KASLO RIVER AND CRAWFORD CREEK
BULL TROUT
SPawner ASSESSMENT

2009

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EXECUTIVE SUMMARY

During August 2009 resistivity counters were placed on the lower portions of the Kaslo River and Crawford Creek in an effort to record downstream movements of spawned out adfluvial bull trout that inhabit Kootenay Lake. Upstream movement of spawners was recorded as soon as the counters were operational and a peak of upstream movement on the Kaslo River was recorded in mid September. The Crawford Creek counter suggested that the peak of upstream movement was earlier in August as far fewer fish were recorded moving upstream compared to downstream numbers. Run timing was well defined by the counters and the peak of spawning was determined after downstream movement increased at the end of September. This information signaled the timing of redd surveys on both systems that were conducted in the first week of October.

The redd survey on the Kaslo River estimated a total of 689 redds of which 542 were observed in the upper Kaslo River, 139 in Keen Creek and the remaining 8 redds were counted between the counter and downstream to the lake a distance of approximately 8 km. Redds per km were 27/km for the Kaslo River, 23/km in Keen Creek and 1.0/km in the main river below the counter. The survey on Crawford Creek counted a total of 268 redds with the majority (n=233) observed in the mainstem while the balance were located in the lower reaches of three tributaries. Redd densities were much lower in Crawford Creek compared to the upper Kaslo River with 11fish/km in the mainstem and a range of 10-31/km in the three tributaries.

The Kaslo River resistivity counter recorded a total of 1,219 spawners while the Crawford Creek count was 486. Comparing the 2009 redd counts to the counter numbers results in a conversion factor of 2.2 fish/redd for the Kaslo system and 1.8 fish/redd for Crawford Creek. The differences between the two systems are attributed to far greater amounts of suitable spawning habitat in the upper Kaslo River compared either Crawford or Keen creeks. The derived expansion factors could be applied to other tributaries where resistivity counters cannot be operated but redd surveys are feasible.
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This project is largely funded by the Habitat Conservation Trust Foundation. The Habitat Conservation Trust Foundation was created by an act of the legislature to preserve, restore and enhance key areas of habitat for fish and wildlife throughout British Columbia.

Anglers, hunters, trappers and guides contribute to the projects of the Foundation through licence surcharges. Tax deductible donations to assist in the work of the Foundation are also welcomed.
# TABLE OF CONTENTS

INTRODUCTION .............................................................................................................. 1

Objectives ....................................................................................................................... 2

BACKGROUND ................................................................................................................ 3

SITE DESCRIPTION ......................................................................................................... 4

  Kaslo River Watershed ............................................................................................... 5
  Crawford Creek Watershed ......................................................................................... 5

METHODS ......................................................................................................................... 9

  Temperature .................................................................................................................. 9
  Discharge Data .............................................................................................................. 9
  Redd Surveys .................................................................................................................. 9
  Redd Identification ....................................................................................................... 10
  Electronic Resistivity Counter ................................................................................... 11
  Counter Operation ...................................................................................................... 11
  Fish Counter Enumeration Estimates ....................................................................... 13

RESULTS ......................................................................................................................... 13

  Temperature .................................................................................................................. 13
    Kaslo River Watershed ............................................................................................... 13
    Crawford Creek Watershed ......................................................................................... 13
  Discharge ...................................................................................................................... 15
    Kaslo River Discharge ............................................................................................... 15
    Crawford Creek Discharge ......................................................................................... 15
  Redd Counts .................................................................................................................. 17
    Kaslo River Watershed ............................................................................................... 17
    Crawford Creek Watershed ......................................................................................... 17
  Fish Counter Enumeration Estimates ....................................................................... 18
    Kaslo River Watershed ............................................................................................... 18
    Crawford Creek Watershed ......................................................................................... 22

DISCUSSION ................................................................................................................... 25

RECOMMENDATIONS .................................................................................................. 28

REFERENCES ................................................................................................................. 29

APPENDIX-1. Photo Documentation ............................................................................. 32

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LIST OF FIGURES

Figure 1. Map of Kootenay Lake ................................................................. 6
Figure 2. Kaslo River watershed ................................................................. 7
Figure 3. Crawford Creek watershed .......................................................... 8
Figure 4. Example of a typical graphical fish trace of an upstream bull trout on the upper Kaslo River ................................................................. 12
Figure 5. Average daily temperatures on the upper Kaslo River, Keen Creek and Crawford Creek, October 2008 to October 2009 ........................................ 14
Figure 6. Average daily temperatures on the upper Kaslo River, Keen Creek and Crawford Creek, August to October, 2009 ........................................... 14
Figure 7. Monthly mean, maximum and minimum discharge (m³/s) on the Kaslo River monitored by Environment Canada from 1964-2009 ......... 15
Figure 8. Mean daily discharge (m³/s) on the Kaslo River and Kemp Creek for 2009 by Environment Canada .............................................................. 16
Figure 9. Monthly mean, maximum and minimum discharge (m³/s) on Crawford Creek monitored by Environment Canada from January 1947 to December 1952 .... 16
Figure 10. Total daily down counts for upper Kaslo River bull trout in 2009 .......... 20
Figure 11. Total upstream and downstream daily fish counts on the upper Kaslo River in 2009 ......................................................................................... 20
Figure 12. Diel migration pattern on the upper Kaslo River in 2009 ................. 21
Figure 13. Percent of fish counts by channel on the upper Kaslo River in 2009 .... 21
Figure 14. Total daily down counts for Crawford Creek bull trout in 2009 ......... 21
Figure 15. Total upstream and downstream daily fish counts on Crawford Creek in 2009 ......................................................................................... 23
Figure 16. Diel migration pattern on Crawford Creek in 2009 ......................... 24
Figure 17. Percent of fish counts by channel on Crawford Creek in 2009 ........... 24

LIST OF TABLES

Table 1. An example of a fish record from the electronic resistivity counter ......... 12
Table 2. Bull trout redd survey data (# counted and density) collected on the upper and lower Kaslo River and Keen Creek from 2006 to 2009 ......................... 17
Table 3. Bull trout redd survey data (# counted and density) collected on Crawford Creek in 2009 ......................................................................................... 18
Table 4. Derivation of expansion factor from estimated reds counts and electronic resistivity counts from select sites. ........................................................... 27
Table 5. Population estimates based on expansion factors and a range of variability for select watersheds. .................................................................................... 27

LIST OF PHOTOS

Photo 1. Remnants of the hydro power dam (1970) near Kalso BC, located approximately 4 km upstream from the lake. ................................................ 32
Photo 2. Typical redd formation on the upper Kaslo River (2.5 m x 0.7 m). .......... 32
Photo 3. Typical redd formation on Keen Creek (2.2 x 1.0 m). ............................. 33
Photo 4. Typical redd formation on Crawford Creek (1.5 x 0.7 m). .......................... 33
Photo 5. The upper Kaslo River counter site installed August 3, 2009, using the flat pad sensor units. Channel 1, near bank and channel 4 far bank. .............. 34
Photo 6. Crawford Creek site installed August 15, 2009, using the flat pad sensor units. Channel 1, near bank and channel 3 far banks. .......................... 34
Photo 7. DVR record of a up-streaming bull trout (Channel 1) on the upper Kaslo River at 5:25:17 AM on August 4, 2009....................................................... 35
Photo 8. Upper Kaslo River barrier near Retallic BC. ................................................. 35
Photo 9. Keen Creek barrier located ~ 6km upstream from confluence with Kalso River............................................................................................................. 36
Photo 10. Barrier on Twelve Mile Creek located ~ 250 m upstream of the confluence with Kalso River. ................................................................. 36
Photo 11. Barrier on Crawford Creek ~21 km upstream of the confluence with Kootenay Lake. ................................................................. 37
Photo 12. Barrier on Canyon Creek ~500 m upstream of the confluence with Crawford Creek. ............................................................................................................. 37
Photo 13. Barrier on Hooker Creek ~520 m upstream of the confluence with Crawford Creek. ............................................................................................................. 38
Photo 14. Barrier on Houghton Creek ~520 m upstream of the confluence with Crawford Creek................................................................. 38
Photo 15. Redd distribution on the Kalso River watershed in 2009. ...................... 39
Photo 16. Redd distribution on Crawford Creek watershed in 2009................. 40
INTRODUCTION

Bull trout (*Salvelinus confluentus*) are a dominant large piscivorous salmonid that are native to Kootenay Lake, and contribute to a popular sport fishery with an estimated annual catch of over 10,000 fish (Redfish Consulting 2006). However, very little is known about the status of the adfluvial bull trout populations in Kootenay Lake including: location of major spawning systems and specific spawning sites within these systems, the relative importance of the different systems to overall bull trout production, and spawner numbers to any of these systems. This lack of information is very problematic since bull trout are known to be highly vulnerable to fishing, and very sensitive to habitat alterations and climate change. Many of these aforementioned factors led the provincial government to list bull trout as a species of concern throughout BC.

It has been known for a long time that many of Kootenay Lake’s tributaries support adfluvial spawning bull trout and virtually all these streams have been closed to bull trout fishing for decades. The Kaslo River and Crawford Creek are two systems known to support one or more of the various forms of bull trout populations. Due to the intensive sport fishery on Kootenay Lake, the potential exists for overexploitation on this species, as they are subjected not only to a year round lake fishery, but also can be exposed to concentrated fisheries at the mouths of rivers and creeks as they stage before ascending to spawn. The lack of knowledge on the status of any of these adfluvial populations, in lieu of an understanding of whether ongoing harvest is sustainable, is a concern for fisheries management.

Bull trout are often considered an indicator species of the health and status watersheds due to their specific habitat requirements (McPhail and Baxter 1996). As with many salmonids populations, they are highly sensitive to habitat alteration, degradation and fragmentation (Rieman and McIntyre 1995). Kootenay Lake and many of its fish populations have undergone major perturbations, as a result human of impacts (Northcote 1973). As well, the effects of climate change could have serious implications to bull trout populations, since they require cold water temperatures (Selong et al. 2001; Dunham et al. 2003; Rieman et al. 2007). Understanding the cumulative effects and at what life stage factors that affect the status of bull trout populations on Kootenay Lake is imperative for future management.

In an attempt to better understand Kootenay Lake bull trout, an annual monitoring program has been established on the Kaslo River. Over a period of time, development of an index of abundance on this system will better inform fisheries managers on the status of this bull trout population and their sustainability within the recreational fishery, while assisting with upper trophic level monitoring associated with the nutrient restoration project on Kootenay Lake.

This report summarizes a monitoring program initiated in 2006 by the Ministry of Environment (MOE), and the FWCP in partnership with the HCTF, to determine the status and health of the bull trout populations in the Kootenay Lake region. The project combines the use of electronic resistivity counters with redd surveys in an attempt to
obtain an accurate, unbiased estimate of adfluvial bull trout spawner abundance in the Kaslo River and the Crawford Creek watersheds.

**Objectives**

- Utilize electronic resistivity counters in the Kaslo River and Crawford Creek to enumerate adfluvial out-migrating bull trout
- Conduct redd surveys in both systems
- Use both methodologies in combination to establish an index of abundance for bull trout
- Identify whether the methodology used in this study can be employed for the enumeration of other bull trout populations in the Kootenay Lake region
- Use the estimate of bull trout abundance from the resistivity counters to develop an expansion factor for redd surveys
- Provide estimates of bull trout escapement to the two watershed
- Reduce uncertainty and variability inherent in redd surveys
BACKGROUND

Variable life history characteristics, behaviour, and spatial and temporal distributions make spawning bull trout difficult to assess (Rieman and McIntyre 1996; Rieman and Myers 1997; Dunham et al. 2001). 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 actions that are implemented. In many systems, redd surveys have provided an inexpensive and less invasive index of abundance for monitoring bull trout trends (Dunham et al. 2001). However, despite widespread use of redd counts for monitoring population trends few studies have evaluated the validity of this method for detecting trends in population size (Muhlfeld et al. 2006). Uncertainty exists in expanding redd counts to estimate population size due to the unknown relationship that exists 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 invite considerable uncertainty.

Establishing a quantitative, standardized methodology to establish population/escapement trends within different watersheds is highly desirable for management of the Kootenay Lake bull trout populations. The premise of this study focused on the Kaslo River and Crawford Creek is that combining electronic counter data in concert with redd surveys should allow for a better understanding of bull trout population size and trends.

Prior to 1970 an old hydro power dam, located on the Kaslo River approximately 4 km upstream from the lake, was a complete barrier to all fish movement with a vertical drop of ~7 m (Photo 1 in Appendix 1). The provincial government removed the dam in the early 1970s and by the 1980s reports of large size bull trout in the upper river were received from the public. To date, it is unclear if remnants of the dam remain a migration barrier to smaller fish but large spawners have been observed well upstream (~25 km) of the old dam site.

Kootenay Lake has undergone major perturbations over the last four decades affecting many of its salmonid species (Northcote 1973). Until 1992, when lake fertilization commenced Kootenay Lake was in a state of trophic depression as a result of upstream hydro-electric development (Ney 1996), which had adverse affects on lake productivity and many of its fish populations (Ashley et al. 1997; Schindler et al. 2006). On a smaller scale, much of the Kaslo River has been destabilized due to road developments, as well as through forestry and historical mining practices. As noted below, logging has also been a major factor in destabilization of the Crawford Creek watershed. Baxter et al. (1999) demonstrated that there is a negative correlation with bull trout numbers and the
density of road development in spawning tributary catchments. This has serious implications as bull trout have highly specific micro-habitat selection requirements during spawning (Baxter and McPhail 1999). Thus, identifying and protecting this habitat is critical for sustaining and conserving bull trout. As well, climate changes will potentially have consequences on the distribution of bull trout locally, regionally and provincially. Increased water temperatures as a result of hydrologic impacts have been cited as major factor influencing bull trout distributions and requirements for conservation (Dunham et al. 2003; Rieman et al. 2007).

The Kaslo River supports a large number of bull trout spawners that ascend the river from Kootenay Lake during July-September. Prior to 2006 it was unknown how many spawners might actually use the river. It is believed these fish ascend the lower part of the river and then hold during mid-summer before moving upstream in September to spawn in the upper reaches of the river ~20-35 km upstream from the lake. Low seasonal flows and good access along much of the Upper Kaslo River makes this system an ideal site for redd surveys and the use of a resistivity counter to enumerate fish.

Crawford Creek, similar to many other watersheds in the Kootenay Region, has undergone major habitat disturbance as a result of several decades of poor logging practices (Northcote 1973). Harvesting in Crawford Creek first began in 1961 with selective white pine removal by Strom Brothers (G. Fitchett, retired logger Balfour BC pers. comm.). Large-scale harvesting operations were initiated in the late 1960s by Kootenay Forest Products Ltd. with most of the first pass wood having been removed. Accordingly, it will be some time before conditions recover to allow further large-scale entries (second pass) into the drainage area (Timberland Consultants 1997).

Unfortunately, most of the harvesting activities in the Crawford Creek drainage were carried out prior to the implementation of legislation such as the Forest Practices Code Act of British Columbia. Consequently, much of the early harvesting and road building was on high steep gradients throughout the watershed, destabilizing many of the slopes while increasing peak flows and run-off. An Interior Watershed Assessment Plan undertaken in 1997 identified that sixty percent of the watershed area is located above the H60 elevation line, used to calculate the Peak Flow index (Timberland Consultants 1997). The report also demonstrated that clear-cutting above this elevation has had a significant impact on peak flow compared with clear-cutting below this elevation line. Although data is limited, Crawford Creek is known to support rainbow trout and spawning populations of kokanee and bull trout. Recovery of the kokanee population is currently underway and is part of a greater initiative to restore kokanee to the south arm tributaries to Kootenay Lake (Schindler et al. 2006). To date, little quantitative data exists on the health and status of the other species of fish that utilize or inhabit Crawford Creek and its tributaries.

SITE DESCRIPTION

Kootenay Lake is located in the upper Columbia River drainage of Southeast British Columbia, and lies between the Selkirk and Purcell Mountain ranges (Figure 1). The
main lake is 107 km long and 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 Kootenai/y River that flows into the south end (South Arm). The North Arm of Kootenay Lake receives 21% of the entire inflow to the lake via the Duncan/Lardeau River drainage and represents about one quarter of the entire lake surface and volume while the South Arm of the lake receives 56% of the entire inflow to the lake via the Kootenai/y River drainage and represents about two thirds of the entire lake surface and volume (Daley et al. 1981, Binsted and Ashley 2006). The outlet of the main lake, at Balfour, British Columbia, forms the upper end of the West Arm before becoming the lower Kootenai/y River which flows into the Columbia River at Castlegar, BC.

Kaslo River Watershed

One of the larger secondary tributaries that flows into the north arm of the lake at Kaslo BC (Figure 2) is the Kaslo River. This river is paralleled by Highway 31(A) and therefore is quite accessible. The Kaslo River watershed covers a gross drainage area of 453 km$^2$ and is also considered a moderate gradient system varying from 1 to 10%. The confluence with a major tributary Keen Creek is ~8 km upstream of the lake. The upper Kaslo River extends another ~19 km parallel to Highway 31(A) before an impassable barrier impedes fish passage. Beyond these falls the river continues to parallel Highway 31(A) for another ~3 km to its headwater origin at Fish Lake. The upper Kaslo River is a highly complex mixture of heterogeneous habitats characterized by differing gradients, cobble-gravel substrates and LWD accumulations. In contrast, Keen Creek extends ~30 km beyond the confluence to its headwater origin in Kokanee Glacier Provincial Park and covers a gross drainage area of 92.2 km$^2$. Similar to the upper Kaslo River, Keen Creek has an impassable barrier that impedes fish passage ~6 km upstream of its confluence with the Kaslo River. Habitat on Keen Creek is more homogeneous, consisting of mostly high gradient, large boulder-cobble substrates and a high procession of step pool morphology.

Crawford Creek Watershed

Crawford Creek, considered another secondary tributary to Kootenay Lake, flows into Crawford Bay on the south arm (Figure 3). The watershed covers a gross drainage area of 172 km$^2$. Crawford Creek extends ~21 km upstream of its confluence with Kootenay Lake draining from the west slopes of the Purcell mountain range. Habitat consists of mostly large cobble substrates dominated short run-riffle sections. 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 dominated by boulders and cobble with little LWD hence few pools. 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.
Figure 1. Map of Kootenay Lake.
Figure 2. Kaslo River watershed including the upper and lower Kaslo River and Keen Creek, a tributary to Kaslo River. Polygon indicates location of the resistivity counter site (2006-2009) and the Environment Canada hydrometric station.
Figure 3. Crawford Creek watershed including all major tributaries. Polygon indicates location of the resistivity counter site in 2008 and 2009.
METHODS

Temperature

Onset StowAway™ Tidbit™ data loggers set to record water temperature every 60 minutes were installed on the upper Kaslo River and Keen Creek in October 2009. In Crawford Creek water temperatures were recorded every 30 minutes by the same model data logger installed at the resistivity counter site in August 2009. Temperature data was periodically downloaded to a laptop computer and stored in Excel files. Loggers were attached to small light-weight cables that were fixed to a piece of LWD or small woody vegetation in a shaded area in a minimum depth of 20 centimetres. Additionally, spot temperatures (°C) were measured using a handheld YSI 85 multi-probe.

Discharge Data

Kaslo River discharge (m$^3$/s) is actively monitored by an Environment Canada hydrometric station below Kemp Creek (station # 08NH005). Daily and annual discharge data has been compiled since 1964. As well, Keen Creek discharge (m$^3$/s) is actively monitored by an Environment Canada hydrometric station (station # 08NH132). Daily and annual discharge data has been compiled since 1973.

Crawford Creek discharge (station # 08NH104) has been discontinued by Environment Canada since 1952. However in light of current hydrometric data, data collected from six years (1947-1952) is used as a surrogate for average seasonal flows on this system.

Redd Surveys

Upstream and downstream migration data collected from the resistivity counters was used to determine when to conduct the redd surveys. Specifically, the cumulative number of bull trout migrating upstream through the counter was used to determine run timing. The redd surveys were initiated when it appeared downstream migrations were diminishing. Once run timing and out-migration was determined a reconnaissance survey was conducted to confirm the majority of spawning had been completed. Redd counts were conducted on the Kaslo River and Crawford Creek systems by two survey crews, each consisting of two experienced observers between October 2nd and October 6th, 2009. The crew walked in a downstream direction from barriers assessed as impassable on each system while recording possible test redds, actual redds and any accompanying adult bull trout near redds. All actual redd locations were geo-referenced using hand-held GPS units and their locations were entered into an Excel spreadsheet. In addition, distance from known barriers were recorded to compare the year to year spatial distribution of redds within the system.

The Kaslo River was divided into the upper Kaslo River and lower Kaslo River which is separated by the confluence with Keen Creek. The upper Kaslo River was surveyed (~20 km) by the two person crew dividing it into two sections of approximately equal lengths below the barrier near Retallic, BC. All small tributary streams were assessed along the
entire 20 km of the upper Kaslo River, including Rossiter Creek, Twelve Mile Creek and Ten Mile Creek. The lower Kaslo River ~8 km was surveyed by a crew dividing it into two sections of approximately equal length above and below the barrier ~4 km upstream from Kootenay Lake.

As well, Keen Creek ~6 km was surveyed in a downstream direction from an impassable barrier to the confluence with the Kaslo River. However, unlike the upper Kaslo River, Keen Creek had a small number ephemeral tributary streams but due to their exceedingly high gradient were considered inaccessible by adfluvial bull trout. Surveys conducted on Keen Creek were much more difficult and time consuming due to the large boulder and step-pool morphology of the creek that made walking difficult.

Similarly, the Crawford Creek (~21 km) watershed was systematically surveyed by one two person crew conducting surveys that averaged ~8 km per day. Major tributaries to Crawford Creek, including Canyon Creek, Hooker Creek and Houghton Creek, were assessed for adfluvial bull trout access and spawning activity.

**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 (Photo 2, Photo 3 and Photo 4 in Appendix 1). 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 (Baxter and McPhail 1999). For this study, the redd count was based on a subjective evaluation, with
the most recent complete redd(s) counted and the disturbed remains of prior redds being included. 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. Fortunately, such cases usually represented a very small proportion of the total redds present.

**Electronic Resistivity Counter**

The resistivity counter detects the passage of fish across an array of three electrodes (positive, ground and negative), placed across the river, or in a channel, in an insulated base (Aprahamian et al. 1996). The counter electronics continually monitor the resistance (bulk resistance) of the water above the counting array and calibrates the hardware for changes in this resistance every 30 minutes. When a fish passes over the three electrodes, a change in resistance occurs, as a fish is more conductive than the water it displaces. This change of resistance is recorded and analyzed by the counter using a firmware algorithm to determine if it fits a typical fish pattern. If the counter assessed that a fish passed over the array the time, direction of travel and peak signal size (maximum change of resistance measurement) of the fish event, was recorded and stored for later downloading and analysis (see Aprahamian et al. 1996 for more details of counter design and operation).

The design of the flat pad sensor units in this project were similar to that used on McKinley Creek in the Cariboo Region, with an outer aluminium frame and an inner vinyl sleeve into, which were set 3 stainless steel electrodes (Photo 5 in Appendix 1; McCubbing et al. 1999; Galesloot and McCubbing 2003; Peard et al. 2005). The flat pads were held in place and weighted down by biodegradable burlap sand bags. The sand bags were placed on the periphery of each pad (6-8 per pad) to ensure they did not interfere with fish passage over the electrodes.

The sensor units installed (4 in total on upper Kaslo River) covered a width of 12 m, with channel 1 on the near bank and channel 4 on the far bank (Photo 3 in Appendix 1). The remaining margin areas, in shallow water (< 20 cm), were blocked off by natural rock weirs to discourage fish passage. On Crawford Creek, installation was similar but only 3 sensor units were used (Photo 6 in Appendix 1). At both sites, the Logie 2100C counter was hard wired into the electrodes and positioned on the bank along with video validation equipment stored in a metal work box.

**Counter Operation**

Data collected from the counter was stored as buffer files (on the counter) and downloaded on a regular basis by field staff. The data contains the date of download, the settings of the counter, followed by fish records. The fish records contain a date, time, conductivity, channel of count, direction of travel (up or down) and estimated Peak Signal Strength (PSS) (see Table 1 as an example).
Table 1. An example of a fish record from the electronic resistivity counter.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Channel Conductivity</th>
<th>Channel #</th>
<th>Channel Direction</th>
<th>PSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/9/2006</td>
<td>3:51:06</td>
<td>100</td>
<td>3</td>
<td>U</td>
<td>98</td>
</tr>
</tbody>
</table>

Graphical trace records were collected for fish through much of the migration period. This data was logged directly to a portable PC for storage, as the counter memory is insufficient for this purpose. Graphical trace data and signal size was used for analysis and assisted in the assessment of fish behaviour, directional movement and counter performance (i.e. noise events vs. fish events) (Figure 4). This type of data which can be collected in addition to standard counter output allows for increased confidence in fish counter performance. Many graphical traces were recorded on multiple channels which conformed to typical (McCubbing et al. 1999, Galesloot and McCubbing 2003, Peard et al. 2005) upstream and downstream counts. These traces provide the ability to visually validate the counts recorded by the counter, increasing the overall efficiency. In addition all variations in peak signal size above threshold values were recorded by the counter and in trace form for later analysis.

Figure 4. Example of a typical graphical fish trace of an upstream bull trout on the upper Kaslo River.

As well, digital video of all daytime records were collected through much of the migration period in 2009 on the upper Kaslo River and Crawford Creek. The digital video recorder (DVR) was linked to a fixed outdoor camera positioned on a nearby tree (~ 4-5 m height). The electronic counter sensor unit initiated the DVR into recording an event in frames of 5 milliseconds, capturing all events and direction during the daytime (Photo 7 in Appendix 1). Similar to the graphics trace data, digital video data was used for analysis and assisted in the assessment of fish behaviour, calibrating fish size to PSS, directional movement and counter performance.
Fish Counter Enumeration Estimates

Estimates of kelted bull trout on the upper Kaslo River and Crawford Creek were calculated by methods similar to those used on the Deadman River in the Thompson-Nicola Region in 1999 (McCubbing 1999). In summary they were calculated by the following process:

1. All obvious spurious debris or wave actions from graphics data were removed from the raw data set. These are usually characterized by large numbers of events on a single channel over a short period of time.

2. All trace data were visually examined and used as an efficiency check for counter validation.

3. Further validation was obtained from digital video data for all daytime events.

4. A daily summary of up and down counts was examined to determine, at what time during the migration window kelted fish began dropping back over the counter.

5. A value for net down counts was determined for char passage based on peak signal size distributions and the pattern of downstream counts.

RESULTS

Temperature

Kaslo River Watershed

In 2009, temperatures increased from April to August followed by a decline from late August to October for the upper Kaslo River and Keen Creek (Figure 5). Temperatures peaked in August at their maximum of 14.9°C and 14.5°C on the upper Kaslo River and Keen Creek, respectively. Following the peak, temperatures declined rapidly on both systems, averaging 8.2°C and 7.8°C from mid-August to mid October on the upper Kaslo River and Keen Creek, respectively (Figure 6). Overall, temperature data indicated that Keen Creek was a colder system by an average of ~ 1°C, compared to the upper Kaslo River.

Crawford Creek Watershed

In 2009, temperature data recorded in Crawford Creek indicated a decline in temperature after August, similar to the Kalso River system (Figure 5). Temperatures peaked in August at their maximum of 16.6°C, rapidly declining from this date onward. Following the peak temperature, the mid-August to mid October temperatures averaged 9.6°C (Figure 6).
Figure 5. Average daily temperatures on the upper Kaslo River, Keen Creek and Crawford Creek, October 2008 to October 2009.

Figure 6. Average daily temperatures on the upper Kaslo River, Keen Creek and Crawford Creek, August to October, 2009.
Discharge

Kaslo River Discharge

Kaslo River discharge (m$^3$/s) is monitored by an Environment Canada hydrometric station below Kemp Creek (station # 08NH005). Daily and annual discharge data has been compiled since 1964. Mean monthly discharge (m$^3$/s) indicates that the flows in 2009 were well below the average recorded from 1964 to 2009 (Figure 7). Importantly, discharge demonstrates that bull trout ascend the Kaslo River on a declining hydrograph beginning in July. Discharge data suggests indicates a discharge of ~29 m$^3$/s in July when adult bull trout are ascending the river, declining to ~6-7 m$^3$/s in September-October during the peak of spawning. Moreover, daily flow data indicates that bull trout ascend the major tributaries (Keen Creek and upper Kaslo River) on further reduced flows, often < 5 m$^3$/s (Figure 8).

Crawford Creek Discharge

Although Crawford Creek discharge (m$^3$/s) monitoring was discontinued in 1952, six consecutive years of data (1947-1952) by Environment Canada (station # 08NH104) does provide some insight into the seasonal flow pattern on this system. Importantly, similar to the Kaslo River, flow data indicates that bull trout would most likely ascend Crawford Creek on a declining hydrograph (Figure 9). Historical mean monthly discharge (m$^3$/s) from 1947 to 1952 indicates a discharge of 7.9 m$^3$/s in July when adult bull trout are ascending the river, declining to 1.71 m$^3$/s in September during the peak of spawning.

Figure 7. Monthly mean, maximum and minimum discharge (m$^3$/s) on the Kaslo River monitored by Environment Canada from 1964-2009.
Figure 8. Mean daily discharge (m$^3$/s) on the Kaslo River and Keen Creek for 2009 by Environment Canada.

Figure 9. Monthly mean, maximum and minimum discharge (m$^3$/s) on Crawford Creek monitored by Environment Canada from January 1947 to December 1952.
Redd Counts

Kaslo River Watershed

A total of 689 redds were enumerated within the Kaslo River watershed during October 2\textsuperscript{nd} - 6\textsuperscript{th}, 2009. Of these, 542 redds were enumerated in the upper Kaslo River, 139 redds in Keen Creek, and 8 redds in the lower Kaslo River (Table 2) As previously noted, the barrier on the upper Kaslo River is located ~20 km upstream near Retallic, BC (Photo 8 Appendix 1). The Keen Creek barrier is located ~6 km upstream from the Kaslo River confluence (Photo 9 in Appendix 1). These estimates translate into an average density of 27 redds per lineal km on the upper Kaslo River (~20 km), 23 redds per lineal km on Keen Creek (~6 km) and only 1.0 redds per lineal km on the lower Kaslo River (~8 km).

Small tributaries including Rossiter Creek, Ten Mile Creek and Twelve Mile Creek accounted for a small proportion (<3 %) of the total redds observed on the upper Kaslo River. A total of 11 redds observed in ~400 m of habitat in Rossiter Creek before a fish passage barrier (falls) was located. Likewise, a total of 6 redds were observed in Twelve Mile Creek before a barrier (falls) was located ~320 m upstream from the confluence with the upper Kaslo River (Photo 10 in Appendix 1).

During the redd surveys, 40 adult bull trout (24 male, 16 female) were observed and considered to be associated with redds on the upper Kaslo River, while 21 adult bull trout (12 male and 9 female) were observed on Keen Creek. These low numbers confirmed that the vast majority of spawning had been completed. Estimated lengths from visual observation indicated male adult bull trout ranged from ~60-90 cm, and slightly smaller for females at ~50-75 cm.

| Year | Upper Kaslo | | Lower Kaslo | | Keen Creek | |
|------|-------------|--------|-------------|--------|-------------|
|      | # Redds | Density (redd/km) | # Redds | Density (redd/km) | # Redds | Density (redd/km) | Total |
| 2006 | 321 | 16 | n/a | n/a | 100 | 17 | 421 |
| 2007 | 458* | 23 | 13 | 2 | 116* | 19 | 587* |
| 2008 | 471* | 24 | 3 | 0.5 | 137* | 23 | 611* |
| 2009 | 542 | 27 | 8 | 1.0 | 139 | 23 | 689 |

Table 2. Bull trout redd survey data (# counted and density) collected on the upper and lower Kaslo River and Keen Creek from 2006 to 2009.

Crawford Creek Watershed

A total of 268 redds were enumerated within the ~22 km (including tributaries) of accessible bull trout spawning habitat in the Crawford Creek watershed on October 5\textsuperscript{th} and 6\textsuperscript{th}, 2009 (Table 3). It should be noted that in 2008 no barrier was confirmed but in 2009 a definite barrier was located ~20 km upstream from the confluence with Kootenay
Lake (Photo 11 in Appendix 1). The estimate for the mainstem of Crawford Creek (~20 km) translates into an average density of 11 redds per lineal km.

The 2009 survey included assessment of all major accessible tributaries namely; Canyon, Hooker and Houghton creeks. Due to their steep gradients and limited access (all <1.0 km), these tributaries accounted for only ~13% of the total redds observed throughout the system. A total of 12 redds were observed in a 308 m section of Canyon Creek, before a log jam barrier (Photo 12 in Appendix 1). A total of 10 redds were observed in Hooker Creek in 327 m, before a barrier was located (Photo 13 in Appendix 1). A total of 13 redds were observed in Houghton Creek in 527 m, before a log jam barrier was located (Photo 14 in Appendix 1).

A total of 34 adult bull trout (24 male, 10 female) were observed during the survey that were considered to be associated with redds on in the Crawford Creek system. These low numbers confirmed that most spawning had been completed. Estimated lengths from visual observation indicated male adult bull trout ranged from ~60-85 cm, and slightly smaller for females at ~55-70 cm.

Table 3. Bull trout redd survey data (# counted and density) collected on Crawford Creek in 2009.

<table>
<thead>
<tr>
<th>Year</th>
<th>Crawford Creek</th>
<th>Canyon Creek</th>
<th>Hooker Creek</th>
<th>Houghton Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># Redds</td>
<td>Density (redd/km)</td>
<td># Redds</td>
<td>Density (redd/km)</td>
</tr>
<tr>
<td>2008</td>
<td>159</td>
<td>8.2</td>
<td>3</td>
<td>6.0</td>
</tr>
<tr>
<td>2009</td>
<td>233</td>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>

Fish Counter Enumeration Estimates

Kaslo River Watershed

The electronic resistivity counter was installed on the upper Kaslo River on August 3rd, 2009. The counter operated continuously until October 12th, 2009, with the exception of a two power interruptions on September 10th and 12th. Final counts were recorded on October 12th, 2009 and on that date the counter and sensors were then removed. A cumulative total of 1,219 adult bull trout migrated downstream after September 17th to the end of the study period in 2009 (Figure 10). This estimate was adjusted for efficiency and confirmed by examining each graphical trace output and daytime video records. It is quite certain that the estimate represents the total post spawner escapement on the upper Kaslo River. It should be noted that upstream migrants were observed in good numbers, >10 fish per day, from the first day of the counter installation (Figure 11). Peak upstream migration of > 100 fish per day was recorded between September 12th and 18th. The high numbers of upstream migrants on the first day of the counter operation suggests many bull trout had already migrated upstream prior to counter installation. Although total upstream counts were not expected it is clear from the total downstream counts that the
vast majority of the upstream migration was recorded. Downstream migration was limited in the early part of the counter operation but highly sporadic, with less than 10 fish per day recorded most days through to September 8th. A gradual increase in out-migrants was then observed from this period onward. Peak downstream migration was observed between September 12th and October 4th after which movements of both upstream and downstream migrants were reduced to less than 10 fish per day through to the end of the study.

Utilizing the net daily count (upstream minus downstream count), with a few exceptions in August, a major shift in migration pattern is evident between early and late data throughout the counting period. Between August 3rd and September 16th a net upstream migration occurred at the counter site, while after September 16th the situation reversed and a net downstream daily migration can be observed. Diel migration patterns were observed, with the majority of fish migrating in either direction from 8:00 pm to 7:00 am (Figure 12), largely during the hours of darkness. Of the total fish counts (up and down), channel 3 (mid left) represented 46% of all the counts while channel 4 (far bank) recorded the least amount of counts at ~2%. From the total channel use, channel 3 represented 37% of all downstream counts and 55% of all upstream counts (Figure 13).

Although not presented in this report more detailed analysis of the 2009 counter data will probably provided some information on size of migrating bull trout. Preliminary analysis of the 2009 up migrating fish suggests a length frequency distribution that represents several age groups.
Figure 10, Total daily down counts (total down minus total up) for upper Kaslo River bull trout in 2009.

Figure 11. Total upstream and downstream daily fish counts on the upper Kaslo River in 2009.
Figure 12. Diel migration pattern on the upper Kaslo River in 2009.

Figure 13. Percent of fish counts (up and down) by channel on the upper Kaslo River in 2009.
Crawford Creek Watershed

The electronic resistivity counter was installed on Crawford Creek on August 15th, 2009. The counter operated continuously until October 20th, 2009. Final counts were recorded on October 20th, 2009 and on that date the counter and sensors were then removed. Similar to 2008, the counter site was located ~2.6 km downstream of Houghton Creek, well below all major tributaries accessible by adfluvial bull trout in the Crawford Creek system (Fig. 2).

A cumulative total of 486 adult bull trout migrated downstream after September 10th to the end of the study period in 2009 (Figure 14). Similar to the Kaslo River count, this estimate represents the total post spawner escapement and was adjusted for efficiency by examining each graphical trace output and daytime video records. The limited upstream movement detected on Crawford Creek from the electronic counter suggests that most fish had migrated upstream prior to counter installation (Figure 15). Peak upstream migration of > 10 fish per day was recorded between September 29th and October 4th. Downstream migration was limited in the early part of counter operations until September 10th when a gradual increase in out migrants was observed from this period onward. Peak downstream migration was occurred between September 15th and October 4th after which movements of both upstream and downstream migrants were reduced to less than 10 fish per day through to the end of the study.

Similar to the upper Kaslo River, diel migration patterns indicated the majority of fish migrated in either direction from 8:00 pm to 7:00 am (Figure 16), largely during the hours of darkness. Again this pattern is consistent with many observed salmonid migrations, likely related to predator avoidance and the fact there was little overhead or in-river cover at the counter site.

Of the total fish counts (up and down), channel 1 (near) represented 62% of all the counts while channel 3 (far panel, shallow water) recorded the least amount of counts at ~3%. Moreover, channel 1 represented 64% of all downstream counts and 54% of all upstream counts (Figure 17).
Figure 14. Total daily down counts (total down minus total up) for Crawford Creek bull trout in 2009.

Figure 15. Total upstream and downstream daily fish counts on Crawford Creek in 2009.
Figure 16. Diel migration pattern on Crawford Creek in 2009.

Figure 17. Percent of fish counts (up and down) by channel on Crawford Creek in 2009.
DISCUSSION

Monitoring trends in abundance and the spatial distribution of bull trout populations, typically of the reproductive adults, requires effective methodologies that provide accurate estimates of escapement. This is especially the case where measuring the response of populations to management and conservation initiatives. In most watersheds where bull trout populations have been monitored, the main methodology utilized has been annual redd surveys, which provide an inexpensive and efficient index of abundance. However, despite the widespread use of redd counts for monitoring population trends few studies have evaluated the validity of this method for detecting trends in population size (Muhlfeld et al. 2006). Factors such as, survey timing, observer efficiency, redd superimposition, and delineation of between test digs and actual redds can reduce the level of certainty in using redd counts to monitor populations (Dunham 2001; Al-Chokhachy et al. 2005). Based on the results reported here, it is suggested that utilization of resistivity counter technology can support and strongly validate current redd assessment methods commonly used for enumeration of migrating fish, while reducing some the uncertainty in estimating abundance (Andrusak and McCubbing 2006).

The short timeframe of the annual bull trout redd counts on the Kaslo River suggests an increased trend in abundance over the four year period. Surveys conducted since 2006, indicate an increase in the number of bull trout redds in 2009 (683) compared to 2006 (421) within the Kaslo River watershed (Table 1). Moreover, these estimates translate into an increase in the average number of bull trout redds per km from 12 redds per lineal km in 2006 to 27 redds per lineal km in 2009 for the entire ~34 km of spawning habitat surveyed. The spatial distribution of redds indicated that the majority of redds were found in the upper portions of the Kaslo River watersheds, mainly confined within the mainstem (Photo 15, Appendix 1). As in previous years, the lower Kaslo River continues to provide limited spawning habitat demonstrated by the low frequency of observed bull trout redds. Similar patterns are observed in other systems in British Columbia where bull trout populations are closely monitored (J. Hagen, Consultant Fisheries Biologist, Prince George, BC; pers. comm.).

Redd surveys conducted in the Crawford Creek watershed in 2009, similar to 2008, confirmed that this system also supports a large spawning population of bull trout. Although considered a smaller watershed by area (km²) compared to the Kaslo River, 268 redds were observed over ~21 km of spawning habitat in the mainstem of Crawford Creek in 2009. This estimate translates into an average of ~11 redds per lineal km within the mainstem of Crawford Creek. The major tributaries actually supported higher densities (range 10-31 redds per lineal km) but natural barriers < 1km upstream from Crawford Creek resulted in only limited spawning habitat thus low numbers. Similar to the Kaslo River watershed, the majority of the mainstem spawning was distributed in the upper third of the watershed, ~ 12-15 km upstream from Kootenay Lake, as evidenced by the distribution of redds in 2009 (Photo 16, Appendix 1). Not surprisingly, the upper reaches of Crawford Creek support some of the most complex and least impacted habitat.
During low stable flows an electronic resistivity counter can be an effective method of obtaining an accurate count of spawning adfluvial bull trout (Andrusak and McCubbing 2006; Andrusak 2009). The electronic resistivity counter enumerated 1,219 bull trout kelts emigrating from the upper Kaslo River in 2009, an increase from the 1,197 estimated in 2008. Likewise, 486 bull trout kelts were estimated to have emigrated from the Crawford Creek system in 2009, compared to the 336 enumerated in 2008. Importantly, these estimates rely on the ability of the counter data to be validated. In both sites in 2009, counter data was validated by graphical output traces made by each event recorded on the counter and independent daytime video recordings (DVR) of each event. While validation of the counts increases the accuracy, it is acknowledged that there can be some uncertainty around these estimates due to power outages. Despite this, the low fall flows and large individual fish size (>400 mm) still indicate a relatively accurate (>95%) escapement estimate with an acceptable error of <5% of the true count.

Although redd surveys provide a good index for monitoring bull trout trends, there has been concern over the variability in actual numbers of fish that spawn per redd (Al-Chokhachy et al. 2005). Use of electronic resistivity counts combined with redd survey estimates reduces some of this uncertainty and provides a standardized expansion factor for numbers of fish that spawn per redd. Counter and redd survey data collected on the upper Kaslo River since 2006, (except 2007 when no counter was installed), suggests relatively low variability in the derived expansion factor with the three year average of 2.3 bull trout per redd (Table 4). On Crawford Creek an average of 1.8 bull trout per redd was determined from the 2008 and 2009 data (Table 4). Differences in the two expansion factors for these systems are likely related the differences in habitat suitability. The upper Kaslo River is considerably more complex, supporting more preferred spawning areas with high proportions of small gravels and cobbles. Conversely, both Keen and Crawford creek habitats are more homogeneous, consisting of mostly high gradient, large boulder-cobble substrates with little available spawning gravel. Most reassuring is that, the observed expansion factors on these two systems are very similar to the average observed by Al-Chokhachy et al. (2005) of 2.68 bull trout per redd and remain within the range (1.2 to 4.3 bull trout per redd) of all studies reported in the literature. Given the high degree of certainty around the total spawner counts obtained from the counters and the fairly consistent redd counts strongly suggest the derived expansion factors can be applied to all other tributaries that flow into Kootenay Lake.

In the absence of operating counters on each tributary the expansion factors derived from this study can be used to generate watershed population estimates. However, due to differences in habitat suitability and availability within each system habitat typing for spawning bull trout in the other tributaries should be conducted to determine which expansion factor should be used.
Table 4. Derivation of expansion factor from estimated redds counts and electronic resistivity counts from select sites.

<table>
<thead>
<tr>
<th>Year</th>
<th># Redds</th>
<th>Electronic Count</th>
<th>Expansion Factor</th>
<th># Redds</th>
<th>Electronic Count</th>
<th>Expansion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>321</td>
<td>716</td>
<td>2.2</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>2007</td>
<td>458*</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>2008</td>
<td>471*</td>
<td>1,197</td>
<td>2.5</td>
<td>188</td>
<td>336</td>
<td>1.8</td>
</tr>
<tr>
<td>2009</td>
<td>542</td>
<td>1,219</td>
<td>2.2</td>
<td>268</td>
<td>486</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Note: * slight adjustments from previous years reporting

It is acknowledged that there is uncertainty in converting the number of redds to the number of fish but choosing a known range can be useful in capturing some of the variability around the estimate. For example, using the average of 2.3 bull trout per redd and a range of 1.8 to 2.5 bull trout per redd, watershed population estimates can be generated for the upper Kaslo River. It is estimated that a total of 1,585 bull trout utilized the entire Kaslo River in 2009, slightly above the estimated 1,405 and 1,350 in 2008 and 2007, respectively (Table 5). Similarly, based on 2.3 bull trout per redd, an estimated total of 616 bull trout utilized the Crawford Creek watershed in 2009. However, it is acknowledged that both Keen Creek and Crawford Creek likely have a lower average fish per redd due to the lack of suitable habitat compared to the upper Kaslo River. Consequently, the estimates on Crawford and Keen creeks are most likely overestimates based on the average 2.3 bull trout per redd. The expansion factor of 1.8 bull trout per redd should be applied to Keen and Crawford creeks thus for 2009 the estimated number of spawners would be 250 and 482 respectively.

Table 5. Population estimates based on expansion factors and a range of variability for select watersheds.

| Year | Kaslo River | | | Crawford Creek | | |
|------|-------------| | | | | |
|      | Estimate\(^a\) | Lower\(^c\) | Upper\(^c\) | Estimate\(^a\) | Estimate\(^b\) | Lower\(^c\) | Upper\(^c\) |
| 2006 | 968         | 758          | 1,053         | n/a          | n/a          | n/a          | n/a          |
| 2007 | 1,350       | 1,057        | 1,468         | n/a          | n/a          | n/a          | n/a          |
| 2008 | 1,405       | 1,100        | 1,553         | 432          | 326          | 326          | 461          |
| 2009 | 1,585       | 1,240        | 1,723         | 616          | 482          | 482          | 670          |

\(^a\) based on average of 2.3 bull trout per redd from upper Kaslo River electronic resistivity counter
\(^b\) based on average of 1.8 bull trout per redd from upper Kaslo River data 2006 and 2008 electronic resistivity counter
\(^c\) based on known variability from upper Kaslo River and Crawford Creek (1.8 to 2.5)

A life history review of bull trout suggests water temperature may be the proximate cue that initiates spawning behaviour and redd development. McPhail and Murray (1979) and McPhail and Baxter (1996) suggested spawning was initiated at a threshold around temperature of 9°C. In all years (2006-2009), run timing data collected by the counter was strongly correlated with declining temperatures for the upper Kaslo River and Crawford Creek.
Crawford Creek systems which averaged < 9°C during September-October. Run timing data suggests that many of the adult spawners probably held in the lower Kaslo River until early September when upstream movement commenced with the peak of spawning most likely occurring in mid-September. In contrast, run time data from Crawford Creek suggests that bull trout ascend this system much earlier and remain there longer compared to the Kaslo River. This may be a result better flow conditions and lower optimal temperatures in the upper reaches of the Crawford Creek system. The upstream and downstream movements of bull trout recorded at both counters in 2009 as well as in previous years provide graphic information on run timing that closely defines the spawning period that in turn can dictate when redd surveys should be conducted.

In summary, both the Kaslo River and the Crawford Creek watersheds support substantial numbers of spawning bull trout. The Kaslo system supports well over 1000 spawners annually whereas Crawford Creek supports annual spawning runs > 300. Although the amount of available habitat is similar in both systems, differences in numbers most likely reflect the quantity and quality of habitat. There appears to be far more suitable spawning habitat (smaller gravels and pools) in the Kaslo River compared to Keen or Crawford creeks. Another habitat consideration is that much of the Crawford Creek watershed has been heavily impacted by several decades of intense logging that resulted in almost complete removal of its riparian zone along much of its length. To a lesser extent, the Kaslo River has also been impacted by linear development such as mining, logging and highways development but much of its riparian zone remains intact. Moreover, it is also speculated that bull trout dominate the Kaslo River system as rearing juveniles that would face little or no competition in the absence of other species whereas rainbow trout cohabit with bull trout in Crawford Creek. Regardless of watershed differences, based on the results from these two systems, adfluvial bull trout appear to be maintaining healthy population levels. Furthermore, increasing numbers in the last three years may be attributed to better in-lake conditions, resulting from nutrient addition, which may have benefited adfluvial bull trout populations (Schindler et al. 2006). The work conducted in 2009 adds more certainty to the development of an expansion factor that can be used to convert redd survey data into estimates of spawner numbers.

**RECOMMENDATIONS**

- In 2010, re-install the electronic resistivity counters in the Kaslo River and Crawford Creek watersheds.
- Repeat redd surveys in both the Kaslo River and Crawford Creek watersheds.
- Conduct a tagging program to ascertain the extent of multiple bi-directional movements over the electronic counting fence that occurs at the peak of upstream migration.
- Examine the feasibility of running a one-way kelt fence.
- Install temperature loggers in upper reaches of Crawford Creek.
REFERENCES


Waters Directorate, Research Institute, Scientific Series, West Vancouver, British Columbia.


APPENDIX-1. Photo Documentation

Photo 1. Remnants of the hydro power dam (1970) near Kaslo BC, located approximately 4 km upstream from the lake.

Photo 2. Typical redd formation on the upper Kaslo River (2.5 m x 0.7 m).
Photo 3. Typical redd formation on Keen Creek (2.2 x 1.0 m).

Photo 4. Typical redd formation on Crawford Creek (1.5 x 0.7 m)
Photo 5. The upper Kaslo River counter site installed August 3, 2009, using the flat pad sensor units. Channel 1, near bank and channel 4 far bank.

Photo 6. Crawford Creek site installed August 15, 2009, using the flat pad sensor units. Channel 1, near bank and channel 3 far banks.
Photo 7. DVR record of a up-streaming bull trout (Channel 1) on the upper Kaslo River at 5:25:17 AM on August 4, 2009.

Photo 8. Upper Kaslo River barrier near Retallic BC.
**Photo 9.** Keen Creek barrier located ~ 6km upstream from confluence with Kalso River.

**Photo 10.** Barrier on Twelve Mile Creek located ~ 250 m upstream of the confluence with Kaslo River.
Photo 11. Barrier on Crawford Creek ~21 km upstream of the confluence with Kootenay Lake.

Photo 12. Barrier on Canyon Creek ~500 m upstream of the confluence with Crawford Creek.
Photo 13. Barrier on Hooker Creek ~520 m upstream of the confluence with Crawford Creek

Photo 14. Barrier on Houghton Creek ~520 m upstream of the confluence with Crawford Creek
Photo 15. Redd distribution on the Kalso River watershed in 2009.
Photo 16. Redd distribution on Crawford Creek watershed in 2009