Duncan Dam Project Water Use Plan

Duncan Reservoir Fish Habitat Use Monitoring

Implementation Years 6-7

Reference: DDMMON-10

DDMMON-10: Duncan Reservoir Fish Habitat Use Monitoring
Year 7 (2014) Interpretive Report

Study Period: April 2014 – January 2015

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November 24, 2015

EXECUTIVE SUMMARY

The Duncan Reservoir Fish Habitat Use Monitoring program (DDMMON#10) is a ten year study developed to determine answer the management question:

> *Will the recommended operations (Alternative S73) improve fish productivity through habitat and fish-food abundance and distribution in the Duncan Reservoir?*

This report summarises the results of Year 7 (2014). With respect to the management question, the following sub-questions have been reviewed in previous years:

What is the relative abundance and distribution of key fish life histories in the littoral and pelagic zones?

This question was addressed in Years 2 and 3 of the study, and no further information is required to address this question. Estimates of kokanee and bull trout escapement were proposed to provide an index of abundance for these species so that long term trends in abundance could be assessed.

What is the relative abundance and distribution of fish food organisms in pelagic and littoral zones?

This question was addressed in Years 2 and 3 of the study, and no further information is required to address this question. In general, zooplankton were found to be the dominant fish-food organism for kokanee, similar to other Upper Columbia Basin systems, although mysid shrimps were also consumed.

What is the life history timing of key species of interest?

The peak spawn timing for kokanee is late September – early October, with spawning activity observed as early as September 14th, and as late as October 14th, slightly more conservative than assumptions used in the WUP. Emergence timing may be earlier than predicted in the WUP as well, with observations of fry in mid-April. The bull trout spawning period is from early September – mid October, consistent with the assumptions made during the WUP process, although likely less broad than assumed.

How are key fish life histories influenced by reservoir management?

The species of interest for this study are kokanee and bull trout. Although both species have life histories that are likely influenced by reservoir management, it is unlikely that the changes in the WUP resulted in any significant impacts. The focus of remaining years of monitoring are to track kokanee and bull trout spawning indices and provide a summary of potential reservoir management influences.

In 2014, an aerial survey on October 2 targeted for the peak spawning period of kokanee enumerated 14,862 fish in the upper Duncan River. The majority of these were located in a 4 km section of the Duncan River upstream of the confluence with East Creek. A second aerial flight on October 10th enumerated 2,074 kokanee. Bank counts were conducted on September 26th, October 2nd and October

10th to provide additional information on spawn run timing, observer efficiency, and conditions in the watershed. Determining the peak spawning time was hampered by high discharge and turbidity in the Duncan River on September 26th, however, the data suggests peak spawning occurred in late September or early October, consistent with other years. Previous spawner surveys on the Duncan River in 2011 and 2012 enumerated 29,030 and 17,347 kokanee, respectively.

A bull trout redd survey in the Westfall River occurred on October 15th. A partial survey of the Westfall River was conducted which encompassed the majority of the high quality spawning habitat in the watershed. Twenty-one bull trout redds were observed over a 7 km distance. All of the redds were faded and had obvious sediment accumulation in their pits, leading the survey crew to believe that many redds may have been missed. Mild weather prolonged glacial melt and the associated sediment load continued throughout the spawning period may have increased redd fading. A rain on snow event that occurred on September 24-25 may also have contributed to redd fading. Two redd surveys, in 2011 and 2012, have been attempted in the Westfall River. In 2011, conditions for surveys were excellent and 114 redds were observed. In 2012, the survey was cancelled due to poor visibility associated with a storm event.

The operation of the Duncan Reservoir in 2014 was similar to the previous years of operation under Alternative S73. Bull trout transfers through the dam occurred on a weekly or fortnightly basis from early June through to the end of August. The estimated number of bull trout passed through the dam in 2014 was 180, which represents the lowest number recorded in the 18 years where data is available.

Recommendations for future years include:

- continue to georeference kokanee enumeration data obtained during the aerial flight,
- a single aerial flight in early October is considered sufficient provided visibility is adequate,
- collect length and weight data on a sample of kokanee during the bank counts to provide supplementary information that can be used to assess reservoir productivity status,
- allow for additional time and resources to conduct the bull trout surveys in the Westfall River to accommodate changes in the road access.

Acknowledgements

The following people are gratefully acknowledged for their contribution to the program.

BC Hydro
Jason Watson – Program Manager
Alf Leake

Field work for this project was carried out by the following personnel.

Masse Environmental Consultants
Ico de Zwart
Al Irvine
Mark Fjeld

Okanagan Nation Alliance Fisheries Department
Katie Beach

and
Clint Tarala

Duncan Wassick (Dam Helicopters) provided helicopter services for the aerial survey.

GIS and Mapping support provided by:
Gary Pavan.

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1 INTRODUCTION

This report summarizes the results of the field studies conducted in 2014 (Year 7) for the Duncan Reservoir Fish Habitat Use Monitoring Program (DDMMON-10), a ten year study program commissioned by BC Hydro. In 2014, kokanee and bull trout spawner enumeration surveys were conducted in the upper Duncan River.

1.1 Background

DDMMON-10 is a long term monitoring program implemented by BC Hydro as part of its water use planning (WUP) process. This process reviewed a variety of scenarios for dam operations and the social, ecological, recreation, and financial implications of each of the options. One of the scenarios (Alternative S73) was chosen as the preferred option, and was implemented in December 2006. As part of this process, a range of studies, including DDMMON-10, were commissioned to confirm the predictions made about Alternative S73, to monitor the impacts of the change in operations, and to address any data gaps identified through the WUP process. Alternative S73 was predicted to result in no change to fish in Duncan Reservoir (BC Hydro 2005) but the WUP process identified several uncertainties with respect to operational influences on fish populations in Duncan Reservoir. The DDMMON-10 program was recommended by the WUP consultative committee to address these uncertainties and help inform decisions in future planning processes (BC Hydro 2008).

The DDMMON10 program was developed to address critical data gaps relating to fish use in the reservoir so that this information can be used to better accommodate fish requirements in future planning processes. Specifically, the objectives were to:

1. determine the habitat requirements of different life history stages for fish species of interest (kokanee, bull trout and rainbow trout), and
2. to document the influence of reservoir operations on life history success for species of interest in the Duncan Reservoir.

Completing the study program would also address clause 6(f) of BC Hydro's Duncan Dam conditional water license 27027, ordered by British Columbia's Comptroller of Water Rights. The clause requires BC Hydro to monitor kokanee and rainbow trout populations in Duncan Reservoir.

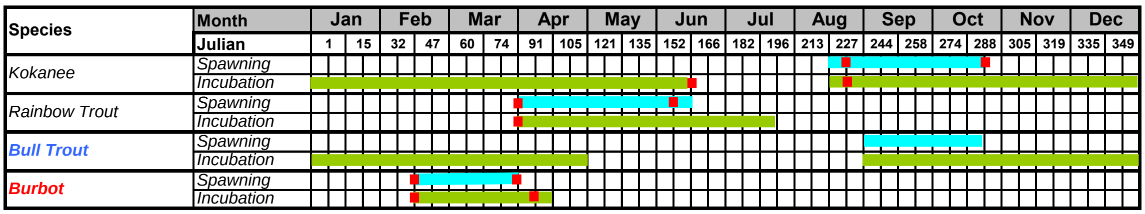
1.2 Management Hypothesis

The study was designed to test the two hypotheses. At the end of Year 3, the study team felt that there was no evidence to reject H_o1, but that sufficient evidence was available to reject H_o2, as described below.

H_o1: Life history timings of fish species of interest are consistent with those defined during the WUP data collection phase (Table 1).

Field observations are generally consistent with the life history timings for bull trout and kokanee defined during the WUP. Field observations suggest that kokanee spawning does not commence until the first week in September, and that the incubation period for kokanee is complete by May (as kokanee fry were observed in the upper Duncan River in April 2010).

Table 1. Assumed life history timing for reservoir fish species of interest (Vonk 2001). Red annotations indicate revised timing utilized in the DDM WUP process based on professional opinion.



Note: rainbow trout were removed as a species of interest (de Zwart *et. al* 2011). Burbot are not included in the DDMMON-10 study program.

H_o2: Reservoir operations do not negatively affect fish life history uses of pelagic, littoral or tributary zones.

This hypothesis was rejected based on the observation of shore spawning habitat use by kokanee and the detection of significant differences in bull trout parr densities in tributaries above and below the high water mark (HWM). Shore spawning and tributary habitat within the drawdown zone are both impacted by reservoir operations. In addition, there is a substantial body of literature documenting the impacts that large annual drawdowns have on littoral and pelagic productivity in reservoirs (Ney 1996, Stockner*et al.* 2005).

1.3 Management Questions

The study was developed to address the following management question:

Will the recommended reservoir operations improve fish productivity through habitat and fish-food abundance and distribution?

The following questions were set out in the study terms of reference (BC Hydro 2008) to support conclusions for the management question:

1. What is the relative abundance and distribution of key fish life histories in the littoral and pelagic zones?
2. What is the relative abundance and distribution of fish food organisms in pelagic and littoral zones?
3. What is the life history timing of key species of interest?
4. How are key fish life histories influenced by reservoir management?

The status of these questions at the end of Year 4 (2011) is summarised in Table 2.

Table 2. Summary of Year 2-4 findings (de Zwart *et. al* 2010. 2011, 2012).

Management Question	**Key Results**	**Recommendations**
1. What is the relative abundance and distribution of key fish life histories in the littoral and pelagic zones?	• Kokanee distributed primarily in pelagic area. • Bull trout and rainbow trout seasonally use the littoral areas. • Rainbow trout removed as a key species due to lack of suitable habitat. • Use of CPUE for index of abundance not recommended due to uncertainty. • Kokanee and bull trout spawners surveys recommended as an index of abundance, consistent with other systems.	• Target upper Duncan River kokanee spawning population as an index of abundance and a measure of pelagic productivity • Conduct bull trout redd surveys in the Westfall River as an index of BT abundance.
2. What is the relative abundance and distribution of fish food organisms in pelagic and littoral zones?	• Zooplankton dominant fish food for kokanee, although mysid used seasonally. • Large bull trout were piscivorous. Sub-adult bull trout also used mysid shrimp seasonally. • Rainbow trout insectivorous.	• Further analysis of stomach contents is not required as the predominant fish food organisms of bull trout, kokanee and rainbow trout have been identified.
3. What is the life history timing of key species of interest?	• Spawn timing for kokanee and bull trout consistent with timing assumed during DDM WUP process. • No information on rainbow trout spawn timing due to low abundance. No longer considered a key species for management purposes.	• Kokanee life history timing data can be further refined during development of kokanee spawner index.
4. How are key fish life histories influenced by reservoir management?	• Annual drawdown due to reservoir operations has negative effect on kokanee shore spawning success. Shore spawning kokanee not genetically distinct from upper Duncan River spawners and estimated to comprise ≤ 2% of spawning population. • Bull trout parr densities lower in drawdown zone of tributaries compared to above the high water mark. However, life history of bull trout is such that majority or juvenile rearing occurs in the upper Duncan River outside of influence of reservoir. • Unknown level of bull trout mortality occurs as a result of recreational fishery on the reservoir in the spring when it is drawn down.	• No further study of shore spawning as effects not expected to have population level consequences as population is not genetically distinct. • No potential to adjust operations to reduce effect on shore spawning due to requirement for drawdown in spring.
5. Will the recommended reservoir operations improve fish productivity through habitat and fish-food abundance and distribution?	• The recommended reservoir operations have had little effect on reservoir elevations compared to historical operations and therefore little to no change in productivity is expected. • Limited data from prior to this study to use as a baseline for comparison.	• Kokanee and bull trout indices of abundance developed through spawner surveys will allow key species to be monitored.

The first three years of the study (2009-2011) included intensive reservoir and tributary sampling, as there was very little existing information on fish species and habitat use within the reservoir. Key findings included:

- That rainbow trout are present in very low abundance and the Duncan Reservoir provides limited habitat for this species.
- That the majority of tributaries to the Duncan Reservoir provided limited habitat for species of interest, primarily due to steep gradients and limited spawning/rearing habitat.
- The majority of kokanee spawning and bull trout spawning and juvenile rearing occurs in the upper Duncan River watershed.
- Productivity in the reservoir is low, with average chlorophyll a concentrations < 2 μg/L
- Phosphorus is the limiting nutrient for biological productivity most of the time, although nitrogen may be co-limiting in late summer.

The study documented two areas, kokanee shore spawning and bull trout tributary use within the drawdown zone, where reservoir management influences key life histories for the species of interest. Kokanee spawning on alluvial fans along the shoreline of the reservoir was observed in 2010 and 2011, and most, if not all, of these shoreline redds are dewatered during reservoir drawdown. Bull trout use of tributary habitat for rearing was approximately three times lower within the drawdown zone of the reservoir than above the high water mark (de Zwart *et. al* 2012). The limited use of tributaries within the drawdown zone was due to the poor quality of habitat in this zone, a consequence of the annual drawdown and refilling of the reservoir. However, in both of these cases, a limited effect on the population as a whole was expected for the following reasons.

- Shore spawning kokanee are not genetically distinct from the kokanee that spawn in the upper Duncan River, and are estimated to represent 2% of the total kokanee spawner population.
- Tributaries to the Duncan Reservoir, with the exception of the upper Duncan River, provide very limited habitat for bull trout spawning and rearing. The upper Duncan River provides essentially all the spawning and rearing habitat for bull trout, and the life history of bull trout is such that use of the upper Duncan River within the drawdown zone is limited. The majority of bull trout in the watershed spawn over 20 km upstream of the reservoir, and rearing in these areas occurs for 2-4 years prior to migration downstream into the reservoir (Figure 1).

After Year 2 (2010), the focus of the program was shifted to develop methods to monitor escapement of bull trout and kokanee as a means of linking life history success for bull trout and kokanee to reservoir operations. These species are regionally managed sportfish species, and are key indicators of ecosystem health for the reservoir. In order to address trends in abundance for these two species, a long term monitoring program consisting, in part, of biennial surveys over a period of initially 10 years was proposed (BC Hydro 2008). Spawner surveys are routinely used as an index of population abundance and provide a means of assessing long-term abundance changes.

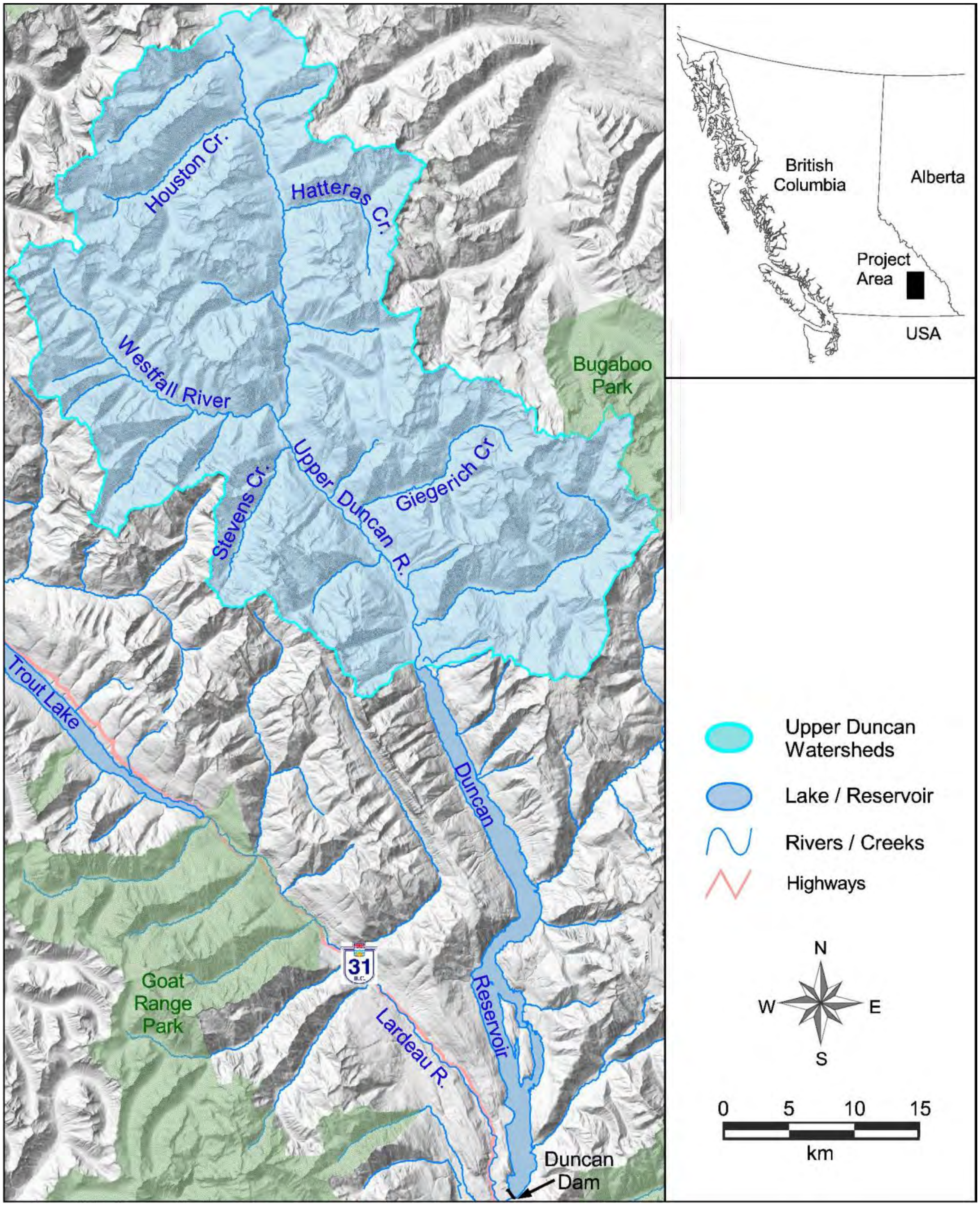


Figure 1. Watersheds in the upper Duncan River. Major tributaries where bull trout spawning occurs are named.

The information obtained from these surveys is directly relevant to management questions 1, 3, 4 and 5, since some measure of population abundance is required to address all of these. Linking changes in abundance of these two species to reservoir operations has been identified as an area of uncertainty. Management action is expected in the event that a long-term decline in abundance for either species is observed.

2 STUDY AREA

2.1 Duncan Reservoir

2.1.1 Physical Characteristics and Operation Constraints

Duncan Reservoir provides water storage for obligations under the Columbia River Treaty (CRT) and downstream flood control on the Duncan River. The reservoir is approximately 44 km long, with a width ranging from 1 - 2.5 km. The Duncan Reservoir has a mean and maximum depth of 52 m and 117 m, respectively (Perrin & Korman 1997). The reservoir has a surface area of 7,350 ha at full pool, declining to 2,190 ha at low pool. As a result, 5,160 ha of reservoir bottom are exposed during drawdown. The current operation of the dam is specified in the Water Use Plan for the Duncan Dam (BC Hydro 2007), which specifies minimum and maximum flow releases for the dam, as well as targets for flows as measured at the Water Survey of Canada (WSC) gauge located below the confluence of the lower Duncan River and the Lardeau River. The operations are also constrained somewhat by the Columbia River Treaty (CRT), which specifies particular elevations the reservoir should be at during various times of the year. Dam operations are summarized in Table 3.

Table 3. Summary of operational constraints on the Duncan Dam.

Reservoir Elevation	Date	Reservoir Elevation (m)	Comment
	July 31	576.68	Targeted to reach full pool
	Dec 31	<569.8	
	Feb 28	<551.0	Target to reach low pool in high snow year
		<564.4	Target to reach low pool in average snow year
Downstream Flows	**Date**	**Discharge (m^3/s)**	**Comment**
Minimum	Daily	3.0	Release from dam
Maximum from LLOG[1]	Continuous	283.17	Release from dam via LLOG
Lardeau/Duncan confluence			
Minimum	Continuous	73	Measured at WSC monitoring station
Maximum	Aug 1 – 24	400	and includes discharge from the
	Aug 25 – Sep 24	250	Lardeau River
	Sep 25 – Sep 27	190	
	Sep 28 – Sep 30	130	
	Oct 1 – Oct 21	76	
	Oct 21 – Dec 21	110	
	Dec 22 – Apr 9	250	
	Apr 10 – May 15	120	
	May 16 – Jul 31	400	

[1]LLOG – low level operating gates

2.2 Reservoir Operations

The key management question of interest to BC Hydro with respect to water use planning is whether the recommended reservoir operations (Alternative S73) will improve fish productivity through habitat and fish food abundance and distribution. Reservoir operations are largely defined by releases from the dam rather than by reservoir elevations (Table 3). The only elevation based constraints on operations are the maximum reservoir elevation at full pool (576.68m), the minimum elevation at draw down (546.87m), and elevation targets on December 31 and February 28 (Table 3). As a result, average daily reservoir operations under Alternative S73 (2006-2014) are similar to what they were before its implementation (Figure 2), although much less seasonal variability has occurred since Alternative S73 was implemented. Most of the variation in reservoir operations occurs between the end of October and the end of February, when biological productivity is low, because the reservoir is drawn down at different rates in different years. By the end of March, reservoir elevations reach a similar level as the reservoir is drawn down to low pool in preparation for the oncoming freshet. Since the current operation of the reservoir is within the range observed prior to the implementation of Alternative S73, it is considered unlikely that operations under Alternative S73 will have a significant effect on fish productivity. Productivity constraints on the Duncan Reservoir are primarily due to the oligotrophic status of the reservoir, which is a consequence of the cold, glaciated, low nutrient nature of the watershed, as well as the short residence time of water within the Duncan Reservoir.

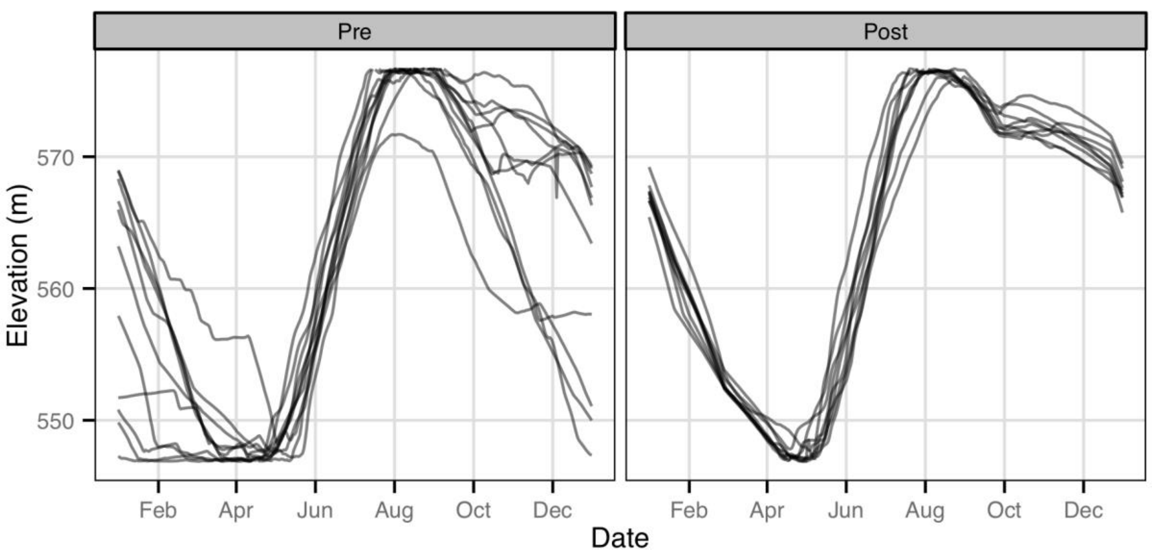


Figure 2. Daily reservoir elevation for the Duncan Reservoir pre (1995-2005) and post (2006-2012) implementation of Alternative S73. Note that reservoir elevations have been more consistent since Alternative S73 was implemented.

2.3 Upper Duncan River Watershed

2.3.1 Upper Duncan River

The upper Duncan River is a 6th order river that drains a watershed of 1,310 km^2 between the Selkirk and Purcell Mountain ranges north of the Duncan Reservoir (Figure 1). Its headwaters originate in Glacier National Park and the river flows in a southerly direction for ~70 km before converging with the Duncan Reservoir. The river consists of low-moderate gradients of 3-6%, with the lowermost 7 km and a 4 km section below the Westfall River having numerous side channels and braided areas. The remainder of the river is more confined. Kokanee spawning is concentrated in the first 15 km of the upper Duncan River upstream of the reservoir. Limited kokanee spawning occurs in tributaries to the upper Duncan River due to the generally steep gradients and the presence of velocity barriers near the mouth of the tributaries (de Zwart *et. al* 2012).

2.3.2 Westfall River

The Westfall River is a 5th order river draining a watershed of 230 km^2 located approximately 25 km upstream of the north end of Duncan Reservoir (Figure 1). The river flows east for ~ 29 km before draining into the upper Duncan River. The lower 2 km section is incised in a steep bedrock canyon up to 200 m deep with a gradient of up to 10%. Upstream of the canyon area the watershed is mostly high-elevation, with moderate gradients ranging from 3-10%. Relative to other tributaries of the upper Duncan River, the Westfall River watershed has less glacial inputs due to its predominately south facing aspects. Notable tributaries to the Westfall River include Marsh Adams Creek and Silvertip Creek.

The Westfall River was identified as a suitable index stream for bull trout redd surveys because it provides spawning habitat for a large proportion of bull trout in the watershed, it is readily accessible by vehicle due to the presence of a FSR along much of its length, and it is generally less turbid than other streams. In 2011, 114 bull trout redds were identified in the Westfall River, with the majority within a 10 km section of low gradient habitat in the river (de Zwart *et. al* 2012). In 2012, partial deactivation of the Westfall FSR was initiated by the Ministry of Lands, Forests, and Natural Resource Operations, largely to reduce human traffic in the upper watershed and protect caribou habitat. This reduced the accessibility of the upper part of the watershed for the redd surveys, although vehicle access was still possible for the majority of the FSR. Redd surveys in the Westfall River in 2012 were cancelled due to storm event that occurred immediately prior to the surveys. The high discharge and increased turbidity as a result of this event flattened and obscured redds and prevented a reliable redd count.

3 METHODS

3.1 Kokanee Spawning Surveys

3.1.1 Stream Spawning

3.1.1.1 Aerial Survey

Aerial surveys were conducted on October 2nd and October 10th, 2014 between 10:00 and 14:00. A two person crew was used for the enumeration, with one person sitting at the front left and the other person sitting directly behind on the left. The helicopter moved slowly upstream at a height of approximately 20-30 m above the river. When surveying the helicopter was positioned perpendicular to the river so that both crew members had a clear view; if necessary, the crew would ask the helicopter pilot to manoeuvre the helicopter to provide a better view. The enumeration crew recorded a total count for the watershed, and also geo-referenced individual counts by recording the time and maintaining a GPS track during the flight.

In addition, the crew recorded separate counts at discrete locations (index sites) to help estimate aerial observer efficiency and to provide information on spawn run timing. At each calibration site, the helicopter crew would note the downstream and upstream ends and record their count for these sections. The ground crew would subsequently perform a count in these sections, to allow comparison between aerial counts and bank counts.

The methodology used for these surveys is consistent with similar surveys on the lower Duncan River conducted as part of DDMMON-4 (Porto et al. 2013)

3.1.1.2 Bank Counts

Bank counts in the upper Duncan River were conducted at index sites on September 26th and October 2nd. Bank counts were also planned to coincide with the October 10th, 2014, but were cancelled after discussion with the aerial survey crew due to the low numbers of kokanee observed. These counts were used to refine run timing, provide information on conditions in the watershed before the helicopter surveys, and allow estimates of aerial observer efficiency. A two person crew was used to conduct the bank counts. Crews walked slowly in an upstream direction at the site, and each crew member counted kokanee separately. Counts were compared during, and at the end of the survey, to ensure that accurate counts were obtained. Individual counts only differed by a few kokanee, and an average count was used when there was a difference in counts that could not be explained by other factors.

Index sites are named based on 1) distance in km upstream of Kootenay Lake, and 2) left bank or right bank.

3.2 Bull Trout Redd Surveys

3.2.1 Redd Surveys

A bull trout redd survey was conducted in the Westfall River on October 14-15. A crew of two began the survey at the upper bridge crossing of the Westfall Forest Service Road (FSR) and walked downstream for recording redds. Where possible, crew members walked on opposing banks, although side channels were typically surveyed by one crew member.

Redds were identified as 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, and can range in area from 0.5 m^2 to 3.0 m^2 (McPhail and Murray 1979; Baxter 1995) depending on the size of the female and the nature of the substrate. Disturbances in the bed material caused by fish can be differentiated 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 may 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) (Decker *et al.* 2005).

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, redds with a greatly extended deposit length (subjectively evaluated to be at least twice the length of a 'typical' deposit length) were counted as two redds. Redd superimposition or redds with an extended deposit length typically represent a small proportion of the total redds present.

Complete redds were enumerated and UTMs recorded by geo-referenced time and waypoints using a handheld GPS unit (Garmin 62s). Data was recorded on waterproof paper for each redd (see Appendix3). 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.

4 RESULTS

4.1 Kokanee Spawning Surveys

4.1.1 Overview

In 2014, field work for the kokanee enumeration was conducted on three separate days at approximately one week intervals.

Table 4. Summary of kokanee field work in the upper Duncan River, 2014.

Date	Discharge (m^3/s)[1]	Visibility	Survey	Comments
Sep-26	78	poor	Bank	Poor visibility and high discharge in Duncan River mainstem and side channels.
Oct-2	32	good	Aerial/Bank	Excellent visibility in side channels, but still residual turbidity from glacial melt in main stem.
Oct-10	27	good	Aerial	Excellent visibility in side channels, but still residual turbidity from glacial melt in main stem.

[1] From Water Survey of Canada station 'Duncan River below BB Creek' (08NH119).

4.1.2 Aerial Surveys

For both survey dates, the aerial survey began at the confluence of the Duncan River and the Duncan Reservoir, and continued upstream until no more kokanee were observed. On the October 2nd flight, 14,862 kokanee were enumerated. Visibility was good during the time of the survey, although turbidity due to glacial flour in the mainstem Duncan River reduced visibility in deeper (> 1 m) areas. The majority of fish were observed in shallow side channels. On the October 10th flight, 2,074 kokanee were observed. Visibility was similar to that on the October 2nd flight, with reduced visibility in the mainstem Duncan River due to turbidity from glacial flour. A map showing the location of kokanee spawning areas in the upper Duncan River is provided in Figure 3. As in 2012, the majority of spawning occurred in the 4 km section immediately upstream of the confluence with East Creek. Examples of spawning sites as observed from the helicopter are provided in Photo 1 and 2.

Photo 1. Kokanee redds, visible as light patches against the darker undisturbed substrate at 62.9R km, October 2, 2014.

Photo 2. Kokanee spawning at 62.9R km, October 2, 2014. Majority of kokanee located within the red outline.

Photo 3. High value spawning habitat in a side channel (64.5L km, centre photo) of the Duncan River.

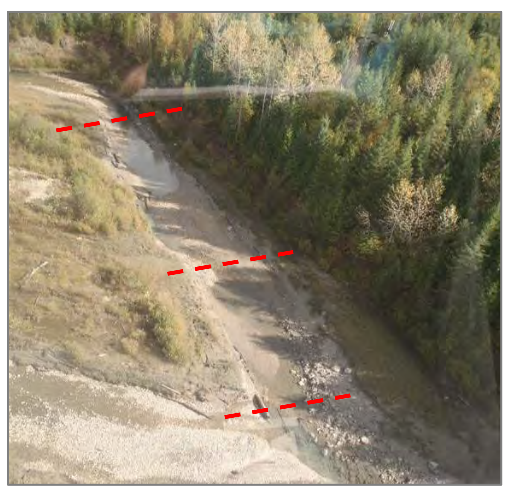


Photo 4. Devils Creek side channel (48.5L km) showing distinct sections used for calibration counts.

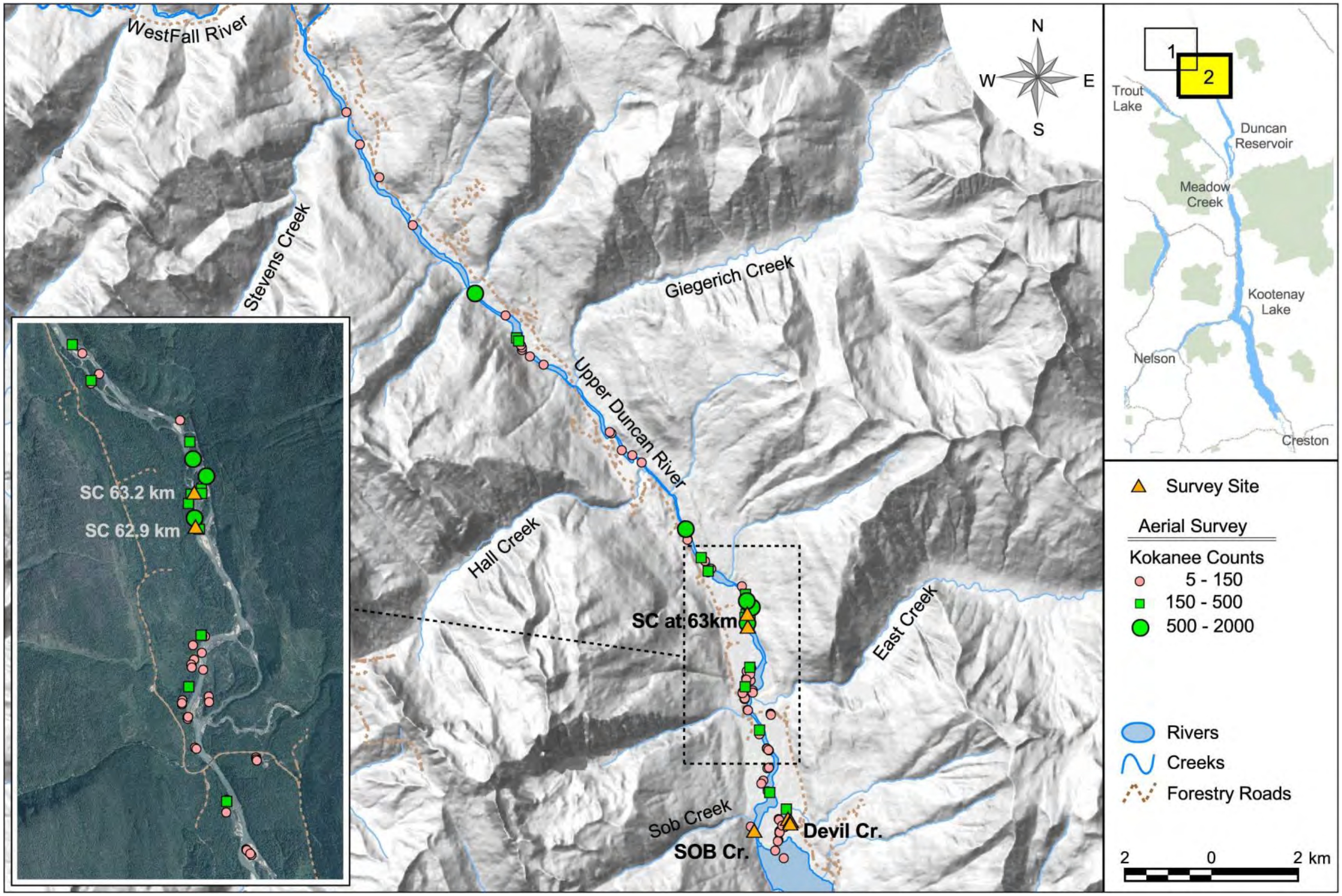


Figure 3. Upper Duncan River kokanee spawning sites – 2014.

4.1.3 Bank Counts

Bank counts were conducted on September 26th and October 2nd. The bank counts were conducted in order to refine run timing, provide information on conditions in the watershed before the helicopter surveys, and allow estimates of aerial observer efficiency.

On September 26th, visibility was poor (< 30 cm) due to high turbidity in the Duncan River (Photo 5, Photo 6). This was the result of a rain event on September 24th. Kokanee were observed in side channels, although accurate counts could not be conducted due to the poor visibility (Photo 7). In the Devils Creek side channel, 165 kokanee were observed and spawning activity was evident (Photo 7). In the 62.9 km side channel, visibility was less than 10 cm, although a few kokanee were observed when they came close to the surface. The very poor visibility prevented any assessment of whether spawning activity had begun at this site. Numerous kokanee (606) were observed in SOB Creek, a small tributary to the Duncan River that was clear. Approximately half of the kokanee were observed to be holding at the mouth of SOB Creek (Photo 8), while most of the remainder were paired up in areas with abundant gravel.

Bank counts were also conducted on October 2nd. The primary purpose of these counts was to provide information on observer efficiency. Five discrete sites were used in 2014 to compare aerial counts with bank counts. Sites were selected by the aerial survey crew based on accessibility, presence of sufficient numbers of kokanee (> 50), and the ability to easily define the site boundaries. Following the aerial survey, one of the aerial surveyors accompanied the ground crew to help identify each site, but did not participate in the count.

Photo 5. Duncan River, September 26, 2014.

Photo 6. Side channel at 63.0R km, September 26, 2014.

Photo 7. Devils Creek side channel (58.5L km), October 2, 2014. Poor visibility but spawning activity occurring.

Photo 8. Kokanee holding at the mouth of SOB Creek (58.4R km), September 26, 2014.

4.1.4 Index Sites

Three index sites were monitored in 2014. Two of these, SOB Creek and the Devils Creek side channel have been monitored in previous years. The third site was selected based on information collected in 2012, which indicated that the majority of kokanee spawning occurs in a braided section of the Duncan River upstream of East Creek. Kokanee counts at these index sites come from both the aerial and the ground surveys. All of the sites are open and accurate counts can be obtained by both aerial and ground methods. Data from the index sites are summarised in Table 5. Observations from SOB Creek and the Devils Creek side channel on September 26th indicate that spawning activity had begun. The kokanee appeared to be in excellent condition, and many of the kokanee were holding in pools, suggesting that the peak of spawning had not yet occurred. Spawning activity in SOB Creek appears to occur earlier than in the mainstem Duncan River.

Table 5. Summary of kokanee counts at select index sites, upper Duncan River, 2014.

Date	SOB Ck (58.5L km)	Devils Creek S/C (58.4R km)	62.9R km S/C	Comments
Sep-26	606	165[a]	NA[b]	Poor visibility in Duncan River mainstem and side channels. Spawning activity observed at SOB Ck and Devils Creek. Kokanee in excellent condition, many observed to be holding in pools
Oct-2	20[c]	425	1170	Excellent visibility. Counts conducted after aerial survey. For calibration counts, sites were subdivided into sections.
Oct-10	0[c]	60[c]	600[c]	No calibration counts due to low numbers of kokanee present in system. Numbers are from aerial estimate.

[a] Poor visibility in side channel (< 50 cm), number may be biased low.

[b] Poor visibility due to high turbidity (<10 cm) – kokanee observed by no count possible

[c] aerial estimate

4.2 Bull Trout Redd Surveys

4.2.1 Redd Surveys

An ~ 7 km section of the Westfall River was surveyed, beginning at the upper bridge crossing of the Westfall FSR (km 19) and ending at ~ km 12, and included the section where the majority of redds have previously been recorded. Water visibility was considered fair on the day of the survey, as there was still some fine turbidity associated with glacial melt. Twenty-one bull trout redds were identified within this section (Figure 4). All of the redds were faded and difficult to distinguish from undisturbed substrate (Photo 9), with most of the redds having a layer of fine sediment accumulated in the pit. An example of an unfaded redd from a previous survey in the Westfall River is provided in Photo 10 for comparison. No adult bull trout were observed during the survey.

Because of the fading and the obvious sediment accumulation that had occurred since the redds were constructed, the survey crew felt that there was considerable uncertainty in the survey. Because of this, the decision was made to terminate the survey at the end of the day, rather than completing the remaining 12 km of the Westfall River.

Photo 9. Bull trout redd. Westfall River, October 15th, 2014. Note lack of contrast with surrounding substrate due to fading.

Photo 10. Unfaded bull trout redd, Westfall River, October 18, 2011. Note contrast between recently disturbed redd and surrounding substrate.

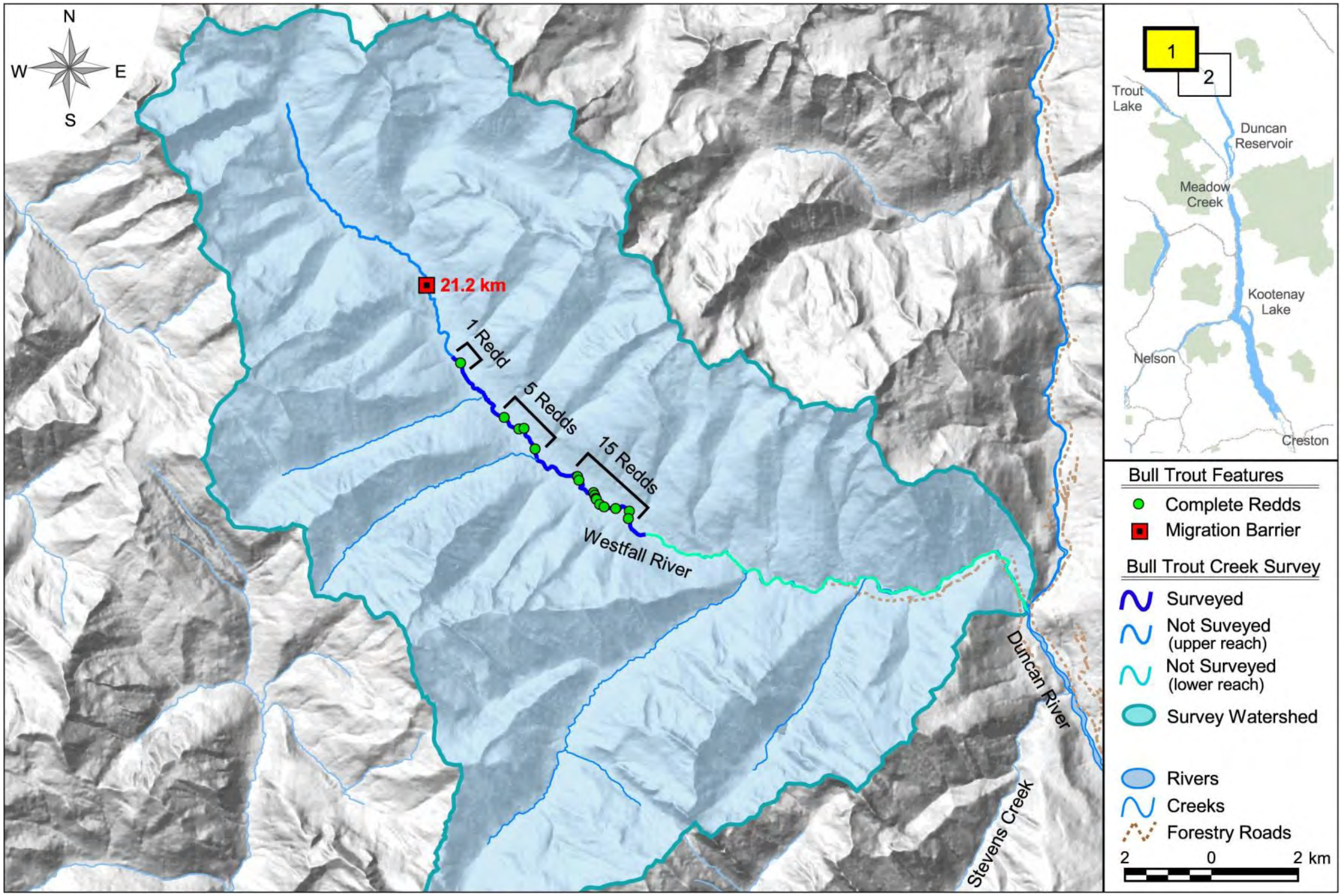


Figure 4. Westfall River bull trout redd locations – 2014.

5 DISCUSSION

5.1 Kokanee

The peak kokanee spawning period in the upper Duncan River occurs between late September and early October (de Zwart et. al 2012). Aerial kokanee surveys targeted during this time period are used to estimate a peak spawner count as an index for kokanee escapement. Supplementary bank counts conducted at approximately weekly intervals during this period are used to confirm that the aerial count occurred during the peak period, and efficiency of aerial observations compared to previous surveys. While the peak count methodology does not provide as robust an estimate of overall kokanee escapement compared to area under the curve (AUC) methods based on multiple surveys, this approach was considered sufficient for the program. High turbidity and flows in the Duncan River due to glacial inputs also limit the ability to conduct counts any earlier than late September in most years. The peak count approach is used to estimate kokanee escapement for similar systems in the region, including on tributaries to the Arrow Lakes Reservoir (A. Chirico pers. comm.) and to the Lardeau River.

Data for the upper Duncan River for 2011, 2012 and 2014 are provided in Figure 5. In 2011, the results of the kokanee enumeration surveys were consistent with the estimates of kokanee productivity developed by Andrusak (in de Zwart *et. al.*, 2011), which were based on estimates of primary productivity and comparison with similar reservoir systems in the region. A kokanee spawning population of ~32,500 was predicted using a kokanee biomass estimate of 5 kg/ha, while between 28,000 and 71,000 kokanee spawners was predicted using the photosynthetic (PR) model and estimates of primary productivity based on similar systems in the region (de Zwart *et. al.*, 2011). Although kokanee numbers were lower in 2012 and 2014, relatively large inter-annual variation in abundance is expected, and has been observed on other systems where kokanee spawner abundance is monitored, such as the lower Duncan River (Porto *et. al* 2011) and the North Arm of Kootenay Lake (A Chirico, MoE, pers. comm.). There is insufficient data to determine any trends with respect to the status of the kokanee population in the Duncan Reservoir, and the current population appears to be consistent with what is expected for the system.

As in previous years, peak spawning in 2014 appeared to occur in late September or early October, although a distinct peak in kokanee spawning is not apparent from the bank counts. This is partly due to the limited number of surveys where a count was completed, as limited counts were conducted on the September 26th survey due to the poor visibility. Conducting effective ground counts in the Duncan River in September is a challenge due to the high flows and turbidity that occurs at this time. Spawning activity appears to be complete by the end of the second week of October.

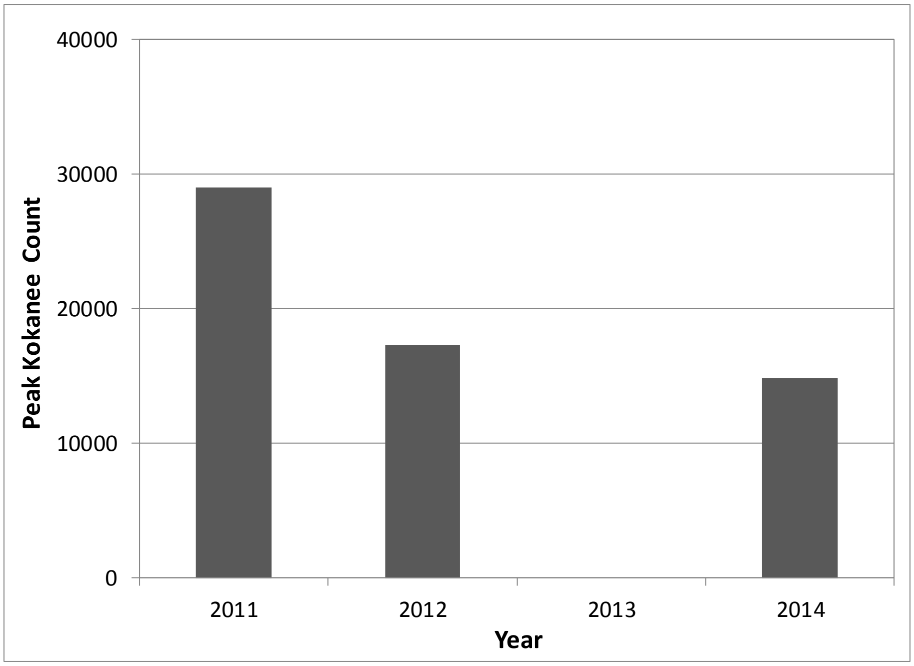


Figure 5. Kokanee index count from 2011-2014 for the Duncan Reservoir. No surveys were conducted in 2013.

An 87% reduction in kokanee was observed over the eight day period between flights, suggesting that there may be significant variability associated with the peak count depending on the day of the survey. Reasons for the rapid decline in the number of spawning kokanee are not known, although it may be related to the high use of side channel habitat for spawning. As flows decline, the available habitat in the side channels rapidly decreases. Kokanee may move to the mainstem, where visibility is lower and they are not observed. Alternatively, declining flows may make kokanee in the side channels more vulnerable to predation. We observed numerous bears, eagles and seagulls in the area feeding on kokanee, and observed very few dead kokanee, suggesting that kokanee are rapidly consumed.

5.2 Bull Trout

The fall of 2014 was characterised by very mild weather with high freezing levels, and glacial melt extended into the second week of October. This meant that turbidity would have been elevated in the Westfall River throughout the bull trout spawning period and until the day of the surveys. A large snow and rain event also occurred on September 24th, which resulted in a large influx of sediment over several days. The increased sediment load resulted in a higher rate of redd fading in 2014, and meant that many redds may not have been identifiable when the survey was conducted.

Two previous redd surveys have been conducted in the Westfall River. In 2011, conditions for surveys were excellent and 114 redds were observed. In 2012, the survey was cancelled due to poor visibility associated with a storm event.

In 2014, the Westfall FSR underwent further deactivation, and now is impassable beyond the first bridge across the Westfall River, approximately 6 km upstream of the confluence with the Duncan River. Beyond this point, access is only by foot, as large sections of the road have been completely deactivated (Photo 11). Future surveys in the Westfall River will be logistically difficult, as the majority of bull trout spawning habitat is upstream of this point.

Photo 11. Deactivated section of the Westfall FSR, October 15th, 2014.

Each year from May to September, bull trout migrating from Kootenay Lake to the upper Duncan watershed pass through the Duncan Dam. This requires a specific series of steps involving the low level operating gates (LLOG) which are manipulated to acts as locks, allowing passage for bull trout. Details regarding specifics of the bull trout transfer protocol are available in the most recent summary report (BC Hydro 2010). Bull trout transfers at the Duncan Dam have been monitored annually since 1995 (Table 6, BC Hydro data on file), although the number of transfers and the dates of first and last transfer have been inconsistent over the years. Transfers usually occur from May until September. In some years all bull trout through the dam were enumerated, while in others a visual estimate was conducted. Typically, the volume of water in the flipbucket is reduced to allow crews access and allows for a reliable estimate. In 2002, 2003 and 2006, the volume of water in the flipbucket was not reduced, and bull trout were enumerated from the walkway above the flipbucket. No data is available for 2004 and 2005. In 2014, the number of bull trout passed through the dam was 180, which represents the lowest number over the 18 years on record.

Table 6. Estimated number of bull trout transferred and number of transfers at Duncan Dam from 1995 to 2012.

Year	Estimated # of bull trout	# of transfers
1995	324	13
1996	226	10
1997	197	12
1998	753	11
1999	337	8
2000	270	10
2001	404	9
2002	376	8
2003	196	7
2004	No data	
2005	No data	
2006	372	8
2007	371	9
2008	553	9
2009[a]	725	9
2010	971	10
2011	515	8
2012[b]	394	10
2013	540	7
2014	180	9

[a]-all bull trout enumerated
[b] no transfers between July 17-August 21 due to high inflows

5.3 Management Hypothesis

5.3.1 H_o1: Life history timings of fish species of interest are consistent with those defined during the WUP data collection phase.

During the WUP data collection phase, kokanee spawn timing was defined as late August – late October (Table 1). The data collected to date by DDMMON10 is generally consistent with this, with spawning observed between mid-September and mid-October. The peak of kokanee spawning activity is from the end of September to early October, with spawning effectively completed by mid-October. Defining the onset of spawning in the upper Duncan River is difficult due to the high flows and high turbidity at this time. In previous years, kokanee have been observed migrating by the second week of September.

Bull trout spawn timing was assumed to be from early September to the third week of October during the WUP data collection phase. Active spawning has been observed on September 24th, 2012, and spawning is effectively complete by mid-October, based on the lack of adult bull trout observed during redd surveys. Telemetry work completed in 1994/1995 indicated that Kootenay Lake bull trout arrive in spawning areas in the last week of August, and have left spawning areas by the second week of October.

5.3.2 H_o2: Reservoir operations do not negatively affect fish life history uses of pelagic, littoral or tributary zones.

This hypothesis was previously rejected (de Zwart *et. al* 2012) as shore spawning and tributary habitat within the drawdown zone are both impacted by reservoir operations.

5.4 Management Questions

5.4.1 What is the relative abundance and distribution of key fish life histories in the littoral and pelagic zones?

This question was addressed in Years 2 and 3 of the study, and no further information is required to address this question. In general, kokanee are primarily distributed in the pelagic area, with bull trout and rainbow trout primarily utilizing the littoral areas throughout the reservoir, seasonally (de Zwart *et al*. 2011). Estimates of kokanee and bull trout escapement were proposed to provide an index of abundance for these species so that long term trends in abundance could be assessed.

5.4.2 What is the relative abundance and distribution of fish food organisms in pelagic and littoral zones?

This question was addressed in Years 2 and 3 of the study, and no further information is required to address this question. In general, zooplankton were found to be the dominant fish-food organism for kokanee, similar to other Upper Columbia Basin systems, although mysid shrimps were also consumed. Stomach content information also revealed that other fish, likely kokanee in the pelagic zone and cyprinids in the littoral, were the dominant fish-food organism for adult bull trout although sub-adult bull trout were also found to utilize mysid shrimp seasonally. Rainbow trout, which were predominantly littoral, primarily foraged on terrestrial invertebrates (de Zwart *et al*. 2011).

5.4.3 What is the life history timing of key species of interest?

The peak spawn timing for kokanee is late September – early October, with spawning activity observed as early as September 14th, and as late as October 14th. This is consistent with the assumptions made during the WUP process, although assumptions made during the WUP process appear to be slightly conservative in that they encompass a wider time period than has been observed to date.

The timing of fry emergence for kokanee used during the WUP process also appears to be slightly conservative. The incubation period for kokanee eggs was assumed to end by mid-June. We have observed kokanee fry in the upper Duncan River in mid-April, suggesting that the incubation period may end well before the assumed end date.

The bull trout spawning period is from early September – mid October, consistent with the assumptions made during the WUP process. Bull trout have been observed spawning on September 24th. The assumptions made during the WUP process appear to be slightly conservative in that they encompass a wider time period than has been observed to date.

5.4.4 *How are key fish life histories influenced by reservoir management?*

The species of interest for this study are kokanee and bull trout. A summary of the different life stages of these species, the key locations where these life stages occur, and potential influences on these life stages by reservoir operations are provided in Tables 8 and 9.

5.4.4.1 Kokanee

Reservoir operations do not appear to have a direct impact on habitat used by the majority of kokanee (Table 7), since kokanee utilise pelagic habitat and the upper Duncan River is the major kokanee spawning tributary for the reservoir. The large annual drawdown in the spring results in the desiccation of shore spawning redds, although shore spawning kokanee are not genetically distinct from stream spawning kokanee, and shore spawning kokanee represent a small fraction (estimated at ~5%) of adult kokanee. The low productivity associated with reservoirs may have an indirect effect on kokanee by reducing the availability of food. However, the implementation of S73 in 2010 is not expected to result in any significant changes in productivity compared to reservoir operations prior to 2010.

Table 7. Summary of kokanee life stages and potential influences due to reservoir operations.

Stage	Location(s)	Influence of Operations
Spawning/Incubation	Majority of redds in upper Duncan River outside of reservoir influence. Estimated <5% of population spawns along the shore of the reservoir on in other tributaries.	No effect on upper Duncan River. Annual drawdown desiccates shore spawning redds.
Juvenile rearing	Juvenile kokanee rear in pelagic habitat.	Reservoir is largely pelagic habitat. Productivity issues due to reservoirs may affect overall biomass, although this is not expected to vary between possible operating scenarios.
Adult rearing	Adult kokanee rear in pelagic habitat	Reservoir is largely pelagic habitat. Productivity issues due to reservoirs may affect overall biomass, although this is not expected to vary between possible operating scenarios.
Migration	Majority to upper Duncan River, small percent to other tributaries or along shoreline	No effect as no migration barriers are present within drawdown zone.

5.4.4.2 Bull Trout

Reservoir operations potentially influence bull trout in the following three areas.

1. Productivity issues that affect kokanee abundance may also affect bull trout since kokanee are a key prey species for bull trout.
2. Drawdown of the reservoir in the spring results in a reduced reservoir volume, and this may lead to an increased harvest of bull trout at this time in a recreational fishery on the reservoir. Drawdown of the reservoir in the spring is similar between pre and post implementation of- Alternative S73 (see Figure 2).

3. Reservoir operations may affect bull trout passage through the Duncan Dam. Passage requires manipulation of the low level operating gates (LLOG), and under some circumstances, other reservoir operations may take precedence over bull trout passage. For example, extreme precipitation events in July 2012 meant that the LLOG's were used to reduce the amount of spill occurring at the dam in an attempt to reduce total gas pressure impacts to fish downstream of the dam. As a result, no bull trout transfers were conducted between mid-July and mid-August.

The passage of bull trout through the Duncan Dam requires active management action, and the effectiveness of this transfer program is monitored in two separate study programs. The upper Duncan River bull trout migration monitoring program (DDMMON-5) is a 10-year monitoring program to determine the effectiveness of the adult bull trout transfer program at Duncan Dam at contributing to Kootenay Reservoir and/or Duncan Reservoir bull trout recruitment. The lower Duncan Dam bull trout passage monitoring program (DDMMON-6) is a 10 year monitoring program to determine the effectiveness of the existing weir, which acts as a fish ladder for bull trout. If necessary, the project team of DDMMON-6 will make recommendations how to improve the weir design and operations to increase bull trout access into the flipbucket.

A summary of bull trout lifestages and the potential influence of reservoir operations on these are provided in Table 8. The implementation of Alternative S73 is not expected to have resulted in any changes that would have an effect on any bull trout lifestage. Neither reservoir drawdown in the spring (see Figure 2), nor the bull trout transfer protocol, has changed with the implementation of Alternative S73.

Table 8. Summary of bull trout life stages and potential influences due to reservoir operations.

Stage	Location(s)	Influence of Operations
Spawning/Incubation	Majority of redds in upper Duncan River watershed outside of reservoir influence.	No effect on upper Duncan River watershed
Juvenile rearing	Juvenile bull trout rear for 2-4 years in tributaries	No effect on upper Duncan River watershed
Adult rearing	Adult bull trout rear in Duncan Reservoir and/or Kootenay Lake	Large drawdown may increase harvest during spring fishery. Productivity issues due to reservoirs may affect kokanee biomass, the key prey species.
Migration	Majority to upper Duncan River watershed. Kootenay Lake bull trout are passed through the Duncan Dam.	Transfer of bull trout through Duncan Dam follows a specific transfer protocol that requires active management.

5.4.4.3 Rainbow Trout

Rainbow trout were originally included as a species of interest, however, the very low abundance of this species in the reservoir despite repeated stocking attempts confirms that the environmental conditions of the reservoir does not support this species.

5.4.5 Will the recommended reservoir operations improve fish productivity through habitat and fish-food abundance and distribution?

No information was collected in 2014 to directly address this question. However, the estimates of kokanee and bull trout escapement provide an index of abundance for these species so that long term trends in abundance can be assessed.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Kokanee

Kokanee are considered indicators of ecosystem health in pelagic systems. The data collected to date suggests that the size of the kokanee population in the Duncan Reservoir is consistent with what is expected based on estimates of primary productivity and comparison with similar reservoir systems in the region. A review of reservoir operations and kokanee lifestages suggests limited direct effects of operations on kokanee, and no significant change in these effects would have occurred with the implementation of Alternative S73..

Aerial surveys remain the most suitable method of enumerating kokanee in the upper Duncan River. The recommended timing for the survey is early October, after flows in the Duncan River have receded and visibility improves. The 85% decrease in kokanee numbers that were enumerated between the October 2 and October 10th suggests that the window for peak spawning is relatively small. In the three years of surveys, we have seen very few dead kokanee in the watershed, and it appears that spawned out kokanee are quickly consumed by other wildlife. For this system, the timing of aerial surveys will always be a compromise between waiting long enough for stream discharge to decrease (and visibility to improve), and not waiting too long that spawning is over.

Recommendations for future surveys include:

- Budget and plan for two aerial surveys in late September or early October so that there is a contingency in place in case the first survey is hampered by poor visibility or weather,
- Only conduct one survey if conditions in the watershed are adequate on the first survey,
- High-resolution images at index sites could be collected during the aerial survey to assist with estimating observer efficiency,
- Collect weight-length information of representative kokanee (requires a fish collection permit).

6.2 Bull Trout

Bull trout are the apex predator in the Duncan Reservoir. A review of reservoir operations and bull trout lifestages suggests limited direct effects of operations on bull trout, and no significant change in these effects would have occurred with the implementation of Alternative S73. Monitoring bull trout in the Duncan Reservoir is complicated as a bull trout are migratory and a large number of bull trout migrate through the Duncan Reservoir from Kootenay Lake to access spawning habitat in the upper Duncan River watershed.

Recent estimates of the number of adult bull trout in the Kootenay Lake system are in the range of 5,000 – 10,000 based on redd surveys conducted in 2011 and harvest data (Andrusak 2012). In 2011, 1,815 bull trout redds were enumerated in 11 major tributaries to Kootenay Lake, including the 114 redds observed in the Westfall River. In the same year, 515 bull trout were observed during bull trout transfers at Duncan Dam. Bull trout redd surveys in several Kootenay Lake tributaries were repeated in 2013, with most of these recording fewer redds compared to 2011 (Andrusak 2014). However, several major spawning tributaries surveyed in 2011 were not assessed in 2013. Ministry of Forests, Lands, and Natural Resource Operations (MFLNRO) are planning to conduct similar surveys in index streams every three years as a way of monitoring the Kootenay Lake bull trout populations, with the next survey scheduled in the fall of 2015.

To date, two of the three surveys in the watershed have been hampered by poor visibility and a high degree of uncertainty in the number of redds observed. Bull trout surveys in the Westfall River now represent a challenge to implement on a regular basis due to the change in access. Future surveys will be complicated by the lack of vehicle access beyond 6 km, and foot access beyond this will become more difficult as vegetation becomes established on the deactivated road. Despite this, the Westfall River remains the best candidate for an index stream, as a significant number of bull trout spawn in the system and there is limited access to any of the other major bull trout spawning tributaries of the Duncan River.

Recommendations for future redd surveys include:

- Plan on conducting bull trout redd surveys in the same year as redd surveys are conducted on other Kootenay Lake tributaries so that the data is directly comparable. Bull trout redd surveys on Kootenay Lake tributaries are currently planned at 3 year intervals, with 2015 the next survey year (MFLNRO pers. comm.).
- Consider using a helicopter to drop off crews at the upstream end of the Westfall River on the first day. Crews could walk out on the road at the end of the day, and complete the lower sections of the Westfall River on foot on subsequent days. This would eliminate the initial ~12 km hike required to access the top of the watershed, halving the distance that crews would have to cover on the first day. A similar method is used to access remote Kootenay Lake tributaries.
- Allow extra time (three full days for a crew of two) to complete surveys due to the increased effort required to access the watershed.

An alternative is to use the results of the bull trout transfer program as an index of spawner abundance for bull trout that utilise the upper Duncan River watershed. At present, MFLNRO considers this a reasonable estimate for bull trout spawning in the upper Duncan River (Steve Arndt, pers. comm.). The advantages to this are that the data is readily available as it is usually collected during transfers, and historical data since 1995 is available. Disadvantages are that the transfer program only counts bull trout that migrate from Kootenay Lake and does not count bull trout that remain upstream of the Duncan Dam, and not all bull trout transferred are expected to spawn. For these reasons, it is not clear if data from this program can provide information on the effect of Duncan Reservoir operations on bull trout, since the number of bull trout returning to spawn will be highly dependent on conditions in Kootenay Lake.

However, the highly migratory nature of bull trout and the large size of the Kootenay Lake bull trout population also suggest that Duncan Reservoir operations can only have a small effect on bull trout provided that access to the upper Duncan River is maintained. The preliminary results of the upper Duncan bull trout migration monitoring program (DDMMON5) indicates that the Duncan River is an important contributor to the Kootenay Lake (Burgoon et. al 2010), and the large numbers of bull trout that are passed through the dam annually indicate that the Duncan Reservoir and Kootenay Lake bull trout populations are the same.

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APPENDIX 1

SUMMARY OF KOKANEE COUNT OCTOBER 2, 2014

Species	Count	Location (UTM)
KO	50	11 U 497165 5606356
KO	5	11 U 496967 5606529
KO	5	11 U 497029 5606748
KO	70	11 U 497029 5606748
KO	10	11 U 497043 5606770
KO	20	11 U 497064 5606944
KO	60	11 U 497069 5606954
KO	20	11 U 497069 5606968
KO	10	11 U 497068 5606983
KO	15	11 U 497182 5607070
KO	15	11 U 497182 5607070
KO	15	11 U 496402 5607088
KO	110	11 U 497130 5607111
KO	100	11 U 497058 5607245
KO	10	11 U 497049 5607264
KO	100	11 U 497225 5607487
KO	300	11 U 497225 5607487
KO	500	11 U 496843 5607873
KO	10	11 U 496797 5607903
KO	15	11 U 496648 5608082
KO	65	11 U 496648 5608082
KO	15	11 U 496694 5608150
KO	30	11 U 496788 5608434
KO	20	11 U 496802 5608441
KO	45	11 U 496822 5608450
KO	10	11 U 496821 5608846
KO	80	11 U 496810 5608859
KO	30	11 U 496798 5608870
KO	40	11 U 496788 5608879
KO	50	11 U 496780 5608889
KO	15	11 U 496774 5608897
KO	100	11 U 496600 5609219
KO	300	11 U 496604 5609314
KO	5	11 U 496606 5609330
KO	50	11 U 496868 5609672
KO	50	11 U 496862 5609684
KO	50	11 U 496859 5609700
KO	100	11 U 496339 5609775
KO	40	11 U 496327 5609784
KO	30	11 U 496264 5610037
KO	20	11 U 496260 5610047
KO	30	11 U 496268 5610054
KO	20	11 U 496268 5610054

KO	5	11 U 496213 5610163
KO	40	11 U 496213 5610174
KO	20	11 U 496218 5610199
KO	10	11 U 496450 5610184
KO	5	11 U 496448 5610233
KO	300	11 U 496274 5610316
KO	120	11 U 496218 5610199
KO	150	11 U 496300 5610486
KO	20	11 U 496299 5610500
KO	40	11 U 496294 5610512
KO	30	11 U 496319 5610554
KO	150	11 U 496663 5608004
KO	100	11 U 496310 5610680
KO	30	11 U 496310 5610680
KO	100	11 U 496310 5610680
KO	20	11 U 496403 5610757
KO	20	11 U 496414 5610757
KO	50	11 U 496391 5610761
KO	200	11 U 496381 5610766
KO	200	11 U 496288 5611790
KO	1000	11 U 496288 5611790
KO	400	11 U 496271 5611918
KO	300	11 U 496293 5611998
KO	300	11 U 496386 5612005
KO	40	11 U 496385 5612021
KO	200	11 U 496384 5612044
KO	50	11 U 496380 5612070
KO	1000	11 U 496401 5611863
KO	2000	11 U 496401 5611889
KO	300	11 U 496391 5611980
KO	50	11 U 496393 5611961
KO	15	11 U 495419 5612966
KO	250	11 U 495420 5612991
KO	80	11 U 495491 5613051
KO	120	11 U 495344 5613230
KO	500	11 U 495256 5613305
KO	60	11 U 494940 5613719
KO	20	11 U 494947 5613727
KO	1000	11 U 494898 5613963
KO	30	11 U 494889 5613999
KO	50	11 U 494876 5614059
KO	20	11 U 493883 5615508
KO	100	11 U 493666 5615674
KO	6	11 U 493419 5615792

KO	6	11 U 493181 5616180
KO	10	11 U 493144 5616212
KO	20	11 U 494817 5617657
KO	40	11 U 491613 5617772
KO	40	11 U 491299 5617962
KO	20	11 U 491112 5618110
KO	30	11 U 491110 5618168
KO	150	11 U 491087 5618220
KO	280	11 U 491039 5618314
KO	220	11 U 490989 5618386
KO	35	11 U 490733 5618908
KO	1630	11 U 490030 5619417
KO	50	11 U 488588 5620999
KO	105	11 U 487815 5622106
KO	40	11 U 487368 5622865
KO	50	11 U 487054 5623612

APPENDIX 2

SUMMARY OF BULL TROUT REDD SURVEY

Species	Redd Count	Location (UTM)
BT	1	11 U 473976 5629882
BT	2	11 U 474314 5629614
BT	1	11 U 474689 5629153
BT	2	11 U 475670 5628512
BT	1	11 U 475702 5628431
BT	1	11 U 476040 5628144
BT	1	11 U 476067 5628084
BT	1	11 U 476094 5628009
BT	3	11 U 476107 5627989
BT	1	11 U 476182 5627868
BT	1	11 U 476286 5627814
BT	1	11 U 476551 5627776
BT	1	11 U 476868 5627713
BT	2	11 U 476844 5627543
BT	1	11 U 472965 5631141
BT	1	11 U 474433 5629631