Duncan Dam Project Water Use Plan

Duncan Reservoir Fish Habitat Use Monitoring

Implementation Year 9

Reference: DDMMON-10

DDMMON-10: Duncan Reservoir Fish Habitat Use Monitoring
Year 9 (2016) Interpretive Report

Study Period: April 2016 – April 2017

Amy Duncan[1], Ico de Zwart[2], Michael Zimmer[1]

[1]Okanagan Nation Alliance Fisheries Department.
101-3535 Old Okanagan Highway, Westbank, B.C., V4T 3L7

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

April 2018

EXECUTIVE SUMMARY

The Duncan Reservoir Fish Habitat Use Monitoring program (DDMMON#10) is a ten year study developed to 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 9 (2016). With respect to the above 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. Adult Bull Trout were piscivorous and sub-adult Bull Trout diet also included mysid shrimp.

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.

In 2016, an aerial survey on October 4 targeted for the peak spawning period of Kokanee, enumerated 13, 041 fish in the upper Duncan River. This value was likely underestimated due to low visibility during time of survey. The majority of these were located in a 4 km section of the Duncan River upstream of the confluence with East Creek, with large groups also found above Giegerich Creek. Bank counts were conducted on September 22nd, 27th and October 4th to provide additional information on spawn run timing, observer efficiency and conditions in the watershed. 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, 2012 and 2014 enumerated 29,030, 17,347 and 14,862 Kokanee, respectively.

A Bull Trout redd survey in the Westfall River occurred on October 23-24th. A partial survey of the Westfall River was conducted which encompassed the majority of the high quality spawning habitat in the watershed. Forty-six (46) Bull Trout redds were observed over a 15 km distance in 2016. All of the redds were faded and had obvious sediment accumulation in their pits, leading the survey crew to believe that some 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. Three redd surveys, in 2011,2012 and 2014, have been attempted previously 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, 21 redds were observed, however this survey was considered incomplete due to poor visibility indicating many redds may have been missed in this year.

The operation of the Duncan Reservoir in 2016 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 late May through to the end of August. The estimated number of Bull Trout passed through the dam as of August 24, 2016 was 101, which represents the lowest number recorded in the 22 years where data is available.

ACKNOWLEDGEMENTS

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

BC Hydro
Trish Joyce – Program Manager
Alf Leake

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

Okanagan Nation Alliance Fisheries Department
Amy Duncan
Michael Zimmer
Evan Smith

Masse Environmental Consultants
Ico de Zwart
Al Irvine

Duncan Wassick (Dam Helicopters) and Mark Homis (Highland Helicopters) provided helicopter services for the aerial survey and access to the Westfall River.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

This report summarizes the results of the field studies conducted in 2016 (Year 9) for the Duncan Reservoir Fish Habitat Use Monitoring Program (DDMMON-10), a ten year study program commissioned by BC Hydro. In 2016, Kokanee spawner enumeration surveys were conducted in the Upper Duncan River and Bull Trout redd surveys conducted in the Westfall 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; Table 3) 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 also addresses 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. Rainbow Trout were removed from the scope of assessment as surveys in Years 3 and 4 indicted their numbers are too few in the Duncan Reservoir to warrant observation.

1.2 Management Hypotheses

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.

Species	Month	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Julian	1	15	32	47	60	74	91	105	121	135	152	166	182	196	213	227	244	258	274	288	305	319	335	349
Kokanee	*Spawning*																								
	Incubation																								
Rainbow Trout	*Spawning*																								
	Incubation																								
Bull Trout	*Spawning*																								
	Incubation																								
Burbot	*Spawning*																								
	Incubation																								

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). However, these operations have little impact, and little biological significance, on fish life histories since the majority of Kokanee spawning and Bull Trout spawning and juvenile rearing occurs in upstream areas outside of the reservoir's influence.

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 9 (2016) is summarised in Table 2.

Table 2. Summary of DDMMON-10 results (de Zwart *et al.* 2010, 2011, 2012, 2013, 2015).

Management Question	**Key Results**
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 and too few observations were made to warrant further effort. • Use of CPUE for index of abundance was not recommended due to uncertainty. • Kokanee and Bull Trout spawners surveys were recommended as an index of abundance, consistent with other systems.
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.
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.
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 of 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.
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.

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:

- Rainbow Trout are present in very low abundance and the Duncan Reservoir provides limited habitat for this species;
- the majority of tributaries to the Duncan Reservoir provide limited habitat for species of interest, primarily due to steep gradients and limited spawning/rearing habitat;
- the majority of Kokanee 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 2009-2011 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 10 years was proposed (BC Hydro 2008). Spawner surveys are routinely used as an index of population abundance and to provide a means of assessing long-term abundance changes.

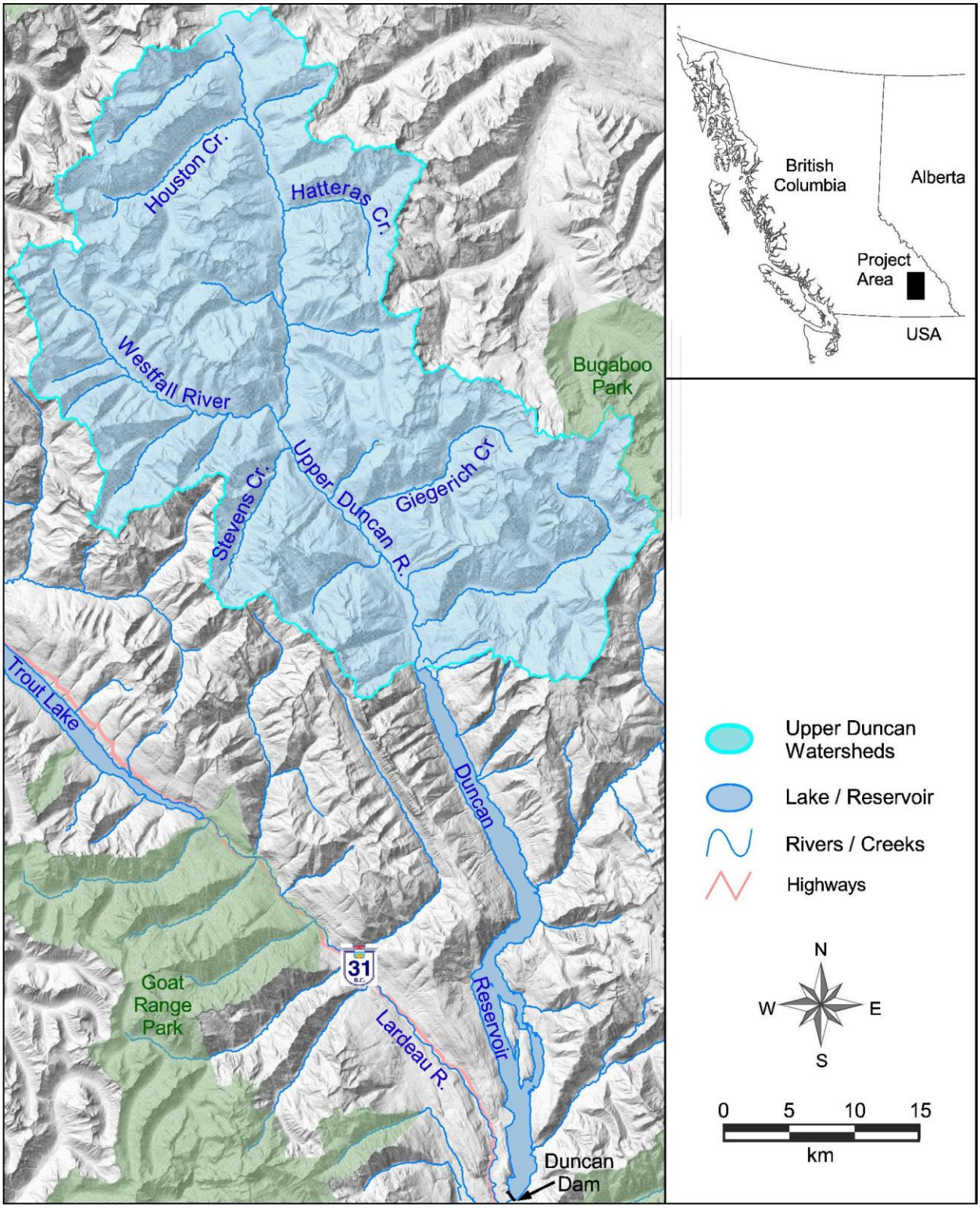

Figure 1. Watersheds in the upper Duncan River. Major tributaries where Bull Trout spawning occurs are named.

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; WSC 2012) 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 as a result of Alt S73 (BC Hydro 2007).

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; * Note – in recent years outflows from DDM have been modified to 95-100 cms minimum flow, to protect spawning Kokanee in the Lower Duncan River (Sept 25-Oct 21).

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 (576.68 m), the minimum elevation at draw down (546.87 m), and elevation targets on December 31 and February 28 (Table 3). As a result, average daily reservoir operations under Alternative S73 (2006-2016) 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.

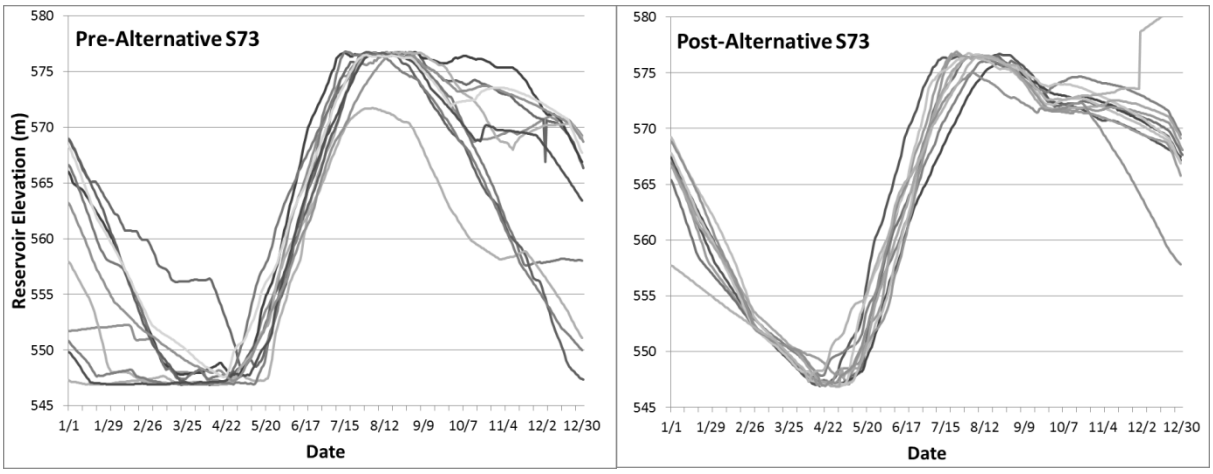

Figure 2. Daily reservoir elevation for the Duncan Reservoir pre (1995-2005) and post (2006-2016) implementation of Alternative S73. Note that reservoir elevations have been more consistent since Alternative S73 was implemented.

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, and it is generally less turbid than other streams. In 2011, 114 Bull Trout redds were identified in the Westfall River, 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 Forest Service Road (FSR) was initiated by the Ministry of Forests, Lands and Natural Resource Operations & Rural Development (FLNRORD), 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, necessitating helicopter access to the Westfall River for Bull Trout redd surveys.

3 METHODS

3.1 Kokanee Spawning Surveys

3.1.1 Stream Spawning

3.1.1.1 Aerial Survey

An aerial survey was conducted on October 4th, 2016 between 13:50 and 17:10 on the Duncan River upstream of the reservoir. A two person crew was used for the enumeration, with one person sitting at the front left of the helicopter 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 flight typically continues until no more kokanee are encountered. 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.

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 22nd, September 27th and October 4th, 2016 (Table 4). These counts were used to refine run timing, and provide information on conditions in the watershed before the helicopter surveys. 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, where the Duncan River above Duncan Reservoir is approximately at RKm 58, and 2) left bank or right bank.

Table 4. Summary of Kokanee spawner bank and aerial (indicated in bold) counts at discrete sites on the upper Duncan River.

Date	SOB Ck (58.5L km)	Devils Creek S/C (58.4R km)	62.9R km S/C	Bar at 60 km	Comments
Sep-22	479	1549	713	180	Excellent visibility in Duncan River mainstem and side channels.
Sep 27	59	909	129	20	Poor visibility. High levels of turbidity likely due to rapid snow melt.
Oct 4	**0**	**240**	**350**	**200**/242	Only one bank count due delays in aerial survey. Numbers in **bold** are from aerial survey.

3.2 Bull Trout Redd Surveys

3.2.1 Redd Surveys

A Bull Trout redd survey was conducted in the Westfall River on October 23-24, 2016. The survey was scheduled to be earlier in the month; however, it was delayed due to poor weather conditions and high water levels in the Westfall River. A crew of two began the survey near the 21 km mark up 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 Appendix 2). GPS track logs were also initiated at the start of the survey and used as an overlay in GIS mapping for assessing spatial distribution of spawning within each system.

4 RESULTS

4.1 Kokanee Spawning Surveys

4.1.1 Overview

In 2016, field work for the Kokanee enumeration was conducted on three separate days at approximately one week intervals.

Table 5. Summary of Kokanee field work in the upper Duncan River, 2016.

Date	Discharge (m^3/s)[1]	Visibility	Survey	Comments
Sept-22	38	good	Bank	Good visibility
Sept-27	52	poor	Bank	Very poor visibility due to recent snow melt.
Oct-4	36	moderate	Aerial/Bank	Water clarity was excellent, but low light levels during the aerial survey made KO counts more difficult .

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

4.1.2 Aerial Survey

The aerial survey took place on October 4th and began at the confluence of the Duncan River and the Duncan Reservoir, and continued upstream to approximately 5 km below the confluence with the Westfall River. The survey was terminated due to low fuel levels and poor visibility due to the lateness of the day. During the aerial survey, 13,041 Kokanee were enumerated, although this may be considered a lower estimate as some Kokanee were still being enumerated when the survey was terminated. Visibility was considered moderate for the survey, as although water clarity was excellent, it was completed later in the day than preferred as a result of a delayed departure. The increasing length of shadows in the afternoon makes Kokanee more difficult to observe. The majority of fish were observed in shallow side channels. A map showing the location of Kokanee spawning areas in the upper Duncan River is provided in Figure 3. Compared to past years, fish appeared to be further up the river than previously observed. Examples of spawning sites as observed from the helicopter are provided in **Error! Reference source not found.** and 2.

A bank count took place concurrent to the aerial flight at the bar at 60 km. Only one bank count was conducted due to the late start of the aerial flight. At this location, the aerial count enumerated 200 spawning Kokanee and the bank count enumerated 242 Kokanee.

Photo 1. Example of Duncan River mainstem conditions showing high quality side channel habitat for Kokanee spawning.

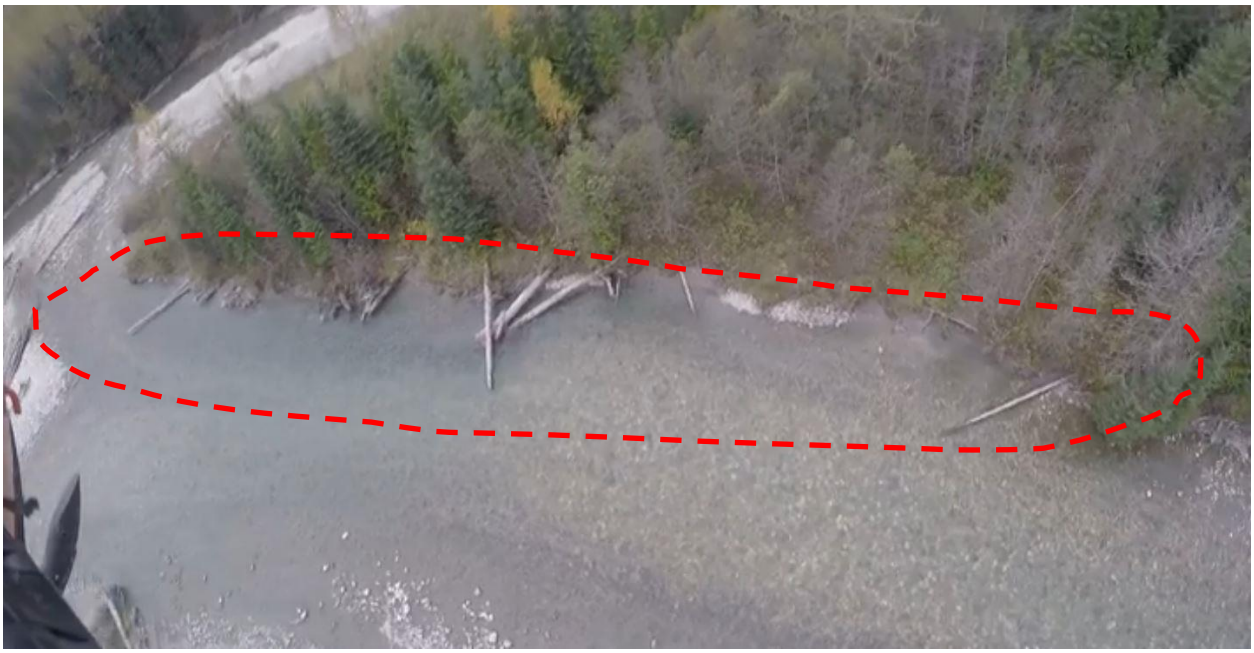

Photo 2. Example of Duncan River mainsteam showing undercut banks and natural cover for Kokanee spawners.

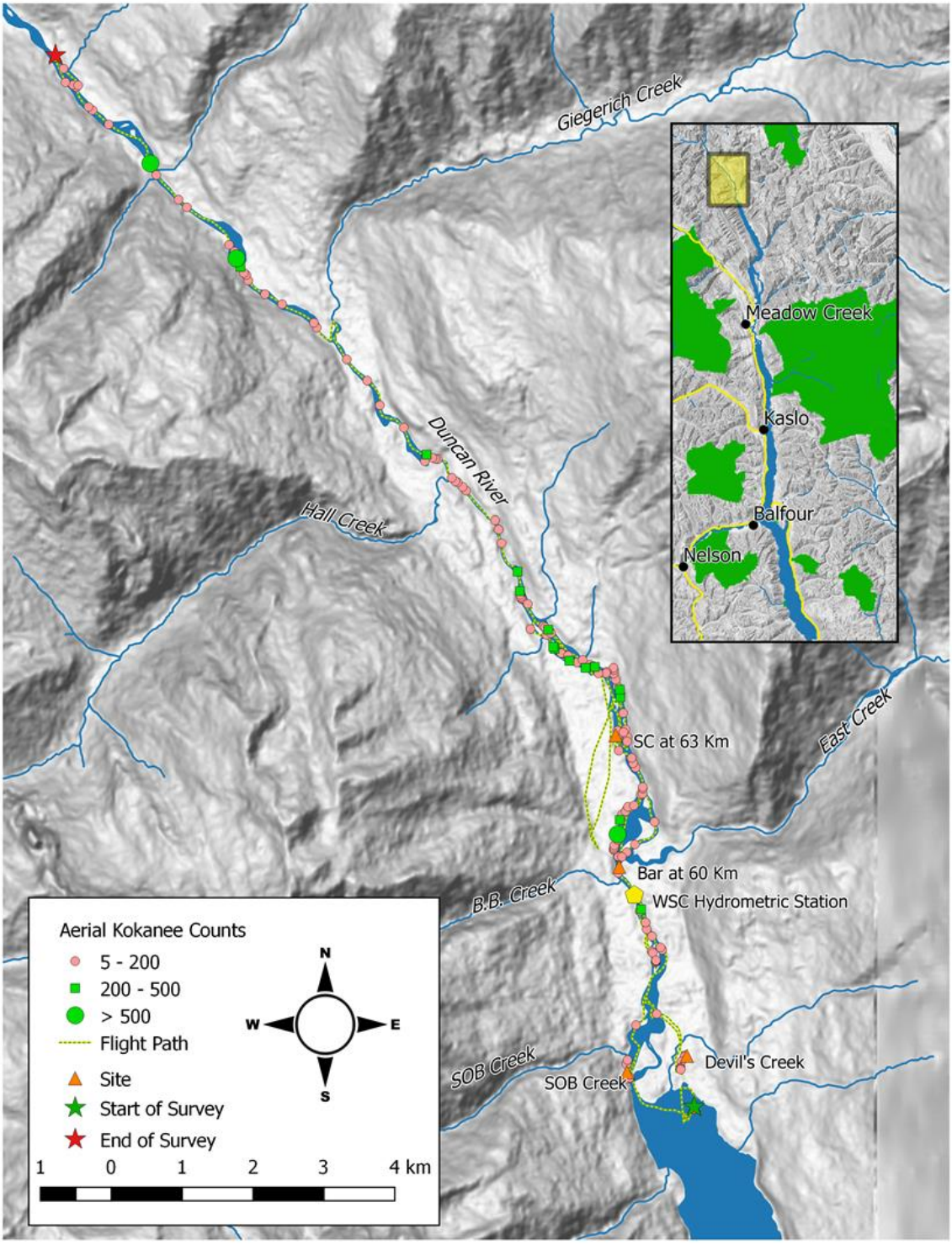

Figure 3. Locations of enumerated Kokanee observed in the upper Duncan River, including flight path track, during the October 4, 2016 aerial survey. Bank count sites are indicated by an orange triangle.

4.1.3 Bank Counts

Bank counts were conducted on September 22nd, 27th and October 4th, 2016. The bank counts were conducted in order to refine run timing, and provide information on conditions in the watershed before the helicopter survey.

On September 22nd, visibility was excellent in the side channels where most spawning occurs. Kokanee were observed in side channels, and accurate counts were possible (Photo 33). In the Devils Creek side channel (58.4R), 1,549 Kokanee were observed and spawning activity was evident (Photo 33). In the 62.9 (R) km side channel, 713 Kokanee were observed and spawning was evident. We found stranded eggs at this location and also a small isolated pool with approximately 23 Kokanee stranded within it (Photos 4 and 5). Numerous Kokanee (479) were observed in SOB Creek, a small tributary to the Duncan River that was clear. Another 180 Kokanee were estimated to be spawning at the top of the bar at 60 km.

Bank counts were also conducted on September 27th, 2016 however; visibility was poor during these surveys. High turbidity was noted throughout the river, including side channels, and was believed to be due to the rapid melt of snow that had fallen early in September. Very high turbidity was also observed in BB Creek (60.9L), suggesting a large erosion event may have occurred in this watershed. In the Devils Creek side channel, 909 Kokanee were observed spawning, and another 129 observed in the side channel at 62.9 km. Fewer Kokanee were also observed spawning at SOB Creek (59) and only 20 spawners were present at the bar at 60km, suggesting peak Kokanee spawning occurred closer to the earlier bank count survey date.

Photo 3. Devils Creek side channel (58.5L km) to the Duncan River, Sept 22, 2016. Good visibility and

Kokanee spawning activity occurring.

Photo 4. Isolated pool with approximately 23 Kokanee stranded from Duncan River main channel at 62.9L km side channel.

Photo 5. Stranded Kokanee eggs found at Duncan River side channel 62.9L km. Sunglasses shown for size reference.

4.2 Bull Trout Redd Surveys

4.2.1 Redd Surveys

An ~ 15 km section of the Westfall River was surveyed over two days (Oct 23 - 24), beginning at approximately 21 km up the Westfall River FSR to the lower bridge crossing the Westfall FSR (km 6). Water visibility was considered excellent on the days of the survey (see Photos 6 and 7 for examples of water clarity), as discharge was low (37 m^3/s). Forty-six Bull Trout redds were identified within this section (Figure 4).

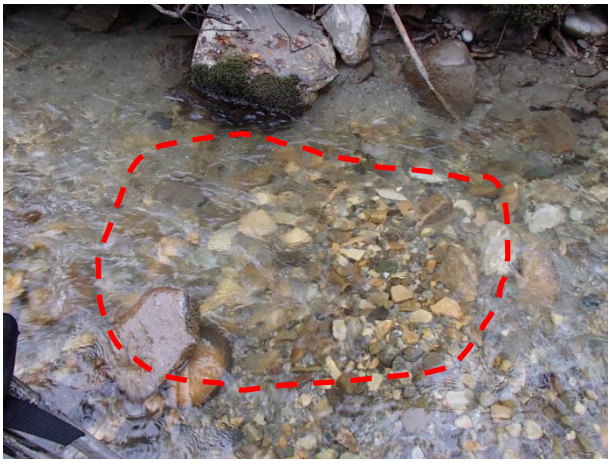

Photo 6. Bull Trout redd. Westfall River, October 23rd, 2016.

Photo 7. Undercut bank habitat along the Westfall River where Bull Trout redds are commonly found, October 23rd, 2016.

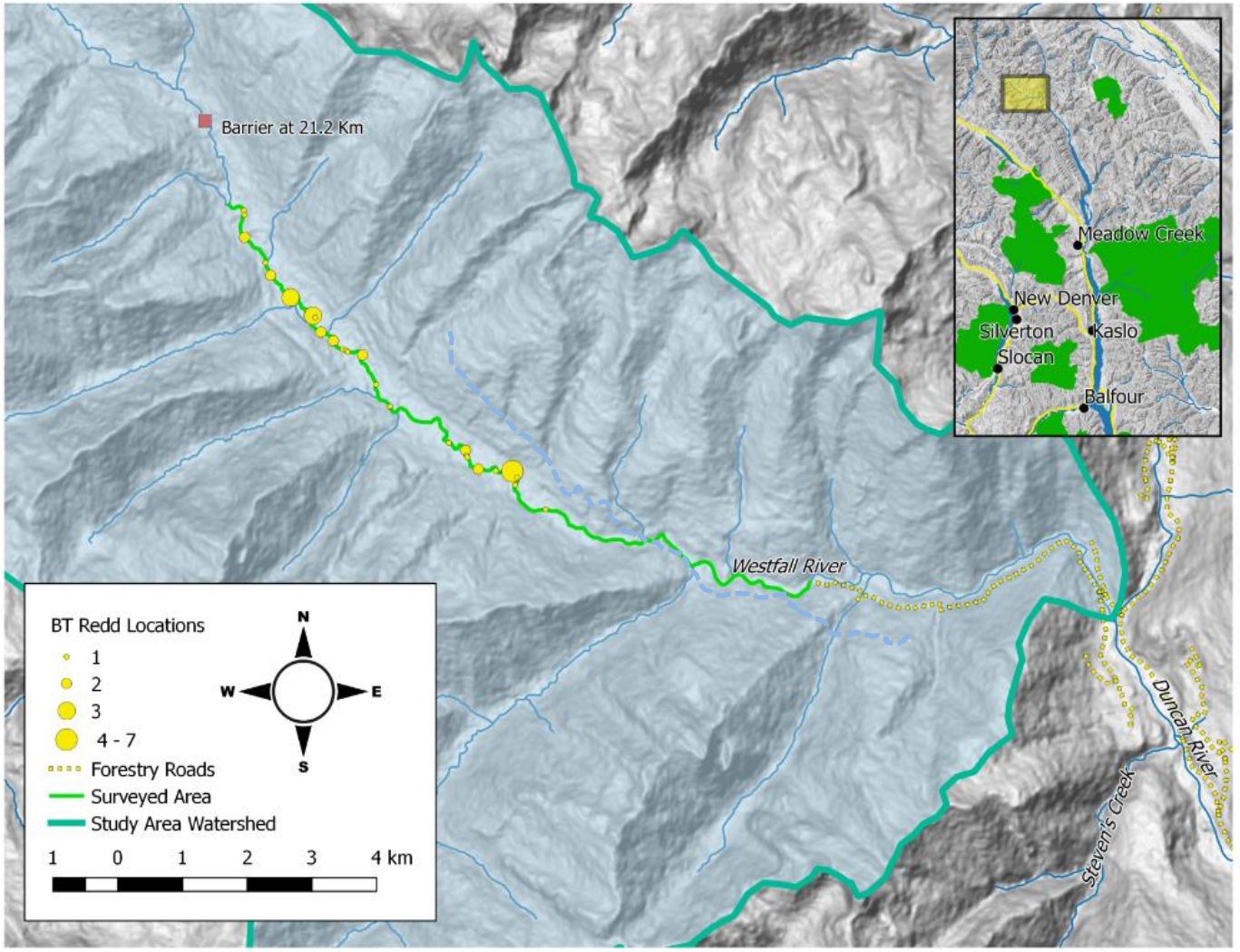

Figure 4. Westfall River Bull Trout redd locations as determined by wading survey– October 23-24, 2016.

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). An aerial Kokanee survey targeted during this time period is 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. 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, MoE, pers. comm.) and to the Lardeau River. The peak count method is subject to increased variation if the timing of the survey does not coincide with the peak spawning.

In previous years, peak spawning has appeared to occur in the last week of September or the first week of October; however, it can be difficult to obtain reliable counts in the Duncan River in September due to the high flows and turbidity that normally occurs at this time. The results of the September 22, 2016 bank count suggests that peak spawning may have occurred slightly earlier than expected. In previous years, conditions in the Duncan River have not allowed reliable counts this early in September.

Kokanee counts from these index surveys in the upper Duncan River for 2011 to 2016 are summarised 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 2014, and 2016, 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 (LGL, ONA and Poisson 2016) and the North Arm of Kootenay Lake (A Chirico, MoE, pers. comm.).

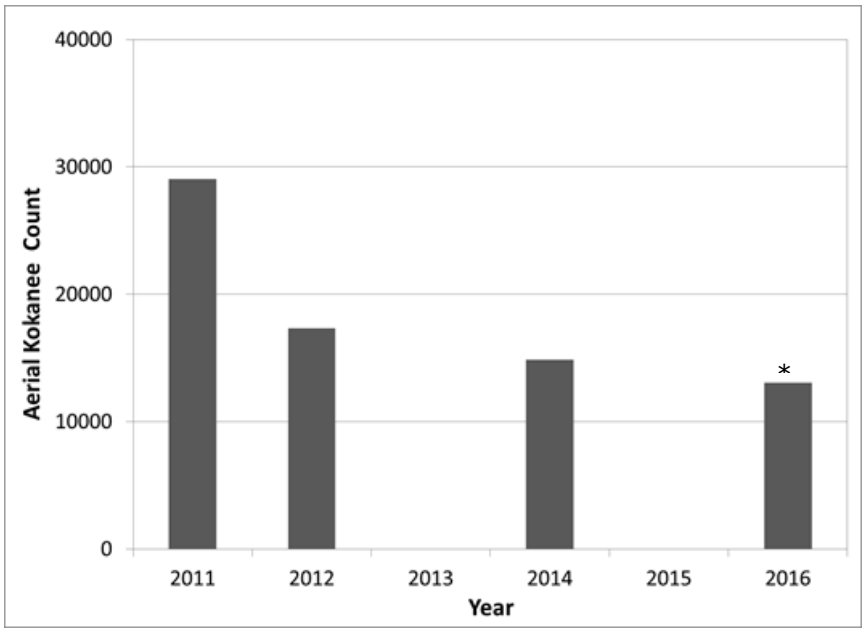

Figure 5. Kokanee index count from 2011-2016 for the Upper Duncan River above Duncan Reservoir. No surveys were conducted in 2013 or 2015. *Note that the 2016 survey was not considered a complete survey as Kokanee were still present upon termination of counts.

5.2 Bull Trout

Bull trout spawn from mid-September to early October in the upper Duncan River. Bull Trout redd surveys in the upper Duncan River are logistically difficult due to access constraints and the glacial nature of the watersheds. Turbidity in most streams is high until glacial melt ends in the fall, and redd surveys cannot be conducted until the turbidity decreases. Typically this occurs by mid-October, 3-4 weeks after the first redds have been constructed. Redd fading reduces the visibility of many redds, although the characteristic pit and mound are usually readily discernable.

Conditions in the Westfall River were excellent for the redd survey, with low water levels and excellent visibility. Although the redd surveys were conducted one week later than planned, redds were still readily apparent. This is only the second redd survey in the Westfall River that is considered successful. Conditions were excellent for the first redd survey (2011), when 121 redds were observed. High river discharge prevented the survey in 2012 from being conducted, and the survey in 2014 was terminated earlier due to poor visibility, although twenty one redds were observed.

The Duncan River watershed is an important contributor to the Kootenay Lake Bull Trout population (ONA/Golder Associates 2017). Each year from May to September, Bull Trout migrate from Kootenay Lake to spawn in the upper Duncan watershed, passing through the Duncan Dam. This requires a specific series of steps involving the low level operating gates (LLOG) which are manipulated to act 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 4, 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.

In 2016, the number of Bull Trout passed through the dam was estimated to be 101, which is the lowest number over the 22 years on record. A large reduction in Bull trout redds in other tributaries to Kootenay Lake has also been observed beginning in 2009, and suggests a widespread decline in the Bull Trout population (MFLNRO 2016). Bull Trout are likely able to adapt to the large reduction in Kootenay Lake Kokanee abundance which started in 2012, as indicated by their ability to prey-switch and forego spawning in poor growth environments. However, if low Kokanee abundance in Kootenay Lake persists, Bull trout populations may be severely impacted (MFLNRO 2016).

Table 4. Estimated number of Bull Trout transferred and number of transfers at Duncan Dam from 1995 to 2016. (BC Hydro data on file)

Year	Estimated # of Bull Trout	# of transfers	Westfall River redd count
1995	461	13	
1996	275	10	
1997	295	12	
1998	855	11	
1999	665	8	
2000	382	10	
2001	286	9	
2002	568	8	
2003	210	7	
2004	399	9	
2005	310	10	
2006	372	8	
2007	371	9	
2008	531	9	
2009[a]	725	9	
2010	1200	10	
2011	742	8	121
2012[b]	424	10	No survey
2013	991	7	
2014	180	9	(21)
2015	255	8	
2016	101	8	46

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

5.3 Management Hypotheses

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

This hypothesis can not be rejected. 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 (O'Brien 2001).

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 for both Kokanee and Bull Trout (de Zwart *et al.* 2012) as shore spawning and tributary habitat within the drawdown zone are both impacted by reservoir operations. However, these have little impact, and have little biological significance, since the majority of Kokanee spawning and Bull Trout spawning and juvenile rearing occurs in areas upstream of the reservoir (see Section 1.23).

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 zone, 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 (Table 1), 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 – early October. Residency time at spawning locations in the upper Duncan River watershed was estimated to be from 29 Aug – 28 September (O'Brien 2001). In 2012, Bull Trout were observed spawning on September 24th (de Zwart et al. 2013), while very few adult Bull trout have been observed in the Westfall River during the redd surveys conducted to date. The assumptions made during the WUP process appear to be slightly conservative in that they encompass a wider time period (early –September – mid-October) 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 7 and 8.

5.4.4.1 Kokanee

Reservoir operations do not appear to have a direct impact on habitat used by the majority of Kokanee (Table 5), 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 ~2%) 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 Alternative S73 in 2010 is not expected to result in any significant changes in productivity compared to reservoir operations prior to 2010.

Table 5. Summary of Kokanee life stages and potential influences due to Duncan Dam reservoir operations.

Stage	Location(s)	Influence of Operations
Spawning/Incubation	Majority of redds in upper Duncan River outside of reservoir influence. Estimated <2% of population spawns along the shore of the reservoir or 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. However, 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 River 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.

A summary of Bull Trout life stages and the potential influence of reservoir operations on these are provided in Table 6. The implementation of Alternative S73 is not expected to have resulted in any changes that would have an effect on any Bull Trout life stage. Neither reservoir drawdown in the spring (see Figure 2), nor the Bull Trout transfer protocol, has changed with the implementation of Alternative S73.

Table 6. Summary of Bull Trout life stages and potential influences due to Duncan Dam 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?

The implementation of Alternative S73 has had little effect on reservoir elevations compared to historical operations, particularly during the growing season (Figure 2), and is therefore expected to result in little or no change in fish productivity. As there is almost no information available from prior to the implementation of Alternative S73, it is difficult to address this question directly, for example by a before/after comparison of kokanee counts.

The expected Kokanee productivity for the reservoir was calculated based on estimates of primary productivity and comparison with similar reservoir systems in the region (de Zwart et. al 2011), and the results of kokanee spawner surveys have been generally consistent with these estimates. Better estimates of the Kokanee biomass in the Duncan Reservoir may be obtained through hydroacoustic monitoring, which was initiated in 2016 as part of DDMMON 17 - Duncan Reservoir Kokanee Stock Assessment.

6 REFERENCES

Baxter, J. S. 1995. Chowade River Bull Trout Studies 1995: Habitat and Population Assessment. Report prepared for British Columbia Ministry of Environment, Lands and Parks, Fisheries Branch, Fort St. John, British Columbia, 108p. St. John, British Columbia, 108p.

Baxter, J.S. and J.D. McPhail. 1996. Bull Trout Spawning and Rearing Habitat Requirements: Summary of the Literature. Fisheries Technical Circular No. 98.

BC Hydro 2005. Duncan Dam Water Use Plan. Consultative Committee Report. September 2005. Prepared on behalf of the Consultative Committee for the Duncan Dam Water Use Plan.

BC Hydro. 2007. Duncan Dam Water Use Project. Revised for Acceptance by the Comptroller of Water Rights. December 20th, 2007.

BC Hydro 2008. Duncan Dam Project Water Use Plan Monitoring Program Terms of Reference: DDMMON-10 Duncan Reservoir Fish Habitat Use Monitoring.

BC Hydro 2010. Duncan Dam Bull trout Passage Monitoring. Implementation Year 2. DDMMON6. Prepared by BC Hydro.

Decker, S, J. Hagen & J. Baxter. 2005. Feasibility of juvenile and adult Bull Trout abundance monitoring in selected tributaries of the Arrow lakes Reservoir. Prepared for the Columbia Basin Fish and Wildlife Compensation and BC Hydro and Power Authority.

de Zwart, I, G. Andrusak, J. Thorley, R. Irvine & S. Masse. 2010. Duncan Reservoir Fish Habitat Use Monitoring (DDMMON-10). Year 2 (2009) Data Report. Report prepared for BC Hydro, Water License Requirements. Prepared by Masse Environmental Consultants Ltd., Redfish Consulting Ltd. and Poisson Consulting Ltd. 57 pp + 2 App.

de Zwart, I, G. Andrusak, J. Thorley, R. Irvine & S. Masse. 2011. Duncan Reservoir Fish Habitat Use Monitoring (DDMMON-10). Year 3 (2010) Data Report. Report prepared for BC Hydro, Water License Requirements. Prepared by Masse Environmental Consultants Ltd., Redfish Consulting Ltd. and Poisson Consulting Ltd. 89 pp + 2 App.

de Zwart, I, G. Andrusak, J. Thorley, R. Irvine & S. Masse. 2012. Duncan Reservoir Fish Habitat Use Monitoring (DDMMON-10). Year 4 (2011) Interpretive Report. Report prepared for BC Hydro, Water License Requirements. Prepared by Masse Environmental Consultants Ltd., Redfish Consulting Ltd. and Poisson Consulting Ltd. 42 pp + 3 App.

de Zwart, I, G. Andrusak, H. McGregor, 2013. Duncan Reservoir Fish Habitat Use Monitoring (DDMMON-10). Year 5 (2012) Report. Report prepared for BC Hydro, Water License Requirements. Prepared by Masse Environmental Consultants Ltd., Redfish Consulting Ltd. and Okanagan Nation Alliance Fisheries Department. 42 pp + 3 App.

de Zwart, I., K. Beach, K & M. Zimmer. 2015. Duncan Reservoir Fish Habitat Use Monitoring (DDMMON-10). Year 7 (2014) Report. Report prepared for BC Hydro, Water License Requirements. Prepared by Masse Environmental Consultants Ltd. and Okanagan Nation Alliance Fisheries Department. 42 pp + 3 App.

LGL, ONA, and Poisson 2016. 2014 Lower Duncan River Kokanee Spawning Monitoring. Implementation Year 7 Data Report. (DDMMON-4). Report Prepared for: BC Hydro, Burnaby.

McPhail, J. D., and C. B. Murray. 1979. The early life history and ecology of Dolly Varden (*Salvelinus malma*) in the upper Arrow Lakes. Report to BC Hydro and British Columbia Ministry of Environment, Fisheries Branch, Nelson BC.

MFLNRO [Ministry of Forests, Lands and Natural Resource Operations] 2016. Kootenay Lake Action Plan.

Ney, J. 1996. Oligotrophication and its discontents: effects of reduced nutrient loading on reservoir fisheries. American Fisheries Society Symposium 16:285-295

O'Brien, D.S. 2001. Bull Trout Spawning Migrations in the Duncan River: Insights from telemetry and DNA. Prepared for the Columbia Basin Fish & Wildlife program.

Okanagan Nation Alliance and Golder Associates. 2016. Upper Duncan Bull Trout Migration Monitoring – Final Report February 2017. Report prepared for BC Hydro, Castlegar, BC. 30 pages + 2 appendices.

Perrin, C.J. and J.S. Korman. 1997. A Phosphorus Budget and Limnological Descriptions in Duncan Reservoir, 1994-95. Report prepared by Limnotek Research and Development Inc., Vancouver, BC for BC Hydro Castlegar, BC 110 p.

Porto, L, C. Lawrence, J. Thorley. 2013. Lower Duncan River Kokanee Spawning Monitoring (DDMMON-4). Year 5 Data Report. Report Prepared for: BC Hydro, Burnaby. Prepared by: AMEC Environment & Infrastructure Ltd. 22 pp + 2 App.

Stockner, J. G., E. Rydin, and P. Hyehstrand. 2000. Cultural oligotrophication: causes and consequences for fisheries resources. Fisheries 25 (5):7-14.

Vonk 2001. Status of Knowledge Report: Duncan Dam. A fisheries assessment and Planning study. Prepared for BC Hydro, Kootenay Generation Area.

WSC 2012. Water Survey of Canada. Hydrometric data. http://www.ec.gc.ca/rhc-wsc/.

APPENDIX 1

SUMMARY OF KOKANEE COUNT OCTOBER 4, 2016

Date	Time	Species	UTM	Count	Comment
04/10/16	1:50:02	KO	11 U 496524 5606899	30	
04/10/16	1:51:02	KO	11 U 496477 5607099	20	
04/10/16	1:51:17	KO	11 U 496492 5607158	5	
04/10/16	1:51:47	KO	11 U 496483 5606897	150	
04/10/16	1:52:02	KO	11 U 496522 5606911	9	
04/10/16	1:58:47	KO	11 U 496611 5607649	20	
04/10/16	2:01:32	KO	11 U 496904 5607808	30	
04/10/16	2:03:17	KO	11 U 497302 5607223	20	Devils 3
04/10/16	2:03:47	KO	11 U 497295 5607206	20	Devils 3
04/10/16	2:04:32	KO	11 U 497250 5607138	150	Devils 2
04/10/16	2:05:17	KO	11 U 497238 5607047	40	Devils 2
04/10/16	2:05:32	KO	11 U 497237 5607035	200	Devils 1
04/10/16	2:05:47	KO	11 U 497242 5607024	20	Devils 1
04/10/16	2:14:47	KO	11 U 496980 5608708	10	
04/10/16	2:15:02	KO	11 U 496957 5608741	5	
04/10/16	2:16:29	KO	11 U 496761 5608997	5	
04/10/16	2:17:29	KO	11 U 496836 5608688	100	
04/10/16	2:17:44	KO	11 U 496848 5608664	30	
04/10/16	2:19:14	KO	11 U 496888 5608531	5	
04/10/16	2:19:29	KO	11 U 496892 5608545	10	
04/10/16	2:19:44	KO	11 U 496892 5608550	50	
04/10/16	2:19:59	KO	11 U 496894 5608559	30	
04/10/16	2:23:29	KO	11 U 496682 5609277	250	
04/10/16	2:24:14	KO	11 U 496665 5609251	50	
04/10/16	2:25:14	KO	11 U 496747 5609092	10	
04/10/16	2:26:29	KO	11 U 496837 5608898	30	
04/10/16	2:27:29	KO	11 U 496607 5609477	2	
04/10/16	2:30:14	KO	11 U 496362 5609787	200	Bat at 60 km, ground count = 242
04/10/16	2:31:29	KO	11 U 496376 5609999	30	
04/10/16	2:32:14	KO	11 U 496376 5610013	150	
04/10/16	2:32:44	KO	11 U 496355 5610016	10	
04/10/16	2:32:59	KO	11 U 496361 5610020	5	
04/10/16	2:34:29	KO	11 U 496298 5610111	20	
04/10/16	2:34:44	KO	11 U 496300 5610123	5	
04/10/16	2:34:59	KO	11 U 496305 5610145	60	
04/10/16	2:35:14	KO	11 U 496308 5610176	50	
04/10/16	2:35:44	KO	11 U 496357 5610251	60	
04/10/16	2:37:14	KO	11 U 496353 5610332	1000	
04/10/16	2:39:59	KO	11 U 496384 5610533	225	
04/10/16	2:40:44	KO	11 U 496418 5610612	5	

04/10/16	2:41:29	KO	11 U 496467 5610654	80	
04/10/16	2:42:29	KO	11 U 496500 5610718	10	
04/10/16	2:43:44	KO	11 U 496584 5610736	20	
04/10/16	2:44:59	KO	11 U 496681 5610889	30	
04/10/16	2:45:14	KO	11 U 496707 5610901	5	
04/10/16	2:47:30	KO	11 U 496873 5610505	20	
04/10/16	2:49:45	KO	11 U 496598 5610189	15	
04/10/16	2:50:30	KO	11 U 496484 5610079	10	
04/10/16	2:51:15	KO	11 U 496413 5610014	10	
04/10/16	2:53:00	KO	11 U 496709 5610972	30	
04/10/16	2:53:15	KO	11 U 496708 5610995	80	
04/10/16	2:54:15	KO	11 U 496606 5611269	30	
04/10/16	2:54:30	KO	11 U 496572 5611329	20	
04/10/16	2:55:30	KO	11 U 496552 5611405	50	
04/10/16	2:58:00	KO	11 U 496371 5611508	50	
04/10/16	2:59:00	KO	11 U 496368 5611713	40	SC at 63 km
04/10/16	2:59:15	KO	11 U 496367 5611736	150	SC at 63 km
04/10/16	2:59:45	KO	11 U 496353 5611788	40	SC at 63 km
04/10/16	3:02:15	KO	11 U 496434 5612035	15	
04/10/16	3:03:00	KO	11 U 496467 5611805	10	
04/10/16	3:03:15	KO	11 U 496492 5611700	5	
04/10/16	3:03:30	KO	11 U 496489 5611635	5	
04/10/16	3:05:15	KO	11 U 496438 5611766	15	
04/10/16	3:07:00	KO	11 U 496392 5612256	350	
04/10/16	3:07:45	KO	11 U 496385 5612365	300	
04/10/16	3:08:15	KO	11 U 496351 5612410	100	
04/10/16	3:09:15	KO	11 U 496329 5612506	80	
04/10/16	3:09:45	KO	11 U 496300 5612590	10	
04/10/16	3:10:30	KO	11 U 496302 5612639	100	
04/10/16	3:10:45	KO	11 U 496296 5612670	30	
04/10/16	3:49:00	KO	11 U 495963 5612716	30	
04/10/16	3:49:15	KO	11 U 496014 5612695	100	
04/10/16	3:49:30	KO	11 U 496035 5612684	350	
04/10/16	3:50:30	KO	11 U 496200 5612615	50	
04/10/16	3:51:00	KO	11 U 496192 5612596	40	
04/10/16	3:53:00	KO	11 U 496085 5612593	10	
04/10/16	3:55:00	KO	11 U 495782 5612746	10	
04/10/16	3:56:00	KO	11 U 495904 5612670	250	
04/10/16	3:59:00	KO	11 U 495676 5612770	250	
04/10/16	4:00:45	KO	11 U 495573 5612873	100	WPT 128
04/10/16	4:01:00	KO	11 U 495563 5612876	100	WPT 128
04/10/16	4:02:15	KO	11 U 495469 5612938	300	WPT 128

04/10/16	4:02:30	KO	11 U 495449 5612966	500	WPT 128
04/10/16	4:03:45	KO	11 U 495352 5613136	50	
04/10/16	4:05:30	KO	11 U 495128 5613216	10	
04/10/16	4:07:00	KO	11 U 495306 5613259	90	
04/10/16	4:07:15	KO	11 U 495331 5613243	100	
04/10/16	4:08:00	KO	11 U 495379 5613207	250	
04/10/16	4:08:15	KO	11 U 495408 5613175	30	
04/10/16	4:08:30	KO	11 U 495417 5613158	30	
04/10/16	4:10:00	KO	11 U 495657 5612844	30	
04/10/16	4:10:45	KO	11 U 495863 5612782	20	
04/10/16	4:13:30	KO	11 U 495006 5613635	150	
04/10/16	4:13:45	KO	11 U 495008 5613647	80	
04/10/16	4:14:00	KO	11 U 494993 5613667	30	
04/10/16	4:14:30	KO	11 U 494985 5613699	100	
04/10/16	4:15:00	KO	11 U 494980 5613749	300	
04/10/16	4:16:00	KO	11 U 495091 5613569	150	
04/10/16	4:17:45	KO	11 U 494947 5614022	500	
04/10/16	4:20:00	KO	11 U 494722 5614423	20	
04/10/16	4:21:00	KO	11 U 494682 5614614	40	
04/10/16	4:22:00	KO	11 U 494631 5614744	40	
04/10/16	4:24:30	KO	11 U 494224 5615161	10	
04/10/16	4:25:15	KO	11 U 494176 5615213	70	
04/10/16	4:25:45	KO	11 U 494104 5615278	20	
04/10/16	4:26:30	KO	11 U 494073 5615292	200	
04/10/16	4:28:15	KO	11 U 494022 5615340	40	
04/10/16	4:30:45	KO	11 U 493824 5615603	10	
04/10/16	4:31:15	KO	11 U 493789 5615608	25	
04/10/16	4:31:45	KO	11 U 493750 5615623	80	
04/10/16	4:33:30	KO	11 U 493668 5615667	400	
04/10/16	4:33:45	KO	11 U 493660 5615663	60	
04/10/16	4:34:15	KO	11 U 493642 5615573	150	
04/10/16	4:37:30	KO	11 U 493348 5616046	20	
04/10/16	4:40:30	KO	11 U 493011 5616360	150	
04/10/16	4:41:45	KO	11 U 492834 5616707	5	
04/10/16	4:42:45	KO	11 U 492632 5616892	2	
04/10/16	4:44:00	KO	11 U 492546 5617006	30	
04/10/16	4:48:30	KO	11 U 492124 5617452	120	
04/10/16	4:48:45	KO	11 U 492084 5617521	10	
04/10/16	4:50:15	KO	11 U 491638 5617781	25	
04/10/16	4:51:00	KO	11 U 491397 5617922	30	
04/10/16	4:51:45	KO	11 U 491161 5618114	5	
04/10/16	4:52:15	KO	11 U 491133 5618193	200	

04/10/16	4:52:30	KO	11 U 491101 5618219	50	
04/10/16	4:53:00	KO	11 U 491052 5618306	400	
04/10/16	4:53:30	KO	11 U 491016 5618387	300	
04/10/16	4:53:45	KO	11 U 490997 5618425	800	
04/10/16	4:54:30	KO	11 U 490970 5618521	200	
04/10/16	4:55:45	KO	11 U 490894 5618616	30	
04/10/16	4:57:30	KO	11 U 490299 5619144	50	
04/10/16	4:57:45	KO	11 U 490182 5619251	20	
04/10/16	4:58:45	KO	11 U 489871 5619598	100	
04/10/16	5:00:15	KO	11 U 489788 5619760	1500	
04/10/16	5:07:00	KO	11 U 489203 5620308	10	
04/10/16	5:07:30	KO	11 U 488976 5620509	10	
04/10/16	5:07:45	KO	11 U 488918 5620555	80	
04/10/16	5:08:45	KO	11 U 488748 5620833	100	
04/10/16	5:09:00	KO	11 U 488703 5620863	50	
04/10/16	5:09:15	KO	11 U 488595 5620900	80	
04/10/16	5:10:15	KO	11 U 488569 5621090	150	
04/10/16	5:11:00	KO	11 U 488773 5620857	50	Stopped survey due to lack of fuel and poor light

APPENDIX 2

SUMMARY OF BULL TROUT REDD SURVEY

ID	Easting	Northing	Elevation (m)	Waypoint	Time	Redds	Comment
1	476897	5627776	1089	134	23-OCT-16 8:40:12AM	0	Heli pickup day 2
2	472572	5631855	1153	135	23-OCT-16 8:50:23AM	0	Start Day 1
3	472677	5631804	1143	136	23-OCT-16 9:13:26AM	1	
4	472688	5631732	1165	137	23-OCT-16 9:21:17AM	1	
5	472688	5631391	1154	138	23-OCT-16 9:44:37AM	2	
6	473009	5630997	1111	139	23-OCT-16 10:07:47AM	1	
7	473084	5630803	1159	140	23-OCT-16 10:20:37AM	2	
8	473351	5630461	1128	141	23-OCT-16 10:51:19AM	1	
9	473392	5630461	1120	142	23-OCT-16 10:58:07AM	3	
10	473648	5630255	1122	143	23-OCT-16 11:17:18AM	1	
11	473679	5630231	1120	144	23-OCT-16 11:23:17AM	1	
12	473735	5630180	1122	145	23-OCT-16 11:26:21AM	3	
13	473772	5630156	1126	146	23-OCT-16 11:28:48AM	1	
14	473856	5629927	1105	147	23-OCT-16 11:40:12AM	2	
15	474047	5629795	1112	148	23-OCT-16 11:51:22AM	2	
16	474187	5629664	1104	149	23-OCT-16 11:58:35AM	1	
17	474239	5629645	1110	150	23-OCT-16 12:12:36PM	1	
18	474268	5629623	1108	151	23-OCT-16 12:14:40PM	1	
19	474496	5629575	1109	152	23-OCT-16 12:25:35PM	2	
20	474702	5629120	1099	153	23-OCT-16 12:43:16PM	1	
21	474912	5628783	1098	154	23-OCT-16 1:02:28PM	1	
22	475820	5628218	1090	155	23-OCT-16 1:52:07PM	1	
23	476078	5628101	1090	158	23-OCT-16 2:07:47PM	2	
24	476092	5628025	1089	159	23-OCT-16 2:11:05PM	1	
25	476104	5627994	1086	160	23-OCT-16 2:13:54PM	1	
26	476273	5627813	1080	161	23-OCT-16 2:22:57PM	2	
27	476543	5627788	1080	162	23-OCT-16 2:39:27PM	1	
28	476796	5627778	1073	163	23-OCT-16 2:51:15PM	7	
29	476870	5627682	1079	164	23-OCT-16 2:58:46PM	1	
30	476841	5627568	1073	165	23-OCT-16 3:05:14PM	1	
31	477307	5627191	1054	166	23-OCT-16 3:37:09PM	1	
32	477488	5627172	1075	167	23-OCT-16 3:44:04PM	0	End Day 1
33	481452	5626055	942	168	24-OCT-16 8:21:39AM	0	Heli pickup day 2