Bull Trout Spawner Escapement in the Salmo River Watershed: 2022

Bull Trout Redd at Sheep Creek Fertilization Station photo: G. Nellestijn

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Prepared by: Gerry Nellestijn and Scott Decker

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Executive Summary (2022 Results)

This project aligns with the Columbia Riparian and Rivers Action Plan priority action COLRRA.SOI.SB.21.01 Focal and Inventory species projects for species at risk-P2'.

Bull Trout Escapement surveys in the Salmo Watershed represents a monitoring action, while the long-term trend analysis provided in this report represents a population assessment action. Bull Trout redd surveys have been conducted annually in the Salmo River watershed over a 25 year period (1998-2022), with only three years when surveys did not occur (2016, 2020, 2021) .

In 2022 surveys took place during October 11-17, under excellent conditions, and redds were clearly identifiable in all survey areas. No live or dead adult Bull Trout were observed

The section of the South Salmo River (SSR) from the United States/Canada border to the upstream migration barrier within the U.S. was once again not surveyed in 2022. Our inability to survey this area is due to a combination of difficult access and sensitivities around crossing an international border in a remote area (the Bull Trout migration barrier is in the US, several kilometers upstream of Canada/US border). In 2022, surveys were completed in Clearwater, Sheep, lower Qua, and Curtis creeks, and in the upper Salmo River mainstem and the South Salmo River. The total number of redds observed in the surveyed reaches was 82, Sheep Creek had the highest number of observed redds with 48; the upper Salmo River held 10 redds, there were 5 redds in the surveyed portion of the South Salmo River, and 16 redds in the surveyed portion of Clearwater Creek. When the observed number of redds identified within the watershed are expanded by assuming two adults were associated with each redd, the aggregate escapement in 2022 (including the expanded estimate for the entire spawning section of the South Salmo River) was 174 adults, which is 137% of the average for the time series, and the highest escapement observed since 2017.

In addition to detailed results for 2022, this report includes an analysis of spawner abundance trends for the period of record, an analysis of population level effects of nutrient addition in Sheep Creek, and a review of conservation status and threats to Salmo River Bull Trout.

Acknowledgements

The first ten years of this monitoring project were a component of the environmental monitoring required by BC Hydro's addition of their fourth turbine at the Seven Mile Power Plant on the Pend d'Oreille River. The Salmo Watershed Streamkeepers Society (SWSS) continued the monitoring voluntarily during 2010, 2011, 2016 and 2017. From 2012 to 2015 financial support was provided from the Fish and Wildlife Compensation Program (FWCP) on behalf of its program partners BC Hydro, the Province of B.C., First Nations and the public, who work together to conserve and enhance fish and wildlife in watersheds impacted by BC Hydro dams. The FWCP also provided the funding for this project in 2022. This project aligns with the Columbia Riparian and Rivers Action Plan priority action COLRRA.SOI.SB.21.01 Focal and Inventory species projects for species at risk-P2'.Field and technical support during this work was provided by several individuals who ensured the project's success. Within the Salmo Watershed Streamkeepers Society: Jayme Anderson provided document review and modification as well as mapping upgrades. How invaluable to have her help in rolling this report forward and to be able to showcase her mapping abilities! Loreen Baker kept her eye on bookkeeping requirements**.** We were lucky to have James Baxter (Msc) to play a significant role in accomplishing field surveys. Paige Mansveld provided a second on the challenging upper South Salmo River reach. Selkirk Recreation Fish and Wildlife students Skye Irvine, Kade Zahariuk, Massimo Smith and James Schafer gained work experience on the Upper Salmo reach. What a pleasure to mentor such enthusiasm. Home-based safety protocols were carried out with diligence and sincerity by Alice Nellestijn. It is super to be surrounded with people who care.

This report owes a great deal to Scott Decker and John Hagen of Hagen and Associates. Both these gentlemen have maintained an interest in Salmo River Bull Trout specifically, and Salmo River watershed aquatic ecosystem health generally. They are exceptionally knowledgeable and also very giving of their time for discussion, idea building and support. In particular Mr. Decker has provided report writing review and analysis. Both Chris Harness and Rylee Haubrich corrected some errors.

Table of Contents

Executive Summary (2022 Results) 2

Acknowledgements 3

Table of Contents 4

List of Figures and Tables 5

Introduction 6

Study Area 7

Field Methods 10

- Number of spawners per redd 11
- Unspawned females 11
- Incomplete surveys in the South Salmo River 12
- Trend in Escapement 14
- Effect of Nutrient Addition in Sheep Creek on Bull Trout Spawner Abundance 14

Results 16

- 2022 surveys 16
- 1998-2022 Escapement Trends 17
- Effect of Nutrient addition in Sheep Creek on Bull Trout Spawner Abundance 19

Discussion 22

- Population level effects of Nutrient Addition in Sheep Creek on Salmo River Bull Trout 24
- Recommended Recovery Planning for Salmo River Bull Trout 25

References 33

Appendix A: Study Area Sub Maps 38

Appendix B: Survey Data Sheets 41

List of Figures and Tables

Figure 1. The Salmo River watershed study area showing 2022 redd survey sections and migration barriers to spawning Bull Trout in the upper Salmo River mainstem. 9

Figure 2. Annual trend (1998-2019, 2022) in Bull Trout spawner escapements for individual spawning tributaries and for the Salmo River Watershed as a whole during 1998-2019 & 2022. 18

Figure 3. Annual Bull Trout spawner abundance in Sheep Creek and aggregate abundance for the remaining spawning tributaries in Salmo watershed during (1998-2018). **Error! Bookmark not defined.**

Figure 4. Proportion of the annual Bull Trout spawning population in the Salmo River watershed that spawned in Sheep Creek during 1998-2018 21

Figure A- 1. Study Area Sub Map 1. Upper Salmo River and Headwaters at the confluence of Apex and Clearwater Creeks showing locations of complete redds and known Bull Trout 38

Figure A- 2. Study Area Sub Map 2: Mid Salmo River showing locations of complete redds and known Bull Trout barriers on Sheep and Curtis Creeks in 2022. 39

Figure A- 3. Study Area Sub Map 3: South Salmo River and tributaries showing locations of complete redds and known Bull Trout barriers in 2022. 40

Table 1. Survey data from 2002-2004, showing proportion of redds upstream and downstream of the Stagleap Creek and South Salmo River confluence. 13

Table 2. Total number of Bull Trout redds and live spawners observed in spawning tributaries in the Salmo River Watershed in 2022 17

Table 3. 1998-2022 Adult escapement estimates for four spawning tributaries 18

Table 4. BACI model results for the effect of nutrient addition in Sheep Creek on Bull Trout spawner abundance. 19

Introduction

Bull Trout are a blue listed species of concern in British Columbia (BC) and have been designated as a high conservation concern in the Salmo River Watershed (Hagen, 2008). Salmo River Bull Trout are a fluvial population characterized by spawning in small, cold, high-gradient tributary streams with adult populations rearing in the mainstem of the River (Baxter and Decker, 2010). A radio Telemetry study by Baxter and Nellestijn (2000) found that individual Bull Trout spawned in multiple tributaries within the Salmo River watershed, suggesting that Salmo River Bull Trout comprise a single population. Conservation biology guidelines for Bull Trout recommend a minimum of 50–100 individuals to minimize inbreeding effects (Reiman & Allendorf, 2001). The Salmo River population is vulnerable to most of the major threats to Bull Trout population perseverance, including isolation from other populations and from productive rearing habitats, small population size, negative population growth, unfavorable thermal regimes in remaining habitats, and encroachment and competition by native and non-native species (Baxter and Decker, 2010; Hagen, 2008).

Redd surveys are recognized as the least invasive, most inexpensive and efficient way to monitor Bull Trout populations (Reiman & Myers, 1997). Bull Trout escapement studies have been conducted annually, with a few exceptions in the Salmo River Watershed since 1998. BC Hydro conducted these studies until 2008 as part of their environmental monitoring requirements associated with the addition of the fourth turbine at the Seven Mile Power Plant. The Salmo Watershed Streamkeepers Society (SWSS) continued the project in 2010, 2011, 2016-2017, and 2012-2015 2021 as volunteers, and in 2018, 2019, 2022 with support from the Fish and Wildlife Compensation Program (FWCP).

The primary goal of this report is to summarize the results of the 2022 redd surveys and to provide an estimate of the aggregate (total) Bull Trout spawning escapement for the Salmo River watershed in 2022, and to compare this to previous years' estimates (1998-2019). Specific objectives of the 2022 survey included:

a) To extend the 1998-2021 time series of annual Bull Trout escapement estimates for the Salmo River watershed to 2022.

b) To conduct Bull Trout redd counts in mid to late October (post-spawning) in known spawning areas (Sheep Creek, South Salmo River, Clearwater Creek and the upper Salmo River mainstem) within the Salmo River Watershed, as well as in potential spawning areas of Qua Creek and Curtis Creek
c) To examine whether a stream fertilization project conducted over the last 19 years in Sheep Creek (2001-2022; Decker 2010; Decker and Nellestijn 2018) has had a significant effect on Bull Trout escapement in that stream relative to the other spawning tributaries in the Salmo River watershed.

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Study Area

The Salmo River rises from the Selkirk Mountains 12km southeast of Nelson, BC. The stream progresses in a southerly direction for approximately 60km from its origin to its confluence with the Pend d'Oreille River (Seven Mile Reservoir). It is a 5th order stream and has a total drainage basin of roughly 123,000ha. Its tributaries that contain known spawning habitat for Bull Trout include Clearwater Creek, Apex Creek, Sheep Creek, South Salmo River, and Stagleap Creek. Additional potential Bull Trout spawning tributaries include: Qua Creek, Waldie Creek, and Curtis Creek. (Figure 1).

Elevation in the basin ranges from 564 m at its confluence to 2,343 m at the height of land. Within this elevation range, the system comprises two biogeoclimatic zones (Braumandl and Curran 1992). At lower elevations, the valley lies within the Interior Cedar-Hemlock (ICH) zone, while areas in the higher elevations are found within the Engelmann Spruce-Subalpine Fir (ESSF) zone. The Salmo River has a total of eight 2nd and 3rd order tributaries (including Apex Creek, Clearwater Creek, Hall Creek, Barrett Creek, Ymir Creek, Porcupine Creek, Erie Creek, and Hidden Creek) and two 4th order tributaries (Sheep Creek and the South Salmo River) (Figure 1). The Water Survey of Canada maintains a gauging station on the Salmo River near the town of Salmo. Mean annual discharge in the Salmo River (1949-1976) was 32.5 m^3/s, with mean monthly minimum and maximum values of 7.5 and 128.6 m^3/s, respectively Baxter and Nellestijn (2000).

There are many fish species found in the Salmo Watershed along with Bull Trout, including: Rainbow Trout (*Oncorhynchus mykiss),* Eastern Brook Trout (*Salvelinus fontinalis),* Mountain Whitefish (*Prosopium williamsoni),* Largescale Sucker (*Catostomus macrocheilus),* Longnose Sucker (*C. catastomus),* Northern Pikeminnow (*Ptychocheilus oregonensis),* Longnose Dace (Rhinicthys cataractae), Redside Shiner (Richardsonius balteatus), and Slimy Sculpin (Cottus cognatus).

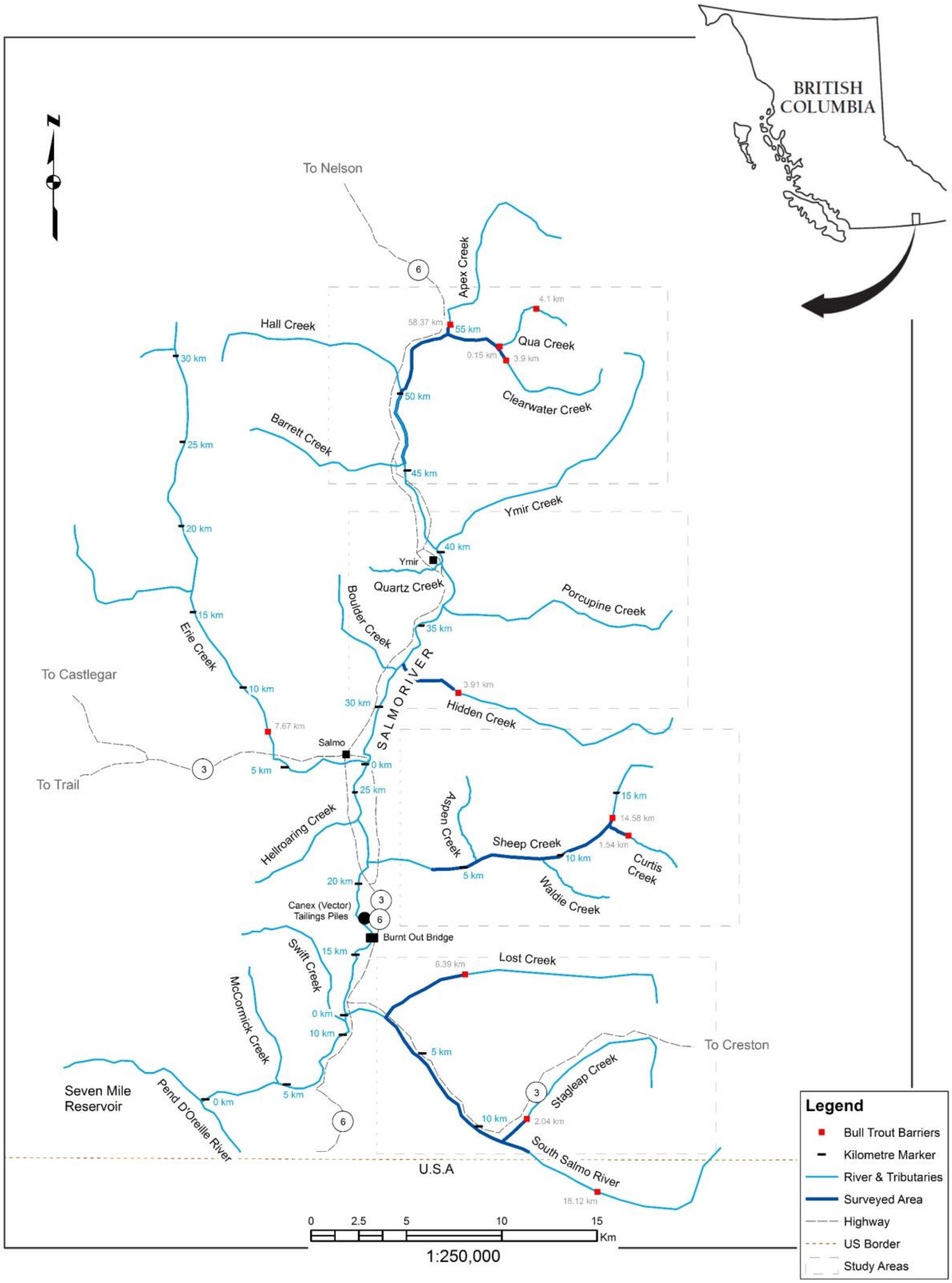


Figure 1. The Salmo River watershed study area showing 2022 redd survey sections and migration barriers to spawning Bull Trout in the upper Salmo River mainstem.

Field Methods

In 2022, Bull Trout redd surveys were were conducted from October 11-17. Field methods remained the same as those used in previous years of the program as detailed in Baxter and Decker (2010) and summarized below:

In order to estimate Bull Trout escapement, we employed the frequently used method of visual counts of redds, or depressions, in the substrate that indicate spawning activity and egg deposition (Rieman and Myers 1997; Dunham et al. 2001). Redd surveys were conducted between October 3rd and 10th in all the previously surveyed areas (Clearwater Creek, Sheep Creek, the upper Salmo River mainstem, and the South Salmo River, including Stagleap Creek) as well as in lower Qua Creek.

The redd survey crew was made up of two observers.. During surveys the observers, each wearing polarized glasses, walked downstream parallel to one another on either half of the stream. Redds were identified as excavated pits in the bed material, often of brighter appearance than surrounding substrates, accompanied by a deposit beginning in the downstream end of the excavated pit and spilling out of it in a downstream direction. Surveys were initiated from the upstream migration barriers (see Figure 1) on each of the known Bull Trout spawning tributaries, and proceeded downstream.. Surveys extended downstream to either a point where redds were no longer observed, or until the confluence with the Salmo River was reached. One exception was the upper section of the South Salmo River that extends from the international border to the upstream migration barrier within the United States. This section was not surveyed due to complications associated with the remote location of the barrier and crossing the international border[1]. Bull Trout also spawn in the upper section of the Salmo River mainstem, and this area was surveyed as well (Figure 1).

[1] This reach was surveyed in three previous years (2002-2004), before these sensitivities arose, and it was found to contain a substantial proportion of the total number of redds in the SSR for those years (see Analytical Methods -

Number of spawners per redd

Surveyors were asked to enumerate what was termed 'possible redds', depositions that carried a small degree of uncertainty. The survey team agreed to quantify these as 1 redd for 2 possible's. Five of these possible were surveyed, 3 in the South Salmo reach's and 2 in Sheep Creek. The use of an expansion factor is necessary to convert a count of redds to an estimate of spawner escapement, but one redd is not necessarily the product of one female and one male Bull Trout. Females sometimes construct more than one redd and spawn with multiple males, and males may spawn with more than one female. Baxter and Decker (2010) proposed an expansion factor of 2.0 for Salmo River spawning tributaries. This was based on a literature search of studies where redds were counted throughout the entire spawning area within a stream or stream system, and these counts compared to complete counts of kelts at downstream weirs or resistivity counters (i.e., a reliable estimate of total escapement was available). Estimates of the number of adults per redd derived from these studies ranged from 1.0 to 4.3 (see Table 2 in Baxter and Decker 2010) and averaged 2.0 adults/redd (some studies reported only the range in values). For consistency, in estimating escapement for each tributary and for the Salmo watershed (as a whole), the same approach described by Baxter and Decker (2010) was followed:

$$N = (\text{number of redds x } 2.0) \qquad (1)$$

where N is the Bull Trout spawner escapement estimate, and 2.0 is the expansion factor.

Unspawned females

In their estimates of escapement, Baxter and Decker (2010) did not include live females still present in the spawning areas at the time of the survey. They assumed, based on previous experience in the Salmo Watershed that so long as surveys were conducted on October 1 or later, live females still present had already spawned and were associated with a complete or nearly

incomplete surveys in the South Salmo River below). Also, in August 2014 the Kalispel Tribe and Seattle City Light personnel reported relatively high catch-per-unit-effort for juvenile Bull Trout (and some adults) in this reach during electrofishing surveys.

complete redd. In 2022 all surveys were conducted from October 11-17th, and escapement estimates were based on the number of redds only.

Incomplete surveys in the South Salmo River

A second expansion factor was required to estimate total escapement to the South Salmo River (SSR) in 2022 because, like most previous years, only the lower part of the spawning area could be surveyed (see *Field Methods* above). Complete surveys of the SSR did occur in 2002, 2003 and 2004 (Baxter and Decker 2010), and redd counts obtained in these years can be used to develop expansion factors to approximate SSR escapements for years of partial survey coverage including 2022. Baxter and Decker required an expansion factor that could be applied to all years including 1998-2000, when the SSR received no survey coverage whatsoever, and opted to approximate escapement to the SSR based on the proportion of aggregate escapement for the Salmo watershed contributed by the SSR during years when complete surveys of the SSR occurred (2002-2004). During 2002-2004, the SSR contributed an average of 20% (range: 11%-36%) of aggregate Bull Trout escapement in the Salmo watershed. From this, Baxter and Decker (2010) developed the following expansion factor (SSR expansion method #1):

$$SSR_{escapement} = \Sigma(\text{Upper Salmo, Clearwater, Sheep})_{escapement} \times 0.25 \qquad (2)$$

The weakness of this approach is that it does not make use of redd count data from partial surveys that occurred in most years (2001, 2005-2019, 2022) in the SSR, and it assumes that the distribution of spawners among tributary spawning areas is constant among years. An alternate, SSR-specific expansion factor can be derived from the 2002-2004 data based on the proportion of total SSR escapement that occurred in the lower portion of spawning area (Lost Creek to and including Stagleap Creek) that received survey coverage in most years. During 2002-2004, the lower portion of the SSR contributed an average of 34% of total Bull Trout escapement in SSR (range: 24%-40%; Table 1). This provides an alternate expansion factor (SSR expansion method #2):

$$SSR_{escapement} = SSR_{lower} / 0.34 \qquad (3)$$

Table 1. Survey data from 2002-2004, years with a complete count of redds in the South Salmo River (from the migration barrier in the USA to Lost Creek) showing proportion of redds upstream and downstream of the Stagleap Creek and South Salmo River confluence.

Complete South Salmo River Survey (USA Barrier to Lost Creek)						
Year	Redds* Upstream of Stagleap Cr.	Redds* Downstream of Stagleap Cr.**	Count	Escapement	Upstream % of Escapement	Downstream % of Escapement
2002	16 (incld. 6 females)	5 (incld. 3 females)	21	42	76%	24%
2003	9	6	15	30	60%	40%
2004	5	3	8	16	63%	38%
Mean					**66%**	**34%**

* includes unspawned females as 1 redd each because surveys were conducted in mid September when active spawning was still underway (See Analytical Methods, unspawned females).
** includes Stagleap Creek counts from powerline downstream to concfluence and South Salmo River counts from Stagleap Creek downstream to Lost Creek.

The weakness of this second method is that it assumes that spawner distribution within the SSR remains constant among years and at varying levels of escapement. This is unlikely to be the case for Bull Trout or salmonids in general. For example, stream temperatures, flows, and fish arrival timing can lead to variability in spawner distribution among years. A more specific consideration for the SSR is that spawners normally show preference for the highest quality spawning habitat, and as competition for this habitat increases at higher abundances, later arriving fish are forced to select less optimal habitat, resulting in expanded spawning distributions. In 2006, 2007, 2010, and 2011, no redds were observed in the lower portion of the SSR, which leads to an escapement estimate of 0 based on SSR expansion method #2. However, it is unlikely that the actual SSR escapement was 0 in these years; the upper portion of SSR (Stag Leap Creek confluence to the migration barrier) was not surveyed in these years, but in 2002-2004 it represented preferred habitat in the SSR, given that it contributed the majority (66%; Table 3) of escapement in those years. In the results section, we include some observations of adult Bull Trout in the US portion of the South Salmo River made by field crews from Kalispel Tribe and Seattle City Light during an electrofishing survey on August 19, 2014 to emphasize this point.

Both expansion methods are uncertain for reasons outlined above, and there is no clear way to determine which is the more reliable. Consequently, to approximate total escapement for SSR in

2022 we used the average of the estimates produced by the two expansion methods (see Results). This is consistent with the approach taken in previous years.

Trend in Escapement

To assess the trend (change over time) in Bull Trout escapement in the Salmo watershed, we smoothed the time series by computing 5-year running averages (arithmetic mean) of aggregate escapement for Clearwater and Sheep Creeks and the upper Salmo River. Escapement for the South Salmo River was excluded for this assessment, owing to the uncertainty in estimates for this tributary that are detailed in the previous section. A 5-year running average was used because age-at-maturity is approximately five years for Salmo Bull Trout, and five years therefore represents one generation.

Effect of Nutrient Addition in Sheep Creek on Bull Trout Spawner Abundance

During 2001-2009, a nutrient addition experiment was conducted in Sheep Creek to determine if this restoration technique could be effective in increasing the size and abundance of juvenile Bull Trout (Decker 2010). The South Salmo River was selected as a control, and the treatment was applied to Sheep Creek during 2004-2009. The treatment consisted of a single point release of agricultural-grade fertilizers to achieve concentrations of 100μg/l of dissolved inorganic nitrogen (DIN) and 10 μg/l of total dissolved phosphorus (TDP) at the midpoint of the stream reach below the migration barrier. Monitoring was based on a before-after-control-impact study design (BACI; Stewart-Oaten *et al.* 1986), with 2001-2003 serving as the control period, and 2005-2009 serving as the treatment period. The results of the experiment showed increases in the average size and abundance of juvenile Bull Trout in Sheep Creek as a result of nutrient addition that markedly increased standing crops of periphyton algae and benthic invertebrates (Decker 2010). During 2012-2022, stream fertilization continued in Sheep Creek as a management initiative (without the experimental monitoring) concurrent with annual Bull Trout red surveys in the Salmo watershed, which provides the opportunity to examine whether the benefits of nutrient addition extended to the final stage of the Bull Trout life cycle.

To test the effect of nutrient addition in Sheep Creek on Bull Trout spawner abundance, we employed a BACI experimental design (Stewart Oaten et al. 1986) similar to that used in the original experiment by Decker (2010), but in this case, the remaining spawning tributaries (South

Salmo, Clearwater, and upper Salmo mainstem as an aggregate) are treated as the control, rather than just the South Salmo River, and the pre- and post-treatment periods were assigned as 1998-2007 and 2008-2022, respectively, to correspond to the cohorts of spawners returning to Sheep Creek that reared in the stream during years before and after nutrient addition began. In the Salmo River watershed, Bull Trout rear for 2-3 years in natal tributaries before emigrating to the rearing habitats in the Salmo River mainstem, and are at least five years old when they return to natal tributaries to spawn for the first time. Spawners returning to Sheep Creek in 2008 were considered the first cohort of the post-treatment period based on the assumption that 2008 was the first year when a 5-year old returning to spawn in Sheep Creek would have spent at least one full year there as a juvenile during the 2004-2022 nutrient addition period (i.e., a fish that emerged from the egg in 2004, spent two years in Sheep Creek, and emigrated to the Salmo mainstem in 2006, would, on average, returned to spawn for the first time in 2008[1]).

A linear mixed-effects models (Pinheiro and Bates 2000) was used to analyze the spawner abundance data. Treatment (fertilized stream versus control stream) and period (pre- and post-fertilization) were treated as fixed effects, and year, as a random effect nested within period. The model assumes the following form:

$$y_{ijk} = \mu + \tau_i + \alpha_j + \tau\alpha_{ij} + \eta_{jk} + \varepsilon_{ijk} \qquad (4)$$

where *i, j, and k* are subscripts denoting treatment stream, period, and year, respectively; y_{ijk} is spawner abundance, μ is the overall mean, τ_i is the *i*th treatment effect, α_j is the *j*th period effect, $\tau\alpha_{ij}$ is the treatment × period interaction effect, η_{jk} is the random year effect within period, and ε_{ijk} is the random experimental error on repeated measures through time (see Decker 2010 for more information). In a BACI experiment, it is the interaction term ($\tau\alpha_{ij}$) that is of interest rather than the main effects (τ_i and α_j). The interaction term compares mean differences between the treatment and control streams during the pre- and post-nutrient addition periods. Nutrient

[1] This analysis also assumes that Salmo Bull Trout spawn predominately in their natal streams.

addition effects are indicated in cases where the interaction term explains a significant amount of the variance in spawner abundance. We used an alpha level of 95% ($P < 0.05$) to reject the null hypothesis of no significant treatment × period interaction. Maximum likelihood was used to find the best model fit. We used the Akaike information criteria corrected for small sample size (AIC_c) to compare models with and without the interaction term included to interpret the importance of the treatment × period interaction (Burnham and Anderson 2002). To provide a sense of the magnitude of any observed effects of nutrient addition, we computed the effect size, or the increase (or decrease) in spawner abundance:

$$Effect\ size = \left(\mu_{treatment,post} - \mu_{treatment,pre}\right) - \left(\mu_{control,post} - \mu_{control,pre}\right) \quad (5)$$

We assessed how well the data conformed to the assumption of normality by examining histograms, scatterplots, and normal quantile-quantile plots of the residuals, and by comparing model results for log-transformed versus untransformed data.

Results

2022 surveys

In total, 79 redds were enumerated in 2022 (Table 2). Sheep Creek saw the highest concentration of spawning activity in 2022, with a total of 48 redds. There were 10 redds observed in the upper Salmo River mainstem, 16 redds in Clearwater Creek, and five redds in the South Salmo River.

The South Salmo River was surveyed from the U.S./Canada border upstream of the Stagleap Creek confluence downstream to the Lost Creek highway rest stop. Stagleap Creek was surveyed from the migration barrier to the South Salmo River confluence. The 5.4 km long upper section of the South Salmo River extending to the migration barrier in the US was not surveyed because it was not possible to arrange permission in 2022 to cross the international border at this remote location.

Table 2. Total number of Bull Trout redds and live spawners observed in surveyed spawning sections in the Salmo River Watershed in 2022.

Watercourse (Index Area)	Date	Total Redds	Total Spawners
Stagelap Creek	11-Oct	0	0
South Salmo River (Border to Lead Creek Bridge)	11-Oct	3	0
South Salmo River (Lead Creek Bridge to Anderson Campground)	16-Oct	2	0
South Salmo River (Anderson Campground to Rest Stop)	17-Oct	0	0
Clearwater Creek	12-Oct	16	0
Upper Sheep Creek (Curtis Creek to Waldie Creek)	13-Oct	38	0
Lower Sheep Creek (Waldie Creek to Aspen Creek)	14-Oct	10	0
Upper Salmo River Apex/Clearwater confluence to Hall Cr.	15-Oct	6	0
Upper Salmo River (Hall Creek to Barrett Creek)	15-Oct	4	0
Total Redds 2022		**79**	

1998-2022 Escapement Trends

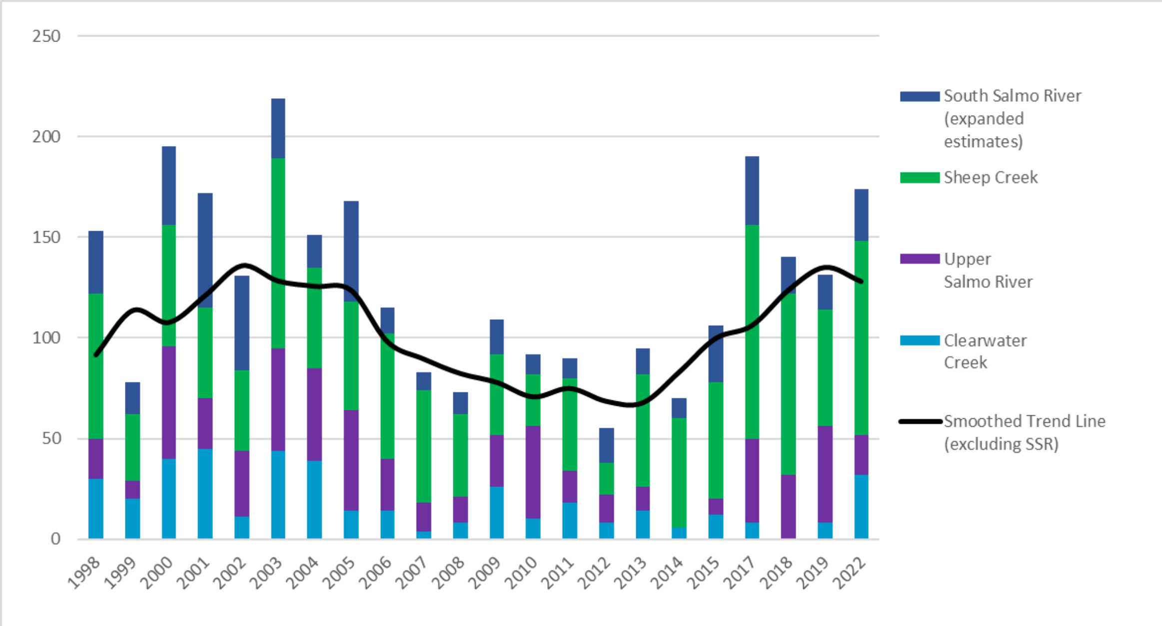
The smoothed (5-year running average) time series of aggregate escapements (excluding South Salmo River) indicates a positive trend in adult abundance from 1998 to 2002, followed by a gradual decline from 2002 to 2014, and then a fairly consistent increase in abundance from 2015 to 2022 (Figure 2, black trend line). Across the times series, annual aggregate escapements have varied about 4-fold (55-219 spawners; Table 3; Figure 2, coloured bars). The redd count data suggests that the number of spawning Bull Trout in the Salmo watershed (including South Salmo River) was less than 100 individuals in six of seven years during 2007-2015, but has exceeded 100 individuals in the five most recent years when surveys have occurred (2015, 2017-2019, 2022). The lowest aggregate Bull Trout spawner escapement was observed in 2012, with only 55 spawning adults. Aggregate escapement in 2022 (169 adults) was the second largest since the population fell below 100 individuals in 2007, and the 5th largest for the 21-year study period. Except for Sheep Creek, all spawning areas (Clearwater, SSR, Upper Salmo) experienced a decline in spawner escapement across the time series as a whole (Figure 2). Sheep Creek supported the highest number of spawners in the majority of years (26%-71% of aggregate escapement), , particularly in years when nutrient addition was occurring in Sheep Creek (see next section).

Table 3. 1998-2022 Adult escapement estimates for four spawning tributaries (values assume *2.0 adults/redd;* see *Analytical Methods)*. Escapement estimates for the South Salmo River (SSR) include partial estimates derived from incomplete surveys (except 2002-2004) and expanded estimates of total escapement based on two different expansion methods (see *Analytical Methods* - *Incomplete surveys in the SSR*). Aggregate escapement estimates for the Salmo Watershed (excluding and including SSR) are also shown. Aggregate estimates that include SSR are based on SSR estimates derived from the mean of the two expansion estimates.

			Escapement by Area							Salmo River Watershed Escapement	
Year	Survey Dates		Clearwater Creek	Upper Salmo River	Sheep Creek	South Salmo River (partial estimates)	South Salmo River expansion (method #1)	South Salmo River expansion (method #2)	South Salmo River (expanded estimates) (mean of methods 1 & 2)	Aggregate Escapement (excluding South Salmo River)	Aggregate Escapement (including mean expanded estimate for South Salmo River)
1998	01-Oct	07-Oct	30	20	72	nc	31	na	31	122	153
1999	21-Sep	25-Sep	20	9	33	nc	16	na	16	61	77
2000	09-Oct	21-Oct	40	56	60	nc	39	na	39	156	195
2001	17-Sep	25-Sep	45	25	45	29*	29	86	57	115	172
2002	12-Sep	24-Sep	11	33	40	47	na	na	47	84	131
2003	29-Sep	09-Oct	44	51	94	30	na	na	30	189	219
2004	27-Sep	14-Oct	39	46	50	16	na	na	16	135	151
2005	04-Oct	14-Oct	14	50	54	24*	30	71	50	118	168
2006	04-Oct	19-Oct	14	26	62	0*	26	0	13	102	115
2007	03-Oct	11-Oct	4	14	56	0*	19	0	9	74	83
2008	23-Sep	03-Oct	8	13	41	2*	16	6	11	61	72
2009	05-Oct	16-Oct	26	26	40	4*	23	12	17	92	109
2010	08-Oct	14-Oct	10	46	26	0*	21	0	10	82	92
2011	06-Oct	27-Oct	18	16	46	0*	20	0	10	80	90
2012	09-Oct	22-Oct	8	14	16	8*	10	24	17	38	55
2013	06-Oct	21-Oct	14	12	56	2*	21	6	13	82	95
2014	06-Oct	12-Oct	6	0	54	2*	15	6	10	60	70
2015	05-Oct	16-Oct	12	8	58	12*	20	36	28	78	106
2017	04-Oct	07-Oct	8	42	106	10*	39	29	34	156	190
2018	03-Oct	10-Oct	0	32	90	2*	31	6	18	122	140
2019	02-Oct	13-Oct	8	48	58	2*	29	6	17	114	131
2022	11-Oct	15-Oct	32	20	96	5	37	15	26	148	174

nc - surveys were not conducted
* - Partial count (survey completed from Stagleap Creek to Lost Creek only)

Figure 2. Annual trend in Bull Trout spawner escapements for individual spawning tributaries and for the Salmo River Watershed as a whole during 1998-2022. The black solid line shows the smoothed trend for the aggregate population based on a 5-year running average. No surveys were conducted in 2016, 2020 and 2021.



Effect of Nutrient addition in Sheep Creek on Bull Trout Spawner Abundance

The mean abundance of Bull Trout spawners in Sheep Creek in years when returning adults would have potentially benefited as juveniles from nutrient enrichment (2008-2022) remained the same compared to that for the pre-treatment period (1998-2007) at 57 individuals (Table 4, Figure 3). In contrast, mean spawner abundance in the remaining Salmo tributaries declined 41% in the post-treatment period relative to the pre-treatment period (53 versus 90 spawners, respectively; Table 4, Figure 3). This significant, positive effect of nutrient addition is confirmed by the significant treatment × period interaction term (P = 0.02, Table 4), and much higher support (lower AIC value) for the model with the treatment × period interaction term included (AIC = 398 versus 409, respectively, Table 4). Sustained spawner abundance in Sheep Creek throughout the pre- and post- treatment periods, versus much reduced spawner abundance in the remaining tributaries in the post-treatment period, led to Sheep Creek supporting a higher proportion of the spawning population in the post-treatment period (51% versus 41%; Figure 4).

Table 4. BACI model results for the effect of nutrient addition in Sheep Creek on Bull Trout spawner abundance. The *P*-value of 0.02 for the treatment×period interaction term indicates a significant nutrient addition effect. A significant treatment effect is also evidenced by a reduction in the AIC score of 10.6 for the

model with the treatment×period interaction included. Effect size is the post- versus pre-treatment change in mean spawners per year in Sheep Creek relative to other spawning tributaries in the Salmo Watershed.

No. observ-ations	*P*-value for treatment × period interaction	Model AIC scores		Effect size (spawners)			Mean spawner numbers			
							Treatment		Control	
		without interaction	with interaction	Esti-mate	lower CI	upper CI	pre	post	pre	post
22	0.02	408.5	397.9	37.7	5.0	70.4	56.6	57.3	89.8	52.7

The estimated effect size for nutrient addition in Sheep Creek is 38 additional spawners per year during the post-treatment period (95% confidence interval: 5-72 spawners/year; Table 4). Given the average annual spawner population in the watershed during the post-treatment period (110 adults for all spawning reaches combined), this represents 34% of the spawning population.

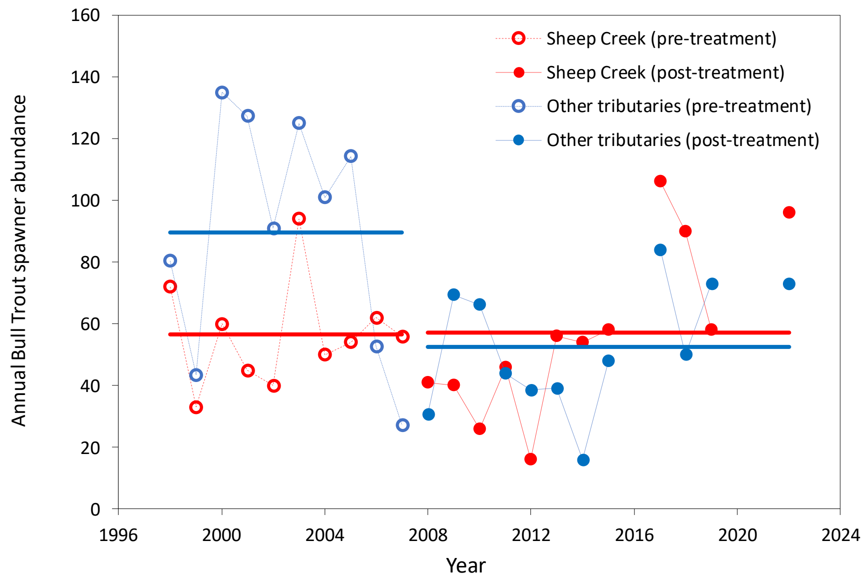


Figure 3. Annual Bull Trout spawner abundance in Sheep Creek (nutrient enriched stream, red circles) and aggregate abundance for the remaining spawning tributaries in Salmo watershed (control streams, blue circles) during (1998-2022). Open circles indicate the pre-treatment period; closed circles indicate the post-treatment period. Solid red and blue horizontal lines indicate pre and post-treatment mean spawner abundances for Sheep Creek and the control streams, respectively).

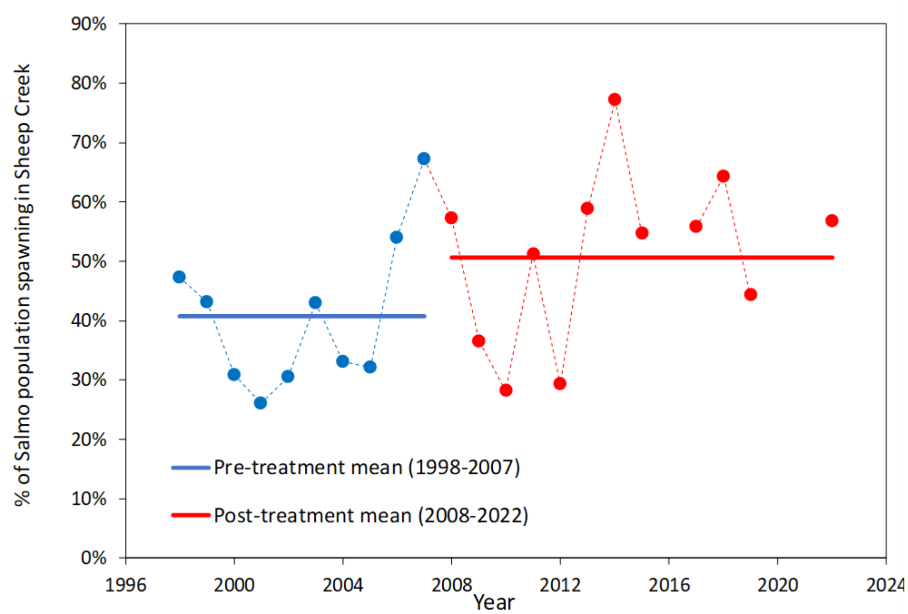


Figure 3. Proportion of the annual Bull Trout spawning population in the Salmo River watershed that spawned in Sheep Creek (nutrient addition treatment stream) during 1998-2022. Solid blue and red horizontal lines indicate mean values for the pre and post-treatment periods, respectively.

Discussion

Conservation status and threats to Salmo River Bull Trout

Twenty-one years of escapement monitoring has documented a formidable Bull Trout (BT) population variation. From the early 2000s to 2012 there was (roughly) two-fold decline in Bull Trout spawners in the Salmo River Watershed. Total escapement were generally between 100 and 200 spawners during the early 2000s, and a low of 55 spawners in 2012. From 2012 to 2022 there has been a positive trend in overall escapement. Declines were more pronounced in Clearwater Creek, the upper Salmo River, and possibly the South Salmo River, compared to that in Sheep Creek. The trend is much less certain for the South Salmo River owing to lack of surveys of the upper section of the spawning habitat, due to its location across the international border in the US. In contrast to the other tributaries, Clearwater Creek exhibited a steady decline across the entire time series, with an estimate of zero spawners for the first time in 2018. However, 2022 saw an increased escapement of 32 spawners in Clearwater Creek.

Redd count surveys suggest that the total adult spawning population for the Salmo Watershed was at or below 100 individuals[1] in at least[2] eight years during the 1998-2022 time series. Conservation biology guidelines for Bull Trout suggest a minimum of 50-100 adults are required to minimize inbreeding effects, and a minimum of 500-1,000 adults are required to maintain adaptive genetic variation (Rieman and Allendorf 2001). Based on these values, the population may be below or close to the threshold where inbreeding depression would be expected, depending on the degree of year-to-year movement of spawners among the four principle spawning tributaries in the watershed. Radio telemetry work by Baxter and Nellestijn (2000), suggests Salmo Bull Trout have fairly low spawning site fidelity, which should be beneficial for a small population in this regard. With respect to maintenance of adaptive genetic variation, he long-term viability of the Salmo population is clearly at risk. Empirical studies of extinction in mammals and birds suggest that populations of 50-200 individuals are marginally secure, while <

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[1] These values include extrapolated estimates for the entire accessible portion of the South Salmo River.

[2] Surveys were not conducted every year

50 individuals is clearly insufficient for a population's long-term persistence (reviewed in Hagen 2008).

The Construction of the Waneta Dam on the Pend d'Oreille River (1954) and dams upstream in the United States has genetically isolated Salmo Bull Trout from other lower Columbia River populations and excluded them from 68 km of suitable adult habitat in the Columbia River mainstem where an abundant prey fish base exists (Hagen 2008). Moreover, dam construction has extirpated anadromous populations of Chinook Salmon and Steelhead within the Salmo River and in other Pend d'Oreille tributaries that were formerly accessible to Bull Trout, and this has further reduced their potential food resources. Access remains to Seven Mile Reservoir (formerly the Pend d'Oreille River mainstem), but to a large extent Bull Trout appear to avoid the reservoir, probably because of an isothermal temperature profile that exceeds 20°C in summer (Hirst 1991). Radio telemetry studies of adult Bull Trout in the Salmo River found little indication of migration to and from the reservoir (Baxter and Nellestijn 2000), although one sub-adult was tracked into the reservoir during a 2008 study (A. Prince, Westslope Fisheries, pers. comm.). Hagen (2008) suggested that the productivity of remaining adult rearing habitats in the mainstem Salmo River is probably a small fraction of that under pre-impoundment conditions. In recent years, average daily temperatures in the mainstem of the Salmo River have exceeded the 15°C threshold for adult Bull Trout preference for up to a month during the summer (A. Prince, Westslope Fisheries, pers. comm. 2008.) SWSS completed a 10-year summer temperature overview in 2020. Competition with Rainbow Trout and non-native Brook Trout may also affect Bull Trout production, particularly at higher water temperatures (see Hagen 2008 for a review), and Eastern Brook Trout can also interbreed with Bull Trout (Rieman and McIntyre 1993). Rainbow Trout are moderately abundant in the Salmo River, while Eastern Brook appear to be increasing in abundance (Hagen and Baxter 2010). Given these cumulative impacts to Bull Trout in the Salmo River and the Pend d'Oreille watershed as a whole, it is reasonable to think that current abundance is substantially lower than historical levels.

Population level effects of Nutrient Addition in Sheep Creek on Salmo River Bull Trout

The results of the BACI analysis suggests that annual[1] addition of nutrients in Sheep contributed to relatively stable Bull Trout escapements to this stream over the 1998-2022 time series whereas spawner numbers returning to the remaining tributaries in the watershed declined over 40%. Results of the original experiment indicate that nutrient enrichment led to increases in both the size and abundance of juvenile Bull Trout in Sheep Creek (Decker 2010). The positive effect of nutrient enrichment on Bull Trout spawner numbers detected in Sheep Creek is presumably the result of better or a more sustained survival at the juvenile life stage or at older life stages owing to larger initial size and condition when they emigrated from Sheep Creek to the Salmo River mainstem. This could explain the higher proportion of the total spawner population contributed by Sheep Creek in the post-treatment period as the number of Bull Trout spawning in the remaining tributaries declined.

There are other possible explanations for the contrasting trend in spawner abundance in Sheep Creek versus the other tributaries, but nutrient enrichment appears the most plausible, especially considering that 1) adults from all tributaries share a common rearing environment in the Salmo River mainstem, and 2) the decline in abundance from the pre- to the post-treatment period was observed in all three of the control tributaries individually (Table 3). In other words, the contrasting abundance trends for Sheep Creek versus the control tributaries was not the result of unfavorable spawning success or juvenile survival conditions unique to one control tributary. However, it is also possible that spawner numbers remained stable in Sheep Creek alone due to some factor unrelated to nutrient, which could lead to a false positive detection of a treatment effect.

One possible example is the tendency in migratory salmonid populations for spawning distribution to contract as total abundance declines. Typically, during a period of poor survival conditions and declining abundance, core habitats or streams that provide the best spawning and rearing environments experience proportionally smaller decreases compared to lower quality streams, with spawners sometimes disappearing entirely from marginal streams during periods of

[1] Nutrient addition occurred annually in Sheep Creek from 2004-2022, with the exception of 2010 and 2011.

severe decline (e.g., Interior Fraser Coho Salmon, Decker et al. 2014). Hagen and Decker (2011) describe this general trend for Bull Trout populations throughout BC. Sheep Creek supported the highest densities of Bull Trout spawners among the Salmo tributaries both before and after nutrient enrichment, so it is reasonable to assume that this stream provides some of the best quality spawning and juvenile rearing habitat in the watershed independent of nutrient enrichment. So it may be expected that Sheep Creek would contribute a higher proportion of total spawners as the overall population declined. However, under a scenario of declining survival or carrying capacity, normally there would still be some degree of decline observed in even the best quality, core habitats, but this was not the case for Sheep Creek. Weighing the evidence, it seems unlikely that spawner numbers in Sheep Creek would have remained stable in the absence of nutrient enrichment, given the large declines observed in the other tributaries.

Recommended Recovery Planning for Salmo River Bull Trout

In 2008 and 2009 the SWSS hosted workshops to discuss the issue of Bull Trout conservation, given the concern about observed declines in adult abundance. These workshops were attended by representatives of many agencies involved in fisheries management in the watershed (BC Hydro, Ministry of Environment (MOE), Fish and Wildlife Compensation Program (FWCP), Canadian Columbia River Intertribal Fisheries Commission, Salmo Watershed Streamkeepers Society (SWSS), Department of Fisheries and Oceans (DFO), Teck Metals Ltd.). The purpose of the workshops was to solicit expert opinion regarding the principal threats to the viability of the Salmo migratory Bull Trout population, and where to best direct conservation efforts. In order of priority, loss of connectivity to adult foraging habitat and genetic diversity due to dam construction, high summer/early fall temperatures in the Salmo River mainstem, habitat degradation, non-native species impacts, and illegal harvest were voted the most important threats.

With respect to allocation of conservation effort, participants ranked restoration of habitat, restoration of habitat connectivity, monitoring and mitigation of high temperatures, reduction of non-native species impacts, and reduction of illegal harvest as the highest to lowest conservation priorities, respectively. Given the current status of the Salmo River Bull Trout population, and evidence of declines in spawner numbers in recent years, these conservation priorities would appear warranted. However, restoration of habitat, restoration of habitat connectivity and mitigation of high stream temperatures are, realistically, long-term objectives at best, and, in the case of the latter two, involve factors that will be difficult to reverse (i.e., river impoundment and climate change). Moreover, there is currently insufficient data to conclude that stream temperatures have increased from historical levels, and to what degree human-induced climate change has been a contributing factor. With these considerations, there are several recommendations which focus mainly on technical information gaps that could be addressed in the short-term, some of which were also discussed during the workshop. In addition, the SWSS and the FWCP are working together to find synchronicities between the SWSS Watershed-based fish Sustainability Plan and the FWCP Streams Action Plan. To this end a multi-stakeholder collaborative transboundary Watershed Planning Team (WPT) has been assembled to look at objectives and related strategies to 'increase aquatic ecosystem health' in the Salmo Watershed. The WPT has agreed that abundance and productivity of Bull Trout and mainstem fluvial Rainbow Trout abundance be used as metrics to assess the effectiveness of any projects to increase aquatic ecosystem health. Recommended Strategies for Bull Trout following recommendations (2, and 4-9) are largely taken from Baxter and Decker (2010), and/or were originally developed during the 2008/2009 Bull Trout conservation workshops. Recommendations 1, 3, 10, and 11 were added in 2014. This year we added recommendation 12 in view of a growing logic focusing on the Rosgen watershed-based hydrological assessment approach in order to increase: 1, success/retention of fish habitat enhancement structures and to 2, consider a watershed-based water temperature reduction strategy.

1. **Develop an inter-agency Salmo River Bull Trout Recovery Plan**

2. **Continued nutrient addition to Sheep Creek on an annual basis**
   Previous results have repeatedly demonstrated positive responses to stream fertilization in Sheep Creek at all trophic levels including juvenile Bull Trout and other fish. This report documents, for the first time, a positive impact at the population level for Bull Trout occupying the Salmo watershed. Consideration should be given to expanding the stream fertilization to additional tributaries.

3. **Redd count survey**

Continue the existing monitoring program, with the second week of October as the optimal timing for single-census redd surveys, as data suggests that spawning is largely complete by early October. It is also recommended that every effort be extended to coordinate with Canadian and U.S. Customs Agencies to allow for complete surveys of the South Salmo River, so that it is not necessary to base spawner escapement estimates on extrapolation of counts from partial surveys.

As mentioned by Dunham *et al.* (2001) and others, conducting two or more surveys distributed over time, can improve the accuracy of redd counts by allowing the progression of individual redds to be monitored over time (redds are individually marked during each survey to avoid double counting), which can help to distinguish redds from 'test digs' or false redds. An additional survey conducted earlier in the spawning period would also help to reduce the risk of redd-obscuring flows occurring prior to a single survey in early October. Decker et al. (2006) found that the likelihood of redd obscuring flows began to increase significantly beyond the end of September in tributaries of the nearby Arrow Lakes Reservoir (ALR). However, experience in the Salmo River suggests that redd-scouring flows are likely less common compared to ALR tributaries.

Another suggestion arising from the Salmo River Bull Trout workshop was to conduct stream walks prior to Bull Trout migrating to the tributary spawning areas to identify and open possible migration barriers. In 2006 and 2007, stream flows were below average in the spawning tributaries, and the survey crews noted that migration conditions for spawners appeared difficult as a result. Several beaver dams, which do not usually impede adult migration at higher flows, were judged to be obstructions at the low flows occurring at that time. In past years, log jams formed during the spring freshet have also been observed to limit the upstream distribution of spawners as were substrate bedload jams perhaps due to shorter 'flashier' spring freshets. Although the 2015 season was one of the lowest discharge years recorded since 1949 (data from the Environment Canada Station in the lower Salmo River) Bull Trout migration did not seem to be impeded to any of the known spawning areas. This was probably due to the 2015 freshet being characterized by a 'low and slow' run-off without the very high flows observed in some previous years that moved large amounts of substrate and contributed to migration barriers. Also, from personal observation, beaver activity in spawning tributaries appears to have been at an all-time low in 2015. Several potential barriers and/or LWD debris accumulation sites were documented during the 2022 survey.

Also, it may be worthwhile to equip redd surveyors with tools and instruction to gently, partially excavate a sample of redds to ensure egg deposits for determining redd certainty. This methodology was successfully incorporated in Bull Trout escapement monitoring in Cultus Creek in 2009 (Nellestijn 2009).

Finally, the South Salmo River genetics project (see above) conducted by the Kalispel Tribe and Seattle City Light in August of 2014 confirmed the presence of spawning adult Bull Trout in the U.S. section of the South Salmo River (SSR). The lack of access to the U.S. section of the SSR to survey redds continues to be an issue and a data gap in this study. In the future it may be worth attempting to coordinate with Kalispel Tribe fisheries staff in the United States to ensure the whole known spawning area of the SSR is surveyed.

4. **Deliver a comprehensive Bull Trout awareness campaign aimed at the angling community and the agencies and industries that impact Bull Trout populations**

5. **Juvenile Bull Trout population assessments**

Juvenile population surveys were conducted annually from 2001-2007 (and in 2009) in Sheep Creek and the South Salmo River as part of a stream fertilization study (Decker 2009), but juvenile populations in other Bull Trout spawning and rearing areas (Clearwater Creek, upper South Salmo River) have not been assessed since 1997 (Baxter *et al*. 1998). Given the sharp declines in, and very low abundance of spawners in these areas in recent years, the current distribution and abundance of juvenile Bull Trout, as well as that of competitor species (Rainbow Trout and Eastern Brook Trout) should be examined. Survey methods should follow those employed in Sheep Creek and the South Salmo River (Baxter and Decker 2010), and ideally, all four Bull Trout spawning tributaries should be included (Sheep, SSR, Clearwater, and upper Salmo) Consideration should also be given to conducting juvenile surveys in reaches above barriers in the spawning tributaries, as resident Bull Trout populations that may reside there are potential reservoirs of genetic diversity within the Salmo River metapopulation (Hagen 2008).

6. **Use of resistivity counters or kelt fences**

A single resistivity counter operated in alternating spawning tributaries each year to enumerate kelts returning downstream from spawning locations (e.g., Andrusak 2009) could provide a more accurate estimate of the ratio of adults per redd that is specific to the Salmo River population. Given the small size of Salmo River spawning tributaries, and their low fall discharge (< 2cm), permanent concrete sills would not be required at counter locations, thereby reducing installation costs considerably.

If carefully monitored to minimize the risk of Bull Trout mortality, kelt fences could be substituted if the use of resistivity counters was deemed unfeasible at certain locations. Given present low escapements, kelt fences installed at three strategic locations: 1) near the mouth of the South Salmo River, 2) near the mouth of Sheep Creek, and 3) just upstream of the confluence of Hall Creek and the Salmo River on the Salmo. If these fences were set up in the early migration period they would likely be effective at capturing very close to if not the entire spawning BT population. Fences could provide reliable annual estimates of the aggregate spawning population for the entire Salmo River Watershed

7. **Develop a comprehensive stream temperature monitoring program in the Salmo River Watershed**

   Recent evidence of average daily temperatures in the mainstem of the Salmo River exceeding the 15°C threshold for adult Bull Trout preference (A. Prince, Westslope Fisheries, pers. comm. 2008) suggests that the Salmo River Bull Trout population is vulnerable to increases in stream temperature arising from climate change and reductions in forest cover and riparian vegetation degradation in the watershed. In the recent past mainstem water temperatures have been monitored at several locations as part of a sub-adult Bull Trout study (Prince 2009). Also, the SWSS have been monitoring mainstem summer temperatures as part of a Columbia Basin Trust (CBT) water quality-monitoring project. The SWSS has, on their own implemented a long-term temperature monitoring in the Salmo River mainstem and expanded it to its tributaries as part of a coordinated program for Bull Trout conservation.

   As of 2019 it appears that the Ktunaxa Nation has increased temperature monitoring in this watershed. SWSS has attempted to connect with them to share our monitoring data.

8. **Consider changes to angling regulations and monitoring of compliance**

   Adult Bull Trout can be highly vulnerable to angling, particularly when they are concentrated below barriers in small spawning tributaries for lengthy periods of time. A recent study in Alberta (Johnson *et al.* 2007) documented a 20-fold increase in Bull Trout spawner abundance over a ten-year period following a harvest ban. In 1999, a harvest ban was placed on Bull Trout in the Salmo River and catch-and-release regulations imposed, but this had no verifiable effect on spawner abundance (Figure 2). It is possible that some individuals who legally harvested Bull Trout prior to 1999 have continued to do so illegally. Alternatively, it is also quite possible that some other bottleneck to adult abundance exists in the Salmo River, and that harvest levels for Bull Trout were very low even before catch-and-release was implemented in 1999. In 2015, due to concerns around high water temperatures and low flows, the Province ordered a mid-summer closure that may have benefitted Bull Trout. We strongly recommend that this mid-summer closure become an enduring regulation.

Of the five potential conservation issues identified by the Bull Trout workshop participants, illegal harvest was ranked as the least likely to be responsible for population decline and as the lowest priority for conservation effort. The Salmo Watershed Streamkeepers have conducted a public education program since the inception of the harvest ban in 1999 to increase public awareness of the conservation concern for Salmo River Bull Trout and to encourage compliance with the harvest ban. Feedback from the local community suggests increasing support for the harvest ban and growing awareness of the current vulnerable status of Salmo River Bull Trout (G. Nellestijn, pers. comm.). Nevertheless, illegal harvest does offer a plausible explanation for the sharp declines in adult abundance observed over short time periods in specific spawning areas. Although it is pure conjecture, one could argue that the relative stability of spawner numbers in Sheep Creek in comparison to other spawning areas is the result of the frequent presence of fisheries personnel in Sheep Creek (to maintain the stream fertilization project) acting as a deterrent to prospective poachers. This deterrent was absent in 2010 and 2011 perhaps leading to lower spawner abundance in 2012 (16 spawners). Since 2013, when the fertilization project was reintroduced, Bull Trout spawner numbers have remained above 50 individuals (Figure 2).

It is recommended that illegal harvest at least be given more serious consideration. It bears mentioning that when the adult population levels are ~100 individuals, each adult removed from the population results in ~1% mortality. Several excellent recommendations addressing this issue were put forward during the 2008/2009 workshops and bear repeating here:

- Closures (as opposed to a ban on retention only) in Bull Trout spawning areas during the period when adult Bull Trout are present (August-mid-October). This is consistent with policy for vulnerable migratory Bull Trout populations in other watersheds in the West Kootenay Region (e.g., Arrow Lakes Reservoir). This would not affect the Rainbow Trout fishery in the mainstem. Current angling effort in the tributaries is low, but closures would make it more difficult for individuals to inconspicuously harvest Bull Trout in these areas;

- Creel surveys in the Salmo River mainstem would provide estimates of incidental catch rate for Bull Trout by anglers predominately targeting Rainbow Trout. It would also provide additional opportunities for public awareness and education regarding Bull Trout conservation and angling/fish handling practices that are potentially harmful to Bull Trout;
- Periodic supported patrols (conservation officers teamed with volunteer stream stewards, or trained stewards on their own) in areas where poaching is most likely to occur (e.g., remote tributary locations) and increased enforcement.

9. Scoping Exercise

Another important element recommended in the 2008/2009 Bull Trout conservation workshops was the idea to hire a consultant to complete a Bull Trout scoping exercise. There have been many research & monitoring programs conducted in the Salmo River Watershed and other areas relating to Bull Trout, and the scoping exercise will assemble all available reports and any other pertinent information that may help shape insights into Salmo River Watershed Bull Trout population dynamics. This element was recognized to be critical in the development of a recovery strategy for Salmo River Watershed. The Scoping Exercise was completed by the SWSS in 2015 (see Hagen, Nellestijn & Decker 2015).

From the information review completed during the Scoping Exercise, the authors were able to:

- Determine what is known about Salmo River Watershed Bull Trout life history and population status.
- Define the information gaps in Salmo River Watershed Bull Trout biology.
- Develop Salmo River Bull Trout population limiting factor hypotheses and review information relevant to each hypothesis.
- Assess the vulnerability of Bull Trout populations.

10. **Collection of genetic samples from Salmo River Watershed Bull Trout to determine if they are genetically distinct from Bull Trout in the Columbia River system**. Whether or not Salmo River Watershed Bull Trout are genetically unique has important implications with respect to the priority status of Salmo River Watershed Bull Trout conservation at a provincial scale. Genetic samples could most easily be collected during juvenile population assessment surveys (e.g., as part of stream fertilization monitoring).

11. **Investigate whether river otter (*Lontra canadensis*) could be a significant threat to adult Bull Trout in the Salmo River.** There is anecdotal evidence that the otter population in the Salmo River watershed is increasing. Otters have been observed eating fish remains in the lower Salmo River area (J. Clarricoates (CCRIFC), pers. comm.), and Bull Trout mortalities have been found by the author in spawning tributaries that may be attributed to otters.

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Appendix A: Study Area Sub Maps

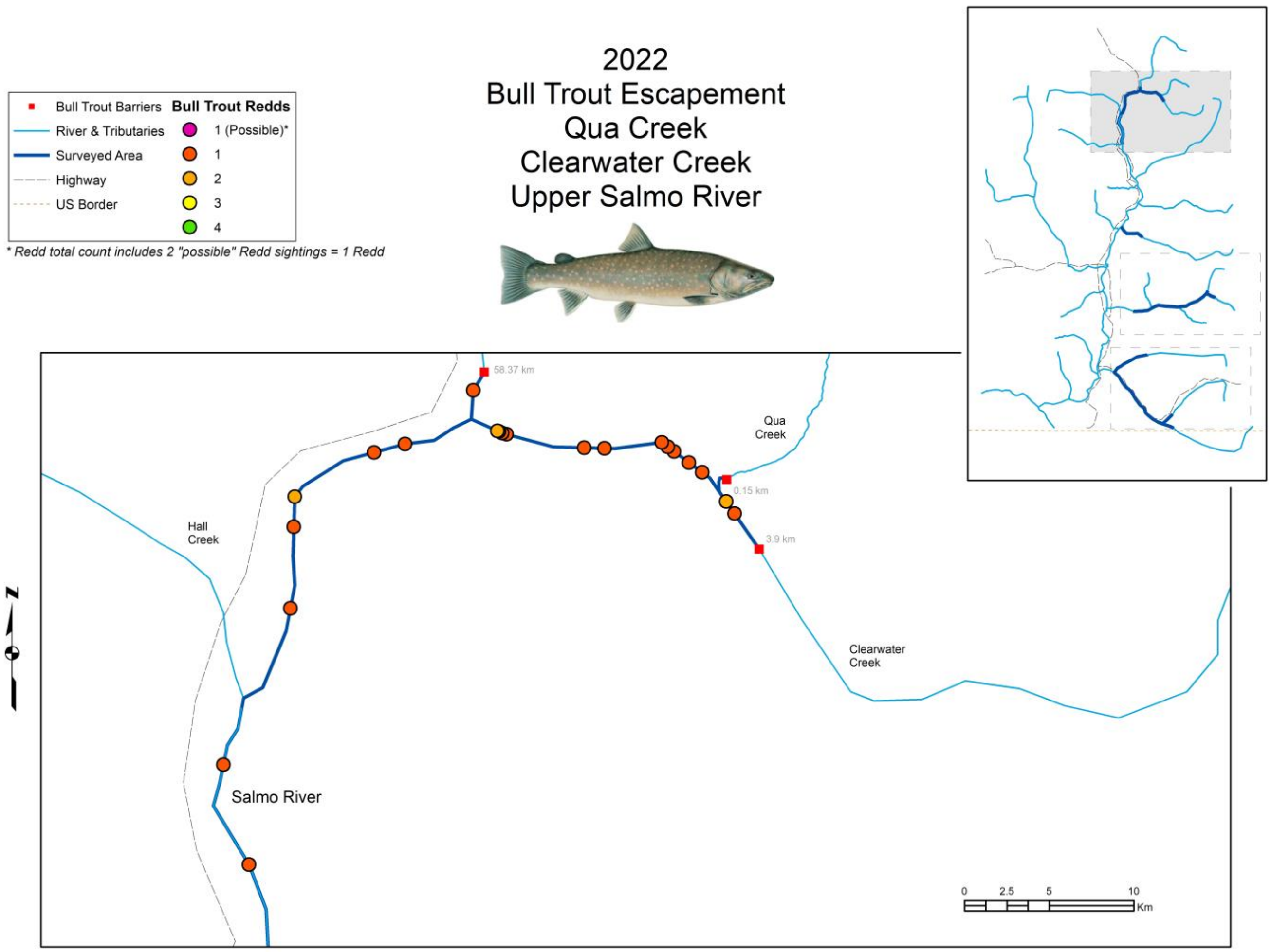

Figure A- 1. Study Area Sub Map 1. Upper Salmo River and Headwaters at the confluence of Apex and Clearwater Creeks showing locations of complete redds and known Bull Trout barriers in 2022.

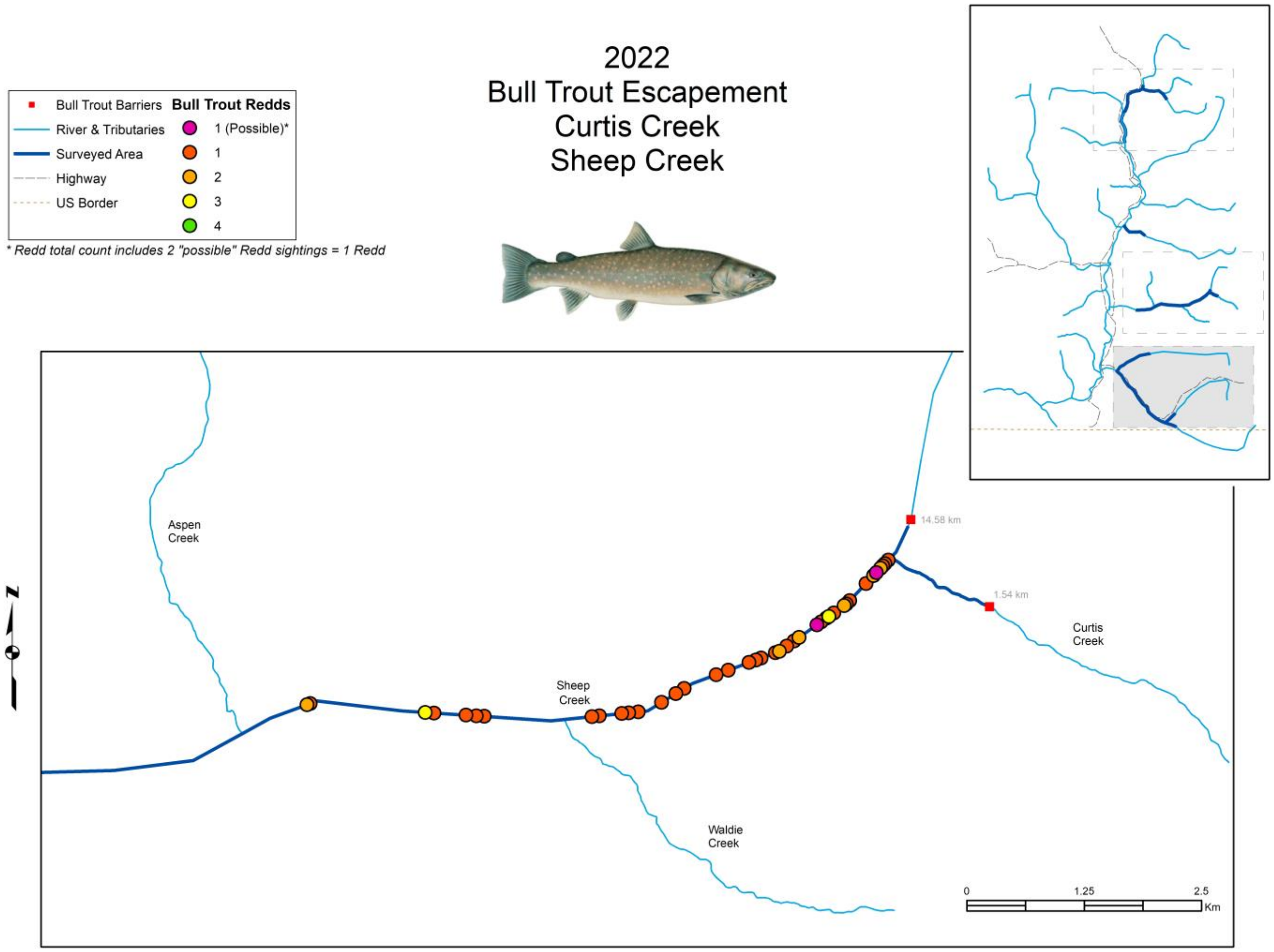

Figure A- 2. Study Area Sub Map 2: Mid Salmo River showing locations of complete redds and known Bull Trout barriers on Sheep and Curtis Creeks in 2022.

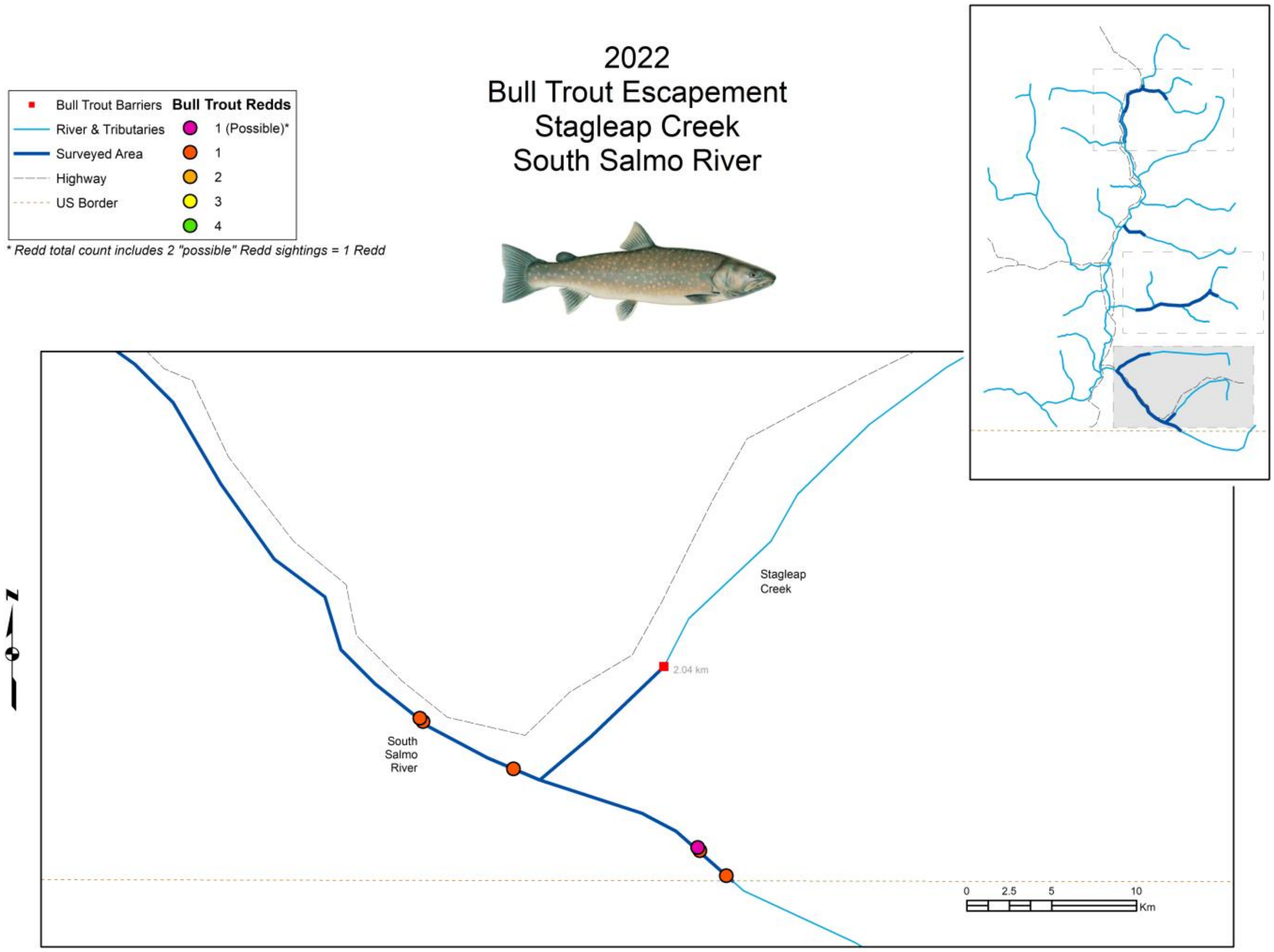

Figure A- 3. Study Area Sub Map 3: South Salmo River and tributaries showing locations of complete redds and known Bull Trout barriers in 2022.

Appendix B: Survey Data Sheets

Salmo River Bull Trout Field Data 2022 - Stagleap Creek						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
11-Oct-22	1	49.01619	-117.16476	0	0	Start of survey on Stagleap Creek
	2	49.01212	-117.16977	0		Flagging tape - trail crossing to the border

Salmo River Bull Trout Field Data 2022 - South Salmo River						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
11-Oct-22	3	48.99891	-117.13395	0	4	Border
	4	48.99957	-117.13626	0		Possible redd
	5	48.99948	-117.13739	1		Redd (older)
	6	49.00164	-117.14175	1		Redd
	7	49.00195	-117.14207	1		Possible redd
	8	49.00698	-117.15207	0		Possible barrier LWD/debris acccumulation
	9	49.00973	-117.16368	0		Large avulsion
	10	49.01039	-117.16599	0		Possible redd
	11	49.01186	-117.17265	1		Redd d/s confluence of Stagleap Creek
	12	49.01482	-117.18328	0		Lead Creek Road bridge (Take Out)

Salmo River Bull Trout Field Data 2022 - Lead Creek Bridge to Andersen Campground						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
16-Oct-22	1	49.01482	-117.18328	0	2	Lead Creek Road bridge - Start Survey
	2	49.01113	-117.11324	1		Redd (slightly fadded)
	3	49.01145	-117.11370	1		Redd (slightly fadded)
	4	49.02063	-117.12244	0		Andersen Campground (Take Out)

Salmo River Bull Trout Field Data 2022 - Andersen Campground						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
17-Oct-22	1	49.02063	-117.12244	0	0	Andersen Campground (Put In)
	2	49.04076	-117.14575	0		Rest Stop (Take Out)

Salmo River Bull Trout Field Data 2022 - Clearwater Creek						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
12-Oct-22	1	49.38271	-117.16724	0	16	Falls/Start Survey
	2	49.38379	-117.16811	0		Possible barrier
	3	49.38042	-117.16931	1		Redd
	4	49.38526	-117.17150	1		Redd
	5	49.38658	-117.17323	1		Redd
	6	49.38071	-117.17368	2		2 redds
	7	49.38791	-117.17489	1		Redd
	8	49.38799	-117.17500	1		Redd
	9	49.38939	-117.17717	1		Redd
	10	49.39025	-117.18559	1		Redd
	11	49.38942	-117.18864	1		Redd
	12	49.38960	-117.19979	1		Redd
	13	49.38990	-117.19970	1		Redd
	14	49.39001	-117.20009	2		2 redds
	15	49.38993	-117.20007	1		Redd
	16	49.39164	-117.20303	1		Redd
	17	49.39204	-117.20888	0		Take Out - Clearwater Cr./Apex Cr. Confluence

Salmo River Bull Trout Field Data 2022 - Lower Sheep Creek						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
14-Oct-22	1	49.14550	-117.14788	1	10	Redd
	2	49.14569	-117.14961	1		Redd
	3	49.14602	-117.15031	1		Redd
	4	49.14688	-117.15511	1		Redd
	5	49.14711	-117.15649	3		3 redds in sidechannel
	6	49.14574	-117.17381	2		2 redds
	7	49.14572	-117.17387	1		Redd

Salmo River Bull Trout Field Data 2022 - Upper Salmo River						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
15-Oct-22	1	49.38853	-117.21565	1	10	1 redd
	2	49.38824	-117.22049	1		1 redd
	3	49.38083	-117.23716	2		2 redds
	4	49.37972	-117.23700	1		1 redd
	5	49.37207	-117.23432	1		1 redd
	1	49.35649	-117.24651	1		1 redd
	2	49.34676	-117.24097	1		1 redd
	3	49.33490	-117.23997	1		1 redd
	4	49.32743	-117.24053	1		1 redd

Salmo River Bull Trout Field Data 2022 - Upper Sheep Creek						
GPS Waypoint Locations						
Date	**WPT**	**Latitude**	**Longitude**	**# Redds**	**Total**	**Description**
13-Oct-22	1	49.15939	-117.09280	0	40	Possible redd
	2	49.15928	-117.09261	1		Redd
	3	49.15900	-117.09287	1		Redd
	4	49.15799	-117.09342	1		Redd
	5	49.15778	-117.09358	1		Possible redd
	6	49.15779	-117.09389	2		2 redds
	7	49.15757	-117.09241	2		2 redds
	8	49.15688	-117.09480	1		Redd
	9	49.15649	-117.09570	0		Possible redd
	10	49.15543	-117.09727	1		Redd
	11	49.15536	-117.09763	1		Redd
	12	49.15535	-117.09766	2		2 redds
	13	49.15485	-117.10040	1		Redd
	14	49.15461	-117.10160	3		3 redds
	15	49.15466	-117.10171	1		Redd
	16	49.15456	-117.10259	1		Redd
	17	49.15436	-117.10297	1		Possible redd
	18	49.15338	-117.10633	2		2 Redds
	19	49.15331	-117.10659	1		Redd
	20	49.15291	-117.10715	1		Redd
	21	49.15252	-117.10903	2		2 redds
	22	49.15237	-117.10929	1		Redd
	23	49.15223	-117.11140	1		Redd
	24	49.15226	-117.11142	1		Redd
	25	49.15223	-117.11169	1		Redd
	26	49.15241	-117.11288	1		Redd
	27	49.15116	-117.11527	1		Redd
	28	49.14917	-117.12174	1		Redd
	29	49.14910	-117.12209	1		Redd
	30	49.14827	-117.12484	1		Redd
	31	49.14767	-117.12608	1		Redd
	32	49.14758	-117.12773	1		Redd
	33	49.14751	-117.12860	1		Redd
	34	49.14627	-117.13155	1		Redd
	35	49.14617	-117.13194	1		Redd