Mill Creek	Aug. 19, 13:30	Oct. 21, 12:00	1	61	Trap failure Sept. 19 (high water event)
	Upper Mill Creek	Sept. 16, 14:30	Oct. 22, 11:45	0	36	Fish passage may have been possible
	South Castle River	Aug. 20, 15:00	Oct. 20, 13:15	1	59	Pulled conduit Sept. 24 – 25 (high flows)
	Carbondale River	Aug. 19, 13:30	Oct. 20, 12:15	0	61	–

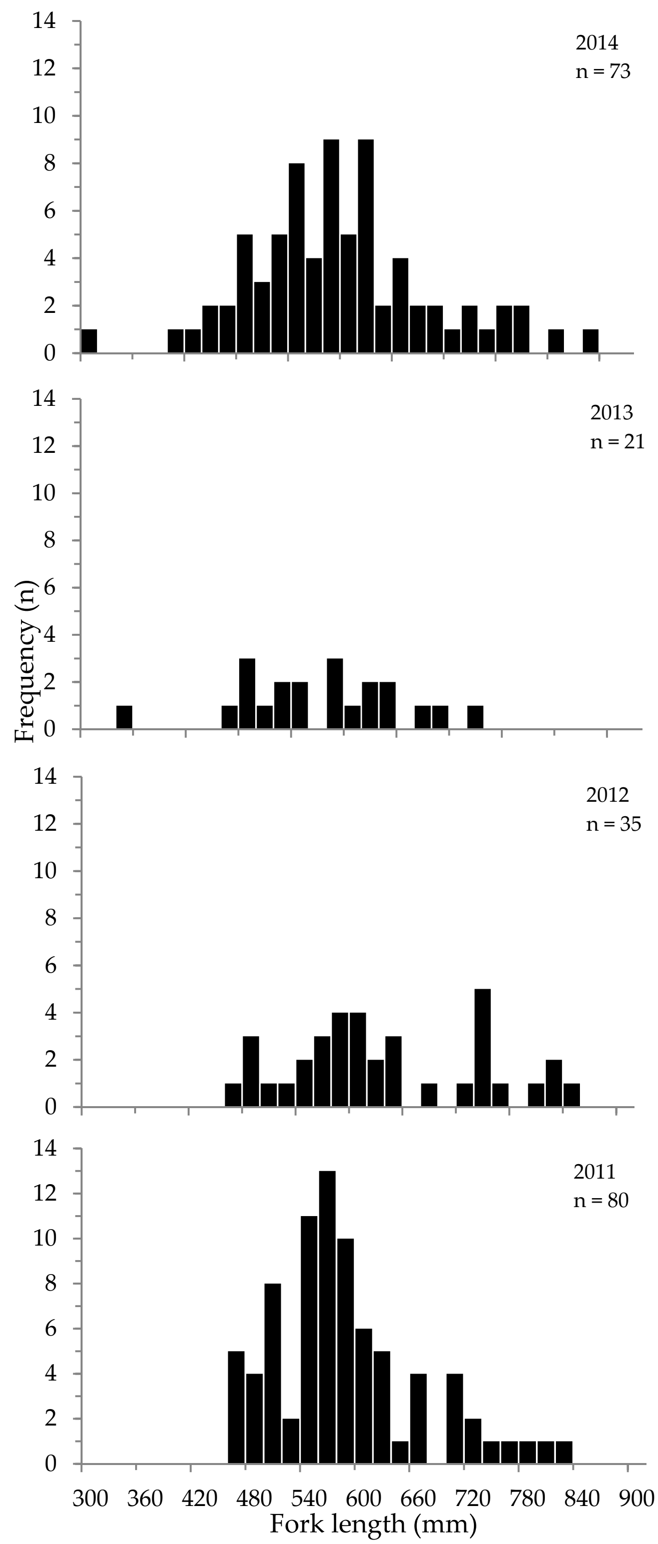
Appendix 3. Fish direction of movement schematic denoting the scanner array and upper trap in Mill Creek, 2012 – 2014. Example shown of fish swimming downstream between antennae before entering trap.



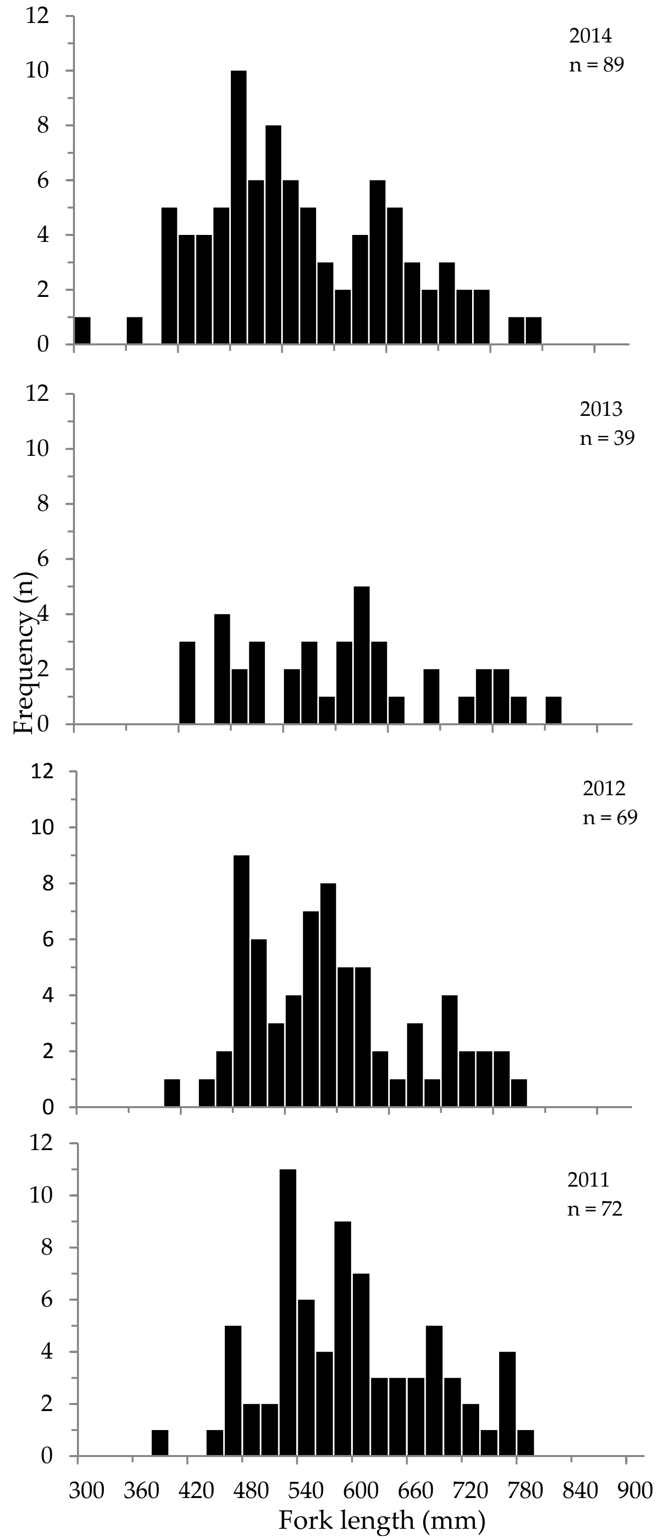
Appendix 4. Spawning habitat categories used during redd counts in the Castle River drainage, 2011 – 2014.

Instream location	Substrate type (mm)	Cover	Stream type
Left-upstream bank	Organic fines (<0.06)	No cover	Run
Mid-channel	Sand (0.07 – 1)	Beneath large woody debris	Riffle
Right-upstream bank	Fine gravel (2 – 15)	Undercut bank	Pool
	Coarse gravel (16 – 63)	Beneath vegetation	
	Cobbles (64 – 249)		
	Boulder (>250)		

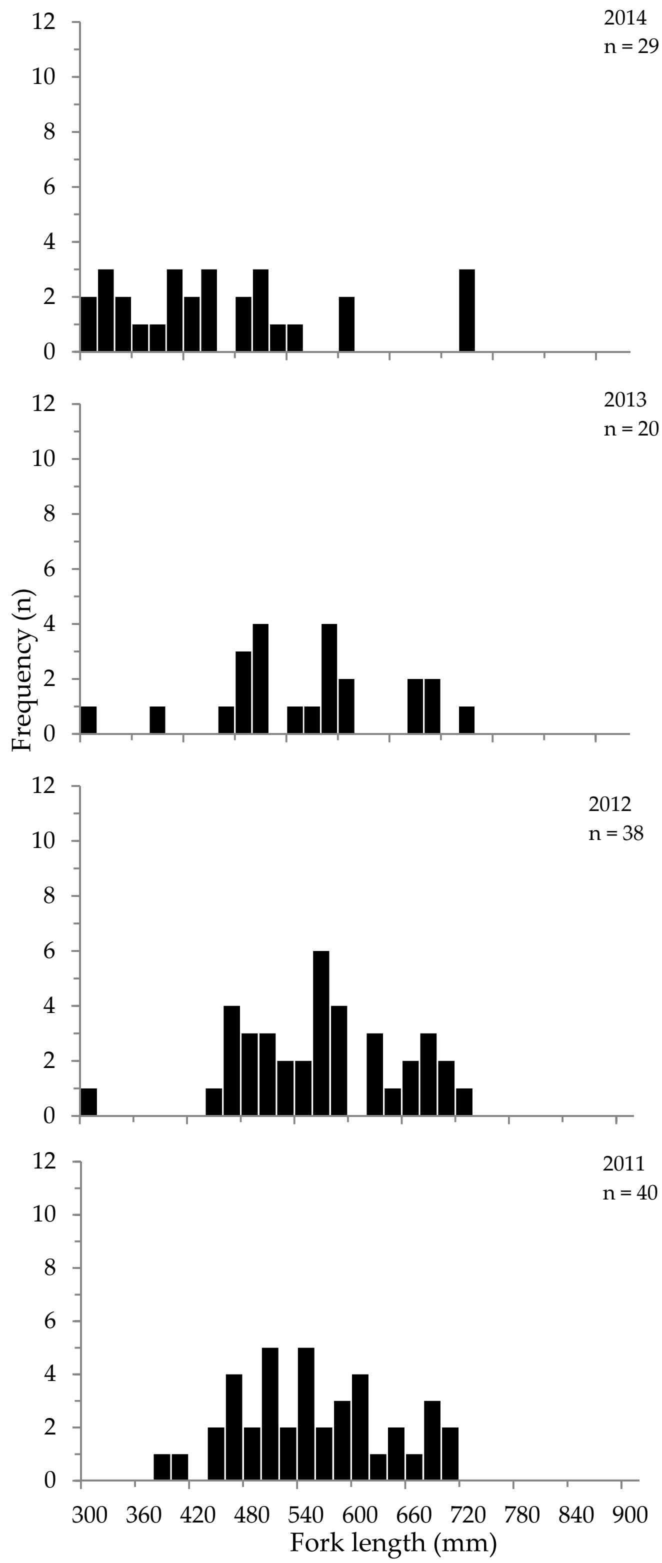
Appendix 5. Length-frequency distribution of bull trout caught in the South Castle River trap, 2011 – 2014.



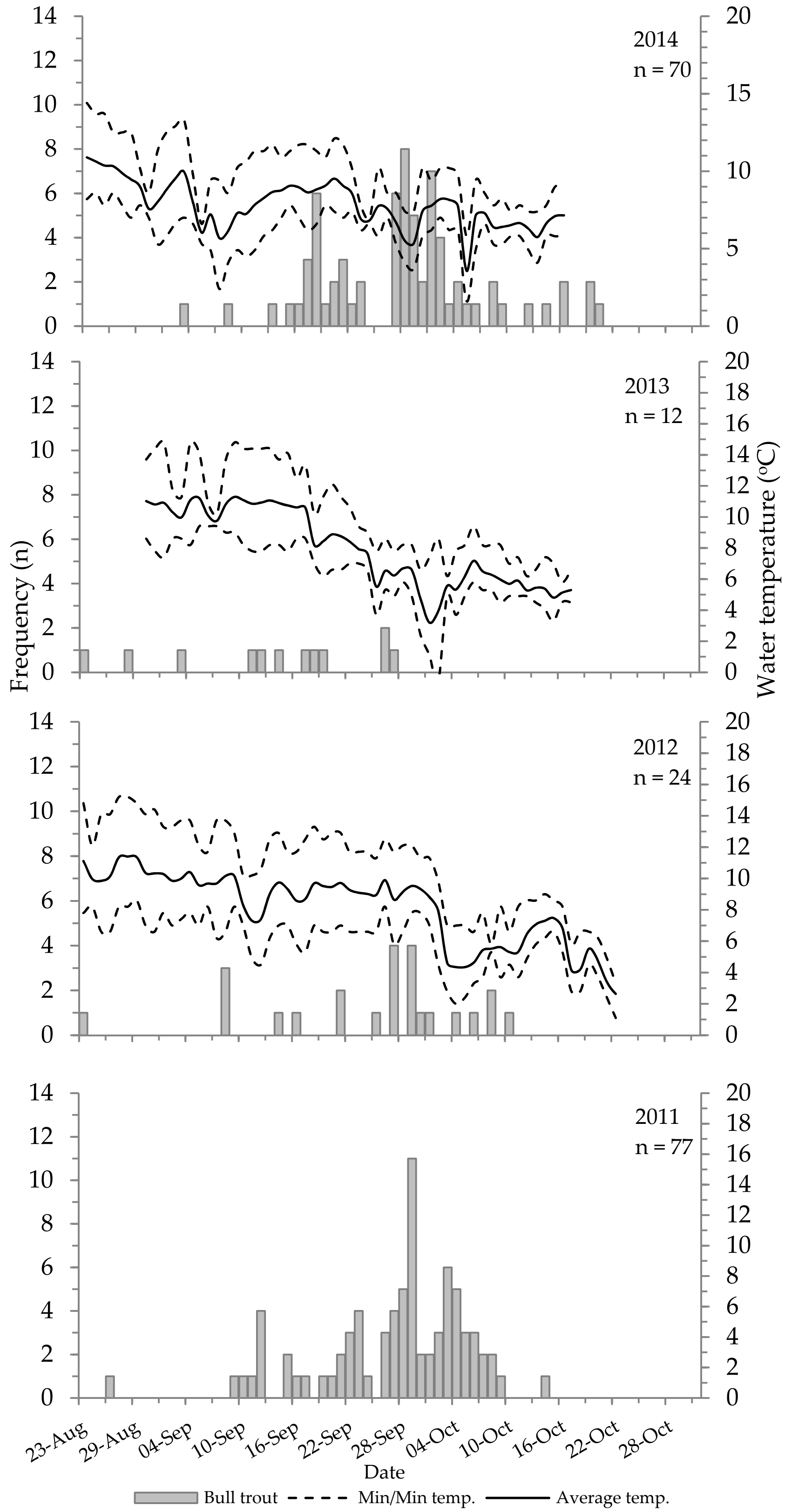
Appendix 6. Length-frequency distribution of bull trout caught in the Carbondale River trap, 2011 – 2014.



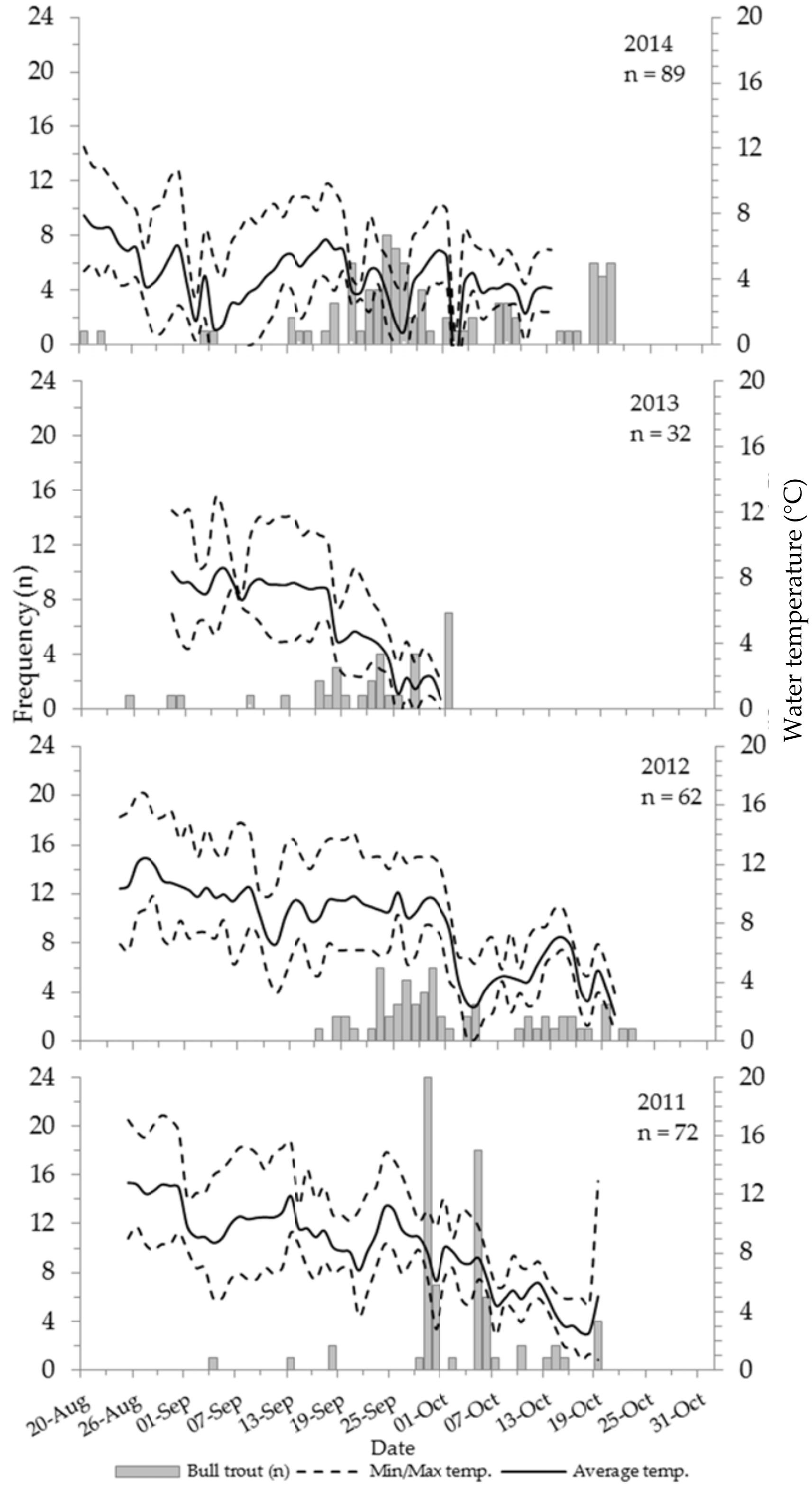
Appendix 7. Length-frequency distribution of bull trout caught in the Mill Creek traps (upper and lower), 2011 – 2014.



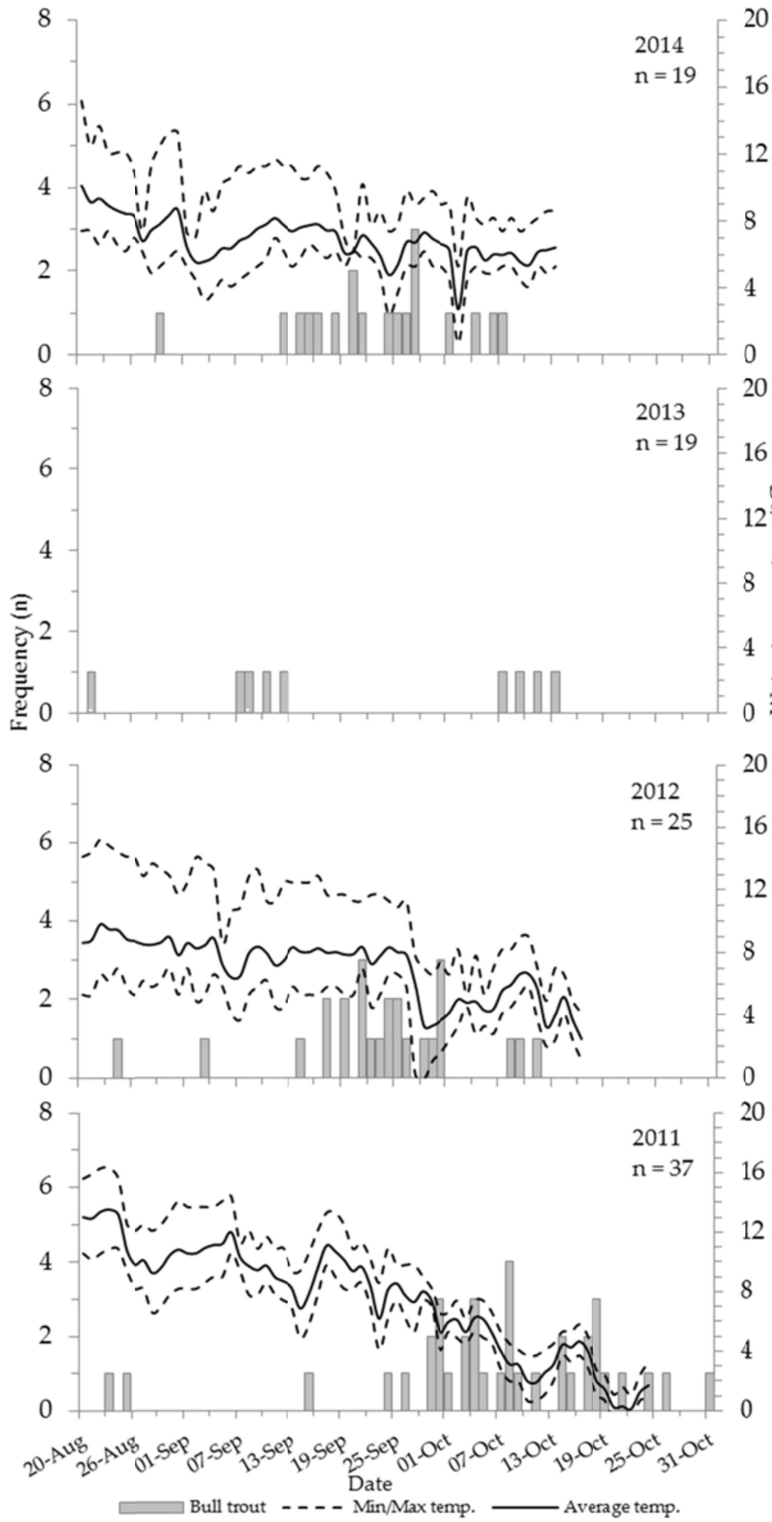
Appendix 8. Timing of the post-spawn migration of bull trout and daily average water temperatures in South Castle River, 2012 – 2014.



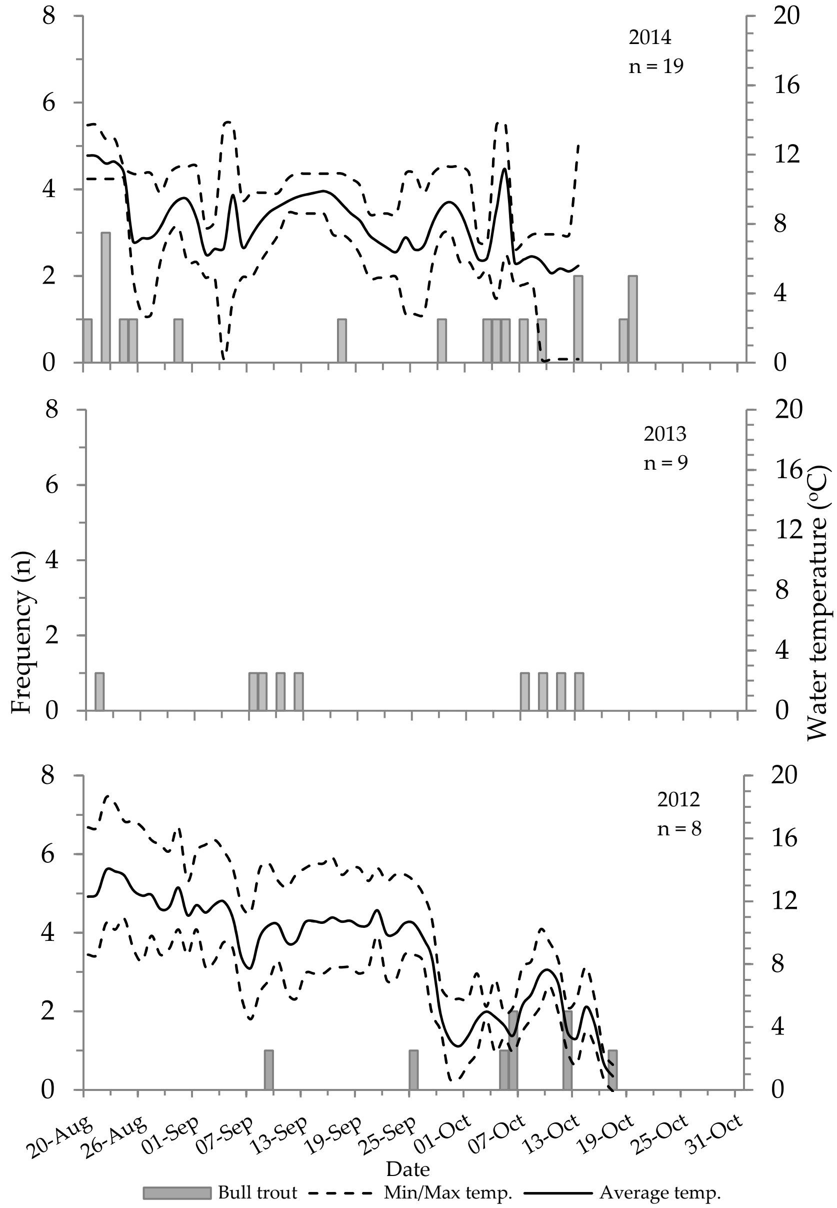
Appendix 9. Timing of the post-spawn migration of bull trout and daily average water temperatures in Carbondale River, 2011 – 2014.



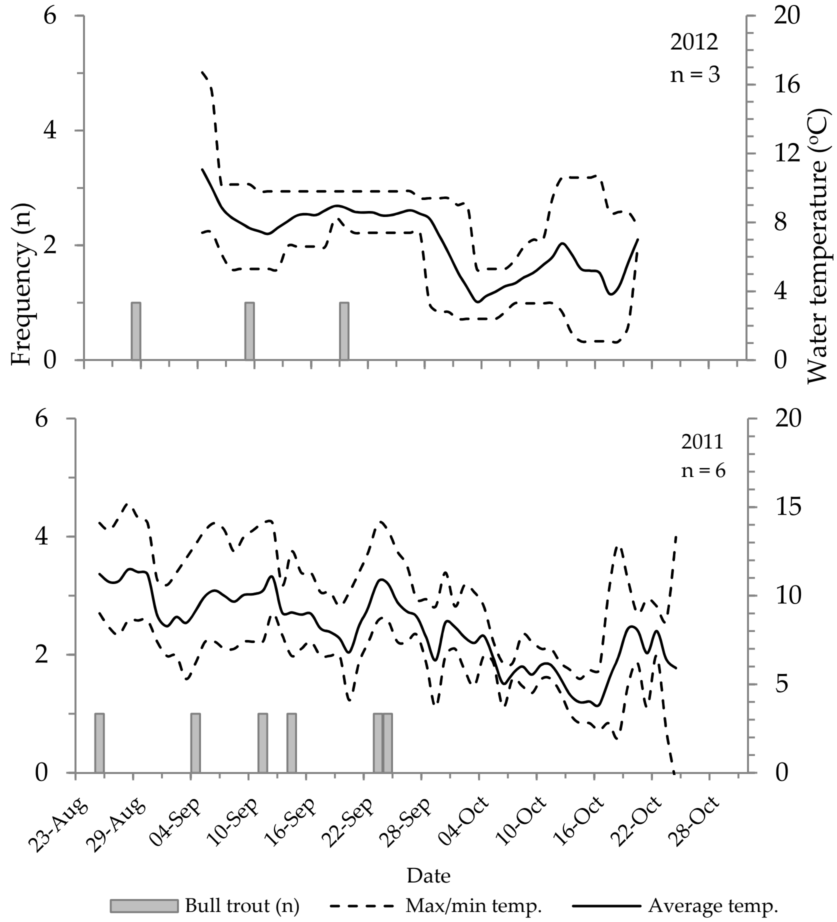
Appendix 10. Timing of the post-spawn migration of bull trout and daily average water temperatures in upper Mill Creek, 2011 – 2014.



Appendix 11. Timing of the post-spawn migration of bull trout and daily average water temperatures in lower Mill Creek, 2012 – 2014.



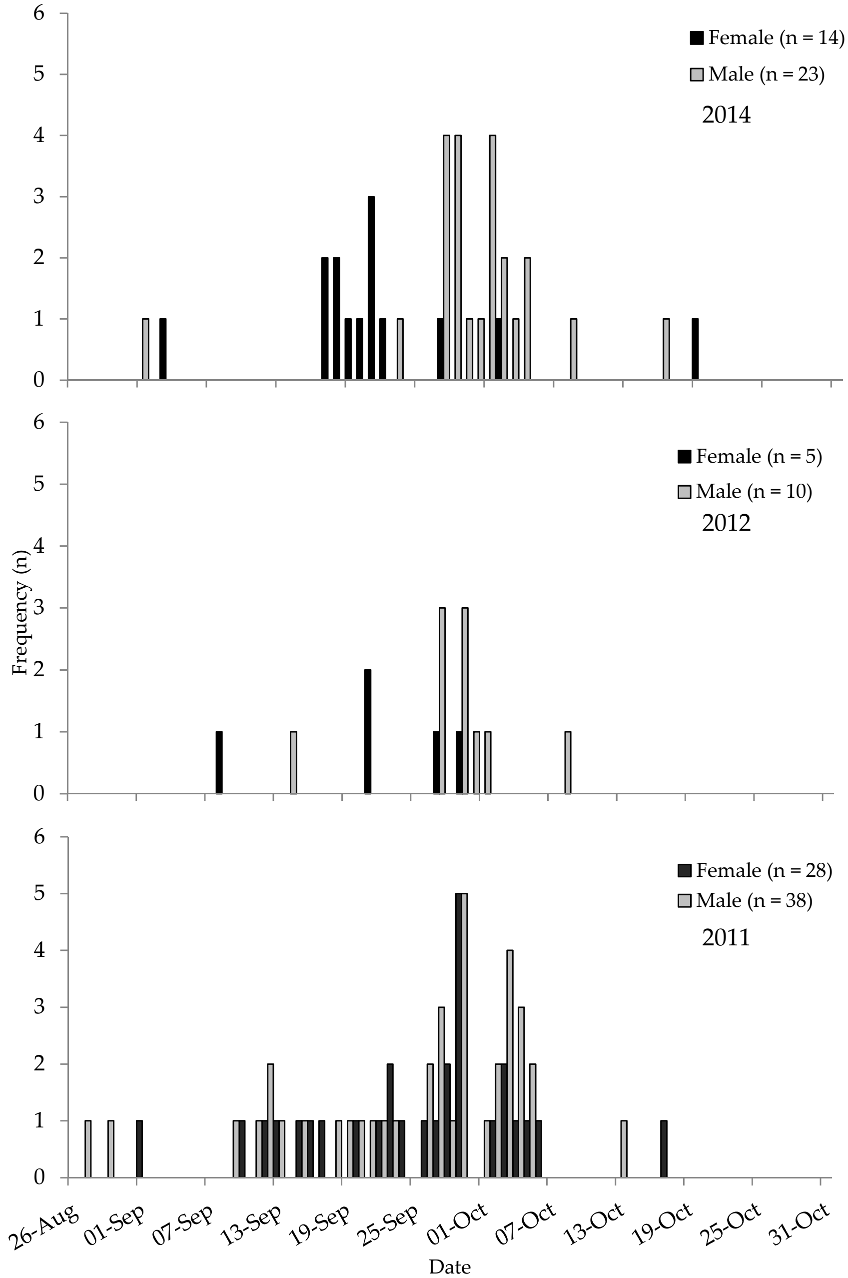
Appendix 12. Timing of the post-spawn migration of bull trout and daily average water temperatures in West Castle River, 2011 and 2012.



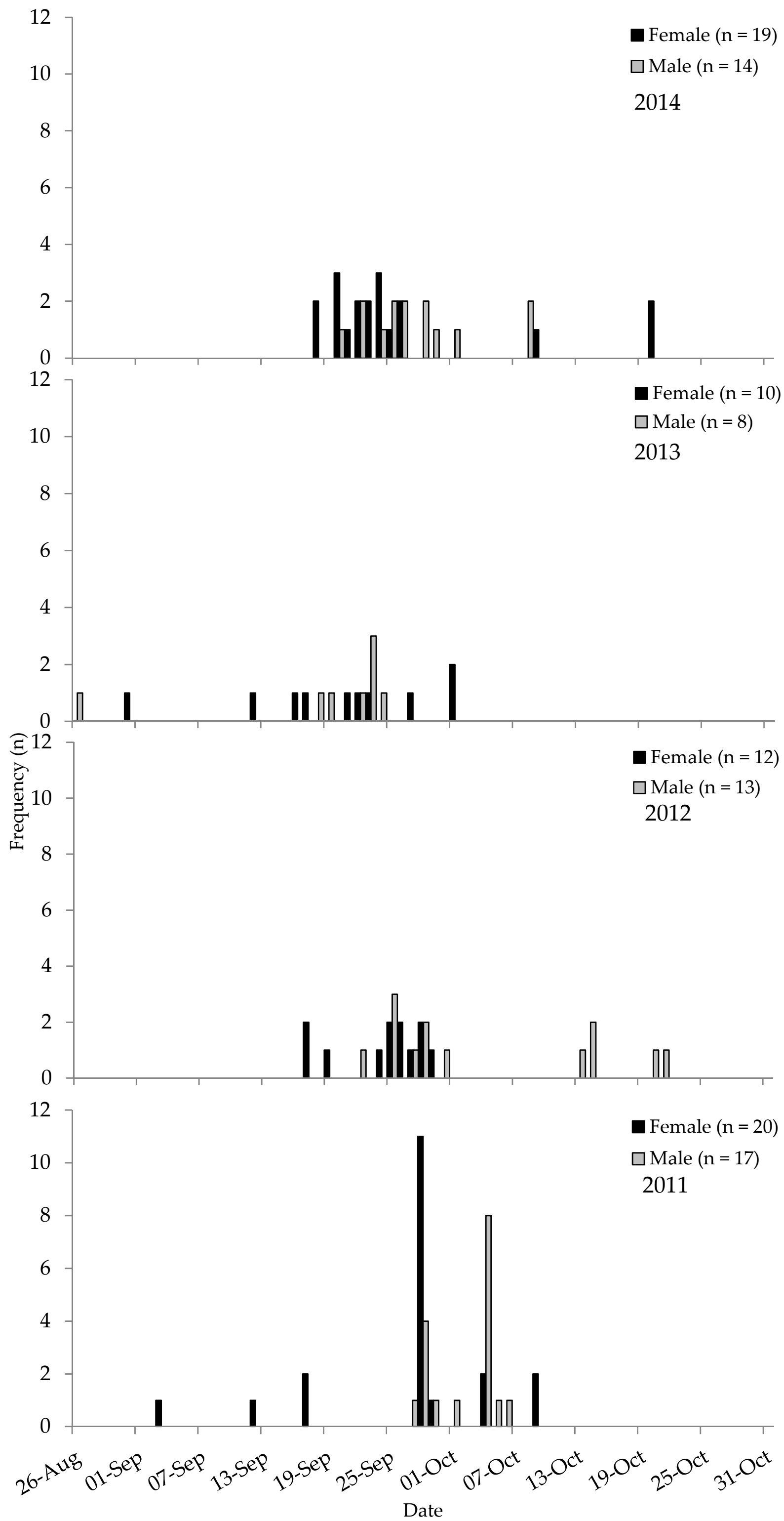
Appendix 13. Sex ratios of post-spawn bull trout captured in fish traps in the Castle River drainage, 2011 – 2014.

Waterbody	Sex	2011		2012		2013		2014	
		n	%	n	%	n	%	n	%
Mill Creek									
	Male	11	27.5	18	47.4	9	40.9	8	27.6
	Female	7	17.5	5	13.2	6	27.3	3	10.3
	Undetermined	22	55.0	15	39.3	7	31.8	18	62.1
	Total	**40**		**38**		**22**		**29**	
Carbondale River									
	Male	17	23.3	14	20.3	9	23.1	21	23.6
	Female	23	31.5	20	29.0	16	41.0	22	24.7
	Undetermined	33	45.2	35	50.7	14	35.9	46	51.7
	Total	**73**		**69**		**39**		**89**	
South Castle River									
	Male	31	38.8	20	57.1	7	33.3	27	36.0
	Female	27	33.8	5	14.3	8	38.1	15	20.0
	Undetermined	22	27.4	10	28.6	6	28.6	33	44.0
	Total	**80**		**35**		**21**		**75**	

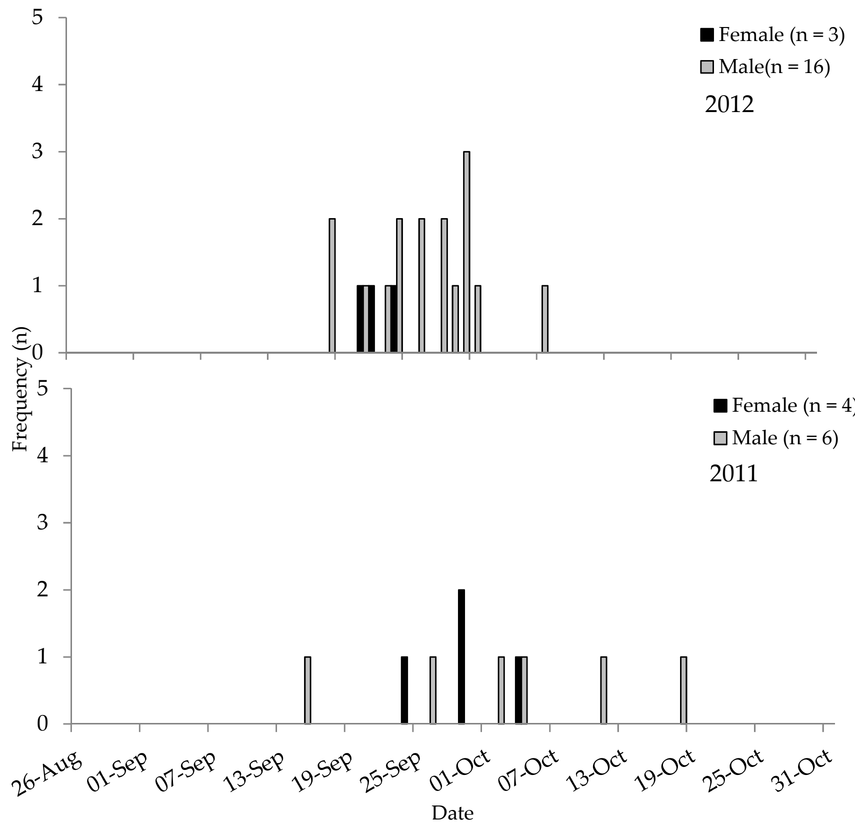
Appendix 14. Post-spawn migration timing of bull trout by gender in South Castle River; fish of unknown gender excluded from comparison.



Appendix 15. Post-spawn migration timing of bull trout by gender in Carbondale River; fish of unknown gender excluded.



Appendix 16. Post-spawn migration timing of bull trout by gender in upper Mill Creek; fish of unknown gender excluded from comparison.



Appendix 17. Bull trout redd dimensions in the Castle River drainage, 2011 to 2014. Abbreviation: LWD = large woody debris.

Waterbody	Year	(n)	Avg. redd length (cm)	Avg. redd width (cm)	Avg. redd depth (cm)	Substrate type (%)			Cover type (%)				Stream type (%)		
						Fine gravel (2 – 15 mm)	Coarse gravel (16 – 63 mm)	Cobble (64 – 249 mm)	No cover	LWD	Vegetation	Undercut bank	Run	Riffle	Pool
S Castle River	2014	44	194.1 ± 88.1 (80 – 600)	105.8 ± 38.1 (40 – 270)	41.3 ± 16.2 (20 – 90)	0	95.8	4.2	39.6	31.2	29.2	0	87.5	12.5	0
	2013	10	105 ± 23.8 (80 – 160)	62 ± 15.7 (40 – 80)	40 ± 16.2 (20 – 80)	10	90	0	70	30	0	0	100	0	0
	2012	126	161.3 ± 53.2 (80 – 380)	71.9 ± 26.0 (30 – 180)	39.5 ± 11.7 (20 – 90)	27.9	54.4	17.7	59.6	34.6	4.4	1.4	89	11	0
	2011	97	150.8 ± 67.6 (50 – 500)	69.3 ± 22.6 (40 – 160)	44 ± 16.8 (20 – 110)	93.9	4.1	2	71.4	22.5	6.1	0	90.8	5.1	4.1
Mill Creek	2014	72	143.5 ± 35.3 (65 – 230)	61.0 ± 14.9 (30 – 110)	43.0 ± 12.0 (20 – 75)	19.4	63.9	16.7	66.7	24.9	4.2	4.2	52.8	43	4.2
	2013	7	146.6 ± 50.3 (70 – 310)	73.3 ± 24.8 (35 – 150)	43.6 ± 13.8 (30 – 50)	13.7	86.3	0	49	35.3	11.8	3.9	86.3	7.8	5.9
	2012	81	144.1 ± 43.1 (80 – 270)	64.9 ± 23.6 (30 – 160)	31.6 ± 9.1 (20 – 70)	21.4	78.6	0	70.2	14.3	14.3	1.2	95.2	4.8	0
	2011	66	132.4 ± 50.7 (60 – 90)	61.6 ± 19.2 (30 – 120)	35.0 ± 9.8 (20 – 75)	51.5	0	48.5	60.6	34.8	4.5	0	77.3	22.7	0
Gardiner Creek	2014	35	168.9 ± 53.7 (90 – 300)	81.1 ± 25.2 (40 – 150)	37.9 ± 12.1 (20 – 65)	0	86.8	13.2	55.3	39.5	5.2	0	57.9	39.5	2.6
	2013	7	157.1 ± 59.9 (90 – 280)	64.3 ± 34.7 (40 – 140)	39.0 ± 7.3 (30 – 500)	57.1	42.9	0	85.7	14.3	0	0	85.7	14.3	0
	2012	55	148.3 ± 61.2 (80 – 320)	62.3 ± 23.0 (30 – 120)	27.2 ± 7.8 (15 – 60)	9.1	76.4	14.5	61.8	12.7	23.6	1.8	96.4	3.6	0
	2011	46	165.2 ± 60.0 (80 – 320)	71.2 ± 23.5 (40 – 150)	28.9 ± 7.5 (17 – 50)	89.4	8.5	2.1	68.1	19.1	8.5	4.3	91.5	6.4	2.1
N Lost Creek	2014	31	175.7 ± 50.3 (120 – 330)	85.3 ± 27.2 (45 – 150)	38.8 ± 10.6 (20 – 60)	44.7	55.3	0	44.8	42.1	10.5	2.6	76.3	21.1	2.6
	2013	26	170.2 ± 45.7 (100 – 250)	66.9 ± 21.5 (30 – 130)	39.0 ± 9.4 (20 – 55)	0	74.2	25.8	61.3	25.8	9.7	3.2	80.7	19.3	0
	2012	15	148.3 ± 40.3 (70 – 200)	61.0 ± 17.8 (30 – 90)	34.3 ± 6.5 (20 – 50)	6.3	93.8	0	50	50	0	0	93.8	0	6.3
	2011	24	130.0 ± 35.9 (90 – 230)	57.0 ± 12.9 (30 – 80)	32.7 ± 7.7 (20 – 50)	66.7	33.3	0	54.2	41.7	4.2	0	87.5	0	12.5

Appendix 17. Continued.

Waterbody	Year	(n)	Avg. redd length (cm)	Avg. redd width (cm)	Avg. redd depth (cm)	Substrate type (%)			Cover type (%)				Stream type (%)		
						Fine gravel (2 – 15 mm)	Coarse gravel (16 – 63 mm)	Cobble (64 – 249 mm)	No cover	LWD	Vegetation	Undercut bank	Run	Riffle	Pool
S Lost Creek	2014	1	–	–	–	–	–	–	–	–	–	–	–	–	–
	2013	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	2012	37	138.0 ± 42.7 (80 – 250)	65.4 ± 24.1 (25 – 120)	25.7 ± 5.9 (15 – 40)	0	75.6	24.4	65.9	34.1	0	0	68.3	31.7	0
	2011	15	143.7 ± 39.2 (70 – 210)	65.0 ± 14.5 (40 – 90)	33.5 ± 8.2 (20 – 50)	86.7	0	13.3	93.3	0	0	6.7	100	0	0
W Castle River	2014	13	185.4 ± 73.3 (100 – 300)	104.6 ± 23.3 (60 – 140)	45.4 ± 10.5 (35 – 65)	0	100	0	92.9	0	7.1	0	92.9	7.1	0
	2013	7	155 ± 66.3 (90 – 250)	64.3 ± 34.7 (40 – 140)	39.0 ± 7.3 (30 – 50)	0	80	20	100	0	0	0	90	0	10
	2012	9	165.6 ± 62.5 (80 – 270)	76.7 ± 19.4 (50 – 110)	45.0 ± 14.8 (30 – 120)	0	100	0	80	20	0	0	100	0	0
	2011	26	129.6 ± 31.8 (80 – 190)	68.5 ± 18.3 (40 – 110)	47.7 ± 18.0 (30 – 120)	84.6	3.8	11.5	96.2	3.8	0	0	30.8	69.2	0
Lost Creek	2014	1	–	–	–	–	–	–	–	–	–	–	–	–	–
	2013	0	–	–	–	–	–	–	–	–	–	–	–	–	–
	2012	14	133.9 ± 46.1 (60 – 220)	56.8 ± 18.8 (25 – 100)	29.9 ± 8.1 (20 – 50)	7.1	78.6	14.3	85.7	0	14.3	0	35.7	57.1	7.1
	2011	5	174.0 ± 36.5 (130 – 190)	80.0 ± 14.1 (70 – 100)	29.0 ± 7.4 (20 – 40)	100	0	0	80	20	0	0	100	0	0

Appendix 18. Anecdotal bull trout spawning-stream concerns.

Off-highway vehicles (OHV) use and random-access camping adjacent to bull trout spawning beds were common in all streams throughout the drainage. These activities open access to these sensitive spawning areas. Uncontrolled stream crossings also were common throughout most spawning streams in the drainage. In these spawning streams, OHV stream crossings intersect the spawning beds likely because of the stream's low gradient and low velocity. We documented several active spawning beds immediately at these stream crossings where redds were driven over and damaged. Spawning beds in the South Castle River were greatly affected by OHV activities as there were numerous uncontrolled stream crossings throughout main spawning areas. In all four years of spawning surveys we observed several OHV tracks running continuously up the stream channel for up to 2 km, damaging bull trout redds. We observed the same behaviour in the West Castle River, North Lost Creek and Gardiner Creek. Evidence of illegal fish harvest was observed over the duration of the study. We observed entrails of two large bull trout immediately downstream of the trap in 2012. Blackburn (2010) observed two large severed bull trout heads adjacent to a heavily used random-access camp area along the West Castle River.

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