

**BULL TROUT REDD COUNT SURVEYS IN SELECT
KOOTENAY LAKE TRIBUTARIES (2013) AND
RECOMMENDATIONS FOR FUTURE SURVEYS**



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BULL TROUT REDD COUNT SURVEYS IN SELECT KOOTENAY LAKE TRIBUTARIES (2013) AND RECOMMENDATIONS FOR FUTURE SURVEYS

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Cover Photo: 'Observed bull trout redd on upper Kaslo River.' Photograph taken on the 4th of October 2013 by Greg Andrusak.

The Fish and Wildlife Compensation Program is a joint initiative between BC Hydro, the BC Ministry of Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) and Fisheries & Oceans Canada (DFO) to conserve and enhance fish and wildlife populations affected by the construction of BC Hydro dams in Canada's portion of the Columbia Basin.



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Executive Summary

The Fish and Wildlife Compensation Program (FWCP) annually funds two major compensation projects on Kootenay Lake: a large scale nutrient restoration project, and operation of the Meadow Creek kokanee spawning channel. One of the primary rationales for these projects is the restoration of the adfluvial bull trout and Gerrard rainbow trout populations, therefore monitoring the status of these apex species is a high priority of the FWCP as reflected in the program's Large Lake Plan. Until 2011 there had been no lake-wide measure of bull trout abundance to use as a performance measure to gauge success of the compensation projects. The purpose of the first bull trout redd survey was to establish an initial lake-wide index of the number of spawning bull trout, their distribution and determine a method of estimating their abundance in Kootenay Lake tributaries. The redd counts, if repeated over the long term, will provide a valuable performance measure for evaluating the response of bull trout to FWCP compensation efforts and management decisions on the lake.

In 2013 the FWCP provided funding to monitor some of the key Kootenay Lake bull trout spawning streams identified by Andrusak and Andrusak (2012). At about the same time the MFLNRO issued an Invitation to Quote to survey some additional streams that were not included in the 2011 or 2013 FWCP surveys. This report summarizes the redd surveys from eight index streams funded by the FWCP and integrates the MFLNRO ITQ survey results from thirteen streams.

A comprehensive assessment of bull trout spawning redds was conducted in a select group of Lardeau/Duncan rivers and Kootenay Lake tributaries in the fall of 2013. Approximately 170 km of stream habitat was surveyed in three geographical areas of the lake that included: Lardeau/Duncan tributaries (Group 1), Central Kootenay Lake tributaries (Group 2) and South Arm tributaries (Group 3). A total of 1,078 redds were enumerated over 170 km of stream habitat surveyed. This total was virtually all (n=1070) from eight streams surveyed (141 km) under the FWCP funded project. The remaining 8 redds were enumerated over 41 km under the ITQ contract directed work. The most prominent bull trout systems included the Kaslo River, Crawford Creek, Midge Creek and Meadow Creek that together accounted for greater than 50% of all redds enumerated in the combined study, affirming their importance as potential index systems for bull trout monitoring on Kootenay Lake.

The 2013 redd counts on key index streams such as Kaslo River, Keen, Midge and Coffee creeks indicated a substantial decline in redd numbers from previous years' surveys. The highest redd counts have been observed in the Kaslo River and tributaries but the 2013 count was 357 a considerable drop from the 2011 and 2012 counts of 512 and 513 respectively and well below the highest count in 2009 of 681. Preliminary model analysis

affirmed a decline in 3 of the 4 important index streams but more years of data is needed to discern whether this is a persistent long-term trend in the population. The apparent decline is somewhat troubling since it is known that the lakes' recreational fishery harvest may already be near or above optimal levels. However, it's unclear whether the decline is solely attributed to high exploitation or natural population variability and/or lower in-lake survival due to lower kokanee abundance. All of these variables support the need for long term monitoring that is required to assist the FWCP in determination of the degree of success of lake fertilization.

In two systems surveyed in 2013, Woodbury and Cultus creeks, it was confirmed that some bull trout spawners were able to ascend beyond partial barriers identified in 2011. Partial fish passages appear to be dependent on high flow conditions and since this varies from year to year these two systems are not recommended for inclusion in long term monitoring. Poplar Creek is also not recommended for inclusion as an index site owing to safety concerns in the narrow canyon area where bull trout spawn. On the other hand Meadow Creek is recommended for long term monitoring since the 205 redds counted in 2013 was the third highest of all tributaries surveyed, the highest amongst Group 1 streams and relatively cost effective to survey.

In general, the redd surveys in the fall of 2013 provided further information on the distribution and abundance of bull trout within the Kootenay Lake drainage. The ITQ data confirmed that systems with less than 1 km of spawning habitat support few bull trout spawners. In light of a possible declining trend in a number of key tributaries and regional and provincial concern for bull trout conservation it would appear to be prudent to continue to monitor redd counts on the key bull trout systems.

Acknowledgements

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Table of Contents

EXECUTIVE SUMMARY	I
ACKNOWLEDGEMENTS	III
TABLE OF CONTENTS	IV
LIST OF TABLES	VI
LIST OF FIGURES	VI
INTRODUCTION	1
RATIONALE AND OBJECTIVES	2
BACKGROUND	3
BULL TROUT LIFE HISTORY OVERVIEW	3
BULL TROUT REDD SURVEYS: SOURCES OF UNCERTAINTY	4
BULL TROUT AND KOOTENAY LAKE OVERVIEW	6
SITE LOCATION	7
<i>Kootenay Lake</i>	7
GROUP 1 (DUNCAN/LARDEAU TRIBUTARIES)	13
<i>Poplar Creek</i>	13
<i>Cascade Creek</i>	13
<i>Meadow Creek</i>	13
GROUP 2 (CENTRAL KOOTENAY LAKE TRIBUTARIES)	14
<i>Davis Creek</i>	14
<i>Fry Creek</i>	14
<i>Campbell Creek</i>	14
<i>Kaslo River</i>	14
<i>Bernard Creek</i>	15
<i>Tam O’ Shanter</i>	15
<i>Woodbury Creek</i>	15
<i>Coffee Creek</i>	15
<i>Crawford Creek</i>	16
<i>Gray Creek</i>	16
GROUP 3 (SOUTH ARM KOOTENAY LAKE TRIBUTARIES)	16
<i>LaFrance Creek</i>	16
<i>Lockhart Creek</i>	17
<i>Midge Creek</i>	17
<i>Akokli Creek</i>	17
<i>Sanca Creek</i>	17
<i>Cultus Creek</i>	18
<i>Next Creek</i>	18
<i>Goat River</i>	18
METHODS	19
RECONNAISSANCE SURVEYS	19
REDD IDENTIFICATION	19
REDD SURVEYS	20
ANALYSIS OF TRENDS	20
RESULTS	21

GROUP 1 (DUNCAN/LARDEAU TRIBUTARIES).....	21
<i>Poplar Creek</i>	21
<i>Cascade Creek</i>	22
<i>Meadow Creek</i>	22
GROUP 2 (CENTRAL KOOTENAY LAKE TRIBUTARIES).....	23
<i>Davis Creek</i>	23
<i>Fry Creek</i>	23
<i>Campbell Creek</i>	24
<i>Bernard Creek</i>	25
<i>Kaslo River</i>	25
<i>Woodbury Creek</i>	26
<i>Coffee Creek</i>	26
<i>Tam O’ Shanter Creek</i>	27
<i>Crawford Creek</i>	27
GROUP 3 (SOUTH ARM KOOTENAY LAKE TRIBUTARIES)	28
<i>Gray Creek</i>	28
<i>LaFrance Creek</i>	28
<i>Lockhart Creek</i>	29
<i>Midge Creek</i>	30
<i>Akokli Creek</i>	31
<i>Sanca Creek</i>	31
<i>Cultus Creek</i>	31
<i>Next Creek</i>	32
<i>Goat River</i>	32
ANALYSIS OF TRENDS.....	33
DISCUSSION	34
RECOMMENDATIONS	40
RECOMMENDED CORE MONITORING PROGRAM	40
<i>Group 1 (Duncan/Lardeau tributaries)</i>	40
<i>Group 2 (Central Kootenay Lake tributaries)</i>	40
<i>Group 3 (South Arm Kootenay Lake tributaries)</i>	40
RECOMMENDED FUTURE RECONNAISSANCE:.....	40
NOT RECOMMENDED FOR MONITORING:	41
REFERENCES.....	42
APPENDIX 1—TRIBUTARY WATERSHED AND LOCATION INFORMATION.....	48
APPENDIX 2—FIELD DATA FORMS.....	49
APPENDIX 3—TRIBUTARY BARRIER INFORMATION.....	50
APPENDIX 4—PHOTOS	51
APPENDIX 5—DECISION MATRIX FOR FWCP STREAM SELECTION	56
APPENDIX 6—REDD SURVEY DISTRIBUTIONS IN SELECT TRIBUTARIES	57
APPENDIX 7— SUMMARY OF BULL TROUT REDD SURVEYS CONDUCTED ON KOOTENAY LAKE TRIBUTARIES 2006-2013.	59

List of Tables

TABLE 1. GROUP 1(LARDEAU/DUNCAN TRIBUTARIES) REDD SURVEY DATA	22
TABLE 2. GROUP 2 (CENTRAL KOOTENAY LAKE TRIBUTARIES) REDD SURVEY DATA.	24
TABLE 3. GROUP 3 (SOUTH ARM KOOTENAY LAKE TRIBUTARIES) REDD SURVEY DATA.....	29
TABLE 4. DERIVATION OF EXPANSION FACTOR FROM ESTIMATED REDDS COUNTS AND ELECTRONIC RESISTIVITY COUNTS FROM THE KASLO RIVER (2006-2013) AND CRAWFORD CREEK (2008- 2013).	38

List of Figures

FIGURE 1. MAP OF KOOTENAY LAKE AND SELECT TRIBUTARIES FOR CONDUCTING REDD SURVEYS IN FALL OF 2013.....	9
FIGURE 2. LARDEAU/DUNCAN RIVER TRIBUTARIES COMPRISING GROUP 1.....	10
FIGURE 3. NORTH AND CENTRAL KOOTENAY LAKE TRIBUTARIES COMPRISING GROUP 2.	11
FIGURE 4. SOUTH ARM KOOTENAY LAKE TRIBUTARIES COMPRISING GROUP 3.	12
FIGURE 5. MODEL ESTIMATES AND 95% CRI'S FROM POISSON GLMM FOR SELECT INDEX SITES ON KOOTENAY LAKE. NOTE*- 2010 KASLO RIVER REDD COUNT CONSIDERED AN UNRELIABLE ESTIMATE DUE TO POOR VISIBILITY.....	33
FIGURE 6. RESISTIVITY COUNTER ESTIMATES AND REDD COUNT DATA FROM KASLO RIVER AND CRAWFORD CREEK SINCE 2006.	37
FIGURE 7. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN GROUP 1 (LARDEAU RIVER) TRIBUTARIES IN FALL OF 2013.....	57
FIGURE 8. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN GROUP 2 (KOOTENAY LAKE) TRIBUTARIES IN FALL OF 2013.....	57
FIGURE 9. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN GROUP 2 (KOOTENAY LAKE) TRIBUTARIES IN FALL OF 2013.....	57
FIGURE 10. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN THE KASLO RIVER (GROUP 2) IN FALL OF 2013.....	57
FIGURE 11. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN GROUP 2 (KOOTENAY LAKE) TRIBUTARIES IN FALL OF 2013.....	57
FIGURE 12. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN CRAWFORD CREEK (GROUP 2) IN FALL OF 2013.....	57
FIGURE 13. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN GRAY CREEK (GROUP 2) AND GROUP 3 (KOOTENAY LAKE) TRIBUTARIES IN FALL OF 2013.....	57
FIGURE 14. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN MIDGE CREEK (GROUP 3) IN FALL OF 2013.....	57
FIGURE 15. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN GROUP 3 (KOOTENAY LAKE) TRIBUTARIES IN FALL OF 2013.....	57

FIGURE 16. DISTRIBUTION OF REDDS AND KNOWN BARRIERS IN GROUP 3 (KOOTENAY LAKE) TRIBUTARIES
IN FALL OF 2013..... 58

FIGURE 17. DISTRIBUTION OF REDDS COUNTED IN THE GOAT RIVER (GROUP 3 KOOTENAY RIVER) IN FALL
OF 2013..... 58

Introduction

In recent years within British Columbia there has been a great deal of focused effort on assessing the distribution and abundance of bull trout (*Salvelinus confluentus*) because of the perception that this species is in decline and threatened by various developments. The province classified bull trout in 1994 as blue listed as a species of special concern (BC Environment 1994, Hagen and Decker 2011). This char species is only found in western North America (McPhail 2007) and was listed as a threatened species under the US Endangered Species Act in 1998 (Hagen and Decker 2011). Despite the impacts of stream habitat alteration and exotic species introduction, British Columbia prevails as a species stronghold for bull trout in North America (McPhail 2007).

Kootenay Lake and many of its tributaries provide a vast area of potentially suitable spawning and rearing habitat for bull trout. The lake itself provides a large lacustrine habitat in which a large portion of the adult population resides for the majority of their life history. Bull trout are known to be highly vulnerable to fishing, and very sensitive to changes or alterations to their stream habitats (Dunham and Rieman 1999, Dunham et al. 2001, 2003).

Kootenay Lake bull trout are the target of an intensive lake fishery with an estimated catch in 2011 of approximately 6,100, of which, 3700 of these harvested (Andrusak and Andrusak 2012b). A recent, large scale exploitation study has also indicated that harvest rates for bull trout may be near or above optimal levels on the lake (Andrusak and Thorley 2013). Concern of over-exploitation and a sizeable annual harvest of potential spawners are good reasons why there was a pressing need to assess their spawning distribution and estimate their abundance. Additionally this apex species is viewed as an important upper trophic level indicator of the highly successful nutrient restoration program on Kootenay Lake (Schindler et al. 2013b). A monitoring plan for Kootenay Lake bull trout in 2009 (Hagen and Decker 2009) and the Fish and Wildlife Compensation program (FWCP) has since identified bull trout monitoring as a large lakes high priority (FWCP 2012-draft).

Initial monitoring of Kootenay Lake bull trout spawning commenced in 2006 on the Kaslo River and Crawford Creek systems (Andrusak 2010, Andrusak and Andrusak 2012a). This work was followed by the first comprehensive assessment of adfluvial bull trout spawning in 19 tributaries to Kootenay Lake that was completed for the FWCP in the fall of 2011 (Andrusak and Andrusak 2012a). The intended outcome of this survey by the FWCP was to identify some key representative Kootenay lake bull trout spawning

systems that can be monitored in an effort to establish a long term data set that can be used for trend analysis (FWCP 2012-draft).

In 2013 the FWCP provided funding to monitor some of the key spawning streams identified by (Andrusak and Andrusak 2012a). At about the same time the MFLNRO issued an Invitation to Quote (ITQ) to survey some additional streams that were not included in the 2011 or 2013 FWCP surveys. This report summarizes the redd surveys from eight index streams funded by the FWCP and integrates the MFLNRO ITQ survey results.

Rationale and Objectives

The FWCP annually funds a large scale nutrient restoration project and kokanee spawning channel on Kootenay Lake that are high priorities for the Program. Since bull trout are likely the most abundant top-piscivore in the lake and a primary rationale for the compensation projects is restoration of bull trout and Gerrard rainbow trout populations, the FWCP supports as a core activity Kootenay Lake bull trout monitoring. This began in 2009 with a comprehensive review of existing information on adfluvial bull trout distribution in the lake's tributaries, and a consideration of several population monitoring options (Hagen and Decker 2009). The priority recommendation from that report was to conduct redd counts in a selected suite of tributaries with documented evidence of adfluvial bull trout presence. The current (2013) study's objectives include:

- ⊙ Summarize results of redd surveys, reconnaissance surveys, barrier locations and accessible habitat on 8 select tributaries to Kootenay Lake, including adjoining tributaries to these systems funded by FWCP.
- ⊙ Summarize results of redd surveys, reconnaissance surveys, barrier locations and accessible habitat on 13 select tributaries to Kootenay Lake, as part of MFLNRO ITQ.
- ⊙ Survey and summarize data by geographical group (i.e. Group 1-Duncan/Lardeau tributaries; Group 2- Central Kootenay Lake tributaries; Group 3-South Arm Kootenay Lake tributaries)
- ⊙ Discuss recommended representative streams for long term monitoring.
- ⊙ Provide estimates of bull trout escapement to the watersheds surveyed

Background

Bull Trout Life History Overview

Bull trout, native to western North America, are widely distributed throughout much of BC (McPhail 2007). They generally display three common life history patterns which consist of fluvial, adfluvial and resident populations distributed throughout their entire geographic range. Stream resident populations are typically separated from migratory populations (fluvial or adfluvial) by an obstacle or barrier to migration, either physical (e.g., waterfalls, dams; Latham 2002), physiological (e.g., unfavorably high temperatures; Rieman and McIntyre 1993; (Dunham et al. 2003)), or biological (e.g., presence of non-native competitor species; Paul and Post 2001). Bull trout spawn in the fall and depending on life history, reach sexual maturity between 5-6 years of age. This char species is considered slow growing and long lived, often exceeding 10 years of age. As well, depending on the life history form, size of older fish usually exceed 400 mm, with adfluvial forms attaining >600 mm at maturity.

Bull trout are exclusively adapted to cold water environments, a requirement for virtually all of their early life history. Egg incubation and development are specifically related to water temperature, with optimal development and survival for bull trout occurring at 2-4°C (McPhail and Murray 1979). As well, water temperature is highly important in the growth and survival of older juveniles and adults (Selong et al. 2001; Dunham et al. 2003). Rearing juveniles also have specific habitat requirements, typically utilizing shallow areas with low current velocities along channel margins with un-embedded substrate (McPhail and Baxter 1996). Density dependent survival during the earliest juvenile stages (egg to age 1) has been found to regulate recruitment into the adult population for most bull trout populations (Johnston et al. 2007). In general, stream resident populations spend their entire life cycle within individual streams or stream reaches, fluvial and adfluvial bull trout rear in natal tributaries for 1-4 years before undergoing migrations downstream to larger rivers and lakes, respectively, with migration at age-2+ being the most common (Fraley and Shepard 1989, Downs et al. 2006).

Fluvial and adfluvial populations usually spawn between mid-August and mid-October within the southern portion of BC, with many northern populations spawning earlier (McPhail and Murray 1979, Andrusak et al. 2011). Spawning redds range in size from 0.5-3.0 m² (McPhail and Murray 1979), depending on the size of the female and the nature of the substrate being utilized. The characteristic form of bright, clean appearance of redds, and the low water conditions generally present during the early fall, allow for counts of redds to be utilized as an index of population abundance. However, a single female may construct more than one redd (Leggett 1980), and the

average number of redds per spawner needs to be assessed if redd counts are to be used to estimate the size of the spawning population (Rieman and McIntyre 1996a, Dunham et al. 2001, Al-Chokhachy et al. 2005, 2009, Howell and Sankovich 2012). Electronic resistivity counters have been reliably utilized in defining the number of adults to redds and the data also reduces some of the uncertainty and variability associated with redd counts (Andrusak et al. 2011, Hagen and Decker 2011, Andrusak and Andrusak 2012a).

Bull Trout Redd Surveys: sources of uncertainty

Obtaining accurate estimates of escapements are essential for managing exploited fish populations and are imperative for monitoring population trends over time (Hilborn and Walters 1992, Rieman and Myers 1997, Dunham et al. 2001, Walters and Martell 2004). Establishment of a reliable monitoring program or index to ascertain trends in abundance and population status relies on and includes: 1) the repeatability of the survey 2) reducing uncertainty and variability around estimates and 3) the ability to provide a cost effective index over time. While redd counts provide a cost effective method of obtaining an index of adult escapement, their precision and accuracy are often compromised as a result of uncertainty in obtaining reliable estimates and ability to detect sensitive changes in population status (Rieman and Myers 1997, Maxell 1999, Al-Chokhachy et al. 2005, 2009, Andrusak et al. 2011, Howell and Sankovich 2012). Moreover, bull trout often spawn in the headwaters of tributaries that are often difficult to access and expensive to establish annual counts. Long term counts can be further confounded by variable spatial and temporal distributions that collectively make spawning bull trout difficult to assess (Rieman and McIntyre 1996, Rieman and Myers 1997, Dunham et al. 2001). Yet, the success of future bull trout conservation and management decisions will be dependent on the ability of biologists to accurately assess and monitor their status or abundance, particularly in response to management and restoration actions that are implemented.

Bull trout monitoring programs aimed at detecting trends in abundance and population status also need to consider the potential sources of uncertainty associated with detection probability and observation error. While much of the variability in counts between observers can be substantially reduced when using experienced crew members (Dunham et al. 2001, Muhlfeld et al. 2006) other potential variable sources include: redd density, habitat complexity, survey timing, water visibility, flow, redd size, redd age and weather conditions. All of these factors potentially can affect detectability when conducting redd counts. Errors associated with redd density include 1) omission, and 2) false identification. Omissions are considered to be related to redd densities because they are proportional to true redd numbers, while false identifications appear to be independent of redd frequency (Muhlfeld 2006). Moreover, false identification are

uniformly distributed and related to the length of stream surveyed (i.e. longer the section the more false identifications). Nevertheless, while false identifications are independent of redd frequency, in systems with low redd densities, redd counts have been observed to overestimate the true redd number due to false positives (Muhlfeld 2006). This latter scenario is most disconcerting when populations are at low abundances. Observer efficiency needs to be measured for each system in an attempt to reduce uncertainty in estimates but this is often impractical due to cost.

The spatial and temporal variability in conducting surveys (Muhlfeld et al. 2006) on such a large scale system such as Kootenay Lake can also be potential sources of uncertainty when trying to ascertain trends in abundance and population status, similar to that detailed on the Williston Reservoir (Andrusak et al. 2011). Decker and Hagen (2008) expressed their concerns of high flows on observability and temporal variability in spawn timing as contributing factors affecting the ability to conduct redd surveys in Arrow Lakes Reservoir (ALR) tributaries in 2005 and 2006. This was also experienced on the Kaslo River in 2010, when less than optimal visibility obscured redds, resulting in poor observer efficiency (Matt Neufeld pers. comm. MFLNRO). In that year, the resistivity counter estimate on the Kaslo River did not indicate a major decline in bull trout numbers as the redd survey indicated, suggesting the redd counts were underestimating under less than ideal conditions (Andrusak 2010).

Uncertainty also exists in expanding redd counts to estimate population size due to the unknown relationship between the number of redds created per fish which has been demonstrated to change through the wide geographic distribution bull trout inhabit, and in the same system over different years. For example, Al-Chokhachy et al. (2005) suggested an average of 2.68 bull trout/redd but indicated ranges between 1.2 to 4.3 bull trout per redd depending on the various life history forms being monitored. It is also suggested in the literature that there is strong correlation on a logarithmic scale between escapement estimates and redd counts, but observer errors and the spatial and temporal variability in bull trout life history can invite considerable uncertainty (Muhlfeld et al. 2006).

While experienced crews are important in reducing uncertainty, survey timing is likely more critical in obtaining accurate redd counts (Dunham et al. 2001). Andrusak and Andrusak (2012) observed that bull trout spawning activity peaked by mid- September and that redd construction was complete by mid-October. This is a very narrow window for conducting redd counts on a large number of systems therefore, the timing of redd counts should be determined for each population of interest by conducting spawners surveys to ensure that spawning is essentially complete. Resistivity counters offer an excellent understanding of the run timing and ideal time to implement redd surveys (Andrusak 2010).

Bull Trout and Kootenay Lake Overview

Kootenay Lake has endured significant ecological changes during the last half century. Hydroelectric developments upstream of the lake during the 1960s and 1970s have been responsible for most of the alterations, although unregulated discharge of phosphorus and other mining developments and discharge into the headwaters also had a significant influence on lake productivity during the 1960s and 1970s (Northcote 1973, Daley et al. 1981, Hirst 1991, Ashley et al. 1997, Moody et al. 2007). Collectively these impacts caused major changes to the primary sport fish populations that have been well documented in a series of publications (Northcote 1973, Daley et al. 1981, Hirst 1991, Ashley et al. 1997, Schindler et al. 2013). Until 1992, when lake fertilization commenced Kootenay Lake was in a state of trophic depression (Ney 1996) as a result of upstream reservoirs that retained nutrients which adversely impacted lake productivity that in turn impacted the many of its fish populations (Ashley et al. 1997, Binsted and Ashley 2006, Schindler et al. 2013).

Adfluvial populations of bull trout, primarily the adult and sub-adult life stage rely upon the large lacustrine habitat such as that found in Kootenay Lake. As with many piscivorous species of fish in Kootenay Lake, bull trout are highly dependent on kokanee (*Oncorhynchus nerka*) as their primary food source. The ecological footprint impacts from hydro-electric impoundment (Hirst 1991, Moody et al. 2007) have had profound negative consequences to kokanee stocks on Kootenay Lake over the past few decades resulting in a cascading effect on the piscivorous populations (Ashley et al. 1997, Schindler et al. 2013a, 2013b). With the recovery of the lakes' kokanee stocks, as a result of the large scale nutrient restoration program (Ashley et al. 1997, Schindler et al. 2013), bull trout populations have likely benefited from increased in-lake survival and growth conditions, similar to that reported on the Arrow Lakes Reservoir (Arndt 2004).

While Kootenay Lakes' bull trout populations have likely recovered to some extent from the ultra-oligotrophic era (Schindler et al. 2013), they are still highly vulnerable to poaching in spawning streams and over-fishing due to the intense recreational fishery. Until recently the lack of more comprehensive data on Kootenay Lake bull trout has been problematic since they appear to be highly susceptible to over-harvest as suggested in other studied populations having exploitation rates exceeding sustainable levels (Post et al. 2002, 2003, Johnston et al. 2007, Andrusak and Thorley 2013, Post 2013). It was the potential of overfishing bull trout and their sensitivity to habitat perturbations in their natal spawning and rearing tributaries (Dunham and Rieman 1999, Dunham et al. 2003) that led the BC provincial government to list bull trout as a species of concern.

Except for redd surveys in the Kaslo River watershed and Crawford Creek (Andrusak 2010) and some earlier work at the Duncan Dam (O'Brien 1999, Olmsted et al. 2001, Hagen 2003), there has been little information on the status of bull trout spawner numbers in most of Kootenay Lakes' tributaries. This changed with a comprehensive survey of 19 tributaries in 2011 (Andrusak and Andrusak 2012) with several streams identified as key systems for bull trout spawners. Fortunately these included Kaslo River and Crawford Creek that have been monitored since 2006 thus providing a good basis for establishment of long-term indices for these two bull trout streams on Kootenay Lake.

Assessment of bull trout spawning in Kootenay lake tributaries has been guided by an action plan developed by Hagen and Decker (2009). Access limitations, visual count limitations due to glacial runoff and safety concerns with some systems experienced in 2011 by Andrusak and Andrusak (2012) led to identification of a reduced number of candidate streams suitable for long term monitoring. Most of the key streams identified from the 2011 survey were included in the 2013 survey reported herein. Further, in an effort to fill in some additional data gaps the MFLNRO provided funding in 2013 for redd counts in a number of previously un-surveyed streams suspected of supporting spawning bull trout (Hagen and Decker 2009) and results of these counts are included in this report as agreed upon with the Ministry (M. Neufeld, Fisheries Biologist Nelson BC pers. comm.).

Site Location

Kootenay Lake

Kootenay Lake, located in the upper Columbia River drainage of Southeast British Columbia, lies between the Selkirk and Purcell Mountain ranges (Figure 1). The main lake is 107 km long, approximately 4 km wide with a mean depth of 94 m and a maximum of 154 m (Daley et al. 1981). The lake is fed by two major river systems: the Lardeau/Duncan system at the north end (North Arm) and the Kootenay River that flows into the south end (South Arm). The outlet of the main lake, at Balfour, British Columbia, forms the upper end of the West Arm. At this outlet, a sill lies at a depth of approximately 8 m producing a distinct boundary between the main lake and the West Arm. The West Arm is about 40 km long with a mean depth of only 13 m. It is physically and limnologically different from the main lake, comprised of a series of shallow basins interconnected by narrow riverine sections. The West Arm of Kootenay Lake flows in a westerly direction becoming the lower Kootenay River, which flows into the Columbia River at Castlegar, BC.

The North Arm of the lake receives 21% of the entire inflow to the lake via Lardeau/Duncan drainage (Binsted and Ashley 2006). Virtually all tributaries of the Lardeau River likely support adfluvial bull trout spawning and rearing given their cold glacial inputs (Chirico 1993, Andrusak and Andrusak 2012a). Only select tributaries surveyed in 2013 are included in this report. Tributaries of the Lardeau/Duncan rivers and the North Arm of Kootenay Lake constitute Group 1 (Figure 2). Select streams include; Poplar, Cascade, and Meadow creeks. Tributaries of the North Arm and central Kootenay Lake constitute Group 2 (Figure 2) and include; Davis, Fry, Campbell, Kaslo, Bernard, Tam O' Shanter, Woodbury, Coffee, Crawford and Gray creeks (Figure 3).

The South Arm of the lake receives 56% of the entire inflow to the lake via the Kootenay River drainage and represents about two thirds of the entire lake surface and volume (Daley et al. 1981, Binsted and Ashley 2006). The Kootenay River drainage originates on the western slopes of the Rocky Mountains in eastern BC and flows southwest to Canal Flats, BC where it enters the Rocky Mountain trench and flows south into Montana. Downstream of the Libby Dam in Montana there is a natural waterfall (Kootenai Falls) that represents a barrier to all upstream fish movement. Below the falls the river flows west through Northern Idaho to Bonners Ferry where it shortly thereafter swings north to flow into the South Arm of the lake near Creston, BC. The primary streams flowing into the east side of the South Arm include the Goat River, Boulder Creek, Akokli Creek, Sanca Creek, Lockhart Creek, LaFrance Creek, Grey Creek, and Crawford Creek. A major bull trout system on the East side of the South Arm is Crawford Creek where bull trout spawning has been well documented by (Andrusak and Andrusak 2012a). Boundary, Summit, Next, Cultus, and Midge creeks flow into the west side of the Kootenay River and Kootenay Lake. Midge, Cultus, and Boundary creeks within this group are the largest systems that support adfluvial bull trout. Tributaries of the South Arm of Kootenay Lake constitute geographical Group 3 (Figure 4).

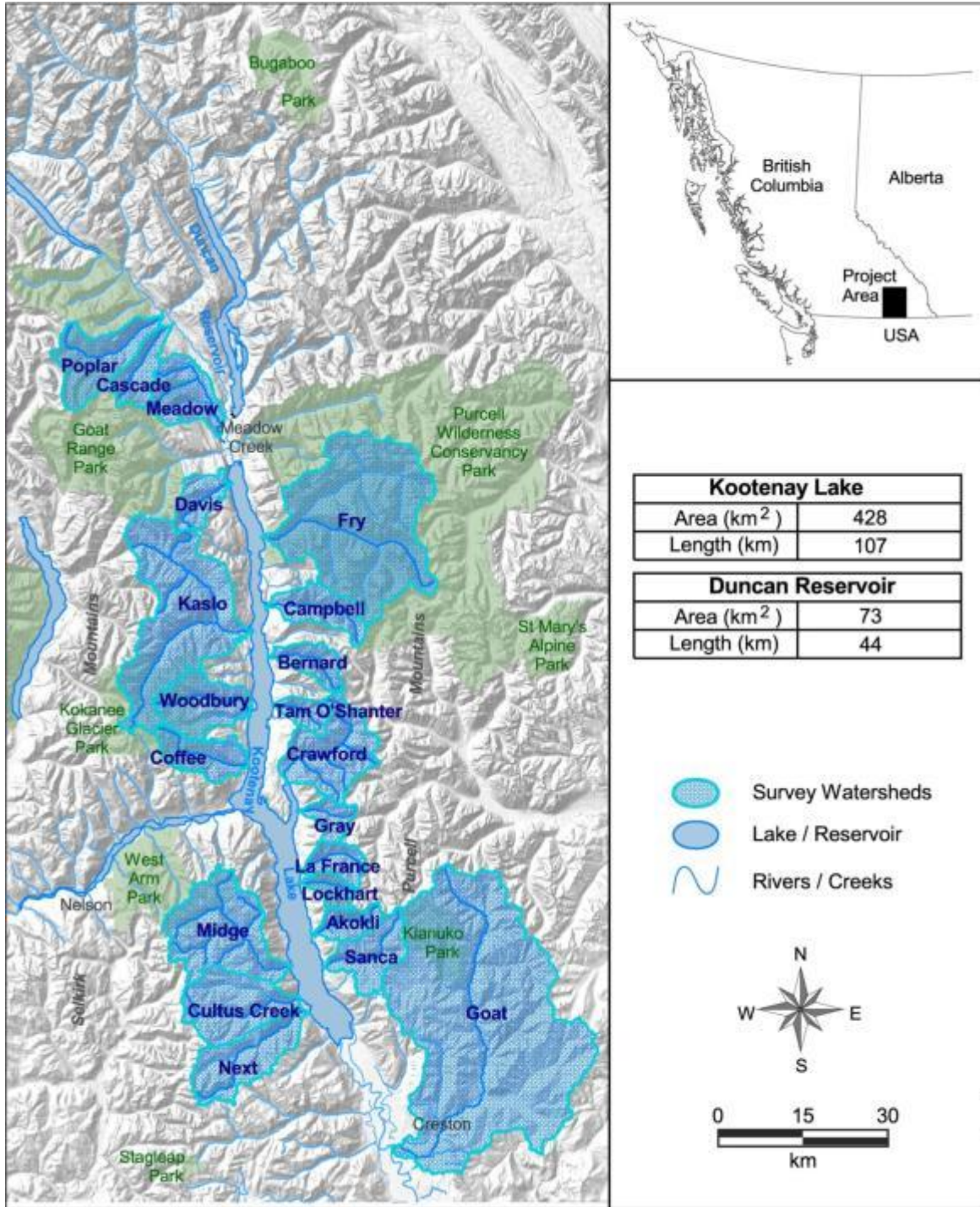


Figure 1. Map of Kootenay Lake and select tributaries for conducting redd surveys in fall of 2013.

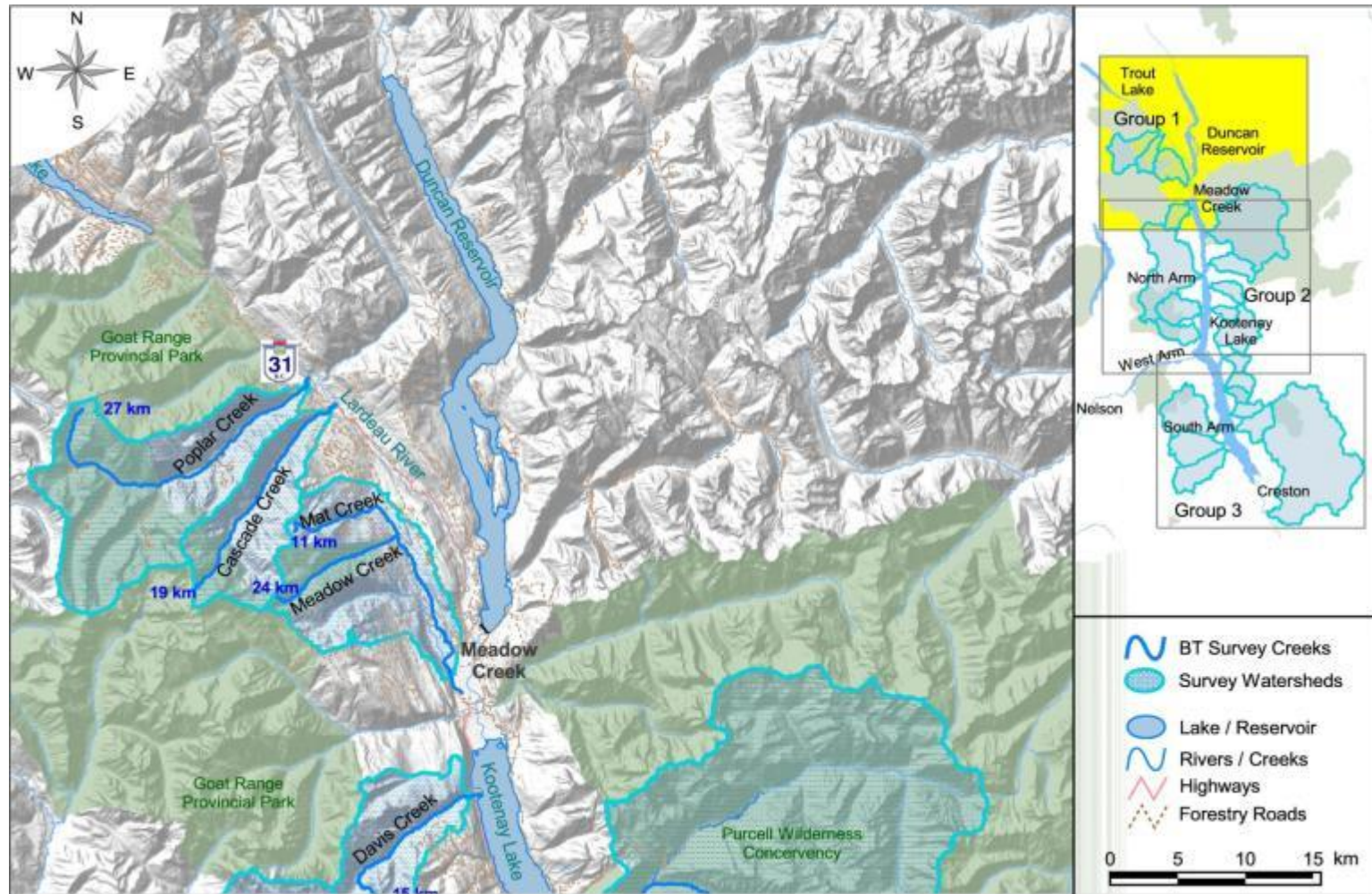


Figure 2. Lardeau/Duncan river tributaries comprising Group 1.

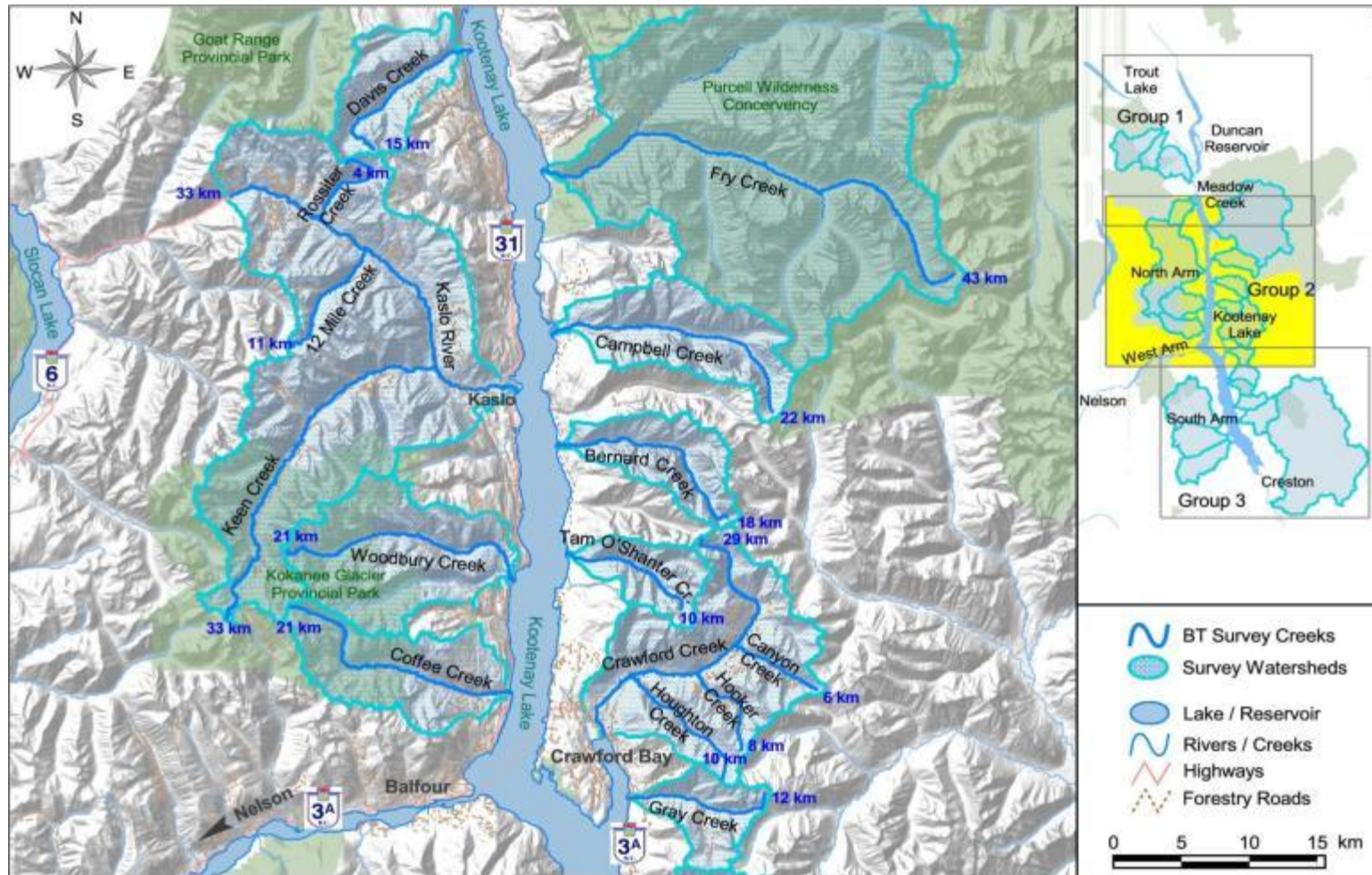


Figure 3. North and Central Kootenay Lake tributaries comprising Group 2.

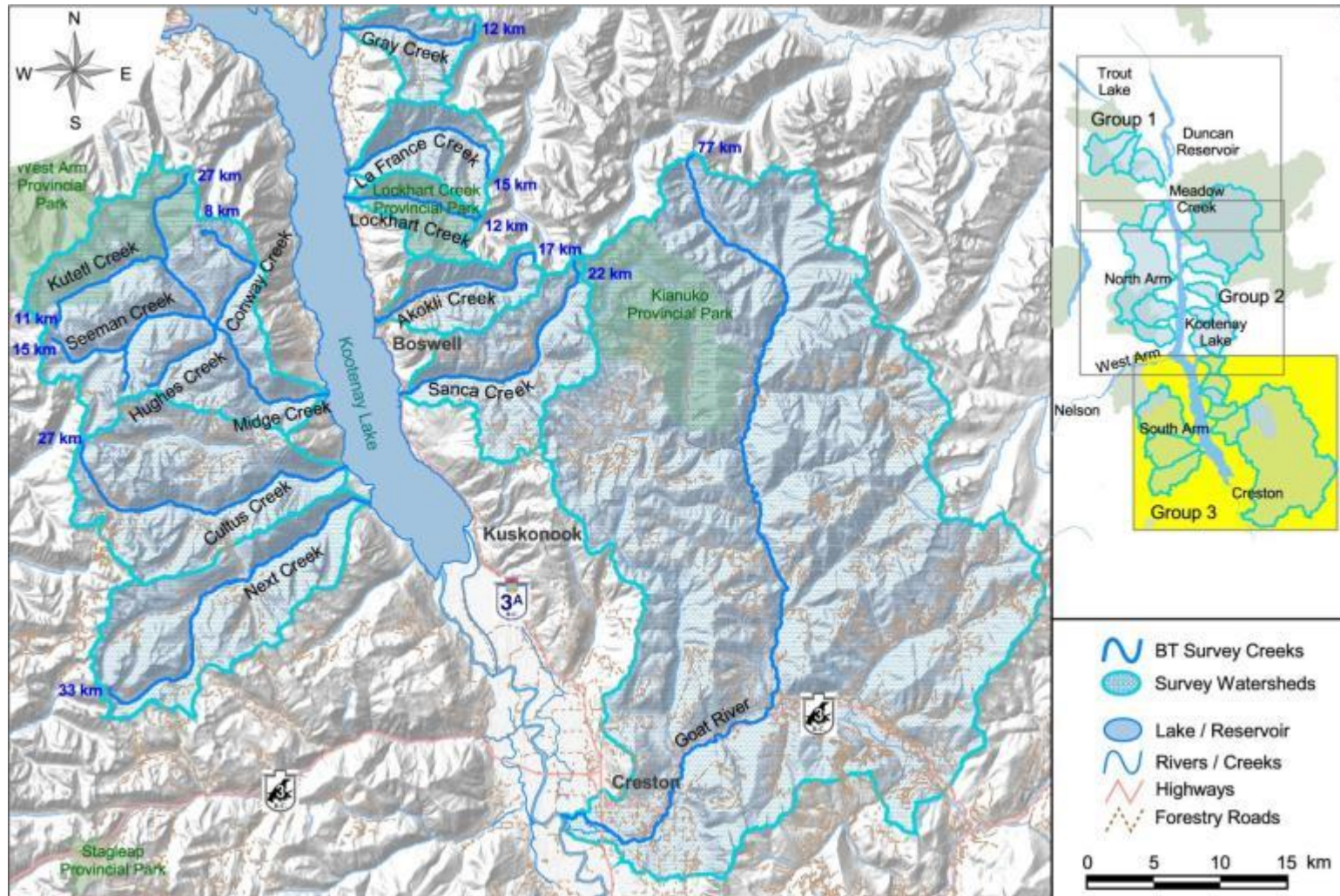


Figure 4. South Arm Kootenay Lake tributaries comprising Group 3.

Group 1 (Duncan/Lardeau tributaries)

Poplar Creek

Poplar Creek, considered a 4th order tributary of the Lardeau River, is a large system that flows east from the Goat Range Provincial Park and the Selkirk Mountain range, covering 156 km² (Figure 1; MOE data on file). The stream is approximately 27 km in length and drains into the Lardeau River near the historic community of Poplar Creek BC (Appendix 1; Figure 2). Much of the habitat consists of high gradient, large boulder-cobble substrates and a high procession of step pool morphology. Similar to Cooper and Hamill creeks, the lower 5 km section is incised in a steep bedrock canyon up to 300 m deep with a gradient of up to 15%. Base elevation at the start of the surveys is approximately 900 m, with gradients ranging from 2-23%.

Cascade Creek

Cascade Creek is considered a 4th order tributary of the Lardeau River that flows east from the Goat Range Provincial Park and the Selkirk Mountain range, covering 72 km² (Figure 1; MOE data on file). The stream is approximately 18.8 km in length from its headwater origins (Appendix 1; Figure 2). Habitat consists of moderate to low gradient, large boulder-cobble substrates below a large waterfall barrier located 685 m upstream of the confluence with the Lardeau River. Historically, this lower section downstream of the barrier has been channelized to protect the Highway 31 Bridge.

Meadow Creek

Meadow Creek is considered a 4th order tributary of the Duncan River that flows in a north to south direction from the Selkirk Mountain range, covering 120 km² (Figure 1; MOE data on file). The stream is approximately 26 km in length from its headwater origins (Appendix 1; Figure 2). Meadow Creek is a highly complex mixture of heterogeneous habitats characterized by cobble-gravel substrates, large woody debris (LWD) accumulations below a large cascade barrier 15 km upstream of the confluence with the Duncan River.

A kokanee spawning channel was constructed in 1967 in order to partially replace kokanee production and spawning habitat lost when the Duncan River was impounded during the construction of the Duncan Dam (Acara 1970, Andrusak 1999). The spawning channel is located in lower portion of Meadow Creek with water supplied from diversions on Meadow Creek and John Creek. The spawning channel is 2.9 km long and on average 9.1 m wide with 26,390 m² of spawning habitat. The theoretical capacity of the channel is 350,000 spawning kokanee with an annual deposition of 45-50 million eggs (Quamme 2008).

Group 2 (Central Kootenay Lake tributaries)

Davis Creek

Davis Creek is considered a 4th order tributary of Kootenay Lake that flows west from the Selkirk Mountain range, covering 64 km² (Figure 1; MOE data on file). The stream is approximately 15 km in length from its headwater origins (Appendix 1; Figure 3). Habitat consists of high to moderate gradient, large boulder-cobble substrates below a large waterfall barrier located 635 m upstream of the confluence with Kootenay Lake. The stream below the barrier has been channelized and contained primarily due to protection measures for the Highway 31 Bridge.

Fry Creek

Fry Creek is considered a 5th order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 617 km² (Figure 1; MOE data on file). The stream is approximately 42 km in length from its headwater origins (Appendix 1; Figure 3). Habitat consists of high gradient, large boulder-cobble substrates below a large waterfall barrier located 835 m upstream of the confluence with Kootenay Lake.

Campbell Creek

Campbell Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 96 km² (Figure 1; MOE data on file). The stream is approximately 22 km in length from its headwater origins (Appendix 1; Figure 3). Habitat consists of high gradient, large boulder-cobble substrates below a large waterfall barrier located 770 m upstream of the confluence with Kootenay Lake.

Kaslo River

The Kaslo River is considered a 4th order tributary of Kootenay Lake (Figure 1). The watershed covers a gross drainage area of 435 km², and is one of the larger tributaries that flow into the north arm of the lake near Kaslo BC (Figure 3; MOE data on file). With its origin at Fish Lake, the river is paralleled by Highway 31A for much of the 33 km length before converging with Kootenay Lake. The upper Kaslo River is a highly complex mixture of heterogeneous habitats characterized by cobble-gravel substrates, large woody debris (LWD) accumulations and moderate gradients varying from 1 to 10%. Small notable tributaries to the upper Kaslo River include; Twelve Mile Creek and Rossiter Creek. Keen Creek is the primary tributary to the Kaslo River, located approximately 8 km upstream of the lake (Appendix 1; MOE data on file). From the confluence Keen Creek extends approximately 29 km to its headwater origin in Kokanee Glacier Provincial Park and covers a gross drainage area of 92.2 km². Habitat on Keen

Creek is more homogeneous, consisting of mostly high gradient, large boulder-cobble substrates and a high procession of step pool morphology (Andrusak 2010).

Bernard Creek

Bernard Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 60 km² (Figure 1; MOE data on file). The stream is approximately 18 km in length from its headwater origins (Appendix 1; Figure 3). Habitat consists of high gradient, large boulder-cobble substrates below a large waterfall barrier located 350 m upstream of the confluence with Kootenay Lake.

Tam O' Shanter

Tam O' Shanter Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 40 km² (Figure 1; MOE data on file). The stream is approximately 11 km in length from its headwater origins (Appendix 1; Figure 3). Habitat consists of high gradient, large boulder-cobble substrates below a large waterfall barrier located 780 m upstream of the confluence with Kootenay Lake.

Woodbury Creek

Woodbury Creek is considered a 4th order tributary of Kootenay Lake (Figure 1). The watershed covers a gross drainage of 131 km² and drains a steep sided glacial valley that extends for approximately 21 km down to the lake (Appendix 1; Figure 3). Its headwaters originate in Kokanee Glacier Provincial Park and the Selkirk Mountain range. Woodbury Creek can be characterized as a cascade-pool morphology system with gradients ranging from 4% to 15%. A 1.5 m waterfall is located at a small hydro structure 600m upstream of the Highway 31 Bridge. Below the bridge the stream has been channelized. The small waterfall is a seasonal migration barrier. Small notable tributaries to Woodbury Creek include; Nelles Creek, Pontiac Creek, Silver Creek and Spray Creek. However, these tributaries do not support spawning adfluvial bull trout due to accessibility and the steep gradients which pose natural barriers to migration.

Coffee Creek

Coffee Creek is considered a 3rd order tributary of Kootenay Lake (Figure 1). The watershed covers gross drainage of 95 km² and drains a steep sided glacial valley that extends for approximately 21 km down to the lake (Appendix 1; Figure 3). Similar to Woodbury Creek, its headwaters originate in Kokanee Glacier Provincial Park and the Selkirk Mountain range. Coffee Creek can be characterized as a cascade-pool morphology system with gradients ranging from 4% to 15%. Coffee Creek channel

morphology has significantly altered following a large a flood/slide event in November of 1999.

Crawford Creek

Crawford Creek, considered a 4th order tributary of Kootenay Lake, flows into Crawford Bay on the east side of the lake (Figure 1 MOE data on file). The watershed covers a gross drainage area of 187 km² (Appendix 1; Figure 3). Crawford Creek extends approximately 24 km upstream of its confluence with Kootenay Lake draining from the west slope of the Purcell mountain range (Figure 3). The lower 3km has been modified and channelized as part of bank protection measures for the Kokanee Springs golf course. A steep sided canyon area with some large pools formed by bedrock exists approximately 10 km upstream of the lake but this site is not a barrier to large migratory fish. Most of the stream is dominated by riffle habitat consisting of boulders and cobble with little LWD accumulation. However, the upper 4 km of Crawford Creek does support some lower gradient highly complex heterogeneous habitat with large LWD accumulations. This habitat then gives way to 1.7 km of high gradient step-pool morphology where the creek origins begin at the base of the Purcell Mountains.

Canyon Creek, Hooker Creek and Houghton Creek are three major tributaries to Crawford Creek that are known to support spawning adfluvial bull trout (Appendix 1; MOE data on file). Canyon Creek, Hooker Creek extend approximately 6-8 km upstream of its confluence with Crawford Creek, while Houghton Creek extends approximately 10 km upstream.

Gray Creek

Gray Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 42 km² (Figure 1; MOE data on file). The stream is approximately 12 km in length from its headwater origins (Appendix 1; Figure 3). Habitat consists of high gradient, large boulder-cobble substrates below a large waterfall barrier located 835 m upstream of the confluence with Kootenay Lake.

Group 3 (South Arm Kootenay Lake tributaries)

LaFrance Creek

LaFrance Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 56 km² (Figure 1; MOE data on file). The stream is approximately 15 km in length from its headwater origins (Appendix 1; Figure 4). Habitat consists of high gradient, large woody debris (LWD) accumulations, large boulder-cobble substrates within the surveyed section until the confluence with Kootenay Lake.

Lockhart Creek

Lockhart Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 37 km² (Figure 1; MOE data on file). The stream is approximately 12 km in length from its headwater origins (Appendix 1; Figure 4). Habitat consists of high gradient, large boulder-cobble substrates within the surveyed section until the confluence with Kootenay Lake.

Midge Creek

Midge Creek, a 6th order tributary of Kootenay Lake, is located approximately 35 kilometres northwest of Creston, B.C (Figure 1). The watershed covers a gross drainage area of 263 km² (Appendix 1; Figure 4). Midge Creek is a large tributary that flows 28 km southeast from its headwaters in West Arm Provincial Park, draining the eastern slopes of the Nelson Range of the Selkirk Mountains into the south arm of Kootenay Lake (Figure 4; MOE data on file). Midge Creek can be characterized as a cascade-pool morphology system with gradients ranging from 4% to 14%.

Kutetl Creek, Conway Creek, Württemberg Creek and Seeman Creek are the major tributaries to Midge Creek that are known to support spawning adfluvial bull trout (Appendix 1; MOE data on file). Seeman Creek is the largest of these tributaries, with a gross drainage of 69 km² that flows into Midge Creek. Seeman Creek is approximately 15 km in length with varying gradients from 3-10% (Appendix 1; MOE data on file). Kutetl Creek is a moderate sized tributary that flows east approximately 11 km before draining into upper Midge Creek. Surprisingly, Kutetl Creek has low to moderate gradients ranging from 3-7%. Württemberg Creek, Conway and Hughes are relatively small systems with < 10 km in total length (Appendix 1; MOE data on file).

Akokli Creek

Akokli Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 52 km² (Figure 1; MOE data on file). The stream is approximately 17 km in length from its headwater origins (Appendix 1; Figure 4). Habitat consists of high gradient, large boulder-cobble substrates below a large waterfall barrier located 350 m upstream of the confluence with Kootenay Lake

Sanca Creek

Sanca Creek is considered a 3rd order tributary of Kootenay Lake that flows east from the Purcell Mountain range, covering 110 km² (Figure 1; MOE data on file). The stream is approximately 22 km in length from its headwater origins (Appendix 1; Figure 4). Habitat

consists of high gradient, large boulder-cobble substrates within the surveyed section until the confluence with Kootenay Lake.

Cultus Creek

Cultus Creek, a 4th order tributary of Kootenay Lake, is located approximately 30 kilometres northwest of Creston, B.C (Figure 1). The watershed covers a gross drainage area of 112 km² (Appendix 1; Figure 4). Cultus Creek is moderate to small tributary that flows approximately 26 km southeast from its headwaters, draining the eastern slopes of the Nelson Range of the Selkirk Mountains into the south arm of Kootenay Lake (Figure 4; MOE data on file). Cultus Creek can be characterized as a cascade-pool morphology system with gradients ranging between 3% and 10%.

Laib Creek and Kloosh Creek are the two major tributaries to Cultus Creek. However, these tributaries are known not to support spawning adfluvial bull trout due the existence of complete barriers near the confluences (G. Nellestijn pers. comm.).

Next Creek

Next Creek is considered a 3rd order tributary of Kootenay Lake that flows west from the Selkirk Mountain range, covering 161 km² (Figure 1; MOE data on file). The stream is approximately 33 km in length from its headwater origins (Appendix 1; Figure 4). Habitat consists of high gradient, large boulder-cobble substrates below a large waterfall barrier located 275 m upstream of the confluence with Kootenay Lake

Goat River

The Goat River is a 5th order tributary of the Kootenay River and is located south of Creston, B.C (Figure 1). The watershed covers a gross drainage area of 1,274 km² (Appendix 1; Figure 4). The Goat River is a large tributary that flows 77 km southeast from its headwaters the Purcell Mountain range (Figure 4; MOE data on file). The Goat River can be characterized cobble-gravel substrates with low gradients of 1-3% substrates below a large municipal dam located 11.4 km upstream of the confluence with the Kootenay River.

For purposes of power generation and flood control, a 25 m reinforced concrete arch dam was constructed on a natural barrier (*i.e.* falls) in 1933. This dam, located 11.4 km from the Goat River confluence, separates the upper Goat River from the lower Goat River and Kootenay Lake. The dam, now abandoned, was a run-of-the-river facility, typically using the entire flow of the river from December to March.

Methods

Reconnaissance surveys

Initial reconnaissance surveys were undertaken on most systems to identify locations of barriers to fish passage and observe the spatial extent of bull trout spawning within the system. Systems with barriers previously documented or confirmed were re-visited to re-confirm the barriers existence. The reconnaissance surveys provided certainty as to the extent and timing of spawning and accessible length of stream to be surveyed particularly when bull trout passage barriers were confirmed. Additional information prior to conducting the reconnaissance surveys was obtained from the Ministry of Environment using the Fisheries Inventory Data Queries (FIDQ) website (<http://a100.gov.bc.ca/pub/fidq/main.do>).

Redd identification

Redds were identified as approximately dish-shaped excavations in the bed material, often of brighter appearance than surrounding substrates, accompanied by a deposit beginning in the excavated pit and spilling out of it in a downstream direction. A bull trout redd can be defined as the entire area of gravel excavated by the female, the size of which can range from 0.5 m² to 3.0 m² (McPhail and Murray 1979) depending on the size of the female and the nature of the substrate being utilized. It also appears that a single female can spawn in more than one redd if gravel accumulations at the first location are of limited size (Leggett 1980). Disturbances in the bed material caused by fish were discriminated from natural scour by: i) the presence of tail stroke marks; ii) an over-steepened (as opposed to smooth) pit wall often accompanied by perched substrate that could be easily dislodged down into the pit, and often demarcated by sand deposited in the velocity break caused by the front wall; iii) excavation marks alongside the front portion of the deposit demarcating the pit associated with earlier egg laying events (bull trout will deposit eggs in several nests as the redd is built in an upstream direction); and iv) a highly characteristic overall shape that included a 'backstop' of gravel deposited onto the unexcavated substrates, a deposit made up of gravels continuous with this backstop and continuing upstream into the pit, and a pit typically broader than the deposit and of a circular shape resulting from the sweeping of gravels from all sides to cover the eggs (in a portion of redds gravels are swept into the pit from only one side, often a shallow gravel bar on the shore side).

A second important determination was whether fish had actually spawned at a location where an excavation had been started. 'Test digs' were considered to be pits, often small, accompanied by substrate mounded up on the unexcavated bed material downstream but with no substrate swept into the pit itself, which would denote at least

one egg deposition event. In the case of a 'test dig' determination the mound of gravels would typically be short and narrow around the downstream side of a relatively small pit.

In areas of limited gravel or high redd abundance, or where spawning site selection is highly specific, superimposition of redds upon one another can occur (McPhail and Baxter 1996). For this study, the redd count was based on the most recent complete redd(s) and the disturbed remains of prior redds being included and considered a redd when the aforementioned criteria was met (see above). A greatly extended deposit length (subjectively evaluated to be at least twice the length of a 'typical' deposit length) was grounds to consider whether a second female had made use of the pit created by a first female to construct a separate redd.

Redd surveys

Experienced two man crews were used for all redd surveys to reduce observer error or variability in counts due to multiple surveyors (Muhlfeld et al. 2006). Candidate streams were surveyed with crew members walking in a downstream direction on opposing banks when possible. Surveys started from the known barrier location to fish passage based on assessments from the reconnaissance surveys conducted during the peak of spawning.

Complete redds were enumerated and UTM's recorded by geo-referenced time and waypoints using a handheld 62s Garmin GPS. Data for each redd was recorded on waterproof paper (Appendix 2). GPS track logs were also initiated at the start of the survey and used as an overlay in GIS mapping for assessing spatial distribution of spawning within each system.

Incomplete redds were also identified where the observed redd was associated with a spawning adult or pair of spawning adults. Similar to complete redds, incomplete redds were enumerated and UTM's recorded by geo-referenced time and waypoints using a handheld 62s Garmin GPS. Incomplete redds were used as a valuable tool in assessing temporal variability in survey timing where no previous information existed (Rieman and McIntyre 1996; Dunham et al. 2001).

Water temperatures (nearest ± 0.1 °C) were obtained from handheld thermometers and recorded in field notes prior to commencing redd surveys (Appendix 2).

Analysis of Trends

Seven years of count information is available for the Kaslo River and Crawford Creek systems to assess population trends. An explicit assumption of the trend analysis and

model is that there is no change in detection probability within year and between years. This assumption is validated by the fact the same experienced crews have been conducting the surveys since 2006 (Muhlfeld et al. 2006).

A Poisson generalized linear mixed model (GLMM) was fitted to the data using software packages R 2.15.2 (R Core Development Team 2013) and JAGS 3.3.0 (Plummer 2003) using Markov Chain Monte Carlo (MCMC) simulation (Kery 2010, Kery and Schaub 2011). Convergence of the model was monitored using the Gelman and Rubin (1992) statistic as modified by Brooks and Gelman (1998). The GLMM model uses the log expected counts as a linear function of random year effects. The trend in the population is assessed on the magnitude of the slope on year. Results of analysis provide estimates bounded by 95% credibility intervals (CRI) based on a Bayesian framework (Kery 2010, Kery and Schaub 2011).

Results

During the 2013 survey all streams were observed within a narrow time frame (October 1-October 17th). Weather conditions were ideal for most of the survey period with only one day deferred due to rainfall and dark cloudy conditions that made visual observations difficult.

Water temperatures taken during the redd surveys from handheld thermometers ranged from 3-8°C for all systems combined (Table 1-3).

Results of the FWCP and ITQ contract work have been integrated and presented in geographic groupings reported by Andrusak and Andrusak (2012).

Group 1 (Duncan/Lardeau tributaries)

Poplar Creek

A reconnaissance survey was conducted on Poplar Creek in late-August, prior to conducting redd surveys to identify any accessibility issues or safety concerns. Similar to 2011, a steep canyon section on Polar Creek was not surveyed due to safety issues (Andrusak and Andrusak 2012a). The canyon was incised in steep bedrock 200 m deep with a gradient of up to 10%.

Redd surveys commenced on October 2 and 3 utilizing a two person ground crew. Similar to 2011, dangerous conditions for surveying prohibited the ground crew from surveying a section from 3.5 to 2.5 km of Poplar Creek. A complete barrier to adfluvial bull trout migrants was identified at 4.4 km upstream on Poplar Creek (Appendix 3; Photo 1). The barrier was a bedrock chute that exceeded 4 meters in height.

Nevertheless, Poplar Creek provided 4.24 km of accessible spawning habitat to adfluvial bull trout.

A total of 23 complete redds were enumerated in the Poplar Creek drainage (Table 1; Figure 7). Eleven adult spawners was observed during the survey and redd survey timing was considered optimal.

Table 1. Group 1(Lardeau/Duncan tributaries) 2013 redd survey data

Project	System	Tributary	Survey length (km)	Temp (°C)	Complete Redds	Incomplete Redds	Fish Count
ITQ BT	Cascade Creek	Cascade Creek	0.73	4.2	1	0	1
KL BT	Meadow Creek	Meadow Creek	6.72	5.5	168	7	19
KL BT	Meadow Creek	Matt Creek	3.41	5.0	37	3	6
KL BT	Poplar Creek	Poplar Creek	4.24	7.0	23	6	11

Cascade Creek

As part of the ITQ contract and prior to conducting redd surveys, a reconnaissance survey was conducted on Cascade Creek in late-August to identify any accessibility issues or safety concerns. Prior knowledge of the system was invaluable and assisted with ease of access to the creek.

Redd surveys commenced on October 1 utilizing a ground crew. A complete barrier to adfluvial bull trout migrants was identified at 685 m upstream from the confluence with the Lardeau River (Appendix 3; Photo 2). The barrier consisted of two large water falls that exceeded 5 meters in height.

Only 1 redd was observed in the Cascade Creek system below the barrier (Table 1; Figure 7). One adult spawner was also observed during the survey immediately upstream of the confluence with the Lardeau River. Cascade Creek only provided 730 m of accessible spawning habitat to adfluvial bull trout.

Meadow Creek

Prior to conducting the redd survey; a reconnaissance survey was conducted on Meadow Creek in late-August to identify any accessibility issues or safety concerns. Prior knowledge of the system was valuable and assisted with ease of access to the creek. A number of adult fish were observed during the survey, just below the barrier.

Redd surveys commenced on October 3 and 4 by a two person ground crew. A complete barrier to adfluvial bull trout migrants was identified at 15.1 km upstream from the confluence with the Duncan River (Appendix 3; Photo 3). Habitat was considered highly

complex, with the large accumulations of LWD and large quantities of small gravels which are considered ideal for spawning and potential rearing.

A total of 205 complete redds were enumerated in the Meadow Creek drainage below the barrier and above the upper Meadow Creek Spawning Channel (MCSC) fence (Table 1; Figure 7). Of the total, 37 were observed in Matt Creek, a small tributary of Meadow Creek. Nineteen adult spawners were also observed during the survey above the upper MCSC fence. It should be noted, no surveys were conducted below the MCSC lower fence. However, a MFLNRO reconnaissance survey below the MCSC indicated that bull trout appeared to be utilizing this section of the creek, but redd counts were considered problematic due to the high frequency of kokanee spawning (Matt Neufeld pers. comm.).

Group 2 (Central Kootenay Lake tributaries)

Davis Creek

As part of the ITQ contract and prior to conducting redd surveys, a reconnaissance survey was conducted on Davis Creek in late-August to identify any accessibility issues or safety concerns. At that time 2 spawning bull trout were observed.

Redd surveys commenced on October 1 by a two person ground crew. A complete barrier to adfluvial bull trout migrants was identified at 635 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 4). The barrier consisted of a large water fall that exceeded 6 meters in height.

A total of 4 complete redds were enumerated in the Davis Creek system below the barrier (Table 2; Figure 8). Seven adult spawners were observed during the survey just below the waterfalls. Davis Creek has fairly limited available and accessible habitat to adfluvial bull trout. Approximately 25 spawning kokanee were also observed.

Fry Creek

As part of the ITQ contract and prior to conducting redd surveys, a reconnaissance survey was conducted on Fry Creek in early-September to identify any accessibility issues or safety concerns. Use of a boat was required to access this creek, launched from Lost Ledge provincial campsite. No spawning bull trout were observed.

Redd surveys commenced on October 5 utilizing a three person ground crew. A complete barrier to adfluvial bull trout migrants was identified at 835 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 5). The barrier consisted of a large water fall that exceeded 4 meters in height.

No redds were observed in Fry Creek system below the barrier (Table 2; Figure 8). As well, no adult spawners were observed during the survey. Fry Creek has very limited available and accessible habitat for adfluvial bull trout.

Table 2. Group 2 (Central Kootenay Lake tributaries) 2013 redd survey data.

Project	System	Tributary	Survey length (km)	Temp (°C)	Complete Redds	Incomplete Redds	Fish Count
ITQ BT	Bernard	Bernard Creek	0.33	5.5	0	0	1
ITQ BT	Campbell	Campbell Creek	0.77	4.9	0	0	
ITQ BT	Davis	Davis Creek	0.61	4.5	4	2	7
ITQ BT	Fry	Fry Creek	0.83	4.8	0	0	
ITQ BT	Tam O'Shanter	Tam O'Shanter Creek	2.7	6.0	0	0	
KL BT	Coffee	Coffee Creek	5.7	3.9	30	1	10
KL BT	Crawford	Canyon Creek	0.11	3.5	1	0	0
KL BT	Crawford	Crawford Creek	19.6	3.5	237	2	16
KL BT	Crawford	Hooker Creek	0.05	7.0	2	0	0
KL BT	Crawford	Houghton Creek	0.91	8.0	14	1	6
KL BT	Kaslo	Kaslo River	21.0	5.0	305	22	35
KL BT	Kaslo	Keen Creek	4.77	3.2	50	27	76
KL BT	Kaslo	Rossiter Creek	0.35	4.5	0	0	
KL BT	Kaslo	Twelve Mile Creek	0.29	4.5	2	6	5
KL BT	Woodbury	Woodbury Creek	12.4	3.0	45	11	34

Campbell Creek

As part of the ITQ contract and prior to conducting redd surveys, a reconnaissance survey was conducted on Campbell Creek in early-September to identify any accessibility issues or safety concerns. Use of a boat was required to access this creek, launched from Kaslo BC. No spawning bull trout were observed.

Redd surveys commenced on October 5 utilizing a two person ground crew. A complete barrier to adfluvial bull trout migrants was identified at 770 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 6). The barrier consisted of a large water fall that exceeded 3 meters in height.

No redds were observed in Campbell Creek system below the barrier (Table 2; Figure 9). As well, no adult spawners were observed during the survey. Visibility during the survey was slightly limited due to siltation and reduced clarity. Campbell Creek has very limited available and accessible habitat for adfluvial bull trout.

Bernard Creek

As part of the ITQ contract and prior to conducting redd surveys, a reconnaissance survey was conducted on Bernard Creek in early-August to identify any accessibility issues or safety concerns. Use of a boat launched from Kaslo BC was required to access this creek. No spawning bull trout were observed.

Redd surveys commenced on October 5 utilizing a two person ground crew. A complete barrier to adfluvial bull trout migrants was identified at 350 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 9). The barrier consisted of two large water fall that exceeded 5 meters in height.

No redds were observed in Bernard Creek system below the barrier (Table 2; Figure 9) however one adult spawner was observed. Nonetheless, Bernard Creek has very limited available and accessible habitat for adfluvial bull trout.

Kaslo River

No reconnaissance surveys were conducted on the Kaslo River drainage in 2013 since this system has been part of an ongoing bull trout monitoring program since 2006 (Andrusak 2010, Andrusak and Andrusak 2012a). As in previous years installation and utilization of the resistivity counter greatly assisted with the assessment of run timing and peak of spawning.

Redd surveys commenced on October 3, utilizing three two person experienced crews on the Kaslo River. The crews initiated the redd survey approximately 29 km upstream on the Kaslo River near Retallic, BC (Appendix 3; Photo 7). Similarly, redd surveys were conducted October 4-5th on Keen Creek starting approximately 6.4 km upstream of the confluence with the Kaslo River (Appendix 3; Photo 8).

A complete barrier to adfluvial bull trout migrants was identified at approximately 28.8 km upstream on the upper Kaslo River (Appendix 3; Figure 10). The barrier is a 3 m waterfall near the historic town-site of Retallic BC, adjacent to Highway 31A. As well, a complete barrier to adfluvial bull trout migrants was identified at approximately 6.4 km upstream on Keen Creek. Similar to the upper Kaslo river barrier, the Keen Creek barrier is a 4-5 m waterfall and is clearly marked on the FSR as the boundary for angling (Appendix 3). Small tributaries to the Kaslo River that were surveyed included: Rossiter Creek and Twelve Mile Creek each have established barriers about 400m upstream from the confluence. Both barriers are bedrock chutes that provide a series of steps and drops approximately 2-3 m high.

A total of 357 complete redds were enumerated in the Kaslo River drainage (Table 2; Figure 10). Another 47 redds were observed but rated as incomplete and associated with either an adult or an adult pair in both the Kaslo River and Keen Creek. The upper Kaslo River had the highest redd count of 307, most of which were distributed in the upper 20 km of the system. Keen Creek had a total of 50 redds distributed in the upper 3 km below the barrier. The small Kaslo River tributaries (Rossiter Creek and Twelve Mile Creek) contributed a combined 2 redds to the total. Once again, redd survey timing was considered optimal, although some spawning was observed during the time of the survey, especially in Keen Creek.

Woodbury Creek

During the reconnaissance survey at least twelve spawning bull trout were observed immediately below the small hydro plant where an obstruction to fish passage was observed during the 2011 survey. However the 2013 survey also confirmed a single spawner was present immediately upstream of the barrier. This information led to a full stream redd survey in October 2013.

Redd surveys commenced on October 6, utilizing an experienced two man crew on Woodbury Creek. A partial barrier to adfluvial bull trout migrants was identified at the hydro-electric dam approximately 600 m upstream from Kootenay Lake (Appendix 3; Photo 10). The partial barrier is a 2 m waterfall as a result of concrete sill constructed when the dam was built (Appendix 3). A complete barrier to adfluvial bull trout migrants was identified approximately 13 km upstream from Kootenay Lake. The complete barrier was a cascade chute 3 m in height (Appendix 3).

A total of 45 complete redds were observed below the complete barrier (Table 2; Figure 11). A total of 34 fish were observed above the dam section over 12 km of suitable spawning habitat. Redds of adfluvial bull trout could not be absolutely confirmed (although most were probably adfluvial based on redd size) since upstream of the dam resident and adfluvial population of bull trout have been confirmed (FISS data). Redd survey timing and visibility was considered optimal.

Coffee Creek

A ground reconnaissance survey was conducted on Coffee Creek in August, prior to conducting redd surveys. Coffee Creek drainage is accessible utilizing a FSR that ends at the bridge (6.7 km) where the barrier is located (Photo 11).

Coffee Creek redd surveys commenced on October 16th by an experienced crew. The crew initiated the redd survey approximately 6.7 km upstream from Kootenay Lake

(Appendix 3; Photo 12). This stream is difficult to walk owing to stream wide log jams but despite the challenging survey the crew surveyed the entire system over a long day.

A complete barrier to adfluvial bull trout migrants was identified at approximately 6.7 km upstream from the confluence with Kootenay Lake (Appendix 3; Photo 11). The barrier is a series of 6 m waterfalls at the end of the old Coffee Creek FSR. Coffee Creek provides 6.7 km of accessible spawning habitat for adfluvial bull trout.

A total of 30 complete redds were enumerated in the Coffee Creek drainage (Table 2; Figure 11). Redd survey timing was considered optimal for this system, with a total of 10 spawning bull trout observed over the 6.7 km surveyed.

Tam O' Shanter Creek

As part of the ITQ contract and prior to conducting redd surveys, a reconnaissance survey was conducted on Tam O' Shanter Creek in early-August to identify any accessibility issues or safety concerns.

Redd surveys commenced on October 4 utilizing a ground crew. A complete barrier to adfluvial bull trout migrants was identified at 780 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 12). The barrier consisted of a large water fall that exceeded 25 meters in height.

No redds were observed in Tam O' Shanter Creek system below the barrier (Table 2; Figure 12). Tam O' Shanter Creek has very limited available and accessible habitat to adfluvial bull trout.

Crawford Creek

No reconnaissance surveys were conducted on the Crawford Creek drainage in 2013 since this stream has been part of an ongoing bull trout monitoring program since 2008 (Andrusak 2010, Andrusak and Andrusak 2012a).

Redd surveys commenced on October 5th, utilizing a two person ground crew. The crew initiated the redd survey approximately 24 km upstream on Crawford Creek with a starting elevation of approximately 1500 m (Appendix 3; Photo 13). The conditions during the survey were ideal with excellent visibility over the entire 24 km surveyed on Crawford Creek. The crew surveyed the entire system over the following 3 days.

A complete barrier to adfluvial bull trout migrants was identified at 24.2 km upstream on from the confluence with Kootenay Lake (Appendix 3; Photo 13). The barrier is a series of boulder cascades reaching 10 m in height with a gradient of up to 25%. Small tributaries to Crawford Creek including Canyon Creek, Hooker Creek and Houghton

Creek have barriers less than 800 m upstream from the confluence with Crawford Creek. Canyon Creek and Hooker Creek barriers are a combination steep gradient cascades and falls with drops of greater than a 1 m high (Appendix 3; Andrusak and Andrusak 2012). At these locations the identified obstructions are believed to be complete barriers to adfluvial migrants. Houghton Creek has a complete barrier about 800 m upstream from its confluence with Crawford Creek comprised of a bedrock cascade approximately 4 m in height (Appendix 3; Andrusak and Andrusak 2012). As well, Crawford Creek has two moderate canyon sections at 3 km and 4 km that are considered barriers to other migratory fish species, especially kokanee. In total, Crawford Creek provided >25 km of accessible spawning habitat to adfluvial bull trout.

A total of 254 complete redds were enumerated in the Crawford Creek drainage (Table 2; Figure 12). Houghton Creek had the highest redd count of 14 compared to the other tributary systems. A total of 22 adult spawners were observed during the survey and therefore redd survey timing was considered optimal.

Group 3 (South Arm Kootenay Lake tributaries)

Gray Creek

As part of the ITQ contract, and prior to conducting the redd survey, a reconnaissance surveys was conducted on Gray Creek in early-August to identify any accessibility issues or safety concerns.

Redd surveys commenced on October 11 utilizing a ground crew. A complete barrier to adfluvial bull trout migrants was identified 835 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 14). The barrier consisted of a large water fall that exceeded 15 meters in height.

Two complete redds were observed in Gray Creek system below the barrier (Table 2; Figure 13). It is quite apparent that Gray Creek has limited available and accessible habitat to adfluvial bull trout.

LaFrance Creek

As part of the ITQ contract, and prior to conducting the redd survey, a reconnaissance was conducted on LaFrance Creek in early-August to identify any accessibility issues or safety concerns. LaFrance FSR parallels the creek for most of its entire length of 15 km (Appendix 1).

Redd surveys commenced on October 10 utilizing a ground crew. No barrier to adfluvial bull trout migrants was observed within the ITQ requirement of 5 km surveyed (MFLNRO ITQ contract on file).

No redds were observed in the lower 5 km section surveyed in LaFrance Creek (Table 3; Figure 13). LaFrance Creek appears to have considerable available and accessible habitat for adfluvial bull trout up to 15 km in length. The absence of adfluvial bull trout may be an artifact of the ITQ survey requirement and bull trout may utilize sections well upstream of the surveyed area.

Table 3. Group 3 (South Arm Kootenay Lake tributaries) 2013 redd survey data.

Project	System	Tributary	Survey Length (km)	Temp (°C)	Complete Redds	Incomplete Redds	Fish Count
ITQ BT	Akokli	Akokli Creek	0.35	5.0	0	0	
ITQ BT	Goat	Goat River	11.3	5.0	0	0	
ITQ BT	Gray	Gray Creek	1.97	5.0	2	3	0
ITQ BT	La France	La France Creek	4.91*	5.0	0	0	
ITQ BT	Lockhart	Lockhart Creek	4.56*	5.0	1	1	0
ITQ BT	Next	Next Creek	0.28	3.5	0	0	
ITQ BT	Sanca	Sanca Creek	4.63*	4.6	0	1	2
KL BT	Cultus	Cultus Creek	14.9	5.0	25	0	3
KL BT	Midge	Conway Creek	5.4	3.0	13	0	0
KL BT	Midge	Kutetl Creek	10.1	4.3	2	0	0
KL BT	Midge	Midge Creek	18.1	5.0	77	0	0
KL BT	Midge	Seeman Creek	12.4	3.0	27	0	0
KL BT	Midge	Wurttemberg Creek	0.63	3.0	12	0	0

*contract limit (barrier not located)

Lockhart Creek

As part of the ITQ contract, and prior to conducting the redd survey, a reconnaissance survey was conducted on Lockhart Creek in early-August to identify any accessibility issues or safety concerns. The Lockhart Trail, within the Provincial Park, parallels the creek for most of its entire 12 km length (Appendix 1).

Redd surveys commenced on October 17 by a ground crew. No barrier to adfluvial bull trout migrants was observed within the lower 5 km section surveyed, part of the ITQ requirement (Appendix 3; MFLNRO on file).

One complete redd was observed in the 5 km sections surveyed on Lockhart Creek (Table 3; Figure 13). Similar to LaFrance Creek, Lockhart Creek appears to have considerable available and accessible habitat for adfluvial bull trout for up to 12 km in

length. The presence of one redd suggests spawning might occur well upstream of the surveyed area.

Midge Creek

No reconnaissance survey was required on the Midge Creek drainage since the 2011 work provided all the required information and made the redd survey less difficult (Andrusak and Andrusak 2012). As was the case in 2011 a helicopter (A Star) was used on October 9th to access upper Midge Creek and drop off the survey crew that camped out as they moved downstream towards Kootenay Lake. The crew surveyed the entire system over the following 4 days and were picked up by boat at the Midge Creek delta.

The crew initiated the survey approximately 30 km upstream from the confluence with Kootenay Lake (Appendix 3; Photo 15). Kutetl Creek, Conway Creek, Württemberg Creek and Seeman Creek were surveyed and assessed the extent of fish distribution (Appendix 3; Andrusak and Andrusak 2012).

A complete barrier to adfluvial bull trout migrants was identified at approximately 20 km upstream on Midge Creek (Appendix 3; Photo 15). The barrier was a series of four waterfalls and/or bedrock cascades varying from 2-4 m in height. A partial logjam barrier was also identified at approximately 12 km upstream on Seeman Creek (Appendix 3; Andrusak and Andrusak 2012). Wurttemberg Creek, a tributary of Seeman Creek, had a complete bedrock cascade barrier at approximately 800 m upstream from the confluence (Appendix 3; Andrusak and Andrusak 2012). A complete cascade barrier was identified at approximately 9.9 km upstream on Kutetl Creek (Appendix 3; Andrusak and Andrusak 2012). A partial log jam barrier was identified at approximately 5 km upstream on Conway Creek (Appendix 3; Andrusak and Andrusak 2012). Hughes Creek was observed to be inaccessible to migrating fish at approximately 800 m upstream from its confluence with Midge Creek. In an overview, Midge Creek drainage provided >50 km of accessible spawning habitat to adfluvial bull trout.

A total of 131 complete redds were enumerated in the Midge Creek drainage (Table 3; Figure 14). Of the total, Seeman Creek and Wurttemberg Creek had 27 and 12 redds, respectively. Kutetl Creek and Conway Creek had 2 and 13 redds, respectively. The remaining 77 redds were observed within the main channel of Midge Creek. Redd survey timing was considered optimal with no spawning bull trout observed over the 50 km surveyed.

Akokli Creek

As part of the ITQ contract, and prior to conducting the redd survey, a reconnaissance survey was conducted on Akokli Creek in early-August to identify any accessibility issues or safety concerns (Appendix 1).

A redd survey commenced on October 11 utilizing a single person owing to the small size of this stream and short section of accessible habitat. A complete barrier to adfluvial bull trout migrants was identified at 350 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 16). The barrier consisted of a large water fall that exceeded 10 meters in height and can be readily observed from the Highway 3A Bridge.

No redds were observed in Akokli Creek system below the barrier which has extremely limited and accessible habitat for adfluvial bull trout (Table 3; Figure 15).

Sanca Creek

As part of the ITQ contract, and prior to conducting the redd survey, a reconnaissance of access was conducted on Sanca Creek in early-August to identify any accessibility issues or safety concerns. Sanca FSR parallels the creek for most of its entire length of 22 km (Appendix 1) with the road located well above the stream for at least 6 km.

Redd surveys commenced on October 10 utilizing a ground crew. Similar to other select ITQ streams, only the lower 5 km section of Sanca Creek was surveyed (MFLNRO on file). A partial barrier to adfluvial bull trout migrants was identified 3.8 km upstream from the confluence with Kootenay Lake (Appendix 3).

One incomplete redd was observed in the surveyed section on Sanca Creek. The redd was associated with a spawning pair of bull trout (Table 3; Figure 15). Sanca Creek has appears to have unlimited available and accessible habitat to adfluvial bull trout up to 22 km in length. The presence of the pair of bull trout suggests spawning probably occurs well upstream of the surveyed area.

Cultus Creek

Prior to conducting the redd survey on this system several reconnaissance surveys were conducted in August and September to identify a possible barrier within the creek. Ground crews had good access to the upper portion of the watershed and tributaries utilizing ATVs along FSRs located in the Nature Conservancy of Canada (NCC) property (Appendix 1). These surveys were conducted over approximately 20 km of roads located within the watershed.

Based on the reconnaissance results and the upstream distribution of observed bull trout redd surveys were conducted on October 7 and 8th. The two person crew initiated the redd survey approximately 15 km upstream from the confluence with Kootenay Lake (Appendix 3).

A number of potential barriers were identified during the reconnaissance and redd surveys (Appendix 3; Photo 17). Two potential barriers/obstructions were identified at approximately 14.89 km and 13.5 km upstream on Cultus Creek (Appendix 3; Andrusak and Andrusak 2012). The first partial obstruction was a logjam varying 2 m in height. The second partial barrier was a bedrock cascade varying 2.5 m in height.

A total of 25 complete redds were enumerated in the Cultus Creek drainage (Table 3; Figure 16). Similar to the 2011 survey, most of the redds were distributed below another low water obstruction point (Figure 16) identified by Andrusak and Andrusak (2012). Fish were observed attempting to ascend this section during the reconnaissance survey. Redd survey timing was considered optimal with only 3 spawning bull trout observed over the 15 km surveyed.

Next Creek

No reconnaissance of access was conducted on Next Creek due to known limited access. Next Creek is the adjacent system to Cultus Creek and was suspected to have similar spawn timing (Appendix 1). As well, there was prior information that suggested a complete barrier to migrants existed near the confluence with Kootenay Lake (Crawford 1986).

Following the redd surveys conducted on Midge Creek, the same ground crew commenced a redd survey on October 16 on Next Creek. The crew drove to the mouth of Cultus Creek via the FSR and then walked to Next Creek via the CPR rail line. A complete barrier to adfluvial bull trout migrants was identified 275 m upstream from the confluence with Kootenay Lake (Appendix 3; Photo 18).

No redds were observed in Next Creek system below the barrier which has very limited available and accessible habitat for adfluvial bull trout (Table 3; Figure 16).

Goat River

Several reconnaissance surveys were conducted on the Goat River in August to identify access areas to the river since most of the rivers' banks are private property. It was confirmed that an old dam near the city limits was a complete barrier to migrant fish (Appendix 3; Photo 19) hence the redd surveys would commence from this point downstream.

A redd survey commenced on October 17 using a two person ground crew. The ground crew utilized dry suits for safety given the extensive amounts of wood in the river and also to assist with assessment of redds due to the size of the river. No bull trout redds were observed over 11.3 km in the Goat River system downstream of the barrier (Table 3; Figure 17). As well, no adult bull trout were observed during the surveys.

Analysis of Trends

Preliminary model results suggest a decline in numbers in the Kaslo River and Keen Creek systems (Figure 5). Since the peak counts in 2009, there has been a downward trend in redd counts in both of these systems. Crawford Creek also showed a decline since 2009 but demonstrated a slight increase in 2013 (Figure 5). It is acknowledged the data set is limited requiring more years of counts, thus there is no certainty on a suspected downward trend. Despite this limitation, other reliable redd counts on some systems also suggest a whole lake decline in bull trout numbers. For example, limited to only two years of data, Midge Creek indicates a substantial decline from 400 redds in 2011 to 131 redds in 2013 (Appendix 7). As well, Coffee Creek suggests a similar decline from 77 redds in 2011 to 30 redds in 2013 (Appendix 7) .

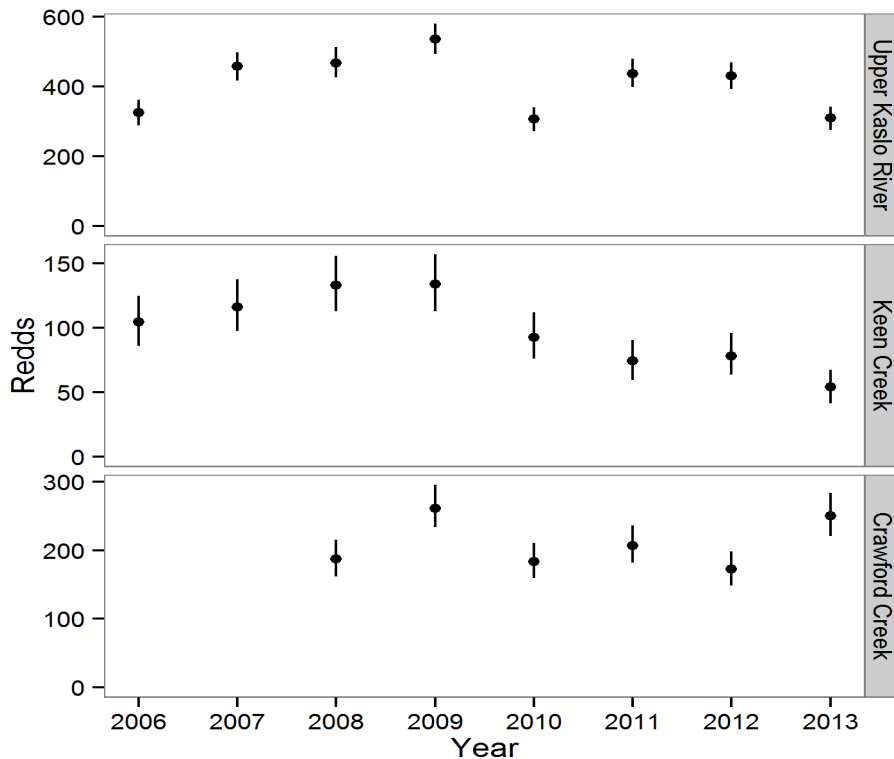


Figure 5. Estimates and 95% CRI's from Poisson GLMM for select index sites on Kootenay Lake. Note*- 2010 Kaslo River redd count considered an unreliable estimate due to poor visibility

Discussion

The FWCP annually funds two major compensation projects on Kootenay Lake: a large scale nutrient restoration project, and Meadow Creek kokanee spawning channel. One of the primary rationale for these projects is the restoration of bull trout and Gerrard rainbow trout populations; however, until 2011 there had been no lake-wide measure of bull trout abundance to use as a performance measure. In 2009, the FWCP initiated and developed a plan to monitor bull trout (Hagen and Decker 2009). The plan consisted of a comprehensive review of existing information on adfluvial bull trout distribution in the lake's tributaries, and consideration of several population monitoring options (Hagen and Decker 2009). The priority recommendation from that report was to conduct redd counts in a selected suite of tributaries with documented evidence of adfluvial bull trout presence and to establish a lake-wide index to monitor bull trout distribution and abundance. Moreover, these counts, if repeated over the long term, will provide a valuable performance measure for evaluating the response of bull trout to FWCP compensation efforts.

Continuation of a bull trout monitoring program on Kootenay Lake is considered a high priority within the region by the MFLNRO and the FWCP (Hagen and Decker 2009, 2011, Andrusak and Andrusak 2012, FWCP 2012 draft plan). The large lake draft Action Plan (AP) of the FWCP reflects the importance of monitoring bull trout as a performance measure. Also in mid-2013 the MFLNRO indicated the importance of continued monitoring by requesting through an ITQ redd surveys of 14 previously un-surveyed systems. It was agreed for this report that results from the ITQ survey would be integrated with results of the 2013 FWCP redd surveys. The primary purposes of the 2013 redd surveys was to address data gaps and build on previous redd counts on some key systems. The ultimate aim is to identify geographically representative streams (i.e. index streams) that can be monitored over the long term thus establishing a long term data set that can be used for population trend analysis. Hagen and Decker (2009) discuss the merits of acquiring this information that combined with juvenile production estimates from the same streams would provide a means of evaluating ecological conditions in the lake on bull trout growth and survival.

The lake and most of its tributaries provide a vast area of potential habitat for adfluvial bull trout populations. However, many of these tributaries to the lake offer limited access to much of the available habitat for spawning and rearing as a result of naturally occurring barriers that obstruct fish passage. It is important therefore to document accurately the locations of such barriers that can be referenced in the decision of what streams are candidates for long term monitoring. Perhaps the most important bull trout system-the Duncan River-has been severely impacted due to the Duncan Dam yet it remains a significant producer of bull trout to Kootenay Lake. This has been possible due

to manual passage of bull trout spawners past the dam (Olmsted et al. 2001) and to this day several hundred stage below the dam (Hagen and Decker (2009). This annual operation was suggested as an index site by Hagen and Decker (2009), but due to a number of uncertainties including extreme flow releases, it is considered too unreliable for long term monitoring. Andrusak and Andrusak (2012) discussed the potential uncertainties associated with redd surveys but concluded they provide a relatively inexpensive method of monitoring trends in populations over time (Rieman and Myers 1997, Dunham et al. 2001, Hagen and Decker 2011, Andrusak and Andrusak 2012a). The literature has evaluated and supports the validity of this method for detecting trends in population size over long time periods (Rieman and Myers 1997, Dunham et al. 2001, Al-Chokhachy et al. 2005, 2009, Howell and Sankovich 2012). Therefore the establishment of a monitoring program requires an inherent understanding between the reliability of an index and the costs associated with long term monitoring of bull trout populations on Kootenay Lake. The streams proposed for the 2013 FWCP survey were selected using a decision matrix ranking to determine candidate streams for monitoring (Appendix 5). This ranking system could be used as a tool for decision making on reliable index sites required to ascertain trends in abundance and population status. A key criterion for index site selection includes; 1) the repeatability of the survey 2) sources of uncertainty and variability around estimates 3) the ability to provide a cost effective index over time.

Results of the 2013 FWCP survey provide confirmation on the importance of some of the key systems. A total of 1,070 redds were enumerated in the eight streams surveyed (141 km). The most prominent bull trout systems included the Kaslo River Crawford Creek and Meadow Creek, together accounting for greater than 50% of all redds enumerated in the study. Not surprisingly, the Kaslo River, Crawford Creek, Midge Creek and Meadow Creek were amongst the highest redd counts of any system, affirming their importance as potential index systems for bull trout monitoring on Kootenay Lake (Andrusak and Andrusak 2012a). Nevertheless, Kaslo, Keen, Midge and Coffee creeks indicated a substantial decline in redd numbers from previous years' surveys (Andrusak and Andrusak 2012a). While data is limited to only eight years, analysis does suggest a declining trend in abundance on 3 of the 4 important index systems. This is somewhat disconcerting since it is known that the recreational fishery is near optimal levels of harvest on the lake (Andrusak and Thorley 2013), which maybe unsustainable for this species (Bison et al. 2003, Post et al. 2003, Johnston et al. 2007, Ward et al. 2013, Post 2013). However, it's unclear whether the decline is solely attributed to high exploitation or natural population variability and/or lower in-lake survival due to lower kokanee abundance. All of these variables support the need for long term monitoring that is required to assist the FWCP in determination of the degree of success of lake fertilization.

Woodbury and Cultus creeks' 2013 results confirmed the speculation that barriers (0.6 km and 3.3 km respectively) noted in the 2011 survey were in fact partial barriers. Andrusak and Andrusak (2012) did not observe redds upstream of these obstructions on either system although they noted that anecdotal information suggested that bull trout spawners had in some years passed by them. Mature adults and redds were observed upstream of the obstructions in both streams in 2013. It appears that some bull trout were able get over or through these partial barriers at high flows but lower flows were barriers, especially in Cultus Creek as evidenced by the concentration of redds downstream of it. Due to the unpredictability of access and the effect on the annual spawner distribution these two systems are not considered to be good index streams compared to other systems for long term monitoring.

The ITQ surveys of 13 streams (34 km) previously not surveyed provided additional information on bull trout distribution while raising further questions. A total of 8 redds were counted within these 13 streams surveyed in the fall of 2013. Streams with <1 km of accessible habitat with confirmed fish barriers supported few if any redds. One important observation with the Group 2 streams was that three systems were only partially surveyed as required by the ITQ contract. These three---Lockhart, LaFrance and Sanca creeks were surveyed in the lower 5 km only and no barrier was confirmed. Distribution information suggests that most of spawning occurs in the upper portion of most watersheds and therefore it is likely bull trout spawners were present upstream of the 5 km surveyed. Based on experience and habitat type, Sanca Creek was deemed to be the most likely candidate that supports adfluvial spawning bull trout. In contrast, the Goat River is unlikely to support any bull trout due to their cold water requirements (Fraley and Shepard 1989, Baxter and McPhail 1999, Selong et al. 2001) and based on lack of detection in other studies (Cope 2001). The Goat River often experiences seasonally high water temperatures that exceed 20°C (Les Fleck pers. comm.)

Despite increased assessment of more bull trout spawning streams in 2013 there remains a number of other potentially important Kootenay Lake bull trout systems. In particular some tributaries to the Lardeau River as well as potentially some to Trout Lake that may be similar to those observed for the upper Duncan (O'Brien 1999, Olmsted et al. 2001, BC Hydro 2009). The 2013 results are considered highly informative, and provide a baseline measurement that can be used for future monitoring. The ITQ survey confirmed that the numerous small systems assessed offer little potential for bull trout spawning except potentially the three previously discussed.

Obtaining a direct measure of total bull trout escapement is proving to be difficult and probably not possible although there is now far more data and a better understanding of their distribution. Nonetheless with the available data some indirect estimates, albeit speculative, can be made using a standardized expansion factor from redd surveys and

resistivity counter information for surveyed streams (see Andrusak and Andrusak 2012; Figure 6). Despite some concerns using redd counts as an estimate of escapement (Rieman and Myers 1997, Dunham et al. 2001, Muhlfeld et al. 2006, Howell and Sankovich 2012), combining the redd count data with the electronic counter data provides the opportunity to calibrate direct spawner counts with redd counts. An average expansion factor of 2.57 bull trout per redd has been derived from the Kaslo River over a six year period [2010 data excluded] (Table 4). Likewise, an average expansion factor of 1.9 bull trout per redd was derived from Crawford Creek over a three year period (Table 4). Despite the differences in the expansion factors between the two systems, likely attributable to the quality of habitat and accessible length, the estimates are similar to the average of 2.68 bull trout per redd (range of 1.2 to 4.3 bull trout per redd) reported by Al-Chokhachy et al. (2005). Based on the low variability of the estimates and the small range observed across two distinctively different systems, the 1.9-2.6 bull trout per redd could be applied to estimate escapement for the surveyed streams.

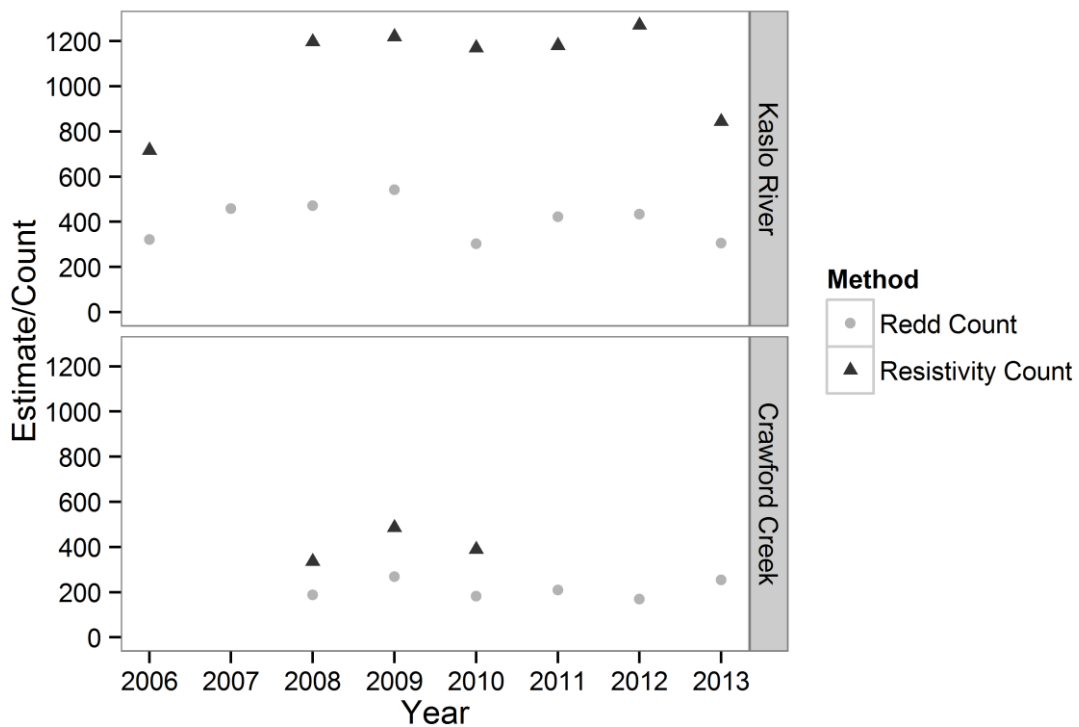


Figure 6. Resistivity counter estimates and redd count data from Kaslo River and Crawford Creek since 2006.

Table 4. Derivation of expansion factor from estimated redds counts and electronic resistivity counts from the Kaslo River (2006-2013) and Crawford Creek (2008-2013).

Year	Kaslo River (upper)			Crawford Creek		
	# Redds	Electronic Count	Expansion Factor	# Redds	Electronic Count	Expansion Factor
2006	321	716	2.23	n/a	n/a	n/a
2007	458	n/a	n/a	n/a	n/a	n/a
2008	471	1,197	2.54	188	336	1.8
2009	542	1,219	2.25	268	486	1.8
2010	302*	1,170	3.8*	182	389	2.1
2011	439	1,180	2.69	209	n/a	n/a
2012	433	1,270	2.93	169	n/a	n/a
2013	305	844	2.77	254	n/a	n/a
Avg.	424	1085	2.57	212	404	1.9

Note*- 2010 Kaslo River redd count considered an unreliable estimate due to poor visibility

Distribution of spawning bull trout within tributaries to Kootenay Lake covers a large geographic area, inter-connected by large sub-basins (Duncan Reservoir, Trout Lake) and rivers (Lardeau and Kootenay rivers). Due to the spatial extent, obtaining a lake wide population estimate most likely will rely upon a bio-standard of redd/km or spawner/km over accessible habitat. However, redd density (redds/km) as a bio-standard over the entire accessible length can be somewhat misleading, since most of the lower portions of many of these systems do not support spawning (Appendix 3; Andrusak and Andrusak 2012)). Nevertheless, the mean redd density in surveyed tributaries (total number divided by total accessible length, summed over all tributaries) was 6.2 redds/km, resulting in a bio-standard of 12.3 spawners/km based on an expansion factor of 2.0 spawners per redd cited in Decker and Hagen (2009). Interestingly, this density is similar to the 12.6 spawners/km identified by Decker and Hagen (2008) and 13 spawners/km presented in Lindsay (1977a, 1977b) on Arrow Lakes tributaries. Obtaining a total escapement for bull trout utilizing accessible habitat may be feasible with increased information on their known distribution.

Redd surveys are arguably the most cost effective method of assessing bull trout spawning. Reducing the uncertainty in redd counts can be accomplished by conducting replicate counts within an index site, measuring observer efficiency and having a better understanding of the spatial and temporal variation in spawning activity (Andrusak et al. 2011). Isaak and Thurow (2006) suggest that conducting redd counts with a spatially continuous, temporally replicated sampling design will reduce errors associated with simple random designs and provide more accurate ecosystem views. In comparison, Jacobs et al. (2009) evaluated the utility of the generalized random tessellation stratified (GRTS) sampling design to determine bull trout population status through redd counts. Gallagher et al. (2010) recommended conducting redd counts over pre-determined 3-5

km stream reaches that are randomly selected with an annual selection of at least 10% of all reaches. However, these designs can often be more time consuming and rely heavily on statistical inference that often cannot capture the spatial and temporal variation unless substantial effort is appropriated through replication. Lack of randomization in site selection and shifts in fish distribution may bias results from index site monitoring and mask population trends (Isaak and Thurow 2006). Invariably, there is a trade-off between coverage (more sites) that satisfies population monitoring versus the ability to reduce the uncertainty or inter-annual variability within each index. Moreover, index areas may not represent population dynamics of salmonids at a regional scale (Rieman and McIntyre 1996, High et al. 2008) and may miss redds due to annual variation in spatial distributions or spawning activity (Rieman and Myers 1997, Maxell 1999, Dunham et al. 2001).

While there is much debate over appropriate sampling designs to determine bull trout population status through redd counts, complete surveys of representative index systems are the most appropriate and practical (cost effective) means of monitoring bull trout on Kootenay Lake, alleviating the confounding issues of sub-sampling from stratified random designs.

Recommendations

Recommended Core Monitoring Program

Streams recommended as part of a future FWCP core monitoring program for bull trout and that encompass the majority of annual redds enumerated within distinct geographic areas on Kootenay Lake as detailed in Hagen and Decker (2009) and Andrusak and Andrusak (2012a). Decision matrix detailed in Appendix 5 for FWCP work only.

Group 1 (Duncan/Lardeau tributaries)

1. Meadow Creek
2. Hamill Creek*

*Note-recommended by MFLNRO until future reconnaissance identifies a better Group 1 system to include; despite difficulty in counting due to glacial inputs, safety concerns and high costs associated with conducting surveys. Author notes that these difficulties are similar to that detailed on Incomappleux River in ALR (MFLNRO on file).

Group 2 (Central Kootenay Lake tributaries)

1. Kaslo River
2. Crawford Creek
3. Coffee Creek

Group 3 (South Arm Kootenay Lake tributaries)

1. Midge Creek

Recommended Future Reconnaissance:

List of streams recommended for future reconnaissance and that may be added to core monitoring program based on updated information. These recommendations include streams in geographic groups within Kootenay Lake.

1. Group 1 (Lardeau tributaries) including; Tenderfoot Creek, Mobbs Creek, and Rapid Creek
2. Group 1 (Trout Lake tributaries) including; Wilkie Creek, Lardeau Creek, and Ferguson Creek

3. Group 3 (South Arm tributaries) including; LaFrance Creek, Lockhart Creek, and Sanca Creek

Not Recommended for Monitoring:

List of streams not recommended for inclusion in a bull trout monitoring program due to various factors including; 1) safety concerns 2) inaccessibility 3) glacial turbidity effecting counting conditions 4) repeatable as an annual index 5) non representative 6) limited available spawning habitat (km) and/or 7) associated costs

1. Poplar Creek
2. Cooper Creek
3. Fry Creek
4. Campbell Creek
5. Powder Creek
6. Woodbury Creek
7. Bernard Creek
8. Tam O' Shanter Creek
9. Grey Creek
10. Cultus Creek
11. Akokli Creek
12. Next Creek
13. Summit Creek
14. Goat River

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Appendix 1–Tributary watershed and location information

Project	System	Watershed Code	Length (km)	Area (km ²)	Zone	Easting	Northing
ITQ BT	Akokli Creek	300-625474-131644	16.8	51.5	11	517695	5474909
ITQ BT	Bernard Creek	300-625474-097528	18.25	60.3	11	509987	5524172
ITQ BT	Campbell Creek	300-625474-097332	22.29	96.2	11	509544	5532412
ITQ BT	Cascade Creek	300-625474-096683-076865-340042	18.79	71.5	11	493369	5582913
ITQ BT	Davis Creek	300-625474-096591	14.96	63.7	11	503739	5554500
ITQ BT	Fry Creek	300-625474-097026	42.37	616.7	11	508801	5545168
ITQ BT	Goat River	300-625474-197491	77.24	1273.6	11	531787	5437450
ITQ BT	Gray Creek	300-625474-108435	11.95	42	11	515100	5496732
ITQ BT	La France Creek	300-625474-117162	15.31	56	11	515696	5485745
ITQ BT	Lockhart Creek	300-625474-118962	11.69	37.4	11	515440	5484188
ITQ BT	Next Creek	300-625474-149243	32.93	160.7	11	517440	5460963
ITQ BT	Sanca Creek	300-625474-140045	21.77	109.9	11	519554	5469142
ITQ BT	Tam O'Shanter Creek	300-625474-097728	11.42	40.2	11	510620	5515683
KL BT	Coffee Creek	300-625474-095405	23	95.1	11	506664	5504959
KL BT	Crawford Creek	300-625474-108117	28.75	187.1	11	513510	5501482
KL BT	Canyon Creek	300-625474-108117-571930	7.74	21.8	11	523057	5508586
KL BT	Hooker Creek	300-625474-108117-434178	8.33	20.3	11	520271	5506354
KL BT	Houghton Creek	300-625474-108117-234032	12	26.7	11	515416	5506174
KL BT	Cultus Creek	300-625474-145018	26.76	180.8	11	515674	5463703
KL BT	Kaslo River	300-625474-095953	34.05	450.5	11	507134	5528049
KL BT	Keen Creek	300-625474-095953-237187	33.33	203.3	11	501253	5529601
KL BT	Rossiter Creek	300-625474-095953-747881	8.7	14.7	11	492449	5541444
KL BT	Twelve Mile Creek	300-625474-095953-609703	11.33	24.9	11	496033	5539116
KL BT	Meadow Creek	300-625474-096683-048787	25.72	120.1	11	502359	5561862
KL BT	Mat Creek	300-625474-096683-048787-541762	10.7	27.7	11	497728	5573176
KL BT	Midge Creek	300-625474-138024	28.62	263.4	11	514263	5469253
KL BT	Conway Creek	300-625474-138024-491568	11.69	29.7	11	505739	5474388
KL BT	Kutetl Creek	300-625474-138024-713624	11.94	53.3	11	501758	5479114
KL BT	Seeman Creek	300-625474-138024-529945	15.06	68.6	11	504930	5474964
KL BT	Wurttemberg Creek	300-625474-138024-529945-513259	4.06	23	11	499060	5472990
KL BT	Poplar Creek	300-625474-096683-076865-393082	26.78	155.7	11	491361	5584870
KL BT	Woodbury Creek	300-625474-095600	22.49	132	11	506917	5513502

Appendix 3–Tributary barrier information

Project	System	Dist (km)	Elev_m	Height_m	Gradient	Status	Type
ITQ BT	Sanca Creek	3.885	898	3.5	70	Partial	Cascade
ITQ BT	Davis Creek	0.635	587	6	90	Complete	Falls
ITQ BT	Lockhart Creek	2.035	706	1.5	90	Partial	Cascade
ITQ BT	Lockhart Creek	1.455	662	2	90	Partial	Cascade
ITQ BT	Lockhart Creek	0.915	603	1.5	90	Partial	Cascade
ITQ BT	Fry Creek	0.835	569	4	90	Partial	Falls
ITQ BT	La France Creek	5.045	893	1.5	90	Partial	Cascade
ITQ BT	Next Creek	0.275	575	4	50	Complete	Cascade
ITQ BT	Goat River	11.455	579	20	90	Complete	Dam
ITQ BT	Lockhart Creek	2.15	730	1	35	Partial	Cascade
ITQ BT	Gray Creek	0.835	611	15	90	Complete	Falls
ITQ BT	Next Creek	0.275	575	2	90	Complete	Falls
ITQ BT	Cascade Creek	0.685	657	5	90	Complete	Falls
ITQ BT	Tam O'Shanter Creek	0.78	623	30	50	Complete	Falls
ITQ BT	Tam O'Shanter Creek	1.395	685	3	100	Complete	Falls
ITQ BT	Tam O'Shanter Creek	2.005	765	3	60	Complete	Falls
ITQ BT	Gray Creek	0.95	620	5	90	Complete	Falls
ITQ BT	Campbell Creek	0.77	604	3	90	Complete	Falls
ITQ BT	Bernard Creek	0.35	573	5	90	Complete	Falls
ITQ BT	Bernard Creek	0.345	573	4	90	Complete	Falls
ITQ BT	Akokli Creek	0.35	566	10	90	Complete	Falls
KL BT	Cultus Creek	14.89	1321	1.75	90	Partial	Logjam
KL BT	Cultus Creek	13.585	1268	2.5	50	Partial	Cascade
KL BT	Hooker Creek	0.055	869	1.25	90	Complete	Falls
KL BT	Crawford Creek	24.19	1487	10	45	Complete	Cascade
KL BT	Conway Creek	5.22	1481	1.5	80	Partial	Logjam
KL BT	Coffee Creek	6.695	1017	4	90	Complete	Falls
KL BT	Coffee Creek	6.685	1013	6	90	Complete	Falls
KL BT	Canyon Creek	0.115	994	1.5	90	Complete	Cascade
KL BT	Cultus Creek	3.255	688	4.5	70	Partial	Cascade
KL BT	Meadow Creek	15.055	762	5	40	Complete	Cascade
KL BT	Woodbury Creek	12.755	1244	4.5	70	Complete	Cascade
KL BT	Woodbury Creek	12.195	1221	3.5	80	Partial	Cascade
KL BT	Woodbury Creek	9.42	1118	2	85	Partial	Cascade
KL BT	Twelve Mile Creek	0.275	884	4	85	Complete	Falls
KL BT	Seeman Creek	11.04	1438	0.8	90	Partial	Logjam
KL BT	Rossiter Creek	0.37	951	2	90	Complete	Chute
KL BT	Poplar Creek	4.43	799	4	90	Complete	Chute
KL BT	Kutetl Creek	7.06	1453	2.5	70	Partial	Logjam
KL BT	Midge Creek	19.86	1281	2	70	Complete	Cascade
KL BT	Houghton Creek	0.915	788	4	90	Complete	Cascade
KL BT	Mat Creek	3.415	902	1.5	25	Partial	Logjam
KL BT	Mat Creek	3.15	878	1.5	25	Partial	Culvert
KL BT	Mat Creek	2.12	822	1.5	50	Partial	Beaver Dam
KL BT	Woodbury Creek	12.88	1264	3	80	Complete	Cascade
KL BT	Kutetl Creek	9.975	1610	1.5	90	Complete	Cascade
KL BT	Keen Creek	6.435	957	6	85	Complete	Falls
KL BT	Keen Creek	5.055	895	2.5	90	Complete	Logjam
KL BT	Kaslo River	28.815	1001	5	90	Complete	Falls
KL BT	Poplar Creek	4.385	796	4	90	Complete	Falls

Appendix 4-Photos



Photo 1. Poplar Creek barrier from surveys conducted in 2013 (photo taken from above)



Photo 2. Cascade Creek barrier from surveys conducted in 2013



Photo 3. Meadow Creek barrier from surveys conducted in 2013



Photo 4. Davis Creek barrier from surveys conducted in 2013



Photo 5. Fry Creek barrier from surveys conducted in 2013



Photo 6. Campbell Creek barrier from surveys conducted in 2013



Photo 7. Kaslo River barrier from surveys conducted in 2013



Photo 8. Keen Creek barrier from surveys conducted in 2013



Photo 9. Bernard Creek barrier from surveys conducted in 2013



Photo 10. Woodbury Creek barrier from surveys conducted in 2013

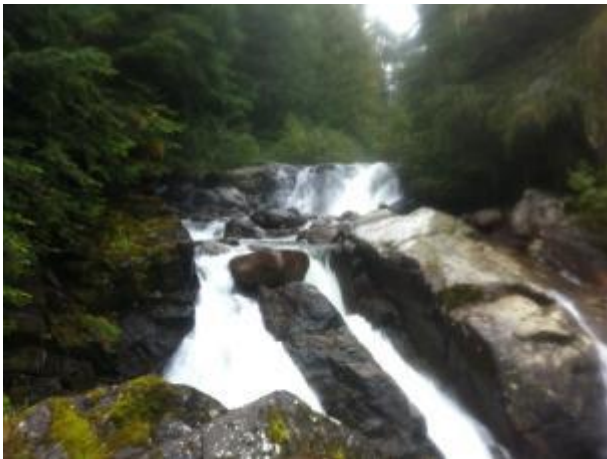


Photo 11. Coffee Creek barrier from surveys conducted in 2013.



Photo 12. Tam O' Shanter Creek barrier from surveys conducted in 2013



Photo 13. Crawford Creek barrier from surveys conducted in 2013

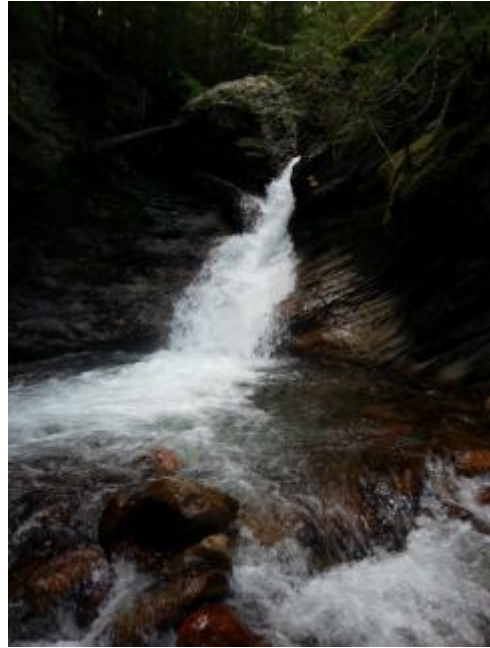


Photo 14. Gray Creek barrier from surveys conducted in 2013



Photo 15. Midge Creek barrier from surveys conducted in 2013.



Photo 16. Akokli Creek barrier from surveys conducted in 2013



Photo 17. Cultus Creek partial barrier fall 2013



Photo 18. Next Creek barrier from surveys conducted in 2013.



Photo 19. Goat River dam in fall 2013

Appendix 5–Decision Matrix for FWCP stream selection

Group	System	Access	Visibility	Danger	Barrier	Habitat (km)	Density	Cost	Rating
1	Meadow	atv	high	low	yes	15	high	low	good
2	Woodbury	atv	high	med	yes	10	low	med	good
2	Kaslo	atv	high	low	no	29	high	med	good
2	Keen	atv	high	low	no	6	high	med	good
2	Coffee	atv	high	med	no	6	high	low	good
2	Crawford	atv	high	low	no	24	high	low	good
3	Midge	heli	high	low	no	20	high	high	good
1	Mobbs	foot	high	med	no	21	low	med	moderate
1	Poplar	foot	high	high	no	5	high	low	moderate
3	Cultus	atv	high	low	yes	21	med	high	moderate
1	Hamill	heli	poor	high	no	24	high	high	poor
1	Cooper	heli	poor	high	no	16	high	high	poor
1	Healy	atv	poor	low	yes	1.1	low	low	poor
3	Summit	vehicle	high	low	no	33	low	high	poor

Group	System	Access	Visibility	Danger	Barrier	Habitat (km)	Density	Cost	Rating
2	Crawford	3	3	3	2	3	3	3	20
2	Kaslo	3	3	3	2	3	3	2	19
2	Meadow	3	3	3	2	3	3	2	19
2	Keen	3	3	3	2	2	3	2	18
2	Coffee	3	3	2	2	2	3	3	18
3	Midge	2	3	3	2	3	3	1	17
2	Woodbury	3	3	2	3	3	1	2	17
1	Poplar	2	3	1	2	2	3	3	16
3	Cultus	3	3	3	1	3	2	1	16
1	Mobbs	2	3	2	2	3	2	2	16
3	Summit	2	3	3	2	3	1	1	15
1	Healy	3	1	3	1	1	1	3	13
1	Hamill	1	1	1	2	3	3	1	12
1	Cooper	1	1	1	2	3	3	1	12

Appendix 6–Redd survey distributions in select tributaries

Figure 7. Distribution of redds and known barriers in Group 1 (Lardeau River) tributaries in fall of 2013

Figure 8. Distribution of redds and known barriers in Group 2 (Kootenay Lake) tributaries in fall of 2013

Figure 9. Distribution of redds and known barriers in Group 2 (Kootenay Lake) tributaries in fall of 2013

Figure 10. Distribution of redds and known barriers in the Kaslo River (Group 2) in fall of 2013

Figure 11. Distribution of redds and known barriers in Group 2 (Kootenay Lake) tributaries in fall of 2013

Figure 12. Distribution of redds and known barriers in Crawford Creek (Group 2) in fall of 2013

Figure 13. Distribution of redds and known barriers in Gray Creek (Group 2) and Group 3 (Kootenay Lake) tributaries in fall of 2013

Figure 14. Distribution of redds and known barriers in Midge Creek (Group 3) in fall of 2013

Figure 15. Distribution of redds and known barriers in Group 3 (Kootenay Lake) tributaries in fall of 2013

Figure 16. Distribution of redds and known barriers in Group 3 (Kootenay Lake) tributaries in fall of 2013

Figure 17. Distribution of redds counted in the Goat River (Group 3 Kootenay River) in fall of 2013.

Appendix 7– Summary of bull trout redd surveys conducted on Kootenay Lake tributaries 2006-2013.

	Name (Tributary)	Name (System)	2006	2007	2008	2009	2010	2011	2012	2013
Group 1	Clint Creek	Hamill Creek						3		
	Hamill Creek	Hamill Creek						213		
	Cooper Creek	Cooper Creek						64		
	McKian Creek	Cooper Creek						53		
	South Cooper Creek	Cooper Creek						17		
	Healy Creek	Healy Creek						0		
	Poplar Creek	Poplar Creek						53		23
	Cascade Creek	Cascade Creek								1
	Meadow Creek	Meadow Creek								168
	Meadow Creek	Matt Creek								37
Group 2	Upper Kaslo River	Kaslo River	321	458	488	542	302	439	433	307
	Keen Creek	Kaslo River	100	116	137	139	94	73	80	50
	<i>Kaslo River & Keen</i>	Kaslo River	421	574	625	681	396	512	513	357
	Crawford Creek	Crawford Creek	n/a	n/a	188	268	182	209	169	254
	Coffee Creek	Coffee Creek						77	92	30
	Woodbury Creek	Woodbury Creek								45
	Bernard Creek	Bernard Creek								0
	Campbell Creek	Campbell Creek								0
	Davis Creek	Davis Creek								4
	Fry Creek	Fry Creek								0
	Tam O'Shanter	Tam O'Shanter								0
Group 3	Conway Creek	Midge Creek						16		13
	Hughes Creek	Midge Creek						0		
	Kutetl Creek	Midge Creek						55		2
	Midge Creek	Midge Creek						160		77
	Seeman Creek	Midge Creek						139		27
	Wurttemberg Creek	Midge Creek						30		12
	Blazed Creek	Summit Creek						1		
	Char Creek	Summit Creek						0		
	Maryland Creek	Summit Creek						2		
	Summit Creek	Summit Creek						26		
	Cultus Creek	Cultus Creek						50		25
	Akokli Creek	Akokli Creek								0
	Goat River	Goat River								0
	Gray Creek	Gray Creek								2
	La France Creek	La France Creek								0
	Lockhart Creek	Lockhart Creek								1
	Next Creek	Next Creek								0
Sanca Creek	Sanca Creek								0	