Duncan Dam Project Water Use Plan

2014 Lower Duncan River Kokanee Spawning Monitoring

Implementation Year 7 Data Report

Reference: DDMMON 4

DDMMON 4 2014 Lower Duncan River Kokanee Spawning Monitoring

Study Period: September – October 2014

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EXECUTIVE SUMMARY

The Duncan Dam (DDM) Water Use Planning (WUP) process was initiated to address flow management issues related to local resources such as Lower Duncan River (LDR) Kokanee populations. Monitoring of the abundance of Kokanee spawning in this area was initiated by BC Hydro in 2008 as part of its Water License Requirements (WLR) DDMMON#4 program. 2014 represented the seventh year of this ten year monitoring program and as in the previous six years, Kokanee spawner counts were carried out from a helicopter. In addition to aerial counts, preferred spawning habitats and observer efficiency verification were determined on the ground during stream walks. Year 7 represents the continuation of the work carried out by ONA and LGL in 2013 (Zimmer et al. 2015) and previous to that by AMEC from 2008–2012 (AMEC 2009, AMEC 2010, AMEC 2011, AMEC 2012, AMEC 2013). For standardization of methods between the surveys carried out by AMEC from 2008–2012 and ONA in 2013, previously established methods were applied whenever possible and improved where necessary. None of the changes made in 2014 affected the comparability of 2014 results with results obtained in previous years.

Based on an Area Under the Curve (AUC) calculation, the 2014 Kokanee spawning population in the Lower Duncan River was estimated to be 22,080 fish, with a lower 95% Confidence Interval (CI) of 7,280 fish and an upper 95% CI of 45,000 fish. In comparison to previous years, the 2014 estimate can be categorized as low but comparable to 2013 (20,300 spawners), 2009 (19,600 spawners) and 2010 (19,000 spawners) levels but much lower than the highest estimate of 75,600 spawners in 2012.

Specific management questions defined in the DDMMON#4 Terms of Reference (TOR) and the progress made in addressing them is summarized in Table 1.

Table 1. Management questions and the status of the answers to them based on field work and data analysis carried out as part of the BC Hydro project DDMMON-4.

Management Question	Status
1. What is the spawn run timing, fry emergence timing, and relative intensity of kokanee spawning in the Lower Duncan River? What potential operational/environmental cues affect this variable?	Spawn Run Timing: Based on AMEC (2013) and ONA and LGL (2015), between 2008 and 2013 Kokanee spawned in the LDR from late August to late October and peak spawning occurred from September 20 – October 10. In 2014, the peak of Kokanee spawning activity was observed on October 5, 2014 within the range of peaks observed from 2008–2013. Changes in LDR flow and decreasing seasonal trend in water temperature did not trigger changes in spawning migration or the distribution pattern of Kokanee spawners in the LDR. Fry Emergence Timing: In general, fry emergence timing is dependent on the Accumulated Thermal Units or ATUs of fish eggs during incubation and early development. Based on observations in AMEC (2013) and ONA and LGL (2015), the DDM low level outlets (LLOs) discharge water may be warmer than surface waters in the winter, resulting in emergence timing that is earlier for LDR kokanee than seen in adjacent systems such as Meadow Creek and Lardeau River. Temperature profiles during the incubation period have not been

	explicitly collected to determine the effect of operations on emergence timing. <u>Relative Intensity of Spawning in the LDR in Comparison to Lardeau River and Meadow Creek:</u> In 2014 the majority of Kokanee in the Duncan River watershed spawned in Meadow Creek (47%) and the Lardeau River (43%) while only a small portion of the fish spawned in the LDR (10%), which is a similar hierarchy as in 2008-2013 (AMEC 2013; Zimmer et al. 2015). <u>DDM operational Effects:</u> According to AMEC (2013), the regulated flow through DDM may have led to substrate compaction and thus reduced the amount of Kokanee spawning habitat when compared with the amount of historical spawning habitat.
2. What are the timing/cues of Kokanee spawners in Meadow Creek and Lardeau River systems?	<u>Spawn Timing:</u> Kokanee spawning in Meadow Creek occurs from mid-August to late October with peak spawning from end of September (AMEC 2013; Zimmer et al. 2015) to first week of October(this study). In this context, water temperature does not appear to either influence the arrival of Kokanee in the LDR or their spawn timing. In 2014, water release through DDM was kept constant throughout most of the spawning period (October 1 – 21) and therefore neither water temperature nor discharge fluctuated enough to act as a possible cue for spawn timing or river entry. It is known that Kokanee spawning in the Lardeau River occurs from early September to mid-October but it is unknown which environmental cues trigger river entry or spawning in the Lardeau River (AMEC 2013).
3. What are the relative distribution of Kokanee spawners in the Lower Duncan River, Meadow Creek and Lardeau River? What potential operation/ environmental/ physical cues (e.g., temperature, velocity, depth, cover, substrate) affect this variable?	<u>Kokanee Spawner Distribution in the LDR:</u> In 2014 and in all earlier years (AMEC 2013; Zimmer et al. 2015) of DDMMON-4, Kokanee spawning has been limited to the upper 9 km of the 12 Km study area (LDR Kms 1-9), where gravel suitability is highest. Gravel suitability is lowest in the reaches proximal to the confluence with Kootenay Lake due to sediment deposition that occurs each freshet (NHC 2010). In 2014 and from 2008–2013 (AMEC 2013; Zimmer et al. 2015), early Kokanee holding and initial spawning starts in side channels but then spreads to the main channel during the peak of spawning. Kokanee may initially move into side channels to seek out low velocity and cooler holding habitat with cover to minimize energy expenditure and avoid predation as has been observed for Kokanee in Meadow Creek (AMEC 2013). <u>Kokanee Spawner Distribution Meadow Creek:</u> In Meadow Creek, the majority of spawning occurs in the 3 km of Meadow Creek Spawning Channel (located approximately 4 km upstream of the confluence with the Lower Duncan River) with idealized conditions for Kokanee egg incubation. Areas outside of the spawning channel are mainly used when the spawning channel itself is filled to capacity with Kokanee

	spawners (AMEC 2013). The bottom substrate of the lower section of Meadow Creek has a high percentage of silt and fewer spawning gravels and is therefore limited in suitability for Kokanee spawning (Quamme 2008). <u>Kokanee Spawner Distribution Lardeau River:</u> Kokanee spawning in the Lardeau River has been observed along its whole length with the highest densities found in the upriver side channels. Based on its natural hydrograph, the Lardeau River experiences typical spring flush flows that aid in removing fines (AMEC 2013). As a general comment, genetic analysis of Kokanee spawning in the LDR, Lardeau River and Meadow Creek revealed that Kokanee spawners from the three locations are not genetically different. They are therefore considered to belong to the same Kokanee stock (AMEC 2012, Lemay and Russello 2011).
4. What physical works or operational constraints could be implemented to minimize operational conflicts associated with recommended Kokanee spawning operations?	A primary goal of this study is to identify opportunities to limit the potential stranding impact associated with kokanee spawning protection flows defined in the WUP. Due to the multiple factors limiting the ability to manipulate flows during the late September – early October period, and the limited feasibility of physical works to minimize access/impact to sidechannels affected by the spawning flows (AMEC 2012), any regime that can minimize flow reductions during peak spawning, and maintain incubation flows close to spawning flows will reduce conflicts with existing spawning operations. In 2014, kokanee spawning flows were reduced starting September 25th (vs October 1st, except for Kokanee Protection Test Flows in 2013 – starting Sept 27th) to a minimum flow of 75 m^3/s for the duration of the spawning period. Egg loss appeared to minimal (redds totalled 62 m^2) however, this is the first year (since 2008) that mainstem redds were dewatered.

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IMPORTANT NOTICE

1.0 INTRODUCTION

The Duncan Dam (DDM) was constructed from 1965 to 1967 for water storage under the Columbia River Treaty (CRT). Since 1967 the Lower Duncan River has been managed as a regulated river and is operated by BC Hydro for flood control purposes. The dam, which is situated 12.4 kilometers upstream of the north end of Kootenay Lake, regulates water levels in the Lower Duncan River (LDR) through daily, seasonal and annual operations (Figure 1) (AMEC 2013) to support Columbia River Treaty requirements. The complexity of up and downstream ecological function, and social and economic interests of the many users of the LDR and Kootenay Lake, poses many challenges for the operation of DDM. Therefore a Water Use Planning, or WUP, consultation process was initiated in 2001 and completed in 2004 to address flow management issues with respect to impacts on competing resources in the area (BC Hydro 2004; AMEC 2013). The DDM WUP Consultative Committee (CC) identified Kokanee (*Oncorhynchus nerka*) spawning success in the LDR as a valuable ecosystem component that could be impacted by DDM operations (BC Hydro 2007).

To address this concern, Kokanee escapement into the LRD has been monitored since 2008 as part of the DDMON-4 project. For the initial 5 years form 2008-2012 the Kokanee escapement was assessed by AMEC (AMEC 2009, AMEC 2010, AMEC 2011, AMEC 2012, AMEC 2013) and assessment was continued by ONA in 2013 (Zimmer et al. 2015).

Unlike 2013, no Kokanee Protection Test Flows (see Zimmer et al. 2015) were conducted in 2014. Flows from DDM were implemented according to Columbia River Treaty requirements. In summary, overall flows were held fairly consistent throughout the spawning and incubation periods for Kokanee which reduced the potential for redd desiccation and subsequent egg loss (mortality).

1.1 Objectives

DDMMON-4 is a 10 year project with the following specific objectives. Bolded objectives were addressed in Year 7 (2014) of this study and all other objectives were addressed from 2008–2013 (AMEC 2009-2013; Zimmer et al. 2015):

1. **Document the annual Kokanee escapement to the Lower Duncan River**, Lardeau River, Meadow Creek, and Meadow Creek Spawning Channel;
2. **Document Kokanee spawning in the Lower Duncan River within and outside of operational constraints**; and;
3. Define Kokanee spawning habitat preferences, timing and Kokanee morphology between spawning runs in the Lower Duncan River, Lardeau River and Meadow Creek for consideration of future decisions.

DDMMON-4 addresses the following management questions based on the terms of reference (BC Hydro 2008) and scope of services (BC Hydro 2013). Bolded management questions were addressed in Year 7 (2014) or this study and all other objectives were addressed from 2008–2012 (AMEC 2009-2013; Zimmer et al. 2015):

1. **What is the spawn run timing**, fry emergence timing, and relative intensity of K**okanee spawning in the Lower Duncan River**? What potential operational/environmental cues affect this variable?
2. What are the timing/cues of Kokanee spawners in Meadow Creek and Lardeau River systems?

3. **What are the relative distribution of Kokanee spawners in the Lower Duncan River**, Meadow Creek and Lardeau River? What potential operation/environmental/physical cues (e.g., temperature, velocity, depth, cover, substrate) affect this variable?; and
4. What physical works or operational constraints could be implemented to minimize operational conflicts associated with recommended Kokanee spawning operations?

1.2 Purpose

Currently, six years of monitoring have been completed (AMEC 2009-2013; Zimmer et al. 2015) with 2014 designated as Year 7 respectively within the total of 10 years of the DDMMON-4 program. This report fulfills the ONA and LGL commitment to provide BC Hydro with a data report for the 2014 (Year 7) monitoring of Kokanee spawning in the LDR, describing findings from assessments targeting the above listed objectives, in support of answering Management Questions, and providing recommendations associated with yearly and future Water Use Planning review.

2.0 METHODS

2.1 Study Area

The LDR is fed by DDM at its upstream end and flows over a distance of approximately 12.4 km into the northern end of Kootenay Lake, which is located north of Nelson in southeastern British Columbia. The Duncan River watershed above DDM receives input from the Selkirk and Purcell mountains. The 2013 study covered the entire 12.4 km of LDR from DDM (River Km 0.0) to Kootenay Lake (Km 12.4) and its side channels (Figure 1).

2.2 Environmental Parameters

Hourly Duncan Dam discharge records were obtained from BC Hydro and, Lower Duncan River flow and water temperature records were obtained from the Water Survey of Canada (WSC) gauge (No: 08NH118) (https://wateroffice.ec.gc.ca/report/report_e.html?type=realTime&stn=08NH118) to relate to Kokanee spawning timing, distribution and fry emergence timing.

2.3 Study Timing

A summary of Kokanee spawning monitoring dates and methods for 2014 is summarized in Table 2. Sampling methods included visual Kokanee counts from a helicopter and simultaneous aerial redd mapping. Simultaneously to two of the aerial overflights and stream walks were carried out on selected side-channels to assess observer efficiency for the helicopter counts. The selected side-channels had low and clear water and were un-shaded and thus offered optimum fish viewing conditions from the ground and air. During the ground count, counters also double counted each section to get the best possible count for validation of their own and the helicopter observer efficiency.

During aerial counts, the helicopter flew at a low altitude of 20–40 m above the river (AMEC 2012) at a low speed. Therefore all aerial surveys conformed with low level, low speed flight planning requirements of BC Hydro. Data collection methods for each type of survey are provided below.

Table 2. Sample timing and survey type for DDMMON-4 Lower Duncan River Kokanee spawner monitoring, 2014.

Date	Survey Type	Helicopter Type
September 15, 2014	Aerial enumeration survey	BO105LS, Dam Helicopters (Twin Rotor), Castlegar, BC
September 27, 2014	Aerial enumeration survey, Ground enumeration validation, Redd survey	
October 6, 2014	Aerial enumeration survey, Redd survey	
October 16, 2014	Aerial enumeration survey, Ground enumeration validation	

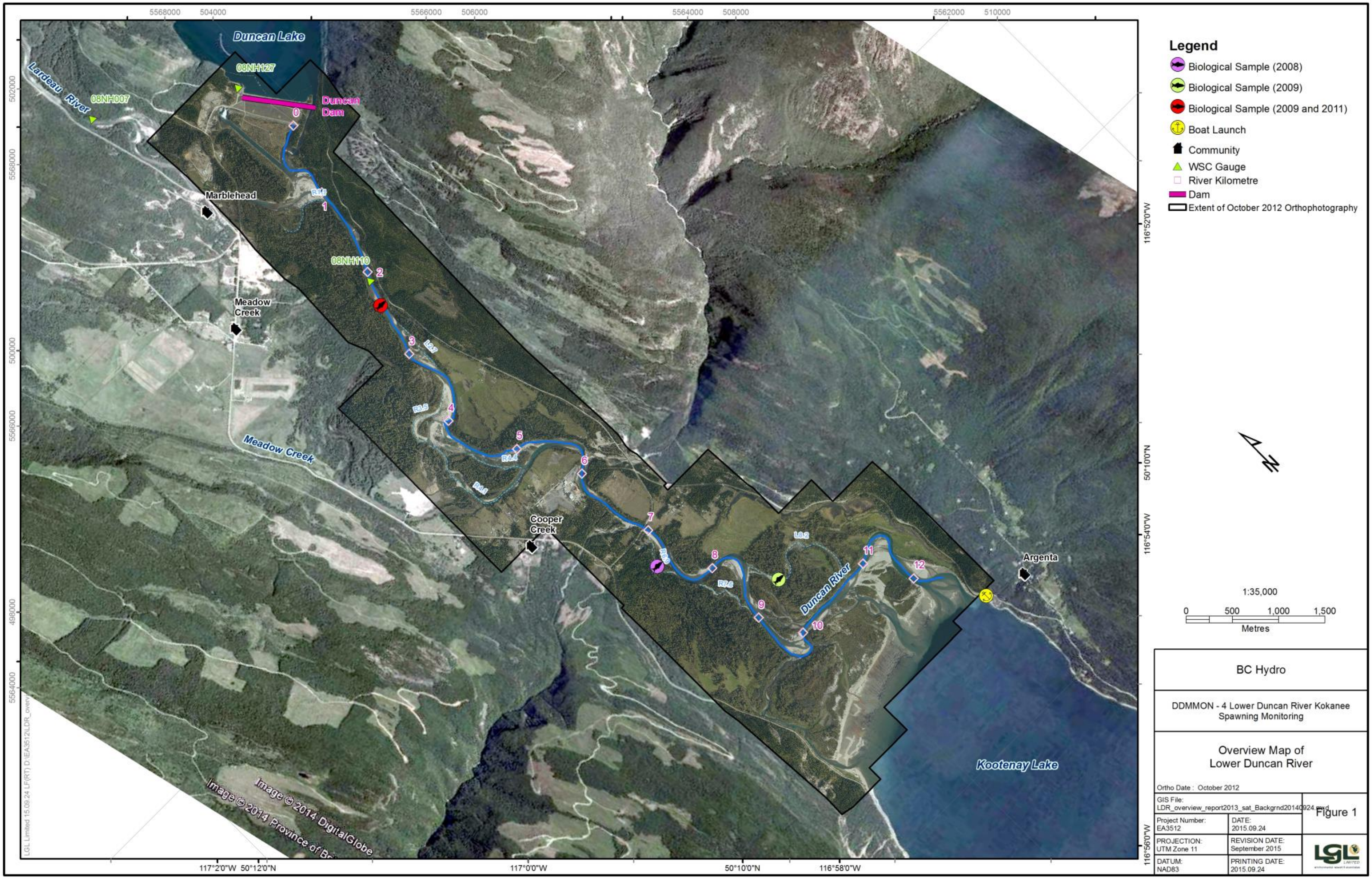

Figure 1. Lower Duncan River (LDR) study area for DDMMON 4 Kokanee enumeration and redd surveys (adapted from AMEC (2013)).

2.4 Helicopter Enumeration Surveys

All helicopter aerial surveys covered the entire length of the LDR from the delta in Kootenay Lake flying upstream to approximately 600 m below DDM and also covered all LDR side channels following the protocol that was used from 2008–2013 (AMEC 2009-2013; Zimmer et al. 2015). In 2014, all surveys were carried out using a BO105LS twin engine helicopter operated by Dam Helicopters (Castlegar, BC) and piloted by Duncan Wassick, who had operated the helicopter in previous surveys for DDMMON-4.

During the surveys, fish were visually counted and their numbers were recorded with tally counters by the lead fish counter in the front of the helicopter. The lead counter had an approximately 180^{o} view of the river because the helicopter was flying upstream at a 45^{o} angle to the direction of the current. The position, number and the extent of the area that Kokanee were using to hold or spawn was then manually drawn on a detailed 1:2,000 orthophoto and later geo-referenced as a polygon layer on a map. The crew member in the back seat of the helicopter also tallied kokanee observed using the same visual methods and recording materials. On the orthophotos of the main stem and the side-channels, 100 m orientation markings helped to describe the exact location of Kokanee over all four surveys. Each side channel and main stem reach was named and the naming conventions conformed to the conventions established in the 2008-2013 studies (AMEC 2009–2013; Zimmer et al. 2015). In addition to the number of fish and extent of the area the main counter categorized Kokanee behaviour as follows:

- **Holding** – Kokanee observed in a school that were holding stationary and did not appear to be spawning;
- **Migrating** – Kokanee observed in a school that were moving in an upstream direction and did not appear to be spawning;
- **Spawning** – Kokanee observed stationary and paired up and distributed evenly throughout an area (sometimes redd digging was observed); and
- **Dead** – Kokanee observed drifting at the surface belly up without any volitional movement.

All flights were conducted at approximately 20–40 m above the ground at a speed of 10–18 km/hr upstream. Depending on the terrain, safety hazards, and weather conditions, the helicopter had to increase elevation or speed at times. During each survey, the main stem of the LDR was surveyed first followed by individual side channels to ensure the surveys could be carried out in a systematic and consistent manner (AMEC 2013; Zimmer et al. 2015). For all surveys, Clint Tarala was the lead counter in the front of the helicopter. Clint Tarala also carried out the aerial surveys during the six previous years of DDMMON-4 and was therefore contracted to maintain consistency of observer efficiency between years. In addition to Clint Tarala, Gerry Nellestijn completed the crew in 2014 and benefited from Clint Tarala's previous experience. The methods used in 2014 followed the standards set for salmonid aerial counts throughout the Pacific Northwest (Jones et al. 2007).

2.5 Data Analyses

2.5.1 Area Under the Curve (AUC) Abundance Estimates

Repeated spawner counts can be converted into abundance estimates by dividing the area under the spawner curve (AUC) by the observer efficiency and residence time (English et al. 1992) where the residence time is the number of days fish spend on the spawning grounds. With the inclusion of an arrival time model, the method provides a basis for statistically describing uncertainty (Hilborn et al. 1999) and estimating spawn timing. When data is sparse hierarchical methods allow "borrowing strength" from years with informative data to improve estimates for years with uninformative data (Su et al. 2001). Here we used hierarchical Bayesian AUC methods with a normal arrival time model to estimate spawn timing and spawner abundance with credible intervals.

Hierarchical Bayesian models were fitted to the LDR Kokanee enumeration data using R version 3.0.2 (Team 2013) and JAGS 3.3.0 (Plummer, 2012) which interfaced with each other via Jaggernaut 1.6 (Thorley 2014). For additional information on hierarchical Bayesian modelling in the BUGS language, of which JAGS uses a dialect, the reader is referred to Kéry and Schaub (2011, pp. 41-44).

Unless specified, the models assumed vague (low information) prior distributions (Kéry and Schaub, 2011, p. 36). The posterior distributions were estimated from a minimum of 1,000 Markov Chain Monte Carlo (MCMC) samples thinned from the second halves of three chains (Kéry and Schaub 2011, pp. 38-40). Model convergence was confirmed by ensuring that Rhat (Kéry and Schaub 2011, p. 40) was less than 1.1 for each of the parameters in the model (Kéry and Schaub, 2011 p. 61). Model adequacy was confirmed by examination of residual plots.

The posterior distributions of the *fixed* (Kéry and Schaub 2011, p. 75) parameters are summarized in terms of a *point* estimate (mean), *lower* and *upper* 95% credible limits (2.5th and 97.5th percentiles), the standard deviation (*SD*), percent relative *error* (half the 95% credible interval as a percent of the point estimate) and *significance* (Kéry and Schaub 2011, p. 37,42).

The results are displayed graphically by plotting the modeled relationships between particular variables and the response with 95% credible intervals (CRIs) with the remaining variables held constant. In general, continuous and discrete fixed variables are held constant at their mean and first level values, respectively while random variables are held constant at their typical values (expected values of the underlying hyperdistributions) (Kéry and Schaub 2011, pp. 77-82). Where informative, the influence of particular variables is expressed in terms of the *effect size* (i.e., percent change in the response variable) with 95% credible intervals (Bradford et al. 2005). Plots were produced using the ggplot2 R package (Wickham 2009).

2.5.2 Observer Efficiency

Observer efficiency was based on a comparison between fish counts provided by ground counters with fish counts provided by aerial counters over the exact same sections. Surveys were completed on September 27 and October 16 at known side channel locations (i.e., SC 3.5 and SC 8.2) in the LDR. The ground surveys were conducted on the same day as the aerial surveys, immediately prior or past the fly-over, coordinated via radio communication. Ratios of ground counts to aerial counts were calculated by Poisson and compared to observer efficiency calculated from 2008-2013.

2.5.3 Relative Intensity of Spawning

Kokanee enumeration counts for the four surveys conducted in 2014 were analyzed to generate an estimate of the relative intensity of spawning run timing in the LDR as part of the AUC analysis. Spawning run abundance estimates for Meadow Creek and the upper Lardeau River were provided by Ministry of Forest Lands and Natural Resource Operations (MFLNRO) (M. Neufeld, unpublished data

2015). Enumeration data provided by MFLNRO were based on a single, aerial survey conducted on October 3, 2014. Clint Tarala led this survey as well.

2.5.4 Potential Egg Deposition and Losses

Potential egg deposition (PED) and loss calculations followed methods and assumptions on dewatering effects, spawn timing/superposition/predation, multiple-redd construction, and sex ratios employed by AMEC (2012, 2013), where peak counts were used to estimate female numbers, and where egg deposition for LDR Kokanee = average fecundity (225) – average egg retention(4). Redd mapping exercises were conducted on September 27 (prior to flow reduction) and October 6 (post flow reduction). Egg losses where calculated separately for side-channel and mainstem redds that were observed to be dewatered throughout the duration of the study period (September 15 to October 16, 2014).

The 1:500 orthophotos with redd locations were scanned and digitized by GIS and areas of redds measured. Comparisons were then made between observed redd locations (area, m^2) in side channels and mainstem to before and after flow reductions (September 28-October 2) to calculate PED.

3.0 RESULTS

Environmental Parameters

3.1 Lower Duncan River Discharge and Temperature

Based on data collected from Lower Duncan River Water Survey Canada (WSC) hydrometric station 08NH118 (Figure 2), the Kokanee spawning period in September and October 2014 was characterized by a regulated decrease from summer period flows through a step-wise decrease during the spawning period in late-September to early October as part of Columbia River Treaty flow release commitments (A. Leake, BC Hydro, pers comm.). Summer flows were stepped down from 262 m^3/s on September 25, 2014 in three steps: to 180 m^3/s on September 25; down to 110 m^3/s on September 28, 2014; (raised to 125 m^3/s on September 29); and reduced to 75m^3/s on October 1, 2014 (Figure 3. Duncan River (Stn 08NH118) discharge (m^3/s) and temperature (°C), September 10 - October 25, 2014. (Source: Environment Canada). Dashed lines indicate survey dates.

The third and final flow reduction between September 29 to October 1, lowered the water level in the LDR from 1.87 m to 1.67 m (Figure 4.), which compared to 2013 and prior levels which displayed slightly higher water levels during this period.

Water temperature data was summarized from the WSC station (Figure 2) to determine any correlations to timing of spawning and to predict incubation and emergence timing. Temperatures during spawning and through the duration of the field investigations followed seasonal trends, from 12.4 °C to 13.2 C (September 15-26), decreasing to 11.4 °C on October 3 and continuing to trend lower through the remainder of the spawning period to 10.3°C on October 25, 2014 (Figure 3).

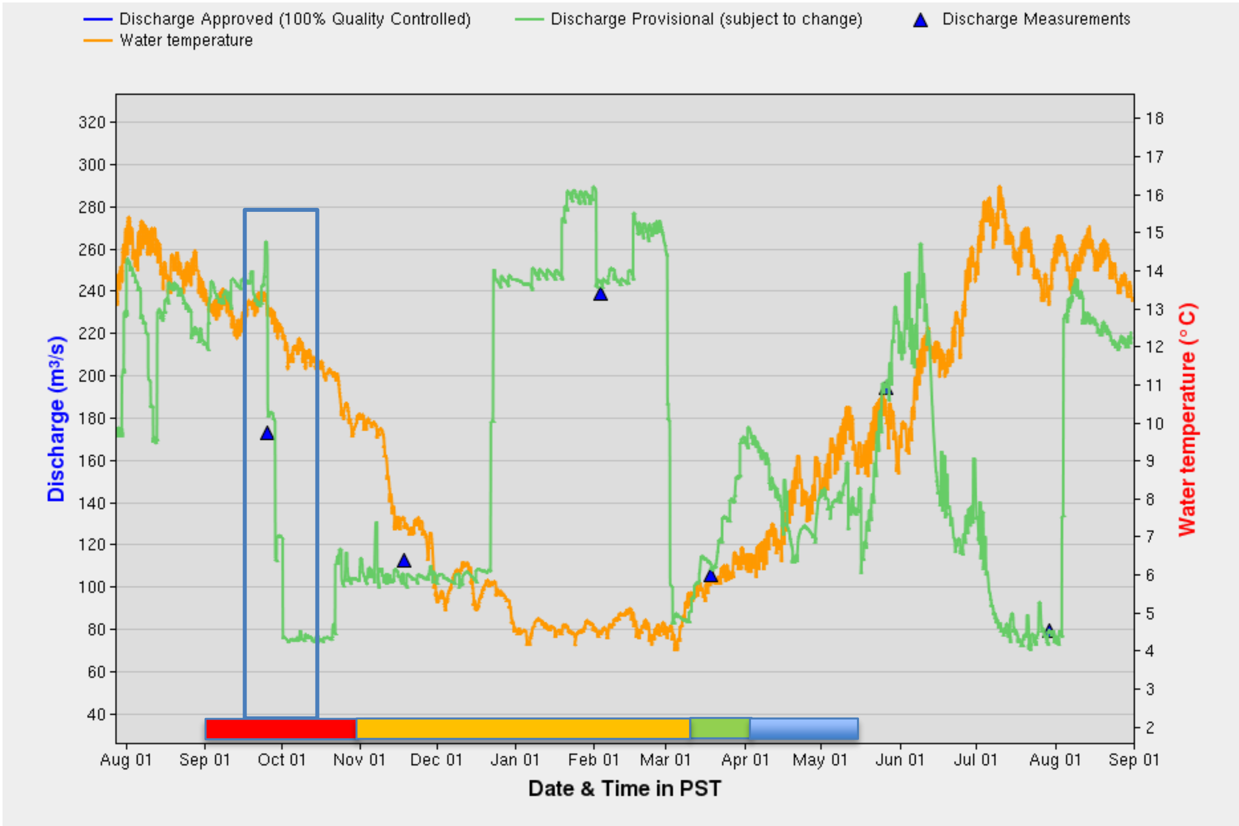

Figure 2. Discharge (m^3/s) and temperature (°C) for Duncan River at Lardeau River confluence for 2014-2015. Blue line box indicates Kokanee enumeration study period for DDMMON 4 (Source: Water Survey of Canada Stn. 08NH118). Solid colour boxes indicate kokanee life history in the Lower Duncan River: Red – Spawning (migration, holding, redd construction); Orange – Incubation; Green – Emergence; Blue – Ponding and out-migration (to Kootenay Lake) (Source: AMEC 2010).

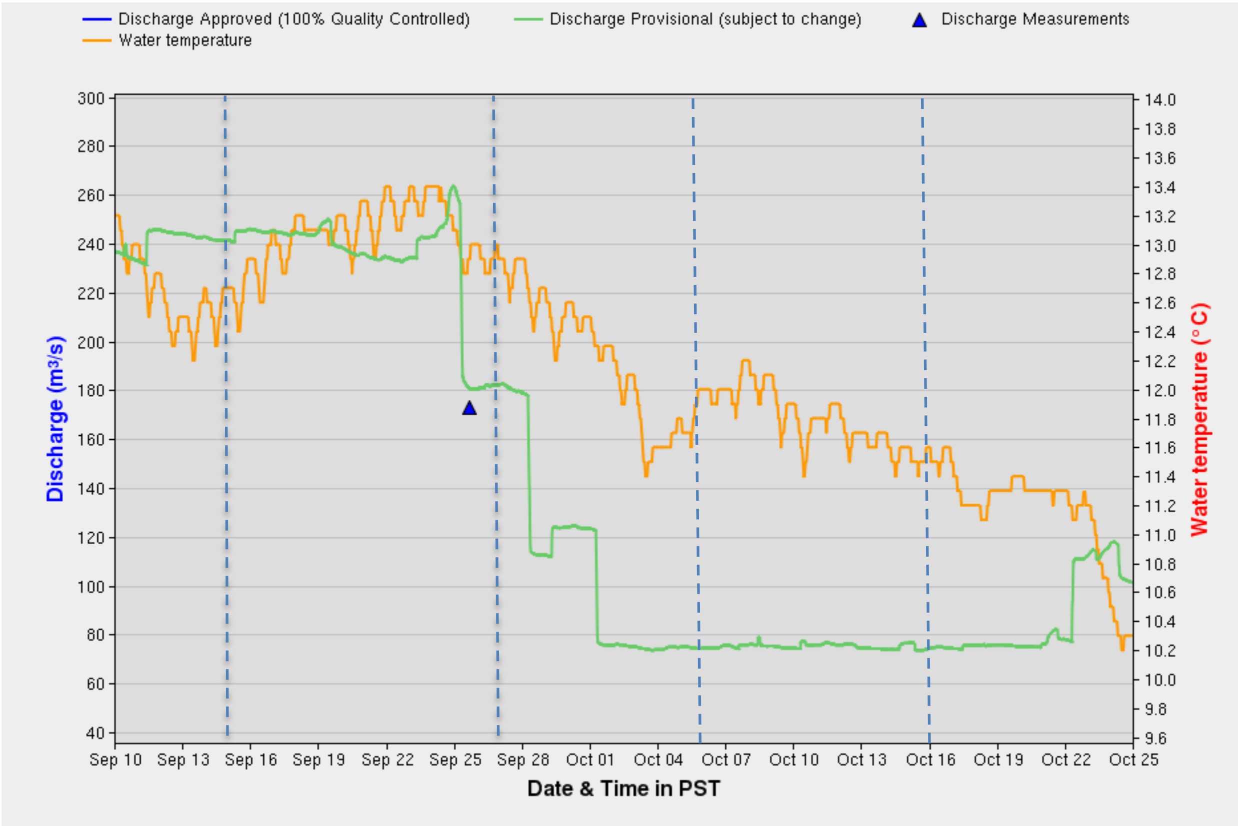

Figure 3. Duncan River (Stn 08NH118) discharge (m^3/s) and temperature (°C), September 10 - October 25, 2014. (Source: Environment Canada). Dashed lines indicate survey dates.

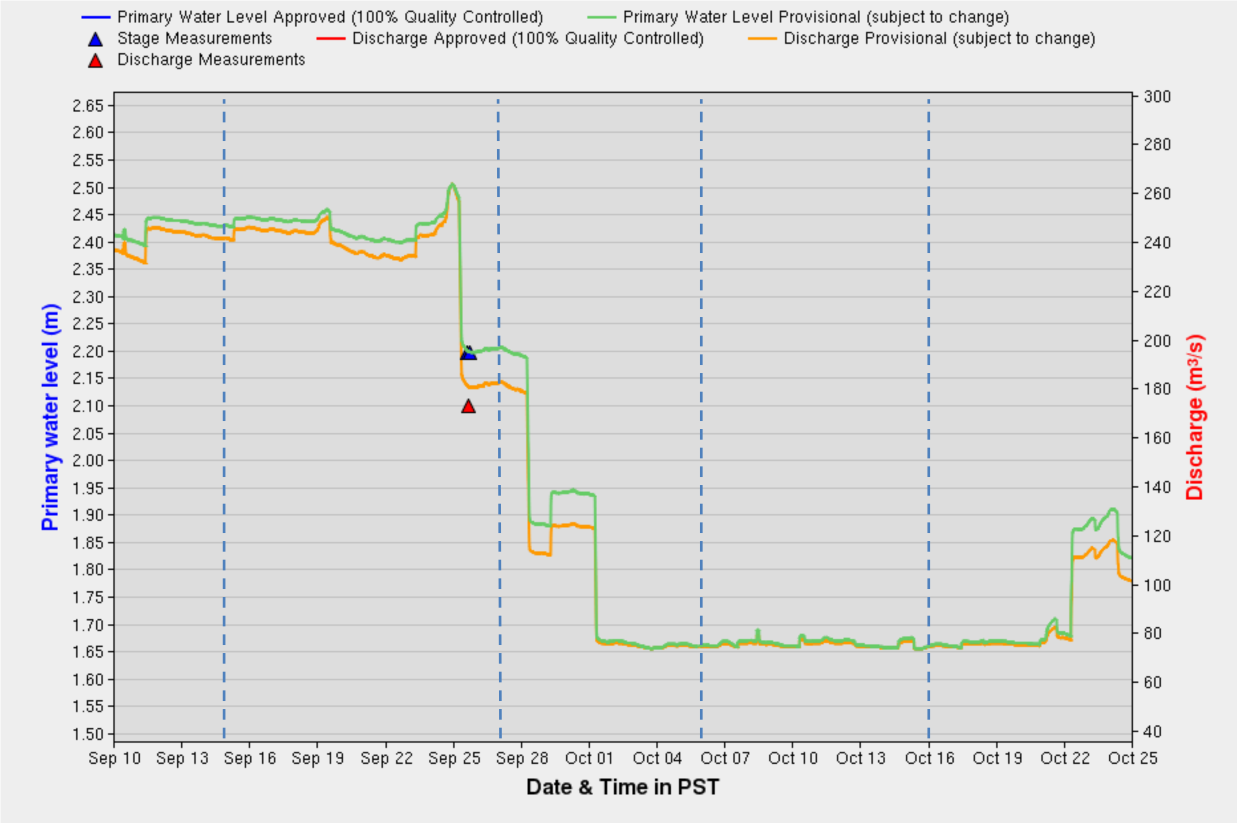

Figure 4. Duncan River (Stn 08NH118) water level elevation (m) and discharge (m^3/s), September 10-October 25, 2014. (source: Environment Canada; direct discharge measurement data not provided here). Dashed lines indicate survey dates.

3.2 Kokanee Peak Count Timing

The estimated peak spawn timing for Kokanee in 2014 and throughout the rest of the DDMMON-4 project period from 2008–2013 is shown in Figure 5 and a tabular summary for the peak spawn timing from 2008–2014 is shown in Table 3. Peak spawning was predicted for October 5 in 2014 (Figure 6). The 2014 peak fell within the range of peaks from September 26–October 7 observed in previous years. The peak timing estimate for 2014 was more certain than in 2013 as the counts showed a distinct decline in the latter part of the survey period.

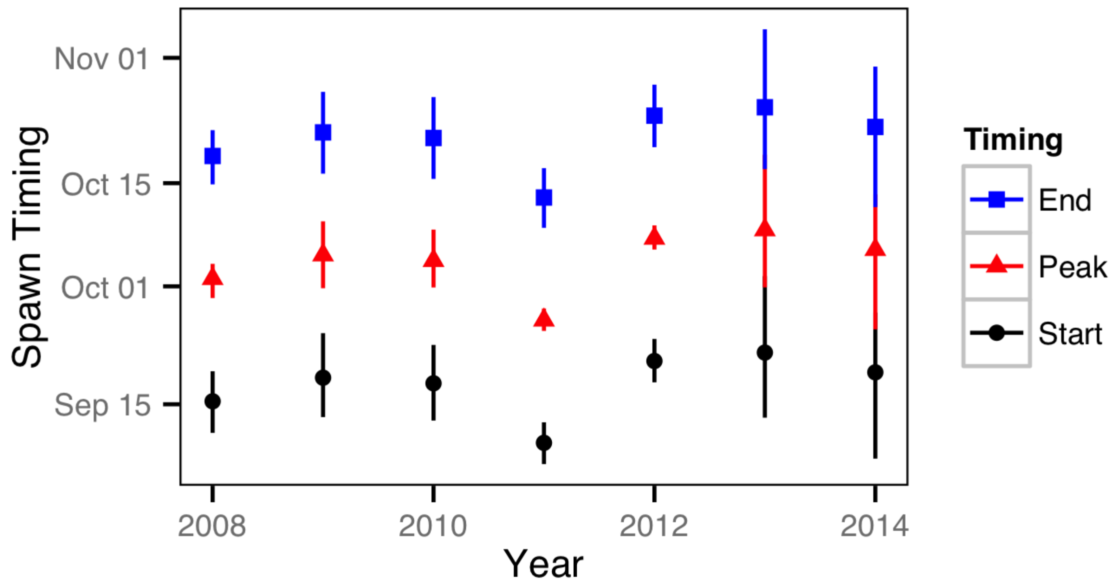

Figure 5. Predicted Kokanee peak spawn timing by year with 95% CIs.

Table 3. Annual peak counts of Kokanee spawners in the LDR study area, 2008-2014

Year	Date of Peak Spawning	Lower 95% CI	Upper 95% CI
2008	Oct 1	Sep 25	Oct 5
2009	Oct 3	Sep 21	Oct 13
2010	Oct 2	Sep 20	Oct 14
2011	Sep 26	Sep 24	Sep 28
2012	Oct 7	Oct 4	Oct 10
2013	Oct 4	Sep 8	Oct 21
2014	Oct 5	Sept 25	Oct 13

3.3 Area Under the Curve Estimates

Figure 6, shows the Area Under the Curve (AUC) estimate of abundance for 2014 (bottom left panel) based on four aerial counts (dots) in comparison to the last six years from 2008–2013. The plot also shows the daily spawner abundance estimates calculated by the hierarchical Bayesian AUC model. In Figure 7, the total 2014 spawner abundance estimate is shown in comparison to the six previous years. The 2014 Kokanee AUC estimate of abundance (22,080 fish) represented a low estimate within those 7 years but slightly higher than in 2013.

AUC estimates, their 95% confidence intervals, their Standard Deviation (SD) and the number of surveys undertaken are summarized in Table 4.

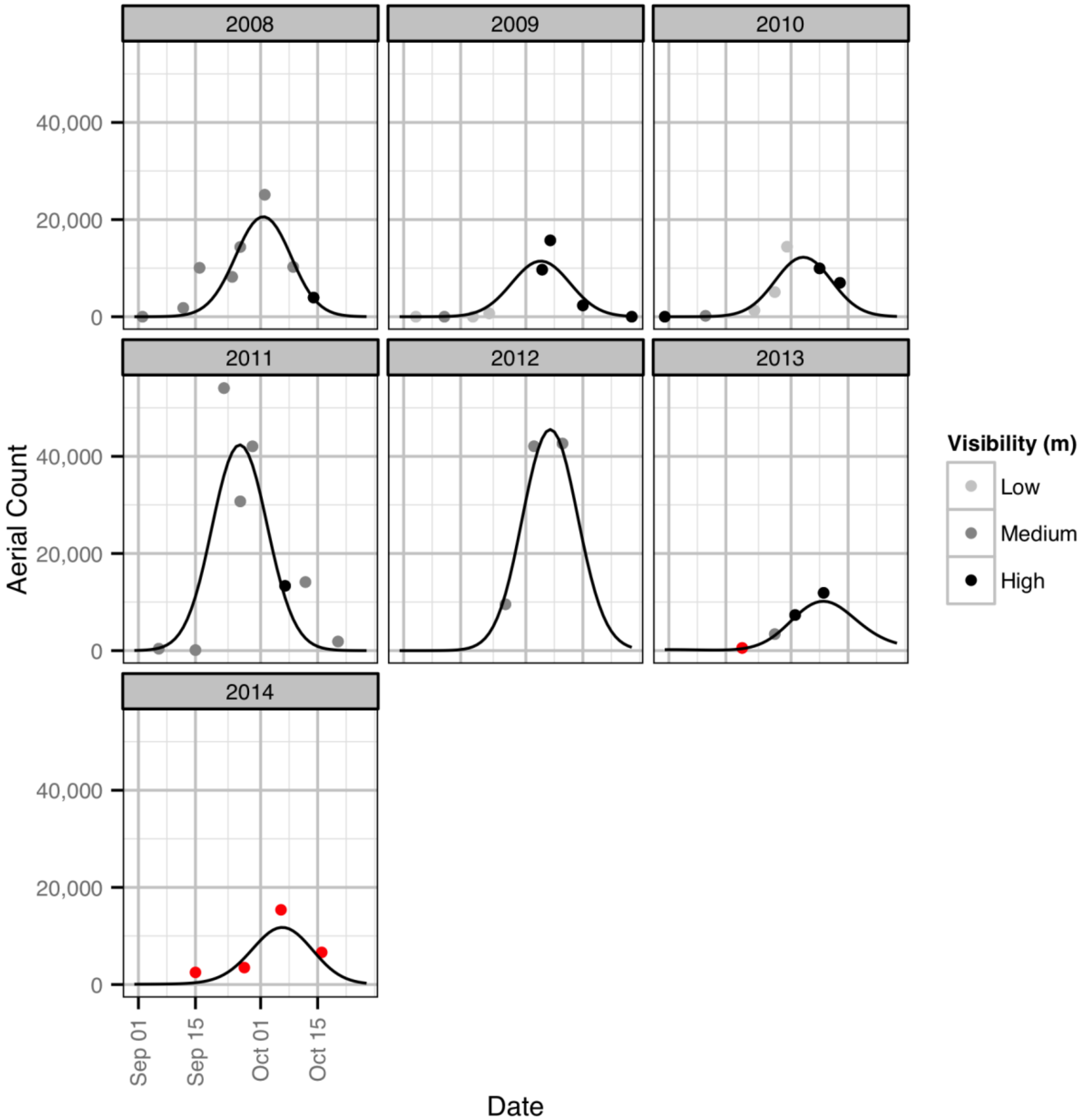

Figure 6. Kokanee spawner aerial counts with predicted aerial counts by date and year (red dots indicate water clarity not documented).

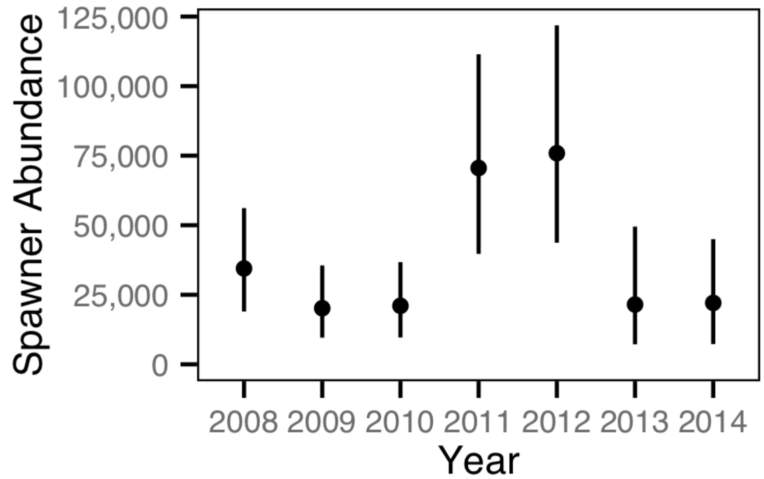

Figure 7. Predicted total Kokanee spawner abundance by year with 95% CIs.

Table 4. Kokanee spawner abundance estimates in the LDR from 2008–2014.

Year	Spawner Abundance	Lower 95% CI	Upper 95% CI	SD	# of Counts
2008	32,300	13,300	58,300	11,770	8
2009	19,600	2,400	42,500	10,745	8
2010	19,000	2,100	42,300	12,305	7
2011	70,700	37,700	117,300	21,141	8
2012	75,600	40,100	128,200	23,784	3
2013	20,300	900	62,000	25,617	4
2014	22,080	7,280	45,000	9,710	4

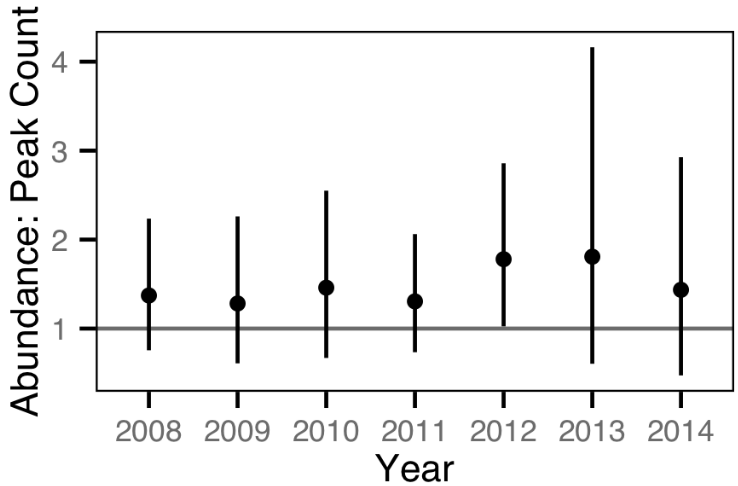

Figure 8. Ratio of estimated annual spawner abundance to peak counts by year for Kokanee in the LDR

As another measure to estimate total spawner abundance, the ratio of peak count to total spawner abundance was calculated and the results are shown in Figure 8. The ratio was 1.4 for 2014 and within the range of 1.3–1.8 observed between 2008–2013 (Table 5).

Table 5. Summary of ratios between annual spawner estimate and peak count for Kokanee in the LDR from 2008–2014.

Year	Estimate	Peak Count	Ratio Estimate to Peak Count
2008	32,300	25,100	1.3
2009	19,600	15,700	1.3
2010	19,000	14,400	1.3
2011	70,700	54,000	1.3
2012	75,600	42,600	1.8
2013	20,300	11,900	1.7
2014	22,080	15,379	1.4

3.4 Relative Intensity of Kokanee Spawning in the Duncan River System

Meadow Creek accounted for 47% of the observed total escapement within the Duncan River system in 2014, followed by the Lardeau River (43%) and the Lower Duncan River (10%) (Figure 9).

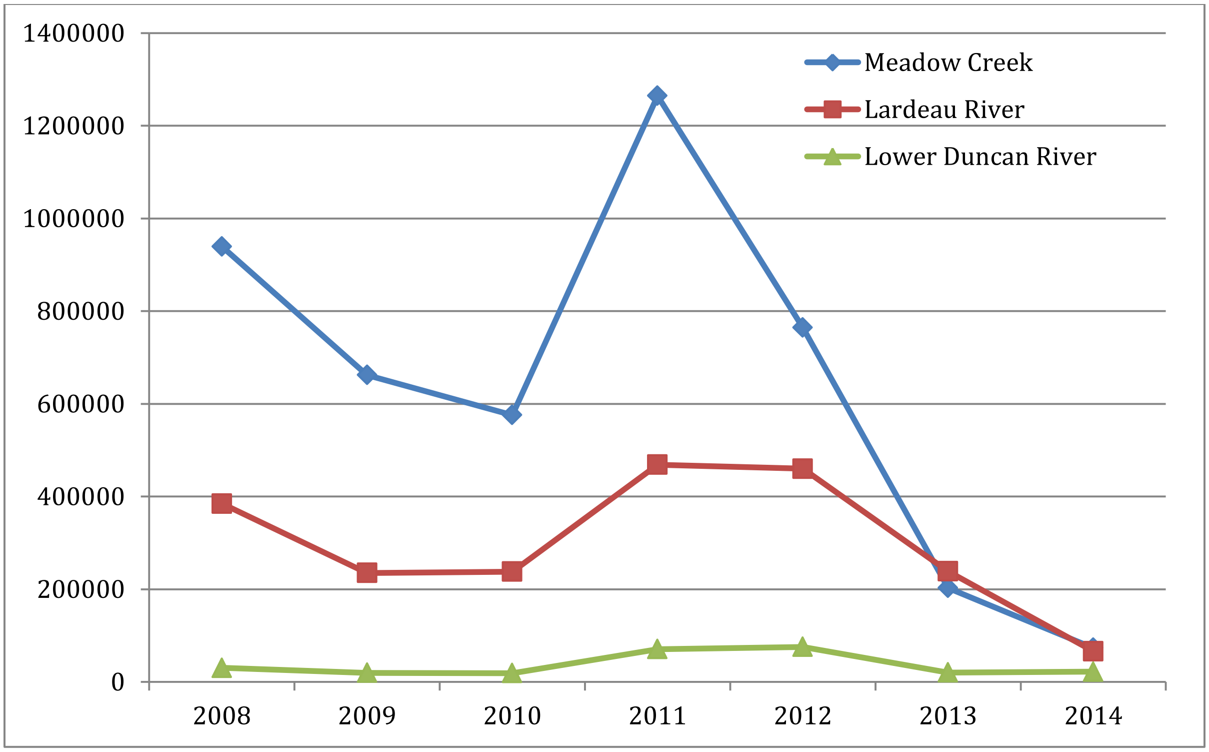

Figure 9. Estimated abundance of Kokanee spawning in Meadow Creek, Lardeau River, and the Lower Duncan River, 2008-2014. (source: Meadow Creek and Lardeau River MFLNRO (M. Neufeld pers comm/unpublished data); Lower Duncan River AMEC (2013); Zimmer et al. 2015)

3.5 Migration, Holding and Spawning Behaviour

The initial survey conducted on September 15 showed low numbers of Kokanee in the LDR, which were heavily skewed to holding and migrating behaviors (Figure 10). As the season progressed, surveys indicated a higher proportion of spawning behaviour. The trend continued through to the last survey on October 16, where the behavioural pattern observed was almost exclusively spawning.

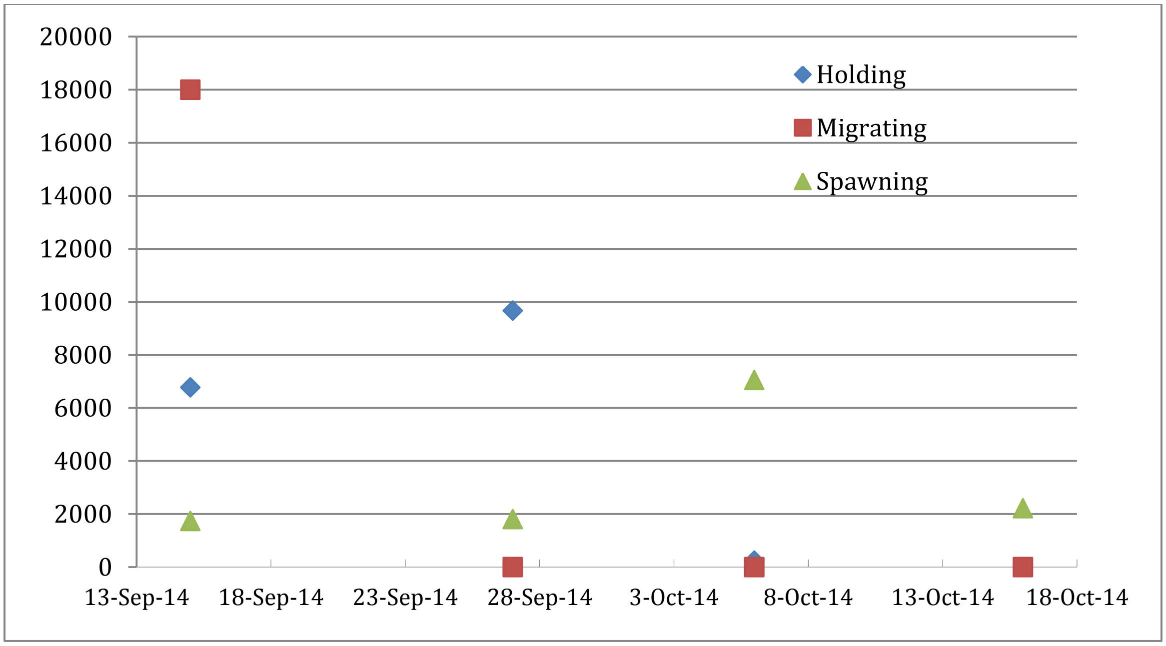

Figure 10. Number of migrating, holding and spawning Kokanee enumerated in the Lower Duncan River for 2014 (September 16 migrating kokanee were observed at the confluence with the Lardeau River).

3.6 Spawner Distribution and Habitat Use in the LDR

As in previous years, Kokanee were observed to spawn in the upper nine kilometers of the study area with main concentrations of redds observed between Kilometers 1.0 and 9.3 (See Appendix A). No redds were observed upstream of Kilometer 1 (Duncan Dam discharge channel, upstream end of the study reach), or from Kootenay Lake to Km 9.3 (downstream end of the study reach). Most notable concentrations were around km 3.0 and 4.0, within the upper third of the study reach. Side channel use was also evident prior to annual DDM flow reduction (September 26), particularly SC 1.1, 8.4 and 8.2 (See Appendix A). Post annual flow reduction (after Oct 6), side channel use for spawning was observed predominantly in SCs 4.4 and 4.1.

Table 6. Number of spawning Kokanee distributed in the side channels and mainstem Lower Duncan River for 2014.

Date	Mainstem	Side Channels
September 15, 2014	185	1550
September 27, 2014	1525	283
October 6, 2014	6921	133
October 16, 2014	2170	47

3.7 Kokanee Spawn Mapping, Potential Egg Deposition & Egg Losses

The 2014 Kokanee spawning locations in the LDR were mapped on a series of six maps attached as Appendix A. Redd mapping was based on redd surveys conducted on September 26 and October 6, 2014. Potential egg deposition and egg losses were calculated from area calculations based on the comparative redd distributions between Side Channel and Mainstem habitats before and after flow reductions, from approximately 180 m^3/s (Sept 26) to 75 m^3/s (Oct 6). These observations of dewatered redds occurred in both Side Channel and Mainstem habitats.

The total area used by spawning Kokanee in the LDR side channels and mainstem was approximately 15,975 m^2, containing an estimated 1,699,490 eggs deposited in 2014 (Table 7; as per AMEC 2013). Total area of redd dewatering was estimated at 62 m^2. Small egg losses (6,595) were calculated between Mainstem (2,340) and Side Channel (4,255) habitats.

3.8 Effectiveness of the 2014 Flow Reductions

Total spawning area in the mainstem and sidechannels is summarized in Table 7 below. Of all the sidechannels, only one side channel showed dewatered redds (SC6.9R), where historically impacts of the Kokanee protection flows have been consistently observed. Contrary to prior years, small areas of redds were also observed to be dewatered in the mainstem LDR at River Km 4.1 (6 m^2) and River Km 5.95 (16 m^2). Overall, dewatering was significantly reduced in 2014 at 0.39% redds dewatered in the entire LDR (Sidechannels at 1.43%, mainstem at 0.17%), compared with 13.2 % of redds dewatered in 2013, and 16.1% in 2012.

Table 7. Total spawning area, area dewatered (difference), Potential Egg Deposition (PED), number of eggs dewatered and spawning success for side channel (SC) and mainstem areas (MS) within the LDR study area before (Pre) and after (Post) Kokanee Protection Flows, 2009 to 2014 (adapted from AMEC 2013; Zimmer et al. 2015).

Year	Period	Total Spawning Area (m^2)		PED	
		SC	MS	SC	MS
2014	Pre	2,795	12,847	297,332	1,366,664
	Post	2,755	12,825	293,077	1,364,324
	Difference	40	22	4,255	2,340
2013	Pre[a]	1,078	1,739	168,623	1,025,771
	Post	936	1,739	146,449	1,025,771
	Difference	142	0	22,173	0
2012	Pre[b]	4,734	N/A	473,172	2,713,272
	Post[c]	3,973	20,922	397,156	2,713,272
	Difference	760	0	76,016	0
2011	Pre	6,902	88,172	3,253,621	2,372,672
	Post	5,902	88,172	2,781,955	2,372,672
	Difference	1,000	0	471,666	0
2010	Pre	4,041	8,055	830,540	642,948
	Post	3,784	8,632	777,601	640,852
	Difference	258	-577	52,939	2,096
2009	Pre	399	0	48,732	-
	Post[d]	267	4219	32,667	-

	Difference	132	-	16,065	-

[a] Based on backcalculating areas based on observed watered and dewatered sidechannel and mainstem redds on one survey – October 2, 2013

[b] Mainstem mapping was not conducted prior to the flow reduction. However, no dewatered redds were observed in the mainstem during post-reduction mapping.

[c] Additional spawning areas were observed post-reduction (3556 m^2) because Kokanee moved into side channels but the information presented reflects the original spawning area dewatered and changes to PED.

[d] Larger area was observed post-reduction because Kokanee moved into side channels to spawn. Only 132 m^2 of area was dewatered from the original pre-reduction mapping, which is reflected in PED.

- Spawning was not observed pre-reduction. It was assumed that post-reduction spawning areas were not dewatered.

3.9 Estimate of Observer Efficiency

The observer efficiency for 2014 was estimated using a comparison of aerial and ground counts in side channels R 3.5 and L 8.2. The ratio of average aerial count to ground count was 0.75 (Table 8), which was within the range of previous 2008-2013 observer efficiencies (

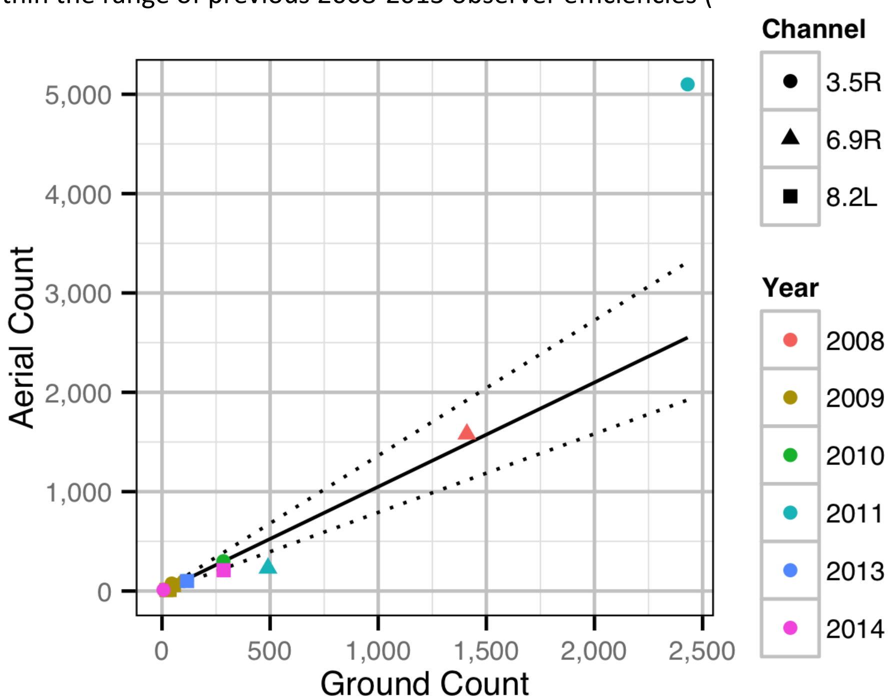

Figure 11, Figure 12).

Table 8. Ratios of aerial and ground Kokanee calibration counts for standardized locations in the LDR.

Year	Average of Aerial Counts for Calibration Locations	Average of Ground Count for Calibration Locations	Average Ratio of Aerial to Ground Count for Calibration Sections (# of surveys with data)
2008	1580	1410	1.12 (1)
2009	51	51	1.00 (5)
2010	300	284	1.06 (1)
2011	2665	1461	1.82 (2)
2012*	-	-	- (0)
2013	100	116	0.86 (1)
2014	220	292	0.75 (4)**

*Not reported (AMEC 2013)
**October 16 surveys in SCs 3.5 and 8.2 (Ground and air) both yielded counts of zero kokanee

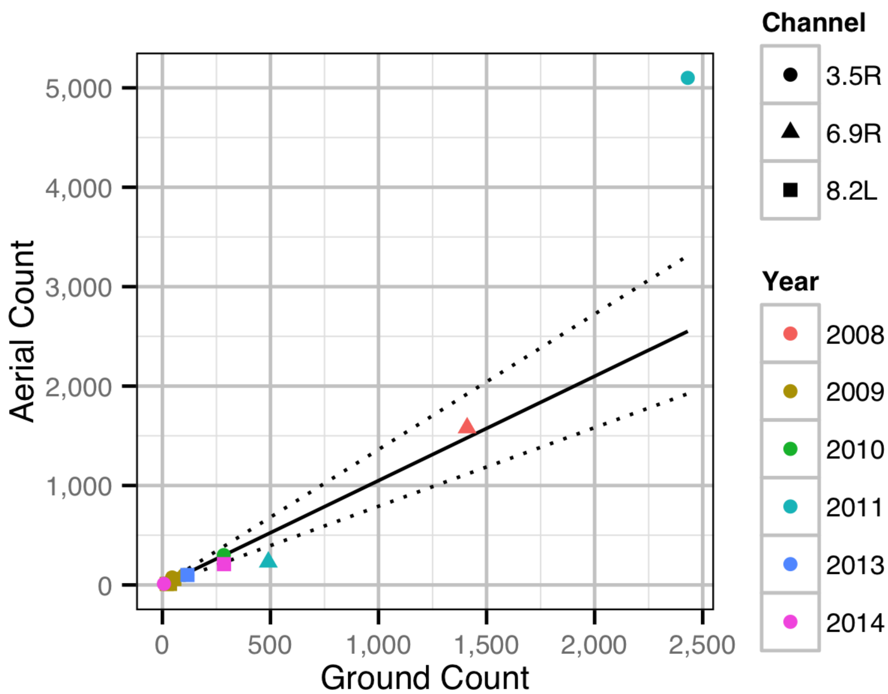

Figure 11. Aerial versus ground Kokanee spawner counts and predicted ground count (with 95% CRIs) by year and channel.

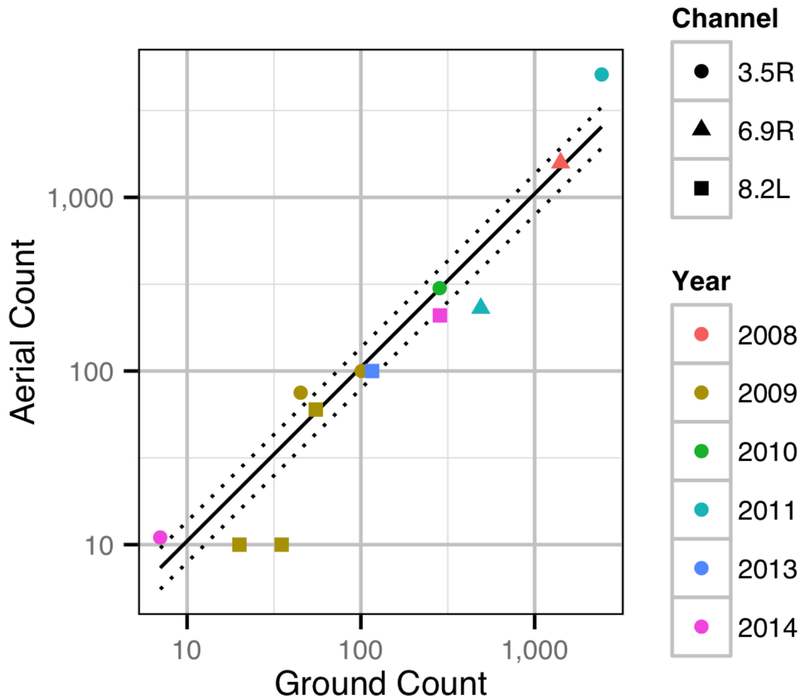

Figure 12. Aerial versus ground Kokanee spawner counts (on log10 scales) and predicted ground count (with 95% CRIs) by year and channel.

4.0 DISCUSSION

The following discussion addresses the management questions applicable to Year 7 of DDMMON-4.

4.1 Lower Duncan River Environmental Parameters: Temperature and Discharge

Following a small (+1 °C) increase in water temperature from September 15-25, water temperature (as measured by Environment Canada at WSC Station No. 08NH118) decreased steadily throughout the spawning period in the LDR in 2014. The temperature was measured (Environment Canada 2014) at maximum of 13.4 °C two days prior to the second survey (Sept 27, 2014) and steadily decreased to 11.5°C at the final survey of October 16, 2014, which was similar to the trend observed in 2013, but with a slightly higher (+1.5 C) temperature at the end of the study period (Zimmer et al. 2015). Similar trends of decreasing water temperatures were observed since 2009, and ranged from 16 °C to 8 °C (AMEC 2012, 2013, no data recorded in 2008). Temperature reductions are primarily due to reductions in DDM discharge, which draws flows from a warmer reservoir during this period when compared to the flow contributions of the Lardeau River. This may also explain the slight increase in temperature at the onset, coincident with higher DDM discharge. It is believed that reducing the proportion of DDM discharge to the Lower Duncan River therefore reduces the temperature (AMEC and Poisson 2012) in the fall. Further monitoring of Duncan Reservoir temperatures, contrasting surface with Low Level Outlet depth temperatures would be required to understand the effects of dam releases on incubation and emergence timing of kokanee.

Discharge (as measured by Environment Canada at WSC Station No. 08NH118) was regulated through DDM in September and October 2014 to manage for protection of Kokanee spawning in the LDR. In comparison with previous years, the 2014 discharge in the LDR showed a stepped reduction from summer highs (230-260 m^3/s) down to around 75 m^3/s for the period October 1 - 22. In past years (2008-2013), discharge varied from highs of approximately 202 m^3/s to lows of 69.8 m^3/s, with intermittent spikes within this range in some years (Water Survey of Canada, 2013 unpublished data).

4.2 Spawn Run Timing

The initial spawning survey took place on September 15, 2014 with 26,508 Kokanee observed throughout the study area mainstem and side channels. 18,000 of these fish were observed at the confluence of the Lardeau River and were categorized as "Migrating" through the LDR for upstream habitats. Kokanee presence at the initial visit indicates onset of spawning migration behaviours before this date. The September 15 survey was also concurrent with higher Duncan Dam discharges preceding the initiation of annual discharge reductions for Kokanee spawning protection September 25 to October 21, 2014. The highest visual (peak) count (7,314) was observed on the third enumeration flight on October 6, 2014, which is similar to 2013 (Peak October 9; Zimmer et al. 2015), but at the later range of previous years' peak counts (ranged from September 19 to October 7, from 2002 to 2011; AMEC 2013). Similarly, however, 2014 spawning run timing in adjacent watercourses (i.e., Meadow Creek) tributary to Kootenay Lake was also delayed (later than usual) according to discussions with MFLNRO staff (M. Pearson and M. Neufeld pers comm.), indicating delayed run timing in the LDR was not unique in 2014, and similar to 2013.

4.3 Relative Intensity of Kokanee Spawning in the LDR

Continued surveys indicated a successive increase in the numbers of Kokanee, culminating in the peak count, on the third survey (October 6), with a significant decrease on the final survey on October 16. MFLNRO also indicated a similar trend in their annual Kokanee enumerations conducted throughout the Kootenay and Arrow Lakes regions. Observing the visual peak during the third enumeration supports the adaptation of extending the survey period to 30 days (minimum), unlike the 20 days in 2013 (Sept 19-Oct 9) which failed to capture the descending limb of spawner abundance.

4.4 Area Under the Curve Estimates

Kokanee spawner abundance and peak estimates for 2014 were the fourth lowest within the seven years of observation from 2008–2013. However, the smallest Standard Deviation (SD) in estimating abundance was calculated for the 2014 data. Interestingly, the low SD is a great contrast to other years with more sample events. For example, in 2009, eight enumerations were conducted and the AUC analysis yielded a slightly higher SD than 2014. Although the 2013 surveys, over a shorter duration, yielded the highest SD computed. This year's narrow confidence limits may be attributable to the extended survey period capturing the broader spawning period, and the lower number of Kokanee escapement and possible ease of enumeration.

Similarly, the ratio of peak count to total spawner abundance estimate in 2014 was near the low end of the range observed under DDMMON 4 and since 2008. From 2008–2011 when either seven or eight surveys were carried out, the ratio was a constant 1.3 while in 2014 a year with less surveys (four) the ratio was 1.4. Likely due, again, to the extended survey period (than 2013) and low numbers of escapement to the LDR.

4.5 Relative distribution of Kokanee spawners in the Lower Duncan River

Kokanee habitat occupation was higher in the side channels during the initial survey on September 15, 2014 which coincided with higher flows in the LDR mainstem and discharge from DDM. As flows were reduced after September 27 at the commencement of the annual Kokanee protection flow reduction, Kokanee distribution shifted to higher numbers in mainstem locations. This shift of spawning locations from side channels to mainstem is very similar to 2013 observations and is likely related to flow-related side channel exclusion, and the subsequent availability of suitable habitat and velocity reduction in the mainstem.

4.6 Kokanee Spawn Mapping, PED and Egg Losses

For the 2014 field data collection program, the cumulative area for all Kokanee spawner locations was calculated from geo-referenced 1:1,000 mapping of water levels and Kokanee redds prior to and proceeding the implementation of the annual Kokanee protection flows. The study team mapped redd areas on September 27 (prior to significant flow reduction), and on October 6 (post flow reduction to seasonal minimum – 75 m^3/s). The difference between the two date-based areas were used for redd dewatering and subsequent egg loss calculations. The Kokanee protection flows initiated on September 27, 2014 appeared to minimize dewatering effects on mainstem and side channel redds. However, the proportion of redds dewatered and subsequent egg loss in sidechannels was near an order of magnitude higher compared to mainstem losses. In general, estimated egg losses in the LDR in 2014 were the very minimal with the lowest on record for the period of study (since 2008). Interestingly, 2014 was the first year on record where mainstem redd dewatering was recorded, although 2012 has incomplete data for comparison.

4.7 Estimates of Observer Efficiency

The observer efficiency in 2014 was below the range of observer efficiencies calculated from 2008–2013. The ratio of aerial counts to ground counts for the same calibration section of the river had an average of 0.86–1.82 from 2008–2013. In 2014, the ratio was slightly lower with 0.75 but based on this value the aerial counts would predict the ground counts well and within the range of predictions in previous years. Different from other years, the 2014 ratio was below 1 for the second time since aerial counts started in 2008. This means that until 2013, aerial counts were always higher than ground counts although the slow and thorough ground counts in the selected side-channels should always be higher than the faster aerial counts that are carried out from a distance. Therefore the 2013 and 2014 calibration counts are suggesting that aerial counts were not over-counting the number of fish in the river.

5.0 RECOMMENDATIONS

1. Annual Kokanee spawner protection flows implemented in the DDM WUP provide a benefit to kokanee spawning October 1-21st each year but there is a measurable impact to that portion of the run that spawns in higher flows prior to implementing the protection flow regime. It is recommended that the DDM Works 4 program *("Action Plan to Minimize Risk of Stranding Spawning Kokanee")* utilize the information gathered in this monitoring program to evaluate alternatives that minimize impacts to the early kokanee spawning run, in consideration of operating agreements (Columbia River Treaty, International Joint Commission) and other Water Use Plan objectives (flood control and recreation). The outcome of this analysis would be used inform future Water Use Plan review processes on opportunities that minimize stranding while accommodating other important water use objectives.

2. Expanding the survey period by 10 days in 2014 compared to 2013 added to the significant decrease in Standard Deviation of the AUC calculation. Further sampling plans should include a minimum of 30 days centered around spawning peak (Oct 2-9), over a minimum of four enumeration events and designed to capture the annual flow reduction period of September 25 – October 1. Discussions with BC Hydro Operations staff should be ongoing during enumeration planning and implementation stages.

3. Updated orthophoto maps (2012) provided by contractors for DDMMON 3 continue to be very useful for enumeration and redd survey data collection. Since the Lower Duncan River is an active, alluvial channel, we recommend using regularly updated orthophotos as base-maps for enumeration and redd surveys when available.

4. Current methods for spawner enumeration and redd surveys should be continued, including low elevation flights (~20 m). Furthermore, future enumerations will aim to be completed by the same study team, replicating to the furthest degree possible, the most experienced core of the teams used in prior surveys.

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Appendix A – Kokanee Spawner Mapping for the Lower Duncan River 2014 (6 maps)


MAP 1
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
Kokanee Holding
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2014 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date: October 2012
GIS File: LDR_5000_report_for2014_20151208.mxd
Project Number: EA3512
DATE: 2015.12.08
PROJECTION: UTM Zone 11
REVISION DATE: December 2015
DATUM: NAD83
PRINTING DATE: 2015.12.08
R1.1
50°15'0"N
116°57'0"W
50°14'0"N


5564000
5563000
L2.7
R3.5
MAP 2
R 1.1
L 2.7
R 3.5
R 4.1
R 4.4
R 6.9
R 7.6
L 8.2
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
Kokanee Holding
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2014 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_for2014_20151208.mxd
Project Number: EA3512
DATE: 2015.12.08
PROJECTION: UTM Zone 11
REVISION DATE: December 2015
DATUM: NAD83
PRINTING DATE: 2015.12.08
50°14'0"N
116°58'0"W
503000


MAP 3
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
Kokanee Holding
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2014 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_for2014_20151208.mxd
Project Number: EA3512
DATE: 2015.12.08
PROJECTION: UTM Zone 11
REVISION DATE: December 2015
DATUM: NAD83
PRINTING DATE: 2015.12.08
R3.5
R4.1
R4.4
50°13'0"N
116°58'0"W
116°57'0"W
5563000
5562000
503000

5561000
5560000
504000
5.7
5.8
5.9
6
6.1
6.2
6.3
6.4
6.5
6.6
6.7
6.8
6.9
7
7.1
7.2
7.3
7.4
7.5
0.57
0
R6.9
0.1
0.2
0.3
0.4
0.5
116°57'0"W
50°12'0"N
R 1.1
L 2.7
R 3.5
R 4.1
R 4.4
R 6.9
L 8.2
R 7.6
MAP 4
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
Kokanee Holding
1:5,000
0
100
200
300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2014 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_for2014_20151208.mxd
Project Number: EA3512
DATE: 2015.12.08
PROJECTION: UTM Zone 11
REVISION DATE: December 2015
DATUM: NAD83
PRINTING DATE: 2015.12.08
LGL


MAP 5
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
Kokanee Holding
1:5,000
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2014 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_for2014_20151208.mxd
Project Number: EA3512
DATE: 2015.12.08
PROJECTION: UTM Zone 11
REVISION DATE: December 2015
DATUM: NAD83
PRINTING DATE: 2015.12.08

L8.2
MAP 6
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
Kokanee Holding
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2014 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_for2014_20151208.mxd
Project Number: EA3512
DATE: 2015.12.08
PROJECTION: UTM Zone 11
REVISION DATE: December 2015
DATUM: NAD83
PRINTING DATE: 2015.12.08
116°56'0"W