Slocan Lake Bull Trout Redd Counts – 2014

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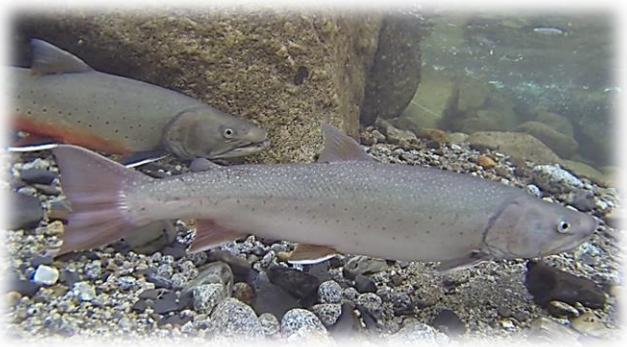

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EXECUTIVE SUMMARY

This report summarizes the results of the second year of study carrying out adfluvial Bull Trout redd counts on all accessible tributaries to Slocan Lake for the Fish and Wildlife Compensation Program (FWCP) in Fall 2014. The Slocan Lake tributaries are well suited to the redd survey method due to their size and accessibility. Prior to the redd surveys, each of the tributaries feeding into Slocan Lake was visited by boat and assessed for the presence of barriers and obstructions at the creek mouth that would preclude spawner access. Several potential tributaries were ruled out for further survey once barriers were identified. The remaining creeks were surveyed in late September and early October to count redds and spawning fish. Redd surveys were conducted in Carpenter, Dennis, Gwillim, Hicks, Hoben, Nemo, Shannon, Sharp, Silverton, Springer, Wee Sandy, Wilson, and Wragge Creeks to estimate adult abundance and determine the relative contribution of individual streams to the Slocan Lake Bull Trout population. Slocan Lake Bull Trout or redds were found in Silverton, Wilson, Shannon, Carpenter and Sharp Creeks.

During surveys of all study streams, 158 redds and 35 Bull Trout were counted. Of the observed fish, 20 were female of which 4 were unspawned, 14 were male and one was of unknown sex. Total redd counts and unspawned female counts were used to estimate Bull Trout spawner escapements for each stream using an expansion factor of 2.4. The escapement was estimated at 389 Bull Trout for the 2014 spawning season as compared to the escapement estimate of 194 Bull Trout for the 2013 spawning season. Since the spawning escapement estimated is less than 500 fish, the Slocan Lake Bull Trout population continues to be ‘At Risk’ as designated in the provincial species status summary report.

In 2014, Silverton Creek contained 78.4% of all redds within the potential Bull Trout spawning habitat, Wilson Creek contained 11.1%, Shannon Creek contained 6.8%, Carpenter Creek contained 3.1% and Sharp Creek contained 0.6% of the Bull Trout redds. In 2013, approximately 90.0% of the Bull Trout spawning occurred in Silverton Creek and the remaining 10.0% occurred in the Wilson Creek drainage. This geographic pattern was similar in 2014 highlighting the critical importance of Silverton Creek as the mainstay for Bull Trout recruitment in this system. This is especially important given current plans for developments in the Silverton Creek area. In both years, redd densities were highest in upstream reaches below the migration barriers, while lower reaches near Slocan Lake contained few or no redds.

ACKNOWLEDGEMENTS

Field and technical support during this work was provided by a number of individuals who ensured the project's success: **Fish and Wildlife Compensation Program:** Trevor Oussoren and Crystal Klym; **Tarala Tech:** Clint Tarala; **AMEC, Foster, Wheeler**: Crystal Lawrence; **Pavan and Associates:** Gary Pavan.

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INTRODUCTION

Slocan Lake Bull Trout (*Salvelinus confluentus*) have a typical adfluvial life history characterized by spawning and rearing in major tributaries for the first 1-4 years of life, and adult rearing in the Lake. Bull Trout are a recreationally important and frequently caught sport fish in Slocan Lake, yet their spawning locations and population size have not been an area of research focus. Hydro-electric development in the Columbia basin likely affected the movement patterns of Bull Trout into and out of Slocan Lake and its tributaries, yet without knowledge of the basic life history and trends of this population, it is difficult to determine risks or compensation opportunities.

Bull Trout are provincially blue-listed and their conservation is a priority to the province of BC. Currently the BC Fishing Regulations allow a harvest of one Bull Trout a day per person over 30 cm in Slocan Lake, yet it is unknown whether this harvest rate is sustainable. The Provincial Conservation Status of Bull Trout in the Slocan Valley was classified as a C2 or "At Risk" in 2011 when it was estimated that between 200 and 500 spawning adults existed and based on estimated habitat, exploitation and competition (Hagen and Decker 2011). It was also determined in the provincial species status report that significant declines likely occurred in the Slocan population following the loss of connectivity with adult rearing habitats in the lower Kootenay and Columbia systems following hydroelectric development in the early 1990s (Hagen and Decker 2011; Hirst 1991).

Redd surveys are useful for providing an index of the abundance of Bull Trout spawners and potential responses of the population to various mitigations and enhancement projects. The study on Slocan Lake Bull Trout began as a pilot program in 2013 with four main tributaries assessed. 2014 was the first year of a full study with all accessible tributaries surveyed for barriers, redds and fish. The escapement estimate in the pilot study year was ~194 fish. This estimate incorporated the survey data from the four main tributaries and an extrapolated estimate using the lineal distance of potentially available habitat to make up for the areas that were not surveyed.

The size of the Slocan Lake Bull Trout population is at the low end of the 'At Risk' designation category. The designation is not just based on abundance, but also on several factors including trends in numbers, habitat quality and redundancy as well as exploitation rates. The next and highest level of risk is 'High Risk' which is defined as 'extremely limited and/or rapidly declining numbers, range, and/or habitat, making the bull trout in this core area highly vulnerable to extirpation' (Hagen and Decker 2011).

In an assessment of the impacts of dam construction and flow regulation on Bull Trout populations throughout the Canadian portion of the Columbia River watershed, Hagen (2008) identified the Slocan Bull Trout as a population of high conservation concern, and recommended that these fish be given priority in future management. This recommendation was based upon the fact that the Slocan population met major criteria with respect to known threats to population perseverance for this species in their native range, including: isolation from other populations and from productive rearing habitats, small population size, possible evidence of negative population growth, unfavorable

thermal regimes in remaining habitats, and encroachment and competition by native and non-native species.

The objective of this study was to complete redd count surveys of all potential Bull Trout spawning tributaries draining into Slocan Lake, with the primary goal of estimating spawner distribution and abundance in this population of Bull Trout. The primary benefits of this project are to improve the basis for establishing potential management reference points which signal: 1) the need for changes in management to meet conservation goals, 2) opportunities for increased recreational fishery benefits, and 3) opportunities for restoration and enhancement. In this report, we describe the second year's results of Slocan Lake Bull Trout redd and spawner counts for all available Bull Trout spawning habitat for this 'At Risk' population of Bull Trout.

STUDY AREA

Slocan Lake is situated between the Valhalla and the Selkirk Mountain Ranges in the West Kootenay Region of British Columbia, and is approximately 39 km long and has an area of 69 km² (Figure 1). The lake is drained by the Slocan River, which flows in a southerly direction for approximately 58 km from the lake to the confluence with the Kootenay River. Elevation in the basin ranges from 480 meters at the Slocan River mouth to 2,800 meters at the height of land in the Selkirk Mountains. Within this elevation range, the system is comprised of two biogeoclimatic zones. At lower elevations, the valley lies within the Interior Cedar-Hemlock zone, while areas in the higher elevations are found within the Engelmann Spruce-Subalpine Fir zone.

We conducted redd surveys in Carpenter, Dennis, Gwillim, Hicks, Hoben, Nemo, Shannon, Sharp, Silverton, Springer, Wee Sandy, Wilson and Wragge Creeks (Table 1). In each stream, the redd survey was initiated at the upstream migration barrier (Figure 1) and extended to the stream mouth or the lake confluence.

Table 1. Geographic information of the surveyed tributaries in the study area.

Gazetted Name	Watershed Code	Total Stream Length (km)	Order	Area (km²)	Region
Carpenter Creek	340-047200-86300	25.80	5th	221	4
Dennis Creek	340-047200-91700-04100	11.35	4th	20.36	4
Gwillim Creek	340-047200-57800	28.07	4th	79.61	4
Hicks Creek	340-047200-91700-13700	7.72	4th	14.13	4
Hoben Creek	340-047200-81300	9.38	3rd	10.49	4
Nemo Creek	340-047200-78500	18.74	4th	70.04	4
Shannon Creek	340-047200-97700	13.76	4th	41.14	4
Sharp Creek	340-047200-86100	8.68	3rd	12.93	4
Silverton Creek	340-047200-82200	21.73	5th	120	4
Springer Creek	340-047200-59900	14.68	3rd	49.66	4
Wee Sandy Creek	340-047200-89600	14.05	4th	55.39	4
Wilson Creek	340-047200-91700	40.40	6th	579	4
Wragge Creek	340-047200-96100	11.37	4th	27.6	4

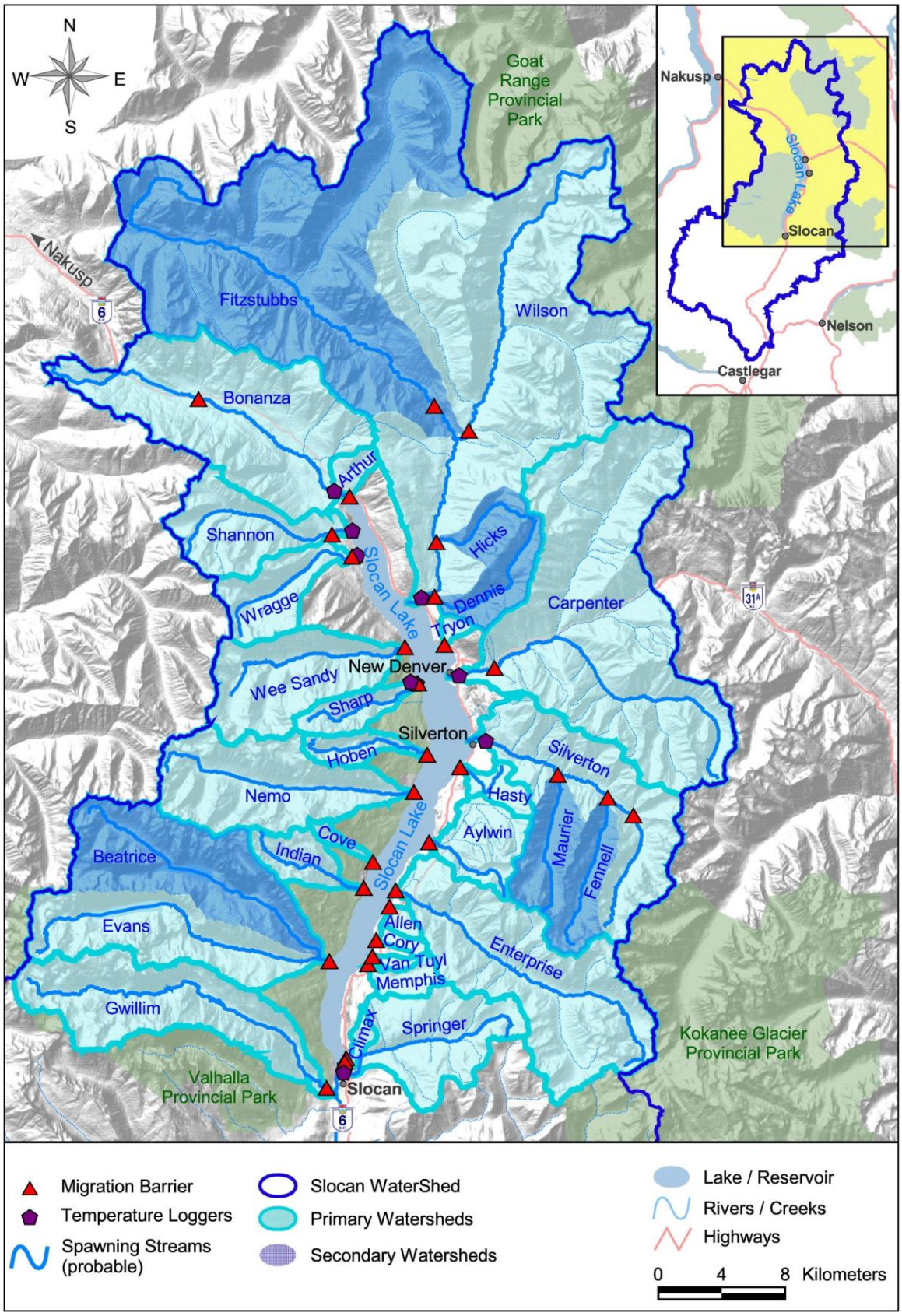

Figure 1. The Slocan Lake study area showing migration barriers to spawning Bull Trout in all tributaries and locations of temperature loggers.

Other fish species present in the watershed include Rainbow Trout (*Oncorhynchus mykiss*), Eastern Brook Trout (*Salvelinus fontinalis*), Kokanee (*Oncorhynchus nerka*),

Burbot (*Lota lota*), Mountain Whitefish (*Prosopium williamsoni*), Largescale Sucker (*Catostomus macrocheilus*), Longnose Sucker (*C. catastomus*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Longnose Dace (*Rhinicthys cataractae*), Umatilla Dace (*Rhinichthys umatilla*), Redside Shiner (*Richardsonius balteatus*), White Sturgeon (*Acipenser transmontanus*), Westslope Cuttroat Trout (*Oncorhynchus clarkii lewisi)* and Sculpin spp. (*Cottus spp.*) (Galena Environmental Ltd. 2011). Natural populations of anadromous Steelhead Trout (*O. mykiss*) and Chinook Salmon (*O. tshawytscha*) were present historically, but were extirpated from the Slocan Watershed in the 1940's as a result of hydroelectric development on the lower Columbia and Kootenay Rivers downstream.

METHODS

Redd Counts

As an index of adult Bull Trout escapement the method of visual counts of redds in the substrate that indicate spawning activity and egg deposition was used (Rieman and Myers 1997; Dunham et al. 2001). Redd counts are one of the least expensive and least invasive of adult population assessment methods and under appropriate conditions, can be precise indicators of abundance (Johnston et al. 2007).

Initial surveys of all tributaries were conducted in early August to confirm the locations of all the upstream migration barriers on the tributaries that had not been surveyed as part of the 2013 pilot study. Redd surveys then began in late September based on timing determined in 2013. Redd surveys were conducted by a crew of two people, each equipped with waders and polarized glasses, who walked downstream from the barriers parallel to one another on either side of the stream. All observed redds and spawners were enumerated, recorded and marked with a handheld GPS device for each survey area. Where possible, the sex and approximate fork length (visual estimate) of individual fish was also recorded and underwater video footage obtained if possible. We assumed that females not associated with redds were unspawned females and would construct redds after the survey was completed. We counted each unspawned female as one redd when estimating the number of redds for each stream. If an index area could not be completed in one day (typically, five kilometers can be surveyed in a day) the survey was resumed the following day.

There are three potential classifications for an excavation found by a survey crew: 1) natural stream scour 2) viable redd, 3) test dig. There are several characteristics that may be present to allow redds to be differentiated from natural scour:

- Circular, dish-shaped excavations in the creek bed material, accompanied by a gravel deposit beginning in the excavated pit and spilling out of it in a downstream direction
- The overall pit is broader than the area where gravel is deposited over the eggs
- A steep pit wall, with perched substrate that can be easily dislodged into the pit
- Bright and clean substrate, and sand deposited in the area of quiet water created by the upstream edge of the pit
- Tail stroke marks or excavation marks around the redd or alongside the front portion of the gravel deposit

Test digs are very similar to redds but are usually smaller in size, with a shorter and narrower mound of gravels around the downstream edge, and have no gravel deposit swept into the pit, which would indicate at least one egg deposition event.

Redd survey dates ranged from September 29th to October 8th (Table 2). Complete surveys from the migration barriers to the mouth were conducted in all creeks listed in Table 2.

Table 2. Redd survey dates for each stream in the study area 2014

Stream	Date Surveyed	Barrier UTM	Distance (km) (Barrier to Mouth)
Carpenter Creek	30-Sept	11 U 475707 5537963	3.34
Dennis Creek	2 Oct	11 U 471944 5542447	0.32
Gwillim Creek	2 Oct	11 U 465131 5511524	0.71
Hicks Creek	2 Oct	11 U 472052 5545883	0.10
Hoben Creek	1 Oct	11 U 471461 5532500	0.12
Nemo Creek	1 Oct	11 U 470632 5530149	0.09
Shannon Creek	1 Oct	11 U 465467 5546352	1.58
Sharp Creek	1 Oct	11 U 470896 5536987	0.04
Silverton Creek	29-30 Sept	11 U 483409 5529352	13.19
Springer Creek	2 Oct	11 U 466275 5513170	0.12
Wee Sandy Creek	1 Oct	11 U 470059 5539265	0.10
Wilson Creek	7-8 Oct	11 U 474092 5552886	14.85
Wragge Creek	1 Oct	11 U 466733 5544963	0.44

Kokanee Surveys

In 2013, the timing of surveys was planned for mid-September so that Bull Trout spawners would still be actively spawning. This was so that fish as well as redds could be observed to confirm use of the creeks in the pilot study. This timing was sufficiently early that Kokanee were still actively spawning in the creeks at the same time so field crews enumerated Kokanee while they were completing their BT surveys and the estimate was considered a reasonable estimate of relative abundance. In 2014, however, the Bull Trout surveys were completed later in the year to be in accord with other censuses throughout the region and in general the Kokanee spawning was completed by the time of survey. Numbers were estimated in Carpenter Creek since Kokanee observed there were still actively exhibiting spawning behavior and a short section of Silverton Creek (from the last bridge to the mouth) was counted in late August when the temperature logger was inspected.

Temperature

Eight Onset TidbiT v2 temperature loggers were deployed in the study area (Table 3). The four loggers in Shannon, Sharp, Springer and Wragge Creeks were set out in August and downloaded in early December. The 4 loggers in Bonanza, Carpenter, Silverton, and Wilson Creeks were deployed in the summer of 2013 and remained deployed in their locations throughout the winter months and were last downloaded in late November, 2014. The loggers recorded the water temperature every 15 minutes and were downloaded in November and December of 2014. Temperature data were imported

into R (Version 3.1.2), inspected for any errors or outliers and plotted for all 2014 data by creek (R Core Team 2014). The logger in Silverton Creek was plotted from its initial deployment in July, 2013 until the most recent download and used for Accumulated Thermal Unit (ATU) calculations to estimate Bull Trout emergence dates.

Table 3. Temperature logger location, deployment and retrieval dates.

Stream	Temperature Logger UTM	Deployment Date	Retrieval Date
Bonanza Creek	11 U 465628 5549120	July 22, 2013	November 21, 2014
Carpenter Creek	11 U 473473 5537503	July 22, 2013	November 21, 2014
Shannon Creek	11 U 466757 5546625	August 5, 2014	December 4, 2014
Sharp Creek	11U 470856 5536977	August 5, 2014	December 4, 2014
Silverton Creek	11U 475163 5533384	July 22, 2013	November 21, 2014
Springer Creek	11U 466317 5512948	August 12, 2014	December 10, 2014
Wilson Creek	11 U 471109 5542398	July 22, 2013	November 21, 2014
Wragge Creek	11 U 467058 5545073	August 5, 2014	December 4, 2014

Escapement Estimate

We searched the literature for studies where redds were counted throughout the entire spawning area within a system, and these counts compared to complete counts of kelts at downstream weirs or resistivity counters (i.e., approximate total escapement). The number of adults (kelts) per redd derived from these studies ranged from 1.0 to 4.3 (Table 4), and averaged approximately 2.4 adults per redd. The average value is approximate since some studies reported only the range in values. To estimate escapement, we used 2.4 adults/redd as an expansion factor.

For the escapement estimate we assumed that all unspawned females not associated with a redd were going to construct a redd. The escapement estimate equation uses total number of *redds* and *unspawned females* multiplied by the *expansion factor (2.4)* (Baxter and Decker 2011, Decker and Hagen 2007) to calculate the total Bull Trout escapement (*N*) for an individual stream. The escapement estimate equation is:

$$N = (redds + unspawned\ females) \times 2.4$$

Table 4. Summary of estimates of adult Bull Trout per redd from other studies of migratory fluvial and adfluvial populations

Method	Spawners per Redd	Reference
Resistivity Counter	2.3	Andrusak 2009 (Kaslo R., 2-yr. avg.)
Resistivity Counter	1.8	Andrusak 2009 (Crawford Cr.)
Weir Counts	1.4-2.1	Baxter and Westover 2000 (Wigwam R.)
Weir Counts	1.7	Baxter and Baxter 2002 (Skookumchuck Cr., 3-yr. avg.)
Mark-recap. & Weir Counts	1.0-2.8	Dunham et al. 2001 (2 streams multi-yr.)
Weir Counts	2.3	Ratliff et al. 1996
n/a	2.1	Sankovich et al. 2003
Weir with Fish Counter	3.5	Taylor and Reasoner 2000
Weir with Fish Counter	4.3	Taylor and Reasoner 2000

RESULTS

Redd Count Surveys

In 2014, redd surveys were conducted from September 29 until October 2 and again on October 7th and 8th in Wilson Creek which was noted to have later spawning in 2013 (Table 2). Water clarity conditions were excellent, and there was no evidence of redd scour prior to the surveys. In total, 35.25 km of stream were surveyed, and 158 redds and 4 unspawned females were observed for all streams combined (Table 5). A total of 35 adult Bull Trout ranging in size from 30 cm to 85 cm were observed during the surveys (Table 6). The total surveyed redds and maps showing the spatial distribution are presented in order of most abundant to least abundant.

Table 5. Total number of Bull Trout redds in surveyed Slocan Lake tributaries 2014.

Tributary	Accessible Length (km)	Number of Unspawned Females	Redd Count
Silverton Creek	13.2	3	124
Wilson Creek	14.9	0	18
Shannon Creek	1.58	1	10
Carpenter Creek	3.34	0	5
Sharp Creek	0.04	0	1
Hoben Creek	0.12	0	0
Nemo Creek	0.09	0	0
Wee Sandy Creek	0.10	0	0
Hicks Creek	0.10	0	0
Springer Creek	0.12	0	0
Gwillim Creek	0.71	0	0
Dennis Creek	0.55	0	0
Wragge Creek	0.44	0	0
Totals	35.25	4	158

Table 6. Bull Trout sex and visually estimated total length in Slocan Lake tributaries 2014.

System	Date	Bull Trout Size (cm)	Sex
Carpenter Creek	September 30, 2014	45	Female
Carpenter Creek	September 30, 2014	65	Male
Shannon Creek	October 1, 2014	50	Female
Shannon Creek	October 1, 2014	55	Male
Shannon Creek	October 1, 2014	45	Unknown
Shannon Creek	October 1, 2014	45	Female
Shannon Creek	October 1, 2014	40	Female*
Silverton Creek	September 29, 2014	70	Male
Silverton Creek	September 29, 2014	50	Female*
Silverton Creek	September 29, 2014	75	Female
Silverton Creek	September 29, 2014	60	Female
Silverton Creek	September 29, 2014	50	Female
Silverton Creek	September 29, 2014	55	Male
Silverton Creek	September 29, 2014	35	Female*
Silverton Creek	September 29, 2014	55	Female*
Silverton Creek	September 29, 2014	75	Male
Silverton Creek	September 29, 2014	70	Male
Silverton Creek	September 29, 2014	80	Male
Silverton Creek	September 29, 2014	50	Male
Silverton Creek	September 29, 2014	75	Male
Silverton Creek	September 29, 2014	45	Male
Silverton Creek	September 29, 2014	60	Female
Silverton Creek	September 29, 2014	40	Male
Silverton Creek	September 29, 2014	30	Female
Silverton Creek	September 29, 2014	50	Male
Silverton Creek	September 29, 2014	60	Female
Silverton Creek	September 29, 2014	40	Female
Silverton Creek	September 29, 2014	60	Male
Silverton Creek	September 29, 2014	40	Female
Silverton Creek	September 29, 2014	45	Female
Silverton Creek	September 29, 2014	30	Female
Silverton Creek	September 30, 2014	40	Female
Silverton Creek	September 30, 2014	40	Female
Wilson Creek	October 7, 2014	85	Male
Wilson Creek	October 7, 2014	80	Female
Mean Size		**54**	

* Unspawned female not associated with a redd.

Silverton Creek

Within the accessible stretch of Silverton Creek (Figure 2) 124 Bull Trout redds were enumerated and 26 spawners were observed including three unspawned females. The redds found in Silverton Creek account for 78% of the total Bull Trout spawning escapement in 2014. The middle section just upstream of Maurier Creek had the highest redd density (Figure 2).

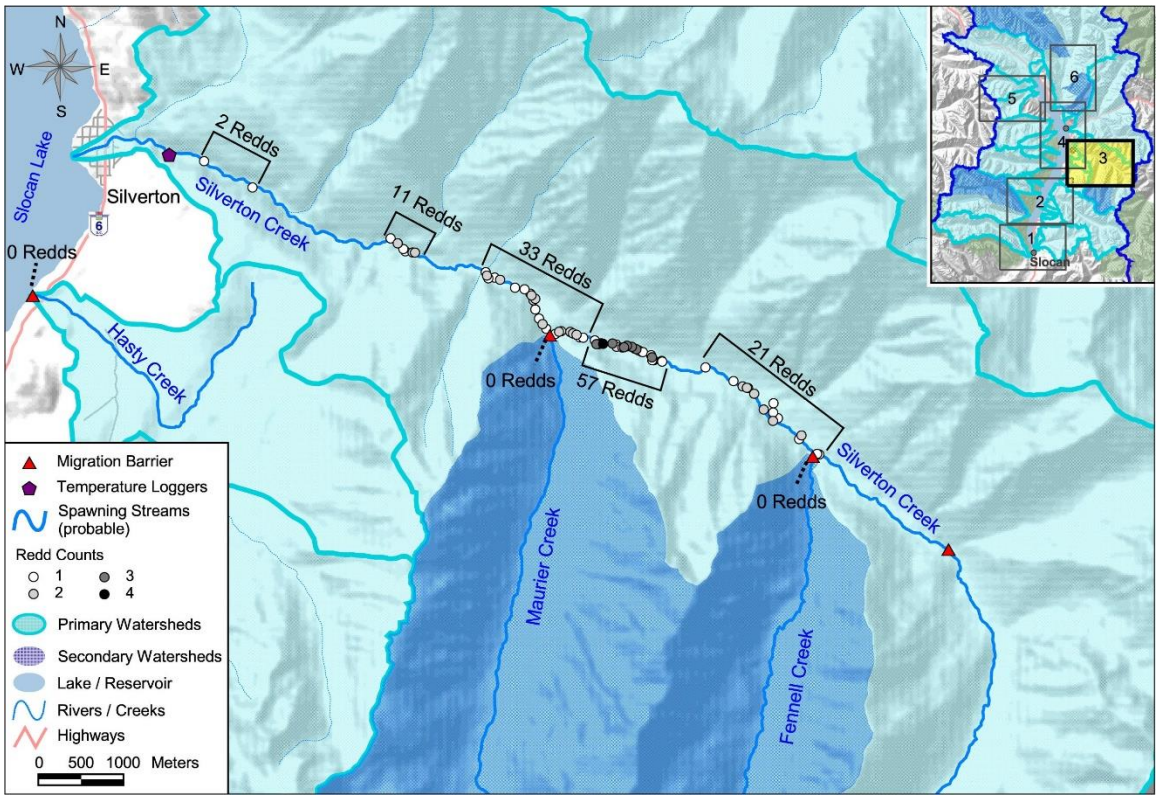

Figure 2. Bull Trout barriers and redd assessment results for Silverton Creek survey area 2014.

Wilson Creek (Dennis and Hicks Creek – tributaries to Wilson)

The redd survey of Wilson Creek (Figure 3) was conducted on October 7-8 from the confirmed barrier to the mouth and the two tributaries of Dennis and Hicks Creeks were surveyed on October 2. Hicks Creek was surveyed for the first time in 2014 and the barrier was confirmed in this survey. We observed eighteen Bull Trout redds in the upper reaches of Wilson Creek mainstem and two adfluvial spawners. No spawners nor redds were observed in Hicks or Dennis Creek (Figures 3 and 5).

Fitzstubbs Creek

Fitzstubbs Creek (Figure 3) was surveyed from the confluence point with Wilson Creek to a point 500m upstream of the confluence. A spot temperature measurement on the date of survey (October 7th) was 10°C. No Bull Trout spawners or redds were observed.

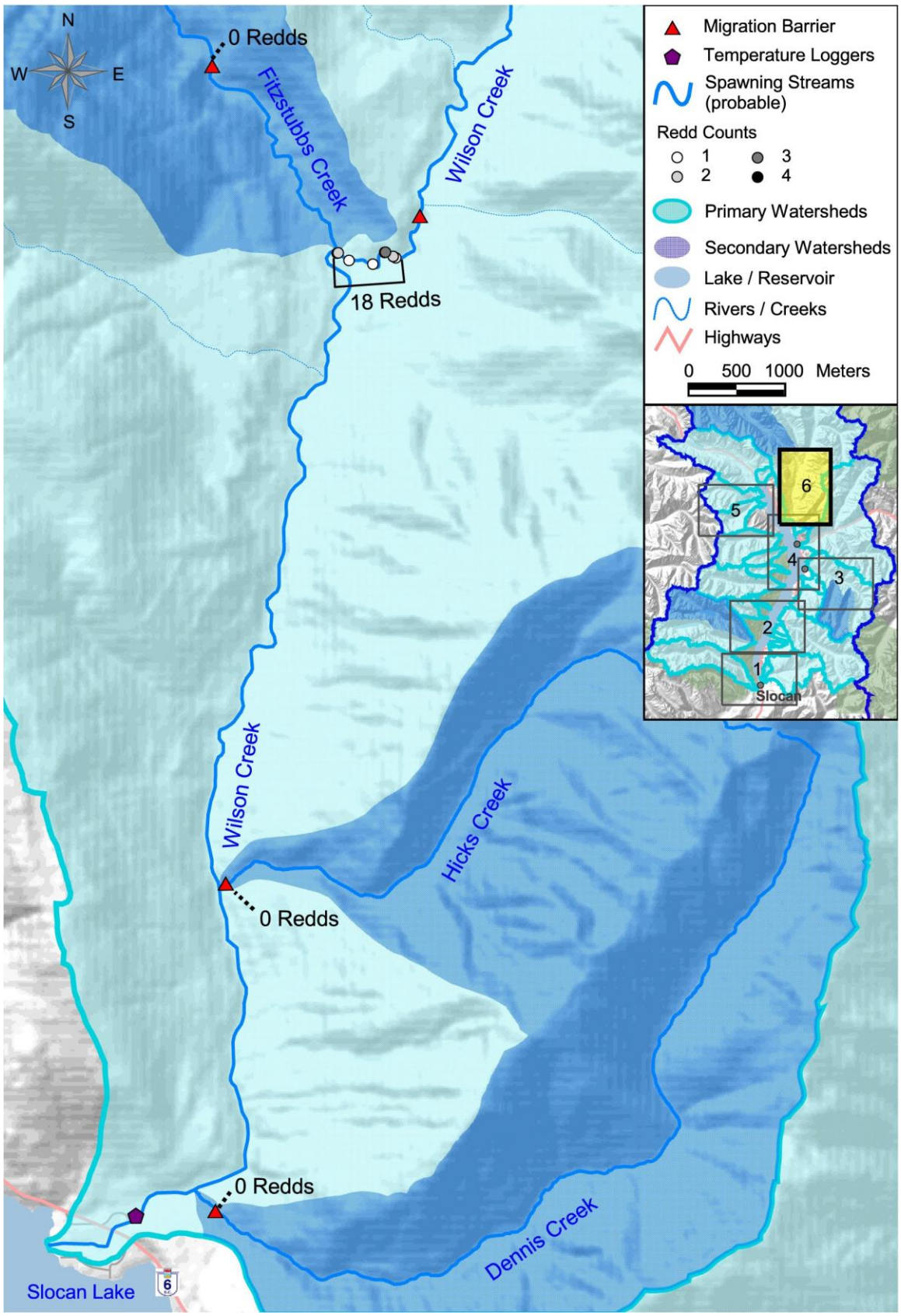

Figure 3. Bull Trout barriers and redd assessment results for Dennis, Hicks and Wilson Creeks for 2014.

Shannon Creek

The survey of Shannon Creek enumerated 10 redds and 5 Bull Trout including 1 unspawned female and identified the location of the barrier (Figure 4). The survey of Wragge Creek found no redds nor Bull Trout and identified the barrier (Figure 4).

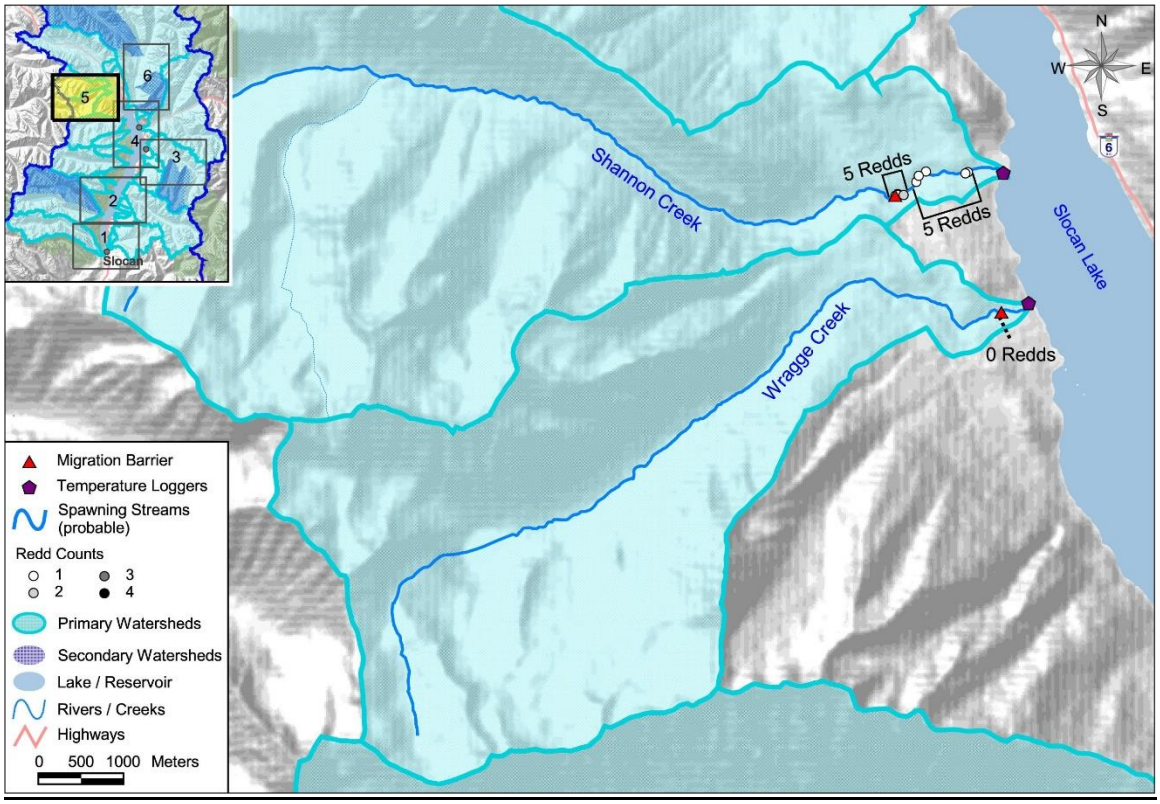

Figure 4. Bull Trout barriers and redd assessment results for the Wragge and Shannon Creek surveys for 2014.

Carpenter Creek

Carpenter Creek (Figure 5) had sufficient water clarity this year to allow a redd survey to occur which was not possible in 2013. Five redds and two Bull Trout were observed from the barrier to the mouth.

Sharp Creek

Sharp Creek had one Bull Trout redd observed (Figure 5).

The remaining creeks either had barriers at the mouth and therefore no access for Bull Trout or had no redds nor spawners observed in them (Figures 2, 6 and 7). Barriers were identified as any obstacle which would prevent fish passage and included large falls, bed loaded log jams, and high gradient shallow creek mouths.

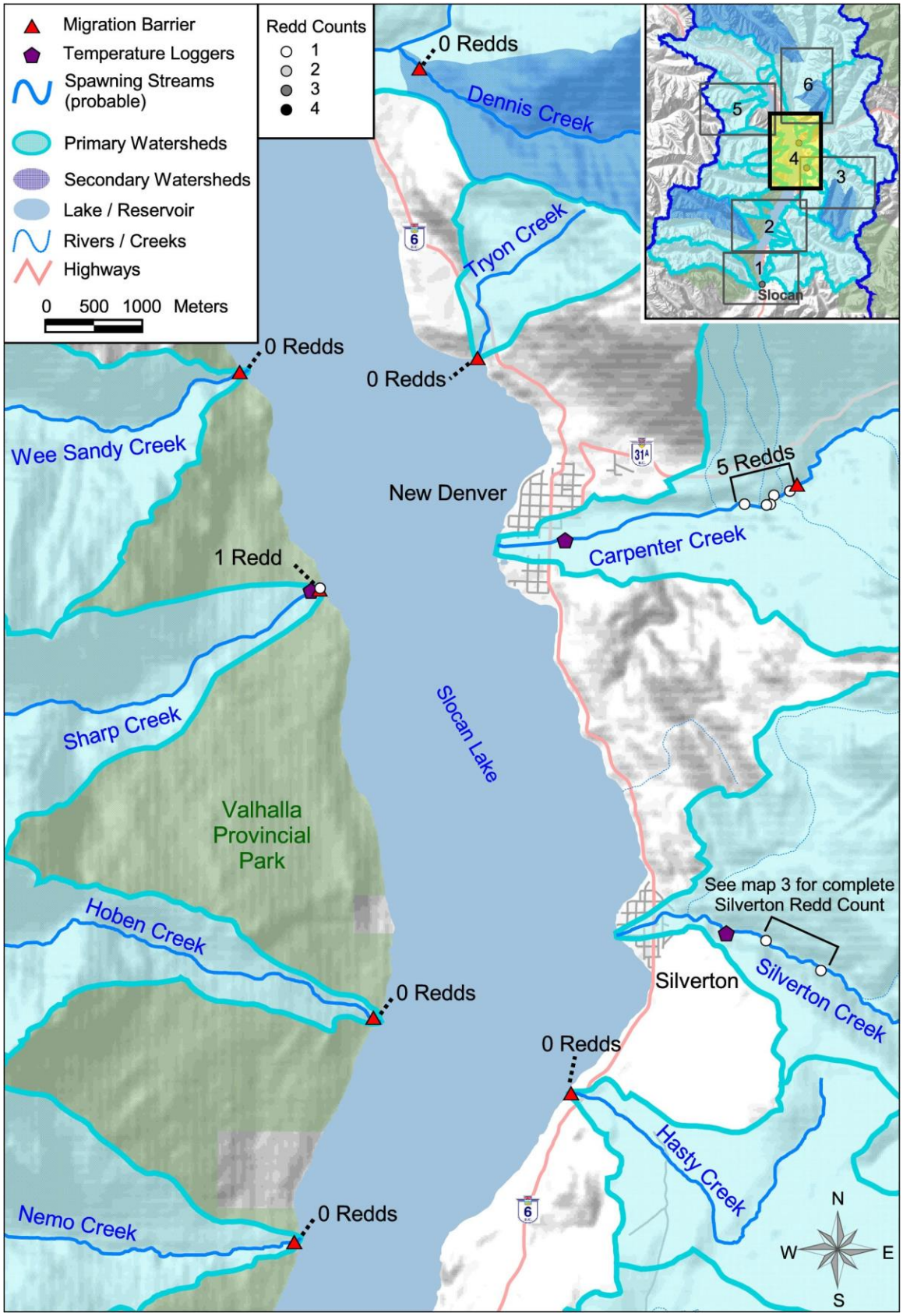

Figure 5. Bull Trout barriers and redd assessment results for Nemo, Hoben, Sharp, Wee Sandy, Hasty, Carpenter, Tryon and Dennis Creeks for 2014.

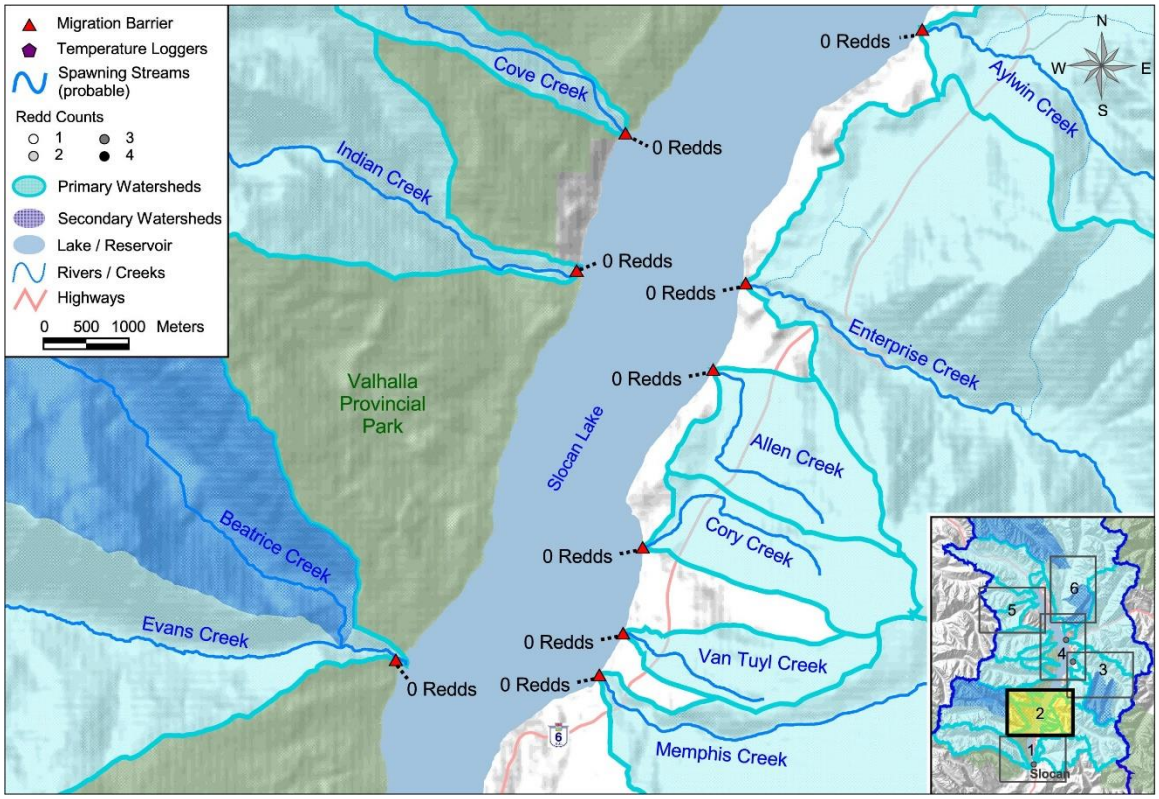

Figure 6. Bull Trout barriers and redd assessment results in Evans, Indian, Cove, Memphis, Van Tuyl, Cory, Allen, Enterprise and Aylwin Creeks for the 2014 survey.

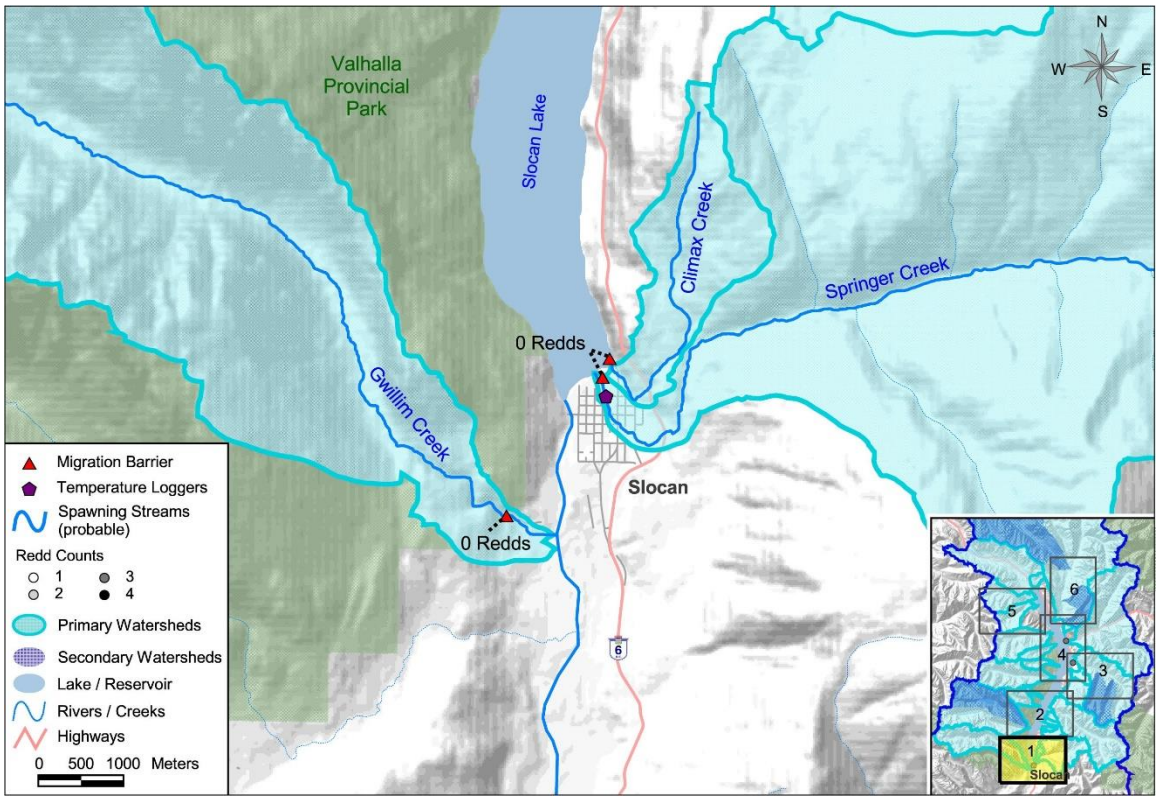

Figure 7. Bull Trout barriers and redd assessment results for Springer, Gwillim, and Climax Creeks for 2014.

Escapement Estimate

Bull Trout escapement (assuming 2.4 adults per redd) of all accessible Slocan Lake tributaries in 2014 was 389 adults with Silverton Creek making up the largest proportion of the total spawning fish with 78% of the redds (Table 7). The escapement estimate was calculated by adding in the four unspawned females that were observed in Silverton Creek (n=3) and Shannon Creek (n=1) to the redd counts and applying the expansion factor.

Table 7. Slocan Lake tributary escapement estimate for the surveyed streams with Bull Trout redd or fish presence 2014 (assuming 2.4 adults per redd).

Tributary	Redd Count Plus Unspawned Females	Percentage of Redds (%)
Silverton Creek	127	78.4
Wilson Creek	18	11.1
Shannon Creek	11	6.8
Carpenter Creek	5	3.1
Sharp Creek	1	0.6
Totals	162	~100%

Kokanee Numbers

As discussed in the methods, the surveys in 2014 were generally too late for assessing Kokanee numbers, but Kokanee were still spawning in Carpenter Creek when it was surveyed and 971 spawners were counted. In the section of river from the last bridge to the confluence with Slocan Lake of Silverton Creek at the end of August, ~250 Kokanee were counted.

Temperature

Data loggers in the eight tributaries were downloaded in November and December of 2014 and are plotted and described. Temperature loggers that were deployed in 2013 and remained through the winter were plotted from January 1, 2014 until the Fall 2014 download.

Bonanza Creek was not surveyed in 2014 since it was determined to be more suited to Rainbow Trout and Kokanee spawning due to its warmer water temperatures and a search of the Provincial Fisheries Information Summary System (FISS) for Bonanza Creek found no known observations or records of Bull Trout in Bonanza Creek (Baxter and Irvine 2014). Bonanza Creek temperatures recorded in 2014 were slightly cooler than in the 2013 year with values around the 9°C threshold value at which spawning is considered to commence occurring in the creek by the last two days of September. Water temperatures In Bonanza reached a high water temperature of 16°C in late July (Figure 8). Carpenter Creek showed the widest diel variation in water temperature throughout the spring and early summer period and a maximum summer temperature of 15.3°C. Temperature in Carpenter reached 9°C in the last few days of September (Figure 8). Water temperatures in Silverton reached a maximum summer temperature of 14.1°C in 2014 and dropped more quickly and were consistently lower during the spawning period than the other two main instrumented tributaries on the east side of Slocan Lake (Figure 8). The maximum summer temperature in Silverton Creek in 2013 was cooler at 13°C (Baxter and Irvine 2014). Wilson Creek temperatures fell below 9°C on September 28th and had a maximum summer temperature of 14.5°C (Figure 8). Shannon, Sharp, Springer and Wragge Creeks were instrumented in August and captured the cooling water temperature trend at the end of summer and into fall. Springer Creek had a higher maximum summer temperature than is considered optimal for Bull Trout at 16.4°C (Figure 8). Shannon, Sharp, and Springer were all below 9°C by early October and Wragge Creek did not drop below the threshold value until mid-October (Figure 8).

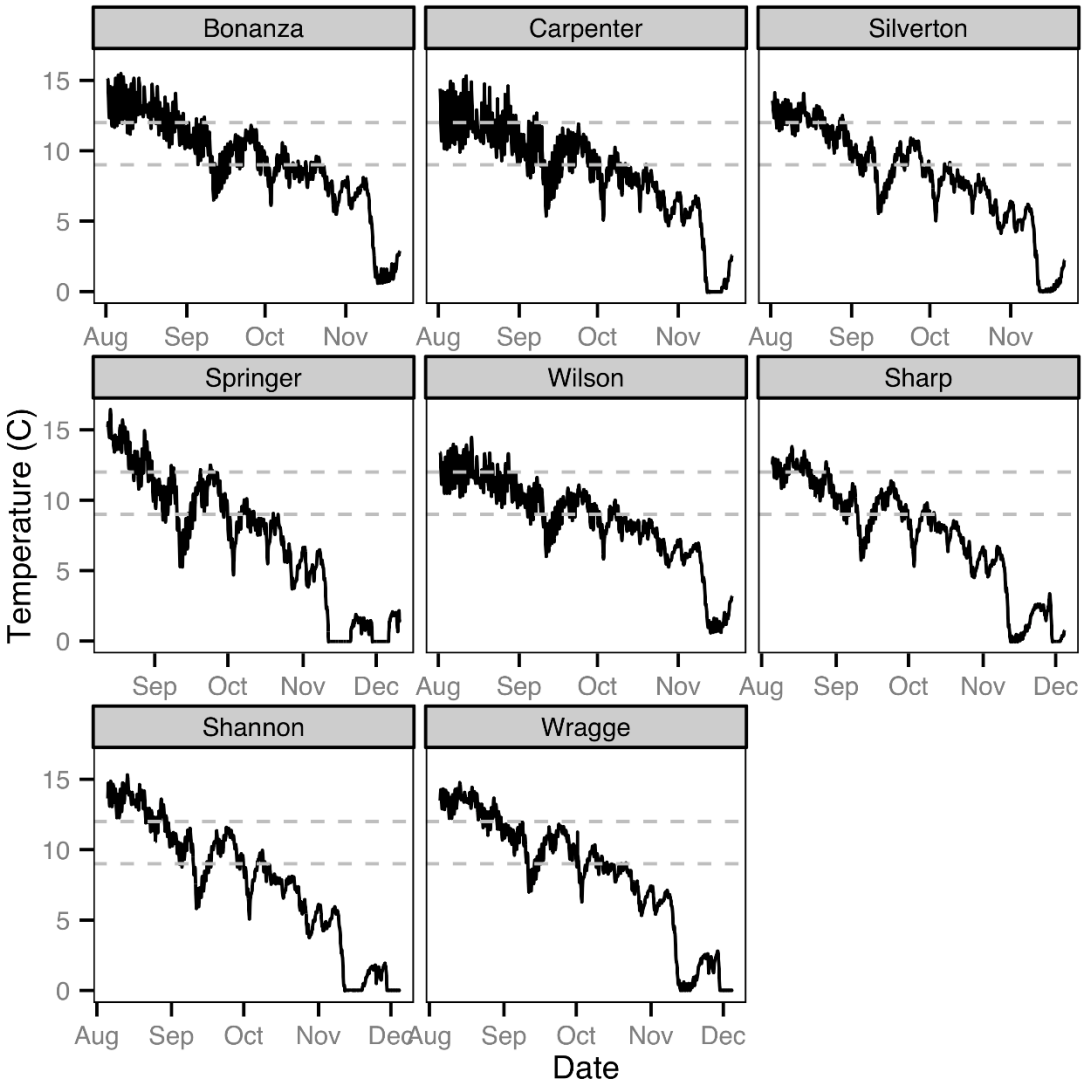

Figure 8. Water temperature (°C) by date for a subset of the surveyed creeks in the Slocan Lake watershed surveyed for Bull Trout spawning, 2014. Temperature thresholds for migration (12°C) and spawning (9°C) are marked with horizontal dashed lines.

The water temperature in Silverton Creek was measured for approximately 18 months throughout the entire incubation period for Bull Trout that spawned in Fall 2013 and was compared to literature values for thermal tolerances and emergence timing (Figure 9). For incubation to 50% hatch, 340 ATUs is cited as typical if the creek temperatures range from 1.2-5.4°C and 635 ATUs is cited as the value at which full fry emergence is considered complete (Fraley and Shepard 1989). When a start date for incubation was assumed to be October 1, 2013, 340 ATUs were reached on March 26, 2014 and 635 ATUs were reached on June 2, 2014. The optimal temperature for egg survival is between 2-4°C and the temperature dropped below 4°C in Silverton on October 10, 2013 and stayed between 0-4°C until April 17, 2014. The summer peak temperature in Silverton was 14.1°C on August 2, 2014.

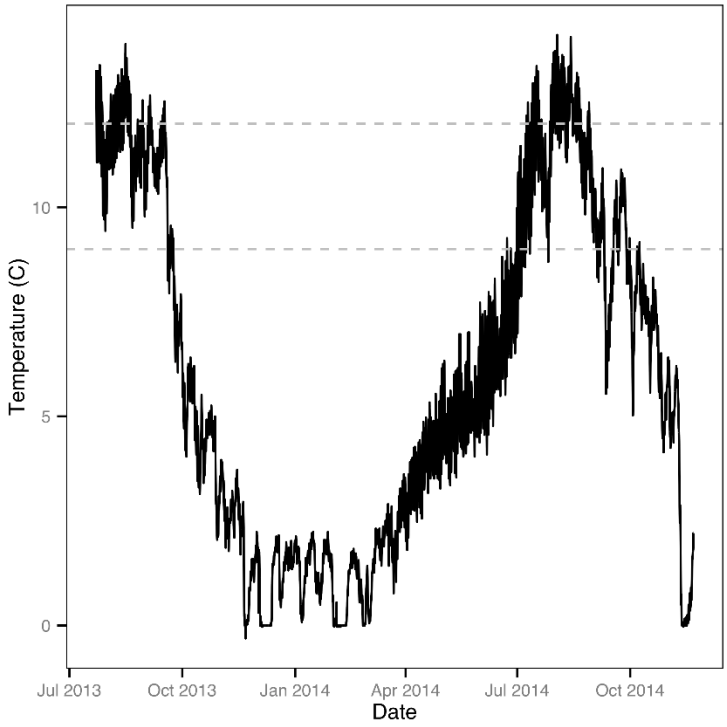

Figure 9. Water temperature (°C) for Silverton Creek 2013-2014. Temperature thresholds for migration (12°C) and spawning (9°C) are marked with horizontal dashed lines.

DISCUSSION

In this second year of study, the estimated Bull Trout escapement was 389 fish. This is higher than the 2013 estimate of ~194 fish which was arithmetically scaled up for the potential lineal distance available to the species from the survey of four tributaries which yielded an estimate of 144 fish. These values align with the assessment of this population of Bull Trout as 'At Risk' and vulnerable to extirpation as defined in Hagen and Decker's (2011) assessment of the province-wide status of Bull Trout. This risk level was based on ratings provided by regional biologists for three different types of threats: exploitation, habitat, and competition. Long term trend data are required for assessing the growth or decline of populations and the minimum US Fish and Wildlife Service criterion is two generations (14 years) and the minimum Committee on the Status of Wildlife in Canada (COSEWIC) duration is three generations (21 years) (Hagen and Decker 2011). The Slocan Lake population assessment is in the very early stages of tracking the trends for this population so any firm conclusions would be premature. The Slocan Lake Bull Trout population should continue to be monitored to assess trends in population abundance and status (in relation to provincial categories of risk) and in order to determine which mechanisms (e.g., density dependent, density independent) are determining the population abundance in Slocan Lake to provide management direction.

The exploitation of the Bull Trout in the Slocan Lake system is moderately high. The model assessing creel survey data from 2010 estimated 135 Bull Trout caught in 2010

(Schwarz 2012). If that level of exploitation was constant and did not occur in 2014, then the escapement estimate would be 524 fish. Put another way, approximately a quarter to a third of the 2014 estimated escapement is harvested if the 2010 creel survey estimated effort has remained similar in the past four years. The 2010 capture estimate is also likely biased low since the estimated angling impact on the population only targets those fishers using the system legally and poachers have been observed by field crews during the spawning period when Bull Trout are aggregated in staging pools and are particularly vulnerable to fishing pressure. Bull Trout are vulnerable to overfishing due to their life history in which they grow to a catchable size prior to becoming fecund and due to their opportunistic and aggressive feeding behavior and their tendency to hold in pools while travelling upstream to spawn (Paul et al. 2003).

Currently, three major abiotic factors currently limit the utility of the seemingly available Bull Trout spawning habitat in the Slocan Lake watershed – water temperatures, turbidity and substrate for spawning and rearing. Carpenter Creek had Bull Trout redds and spawners in it in 2014. In 2013, it was too turbid to survey Carpenter, which was thought to be resulting from erosion of the banks in the upstream reaches. It is hoped that mitigation to maintain water clarity in this system will occur if needed so that it is consistently available for salmonid spawning.

Bull Trout are generally not present in systems where maximum daily temperatures exceed 15°C (Haas and McPhail 2001) and are outcompeted by Rainbow Trout when temperatures are greater than 13°C (Parkinson and Haas 1996). A threshold temperature of 9°C has been suggested as the temperature below which spawning is initiated (McPhail and Murray 1979; Weaver and White 1985). Due to warm water temperatures in the Slocan River likely precluding successful Bull Trout spawning, it has not been surveyed as part of this study. Springer and Bonanza Creeks already exceed 16°C in summer and Carpenter and Shannon Creek's both had summer maximum temperatures in 2014 of 15.3°C. The peak temperature in Silverton Creek in 2014 was 14.1°C, in Wilson it was 14.5°C, and in Wragge it was 14.7°C so any additional warming in these systems could be a significant challenge for continued successful rearing of juvenile Bull Trout (Fraley and Shepard 1989). Linear developments can increase water temperature so careful monitoring and regulation around development in the tributary valleys would minimize potential increases and there is potential for riparian restoration to increase shading. Sharp Creek was the coolest of the instrumented tributaries with a maximum summer temperature of 13.8°C. Water temperature can be a key determinant for the onset of Bull Trout spawning and for spawning habitat selection since they generally reside in the creeks for approximately a month prior to spawning (Baxter 1995). It can also strongly affect egg incubation success and the size of fry at emergence (McPhail 2007). The largest Bull Trout fry at emergence result from eggs incubated between 2-4°C (Fraley and Shepard 1989). Size at emergence can alter survival rates and ability to compete with other fry of the same or different species. A B.C. study on the effect of macrohabitat variables on the distribution of Bull Trout and Rainbow trout found that temperature was the key variable determining which tributaries had Bull Trout present and that width and gradient were not driving variables in the study area (Parkinson and Haas 1996). The shift to dominance of Bull Trout is due in part to physiological tolerances, but also species interactions (Fausch 1988, Parkinson and Haas 1996). The assessment of temperature differences that resulted in a shift from Bull

Trout to Rainbow Trout suggested that land use practices that increase temperatures may result in contraction of the range of Bull Trout with even small changes in temperature (Parkinson and Haas 1996). Logging practices can increase water temperature 2-4°C over a short time period and climate change effects may also increase temperatures (Macdonald et al. 2003). It is one hypothesis for why Wilson Creek and Fitzstubbs Creek appear to be more dominated by Rainbow Trout. A juvenile use and density study would elucidate better what species are dominant in Wilson and Silverton and provide additional insight. There may be opportunities within the Slocan Valley to restore areas that have undergone land use practices that lead to increased temperatures and to manage the landscape to minimize any further increases that may jeopardize Bull Trout success.

The substrate and habitat for spawning and rearing varies considerably amongst the study systems though all of the surveyed systems have appropriate Bull Trout spawning substrate that is not utilized so it is unlikely that this factor is currently limiting spawning as is more fully discussed in Baxter and Irvine (2014).

Competition is an important determinant of where Bull Trout can persist and can take direct or indirect forms. Humans compete for prey items with Bull Trout through the active Kokanee fishery on Slocan Lake and the declining Kokanee numbers in the Slocan watershed may be a very real issue for Bull Trout growth and survival. Kokanee in the lacustrine environment where Bull Trout attain adulthood may enhance the productive capacity (Hagen and Decker 2011). The Kokanee spawning numbers from the rough estimate obtained during the 2013 Bull Trout surveys was 2,623 Kokanee. When compared to 1999 when almost 30,000 Kokanee were estimated to spawn in Bonanza Creek alone based on stream counts (Gebhart 2000), this is a substantive decline in relative abundance. Interference competition with other species is a major determinant of juvenile Bull Trout distribution and abundance (Hagen and Decker 2011). In the warmer creeks, Rainbow Trout likely outcompete Bull Trout as Rainbow Trout are generally dominant in streams with maximum temperatures exceeding 13°C (Parkinson and Haas 1996).

The small difference between the estimates for fishery escapement and angler harvest demonstrates that harvest is a significant component of the adult population, emphasizing the importance of the available spawning habitats and highlighting the need for careful management. With a population this small, Allee or depensatory effects can occur which may result in lower fecundity or survival and can precipitate collapse (Walters and Kitchell 2001). This effect may be worsened by the lack of connectivity to the Columbia and Kootenay mainstems as a result of hydro-electric development (Hagen and Decker 2011). This second year of surveys demonstrates the critical importance of Silverton Creek for sustaining the Bull Trout population. Preservation of the quality spawning habitat in this creek as well as assessing methods for improving the habitat in other creeks that support Bull Trout spawning will continue to ensure that Slocan Lake Bull Trout remain a viable population of native fish.

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Appendix 1. Photographic Plates

Plate A. Bull Trout Redds in Wilson Creek October 7, 2014.

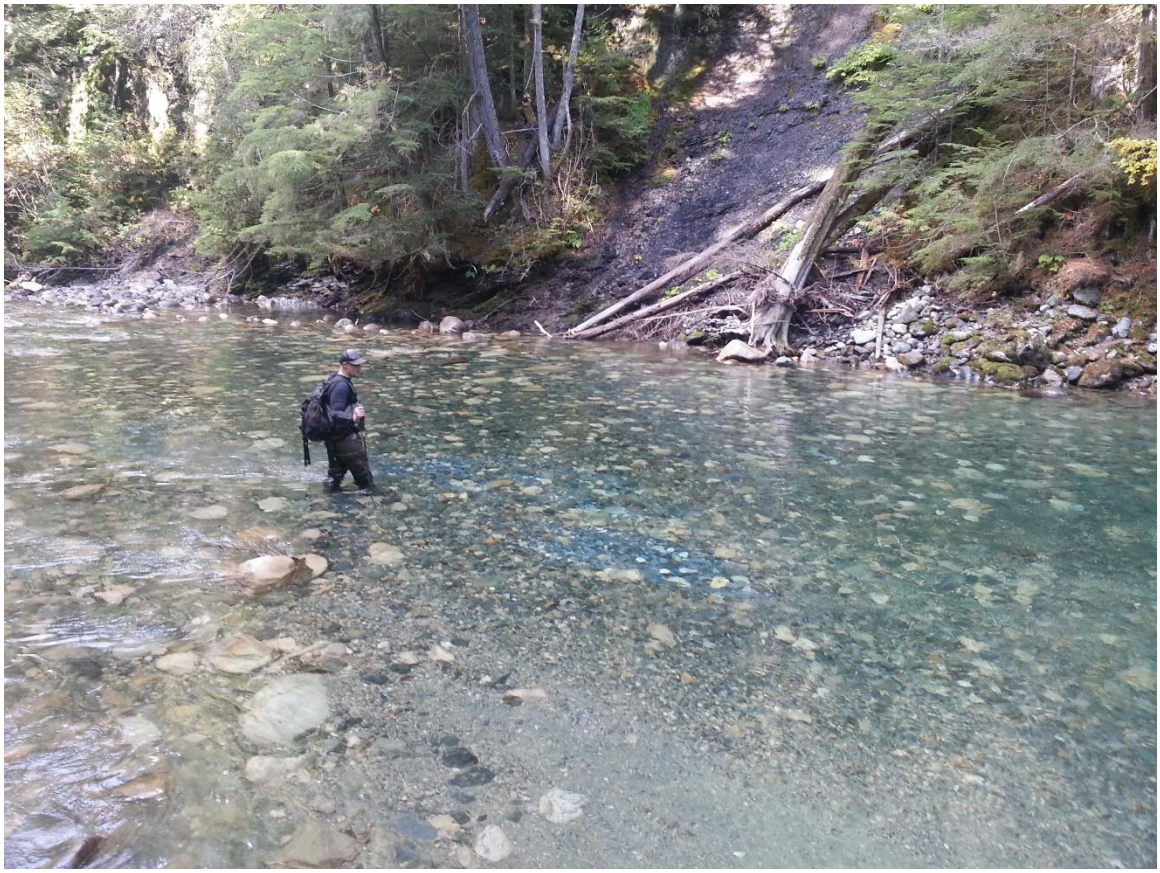

Plate B. Large male Bull Trout spawner in Silverton Creek on September 29, 2014.

Plate C. Bull Trout spawning pair on a redd in Silverton Creek on September 29, 2014