# Duncan Dam Project Water Use Plan

# Duncan Reservoir Fish Habitat Use Monitoring

**Reference: DDMMON-10**

***Year 5 (2012) Report***

**Study Period: April 2012 – January 2013**


**Ico de Zwart[1], Greg Andrusak[2], Heidi McGregor[3].**

**[1]Masse Environmental Consultants Ltd.**
**812 Vernon St, Nelson, B.C., V1L 4G4**

**[2]Redfish Consulting Ltd.**
**5244 Highway 3A, Nelson, B.C., V1L 6N6**

**[3]Okanagan Nation Alliance Fisheries Department.**
**3255C Shannon Lake Road, Westbank, B.C., V4T 1V4**


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# Executive Summary

The Duncan Reservoir Fish Habitat Use Monitoring program (DDMMON#10) is a ten year study developed to determine whether the implementation of the recommended operations (Alternative S73) at the Duncan Dam would improve fish productivity through habitat and fish-food abundance and distribution in the Duncan Reservoir. This report summarises the results of Year 5 (2012).

In 2012, an aerial survey on October 4 targeted for the peak spawning period of kokanee enumerated 17,347 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. Bank counts were conducted between September 24th and October 11th. Spawn run timing appears to have been one week earlier than in 2011, however, a distinct peak in spawning activity was not observed in the data.

A bull trout redd survey was scheduled for October 16-18th, 2012. However, a large rain event immediately prior to the survey resulted in high turbidity and discharge in the Westfall River, and the decision was made in the field to cancel the survey for 2012.

The operation of the Duncan Reservoir in terms of reservoir elevation in 2012 was similar to the previous six years of operation. However, high inflows due to a late snowpack and high rainfall in the spring prevented the use of the low level operating gates (LLOGs) for the bull trout transfer program from July 18 to August 21. Bull trout transfers through the dam typically occur on a weekly basis from May through to September, and this protocol enables bull trout residing in Kootenay Lake to access spawning habitat in the upper Duncan River watershed. The LLOG's were kept open so that total gas pressure downstream of the dam, which is largely due to spill over the dam, could be minimised. The effect of this on the number of bull trout transferred through the dam is unknown, although fewer bull trout were estimated to have passed through the dam during the transfer program than in the previous 5 years.

Recommendations for future years include:

- continue to georeference kokanee enumeration data obtained during the aerial flight,
- conduct bank counts at spawning sites upstream of East Creek in areas with high spawning activity identified during the aerial flight,
- add additional calibration sites to assess aerial observer efficiency,
- schedule the initial bank count for around September 20 to ensure the start of spawning is captured,
- 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 to conduct the bull trout surveys in the Westfall River to accommodate changes in the road access.

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

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Ico de Zwart
Al Irvine
Adrienne Shaw

*Okanagan Nation Alliance Fisheries Department*
Heidi McGregor

Clint Tarala

*Redfish Consulting*
Greg Andrusak

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Jeremy Baxter

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

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# 1 INTRODUCTION

This report summarizes the results of the field studies conducted in 2012 (Year 5) for the Duncan Reservoir Fish Habitat Use Monitoring Program (DDMMON-10), a ten year study program commissioned by BC Hydro. In 2012, 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).

## 1.2 Study Objectives

The Duncan Reservoir Fish Habitat Use monitoring 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.

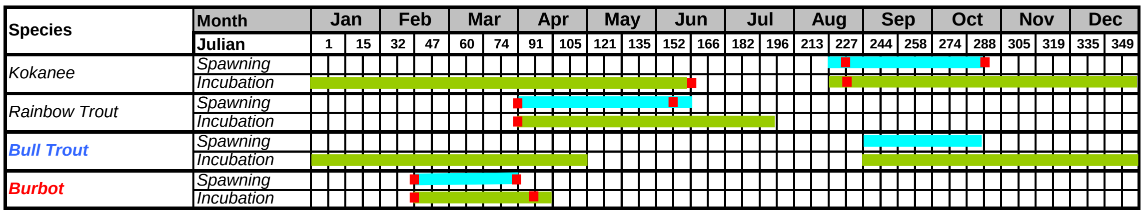
## 1.3 Management Hypothesis

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).*

The results of the two years of data collection are generally consistent with the life history timings for bull trout and kokanee defined during the WUP, although the data suggest that kokanee spawning does not commence until the first week in September. The recommended kokanee spawner surveys in 2011 would further refine this timing.

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_o$2: Reservoir operations do not negatively affect fish life history uses of pelagic, littoral or tributary zones.*

This hypothesis can be 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).

## 1.4 Management Questions

The study was developed to address the following management questions.

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?
5. Key Management Question. Will the recommended reservoir operations improve fish productivity through habitat and fish-food abundance and distribution?

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.<br>• Bull trout and rainbow trout seasonally use the littoral areas.<br>• Rainbow trout removed as a key species due to lack of suitable habitat.<br>• Use of CPUE for index of abundance not recommended due to uncertainty.<br>• 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<br>• 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.<br>• Large bull trout were piscivorous. Sub-adult bull trout also used mysid shrimp seasonally.<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>• 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.

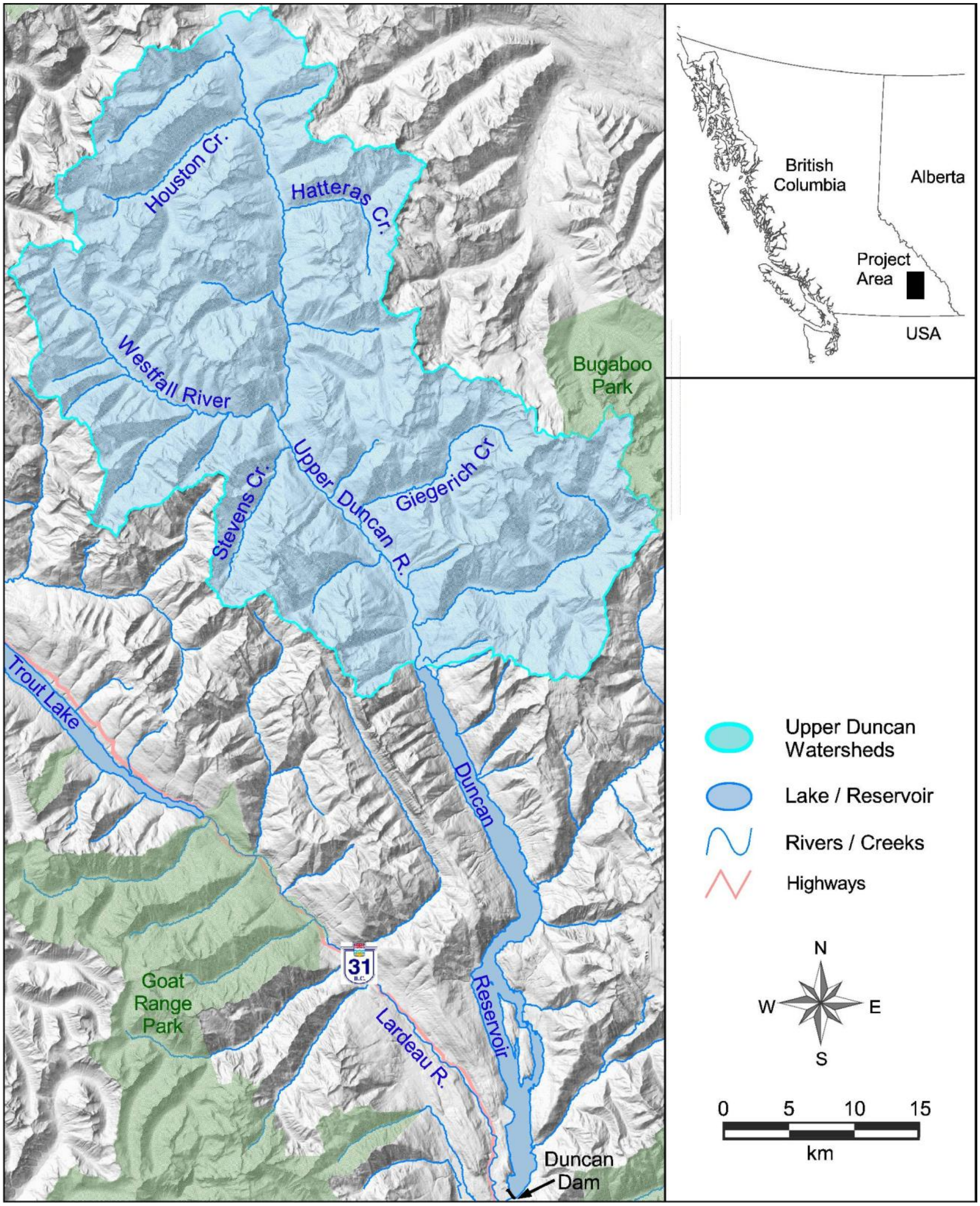



Figure 1. Watersheds in the upper Duncan River. Major tributaries where bull trout spawning occurs are named.

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 (2006-2012) 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.

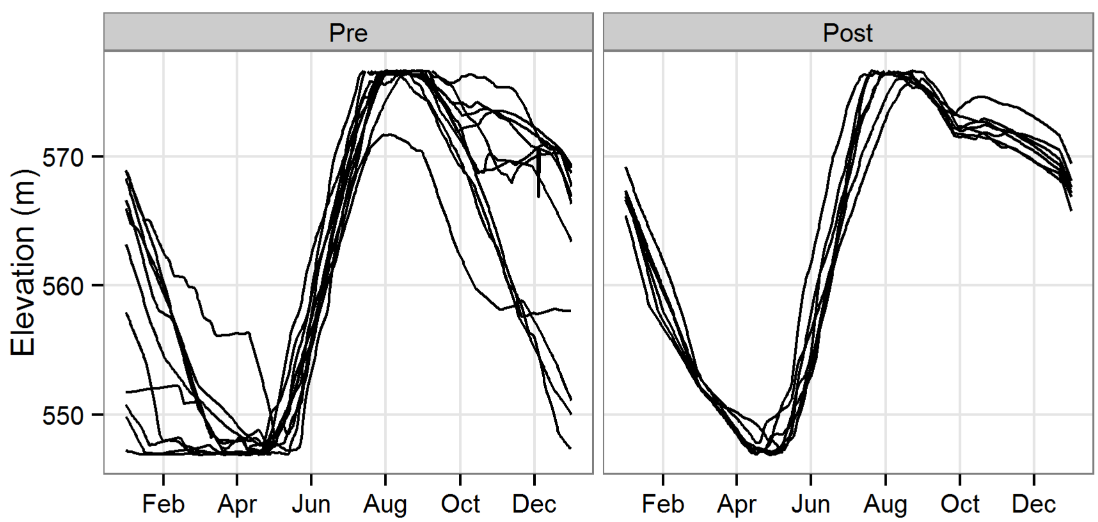



Figure 2. Daily reservoir elevation for the Duncan Reservoir pre (1995-2005) and post (2006-2012) implementation of Alternative S73.

## 2.3 Upper Duncan River Watershed

### *2.3.1 Upper Duncan River*

The upper Duncan River is a 6$^{th}$ 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%. Unlike other tributaries of the upper Duncan River, the Westfall River watershed has limited 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).

# 3 METHODS

## 3.1 Kokanee Spawning Surveys

### *3.1.1 Stream Spawning*

#### 3.1.1.1 Aerial Survey

Aerial surveys were conducted on October 4th 2012 between 10:00 and 14:00. The date of the flight was chosen based primarily on observations from the previous year, as well as helicopter availability. The first week of October was expected to coincide with the peak of kokanee spawning activity in the upper Duncan River. 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 four separate counts at discrete locations (calibration sites) to help estimate aerial observer efficiency. 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.

#### 3.1.1.2 Bank Counts

Bank counts in the upper Duncan River were conducted four times from September 24th until October 10th, 2011. 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.

## 3.2 Bull Trout Redd Surveys

### *3.2.1 Reconnaissance Surveys*

An initial reconnaissance survey of the Westfall River was conducted on September 24th, 2011 to assess vehicle access in the watershed as road conditions had changed from the previous year. The forest service road was deactivated in September 2012 at km 94, approximately 12 km upstream from the mouth of the Westfall River.

### *3.2.2 Redd Surveys*

A bull trout redd survey was scheduled for October 16-17. The field crews encountered high flows and turbidity in the Westfall River that were not conducive to redd surveys. Heavy rains (~ 60 mm) on October 15th and 16th ended a long period of dry and warm weather that the region had experienced since July and resulted in a large increase in discharge and turbidity throughout the watershed. For example, discharge in the Duncan River, measured at the Water Survey Canada hydrometric station below B.B Creek increased from 20 $m^3/s$ to 120 $m^3/s$ overnight on October 15th (WSC 2012). The heavy siltation and high flows from this event were expected to have altered the visibility of bull trout redds through both flattening and the deposition of fines. The decision was made to terminate the redd survey since the data collected would have had a high level of uncertainty due to the conditions.

# 4 RESULTS

## 4.1 Kokanee Spawning Surveys

### *4.1.1 Aerial Surveys*

A total of 17,347 kokanee were enumerated on the flight. Visibility was good during the time of the survey, although turbidity in the mainstem Duncan River reduced visibility in deeper (> 1 m) areas. The flight was timed to coincide with peak spawning when the majority of fish would be present in shallow areas. The survey began at the confluence of the Duncan River and the Duncan Reservoir and continued upstream for ~ 27 km until no more kokanee were observed. A map showing the location of spawning areas in the upper Duncan River is provided in Figure 3. A large number of spawning areas were observed 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. Aerial photo of redds and spawning kokanee. October 4th, 2012.

Photo 2. Aerial photo of spawning kokanee and redds. Devils Ck site, October 4th, 2012.

### *4.1.2 Bank Counts*

Four bank counts were conducted between September 24 and October 10. 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. Five sites were routinely surveyed. Several other sites identified in 2011 were initially included, but were subsequently dropped after it was apparent that no kokanee spawning was occurring at these sites. Regularly surveyed sites are shown in Figure 3. Data from the bank counts is provided in Table 4 and 6.

Visibility during the surveys was generally good as most sites were located in shallow side channel areas. The exceptions were the two sites, LB at 60 km and Bar at 60 km, located in the mainstem Duncan River. Visibility at these sites was fair for the first three surveys due to high turbidity in the Duncan River. Shallow areas (< 0.5m deep) adjacent to the surveyor could be adequately surveyed, but the turbidity reduced the ability to count kokanee at greater distances or depths (Photo 3). An example of kokanee spawning and redds at one of the sites (Devils Ck) is provided in Photo 4 (see Photo 2 for an aerial photo of the same site on October 4, 2012).

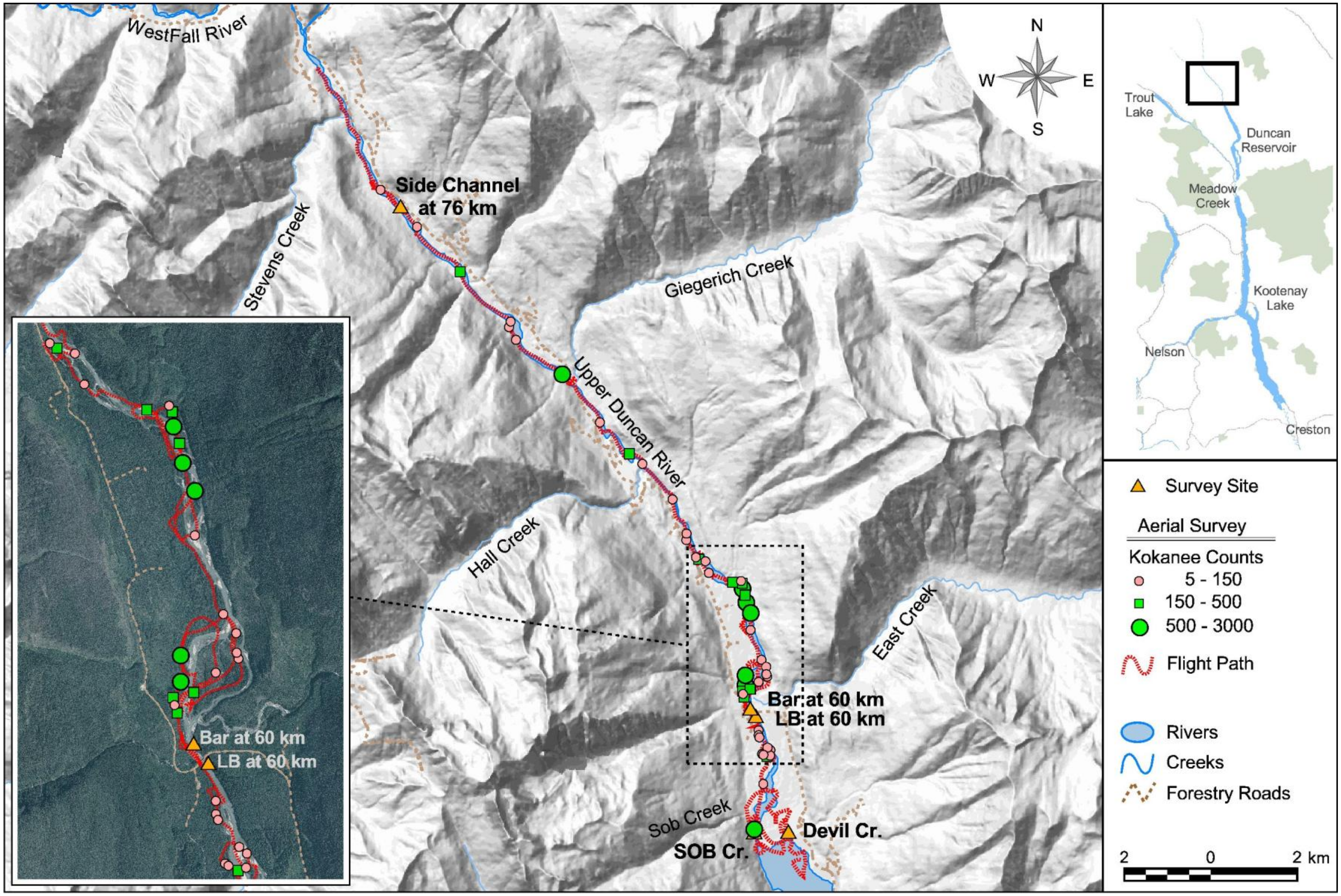



Figure 3. Upper Duncan River Fish Habitat Monitoring Program kokanee spawning sites - 2012.

Photo 3. Bank survey observations at kokanee spawning site, Bar at 60 km, October 4th, 2012. Note slightly turbid water. Survey site circled.

Photo 4. Bank survey observation at spawning kokanee and redds. Devils Ck site, September 24th, 2012.

Table 4. Summary of kokanee bank surveys at index sites, upper Duncan River, 2012.

| Date | SOB Ck | LB at 60 km[1] | s/c at 76km | Devils Ck | Bar at 60 km | Comments |
|---|---|---|---|---|---|---|
| Sep-24 | 14 | 0 | 0 | 215 | NS | Fish in good condition, generally paired up |
| Sep-28 | 7 | 13 | 1 | 242 | 425 | Fish in good condition, generally paired up |
| Oct-4 | 2 | 28 | 0 | 235 | 318 | Most fish in good condition, but some deterioration |
| Oct-10 | 0 | 0 | NS | 240 | 0 | Most fish in good condition, but some deterioration |

[1] migratory site, no spawning habitat, NS – not surveyed;

Table 5. Summary of kokanee redd counts at index sites, upper Duncan River, 2012.

| Date | SOB Ck | LB at 60 km[1] | s/c at 76 km | Devils Creek | Bar at 60 km |
|---|---|---|---|---|---|
| Sep-24 | NR | - | 0 | 305 | NS |
| Sep-28 | 52 | - | 12 | 272 | 140 |
| Oct-4 | 51 | - | 8 | 209 | 85 |
| Oct-10 | 56 | - | NR | 247 | 89 |

[1] migratory site, no spawning habitat, NS – not surveyed; NR – not recorded

### *4.1.3 Observer Efficiency*

Calibration counts were conducted at four sites in 2012, however, two of these sites had low or no kokanee present (Table 6) and were removed from the analysis as small differences in counts at these sites may result in relatively large errors. For example, at a site with 25 kokanee each kokanee represents 4% of the total. The limited number of calibration sites in 2012 prevents observer efficiency from being calculated from the data. Calibration sites are intended to provide supporting information so that aerial counts between years can be compared. For example, changes in the enumeration crew or environmental conditions could affect observer efficiency and if this is the case may be apparent in estimates of observer efficiency.

Six discrete sites have been used to compare aerial counts with bank counts for this program. At all of these sites, visibility was excellent for both aerial and bank crews. The ratios of the helicopter to ground counts used in the Bayesian aerial observer efficiency analysis are plotted in Figure 4. This analysis used calibration counts from 2011 and 2012 as the same crews were used and survey conditions were similar. The Bayesian analysis estimated the median expected aerial observer efficiency to be 1.03, with lower and upper 95% credibility intervals of 0.65 and 1.62 respectively. The aerial observer efficiency is similar to that found for aerial surveys conducted in the lower Duncan River (Porto *et. al*. 2011).

Table 6. Summary of kokanee bank and aerial counts calibration counts (2011-2012).

| Site | Date | Aerial Count | Bank Count |
|---|---|---|---|
| SOB Creek | 04 Oct 2012 | 0 | 2 |
| Devils Creek | 04 Oct 2012 | 400 | 235 |
| SC at 76 km | 04 Oct 2012 | 0 | 0 |
| Bar at 60 km | 04 Oct 2012 | 185 | 318 |
| SOB Creek | 03 Oct 2011 | 575 | 469 |
| SC at 60 km | 03 Oct 2011 | 220 | 115 |
| SC at 76 km | 03 Oct 2011 | 800 | 654 |
| SOB Creek | 11 Oct 2011 | 3 | 8 |
| RB at hydro station | 11 Oct 2011 | 100 | 150 |
| SC at 76 km | 11 Oct 2011 | 200 | 330 |

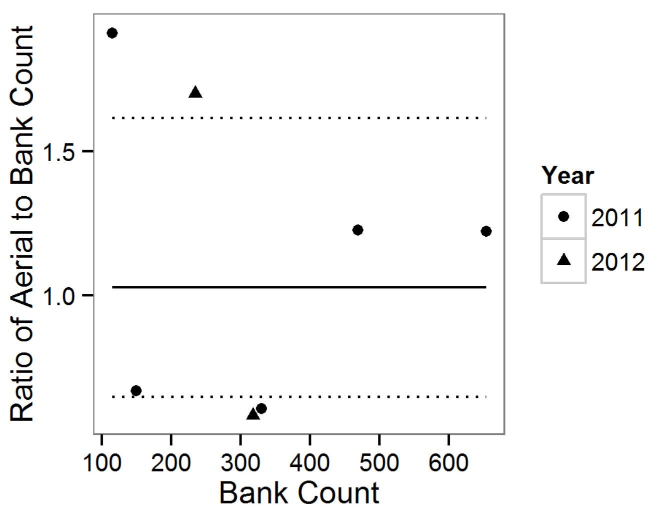



Figure 4. The ratios of the helicopter to ground spawner counts (2011-2012 data combined). The solid line is the median expected aerial observer efficiency and the dotted lines are 95% credibility limits.

The calibration counts from 2011 and 2012 are quite variable, and this likely reflects the low number of sites where calibration counts have been conducted as well as site specific conditions. For example, in 2012, a large number of kokanee were aggregated in one mass adjacent to a piece of large woody debris at the Devils Creek site (see Photo 2), which made an accurate aerial count difficult. The other site (bar at 60 km) where a calibration count was conducted in 2012 is a main stem site that is not as well defined as a side channel site is (see Photo 3), which may have contributed to the difference.

## 4.2 Bull Trout Redd Surveys

### *4.2.1 Redd Surveys*

Due to high discharge and turbidity in the Westfall River (Photo 5), the bull trout redd survey was not conducted this year. Extreme flow events, such as heavy rain occurred immediately prior to the planned survey dates. Heavy rainfall and extreme flow events can alter the visibility of redds by flattening them and depositing fines over them. A redd survey conducted after these events would have a very high degree of uncertainty associated with the results.

During a reconnaissance survey of the Westfall FSR on September 24$^{th}$, bull trout were observed over newly constructed redds in the Westfall River (Photo 6).

Photo 5. Westfall River near mouth on proposed bull trout survey bank survey date, October 16$^{th}$, 2012.

Photo 6. Bull trout (~ 60 cm, arrow) and redd (circle). Westfall River reconnaissance investigation, September 24$^{th}$, 2012.

# 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. Based on similar run characteristics observed between the upper and lower Duncan River kokanee populations in previous years, the expansion factor derived for the lower Duncan River spawning monitoring program (DDMMON-4) (Porto *et. al.*, 2011) to convert peak counts into total escapement was assumed to be suitable. The peak count approach is used to estimate kokanee escapement for similar system in the region, including on tributaries to the Arrow Lakes Reservoir (A. Chirico pers. comm.) and to the Lardeau River.

Recent information from the lower Duncan River kokanee monitoring program (DDMMON-4) suggests peak spawning in this system occurred 1 week later than the previous year (C. Lawrence, pers. comm.). This suggests that the use of expansion factors calculated from this program may not be appropriate for the upper Duncan River in all years.

Data for the upper Duncan River for 2011 and 2012 is 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). The best estimate for total annual spawner abundance in the upper Duncan River for 2011 was 37,739 kokanee, which was derived by applying an expansion factor of 1.3 from area under the curve (AUC) analysis from the lower Duncan River kokanee spawning monitoring program (Porto *et. al.*, 2011) to the peak count of 29,040. Although kokanee numbers were lower in 2012, 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.

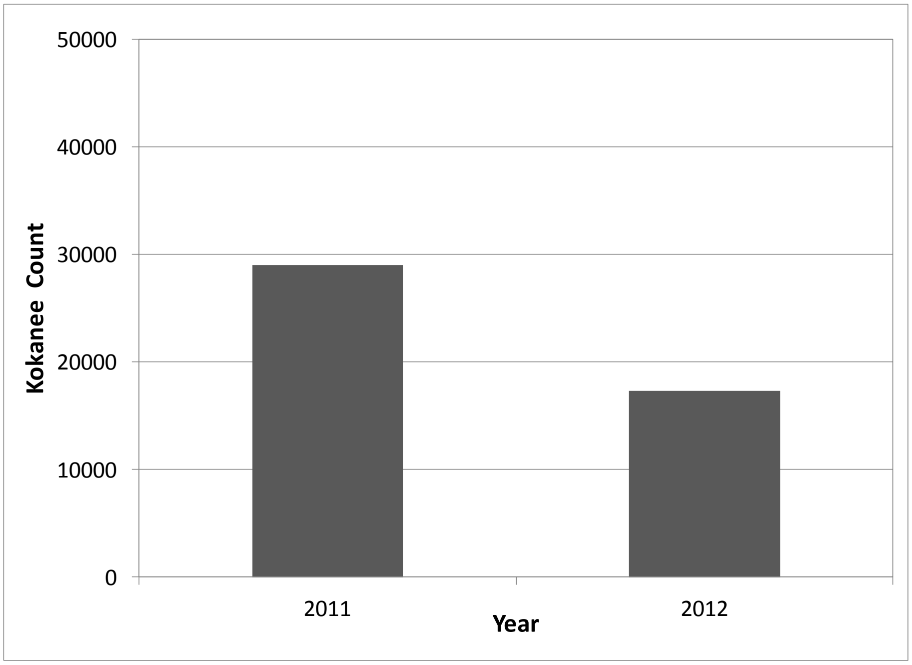



Figure 5. Kokanee index count from 2011-2012 for the Duncan Reservoir.

Peak spawning appears to have occurred earlier in 2012 compared to 2011. However, a distinct peak in kokanee spawning is not apparent from the bank counts, in contrast to 2011 (Figure 6). This may be due to several factors, including:

- a survey schedule for bank counts that targeted the peak spawning period and therefore did not include the lead up to the peak, and
- very low spawning activity in all of the index sites originally identified in 2011, which required adding additional index sites in 2012.

Two of the index sites identified in 2011 were located in side channels, and the lack of spawning in these sites in 2012 was due to little (or no) water in them due to lower flows in the Duncan River. Reasons for the lack of spawning activity in SOB Creek in 2012 are unknown, as the site appeared to have suitable substrate and flows for spawning. However, some aggradation of the site had occurred since 2011 and flows were lower in 2012 compared to 2011.

In response to the variability in index sites that was observed, the aerial survey crew was requested to geo-reference their count so that areas where high spawning activity was observed would be available for surveys in subsequent years. The data (Figure 3) suggests that the 4 km section of the upper Duncan River above the confluence with East Creek should be targeted for index sites in subsequent years. This should also help identify better sites at which to conduct calibration counts.

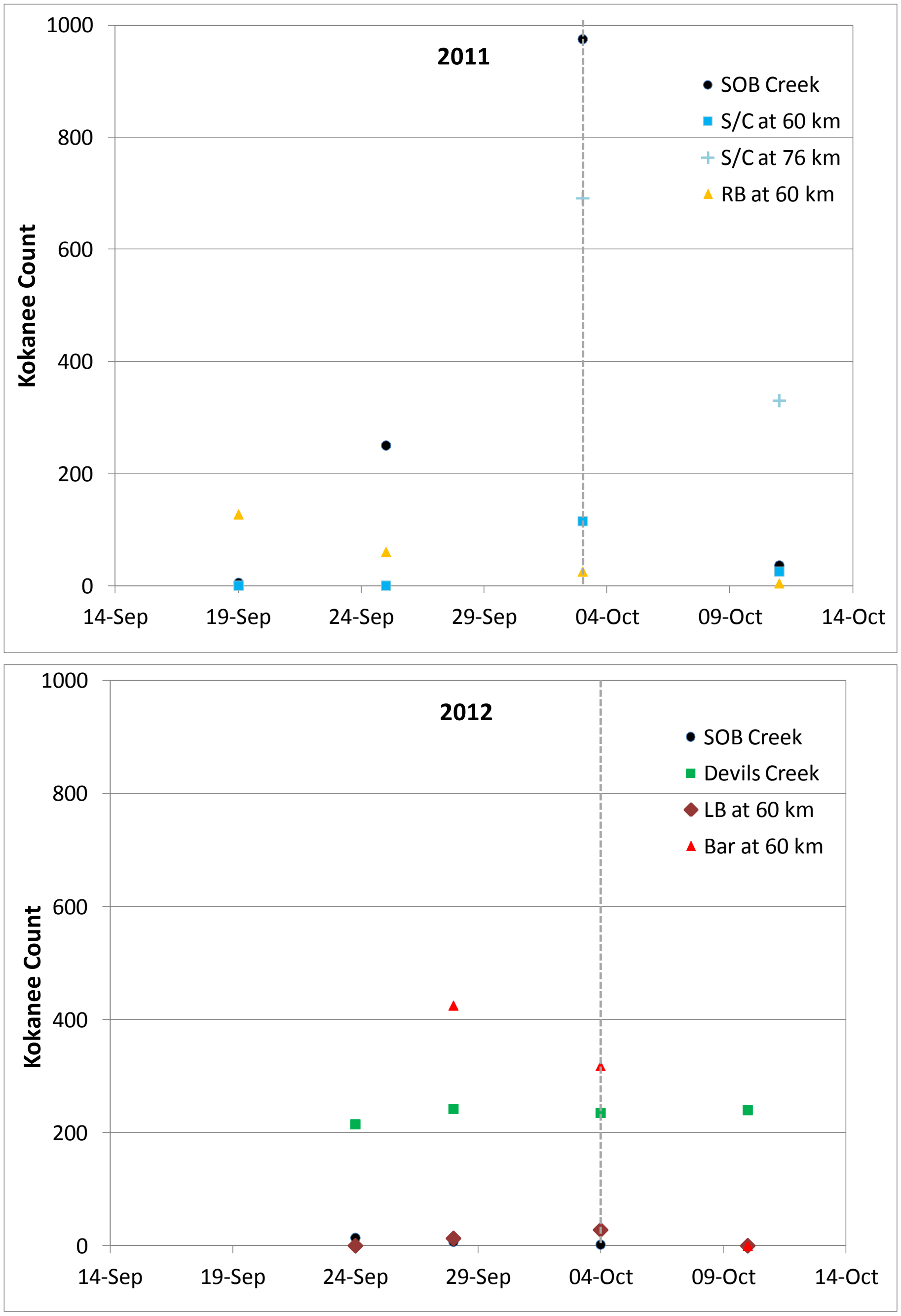



Figure 6. Kokanee bank counts, Duncan River, 2011-2012. Dashed line indicates when the aerial survey was conducted for each year.

## 5.2 Bull Trout

Due to high flows in the Westfall River at the time of the survey, no redd data was collected in 2012. Of note for future surveys, the Westfall FSR underwent a partial deactivation in September 2012, and this affects access. At present, vehicle access is possible to the Canadian Mountain Holidays fuel depot located ~12 km upstream from the confluence with the Duncan River. ATV access is possible for a further

4 km along the road, up to a tributary where a bridge is washed out. From this point, it is 1.7 km further on foot to the uppermost bridge crossing of the Westfall, and 3.7 km to the waterfall that marks the upstream limit of bull trout access.

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 7, 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 2012 bull trout were enumerated visually from the walkway above the flipbucket.

In 2012, a very large and late snowpack in the Kootenay Region resulted in high runoff for a prolonged period of time, with the result that the Duncan Dam low level operating gates (LLOG) were unavailable for use for the bull trout transfer program between July 18 and August 21. The LLOG's were kept open so that total gas pressure downstream of the dam, which is largely due to spill over the dam, could be minimised. The effect of this on the number of bull trout transferred through the dam is unknown, although the 394 bull trout that were estimated to have passed through the dam in 2012 is approximately 75% of last year's total, and the lowest number to have passed through the dam since 2007. This could be considered an effect due to dam operations, however it occurs infrequently, and arose out of a trade-off between reducing the effects of elevated gas pressure to fish downstream of the dam and allowing bull trout to pass through the dam for a four week period. As a result, it will be unlikely to cause a long term effect on bull trout unless it was to occur more frequently.

Table 7. 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 |
| | | |
| 2006 | 372 | 8 |
| 2007 | 371 | 9 |
| 2008 | 553 | 9 |
| 2009[a] | 725 | 9 |
| 2010 | 971 | 10 |
| 2011 | 515 | 8 |
| 2012[b] | 394 | 10 |

[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_o$1: Life history timings of fish species of interest are consistent with those defined during the WUP data collection phase.*

The information collected in 2012 are consistent with the data collected from 2009-2011. The peak of kokanee spawning activity is from the end of September to early October, with most spawning completed by the second week of mid-October.

Limited data was collected on bull trout spawn timing, although the observation of spawning bull trout and redds in the Westfall River on September 24th is consistent with the timing assumed during the WUP.

### *5.3.2 $H_o$2: Reservoir operations do not negatively affect fish life history uses of pelagic, littoral or tributary zones.*

No additional data was collected in 2012 to address this hypothesis. 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?*

No information was collected in 2012 to directly address this question. 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.

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

No information was collected in 2012 to address this question.

### *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, consistent with the assumptions made during the WUP process. The observation of spawning bull trout and redds in the Westfall River on September 24$^{th}$ is consistent with the timing assumed during the WUP.

### *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. Reservoir operations do not appear to have a direct impact on habitat used by the majority of kokanee. However, the low productivity associated with reservoirs may have an indirect effect on kokanee by reducing the availability of food. Reservoir operations potentially influence bull trout in three areas. Productivity issues that affect kokanee abundance may also affect bull trout since kokanee are a key prey species for bull trout. 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. The passage of bull trout through the Duncan Dam requires active management action. 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 DDMON-6 will make recommendations how to improve the weir design and operations to increase bull trout access into the flipbucket.

Table 8. 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. |
| Adult rearing | Adult kokanee rear in pelagic habitat | Reservoir is largely pelagic habitat. Productivity issues due to reservoirs may affect overall biomass. |
| 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. |

Table 9. 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. |

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 2012 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 RECOMMENDATIONS

Spawner surveys are routinely used as an index of population abundance, and information on spawner escapement will be used to help assess fish productivity in the reservoir. The following recommendations for future spawner surveys are suggested:

- continue to georeference kokanee enumeration data obtained during the aerial count flight,
- conduct bank counts at spawning sites upstream of East Creek that were identified this year, in addition to the historical sites. Identifying additional sites will help better define spawn timing so that the peak period can be targeted for the aerial flight, provide more sites that can be used for calibration purposes, and reduce the level of uncertainty that arises from monitoring a small number of sites when spawner numbers and river conditions are highly variable,
- add additional calibration sites to assess aerial-count observer efficiency,
- schedule the initial bank count for around September 20 to ensure the start of spawning is captured,
- 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. High kokanee population densities can result in a smaller fish due to density-dependent growth. Conversely, lower kokanee densities can result in larger sized fish.
- allow for additional time to conduct the bull trout surveys in the Westfall River to accommodate changes in the road access.
- using one crew of two, rather than two crews of two, for the bull trout surveys would provide additional flexibility in scheduling surveys.

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