Wahleach Project Water Use Plan

Lower Jones Creek Fish Productivity Monitoring

Implementation Year 8

Reference: WAHMON-1

Lower Jones Creek Fish Productivity Monitoring, WAHMON-1, Year 8 2013 2014

Study Period: 2013-2014

Greenbank Environmental Services
Living Resources Environmental Services

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Lower Jones Creek Fish Productivity Monitoring WAHMON#1 Year 8 2013-2014

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Executive Summary

As required by the Wahleach Water License, BC Hydro has been overseeing a fish productivity monitoring program in Lower Jones Creek since 2005. The objectives of the monitoring program are outlined by the Consultative Committee (CC) of the Wahleach Water Use Plan (WUP).

The primary focus of the monitoring program was to examine the impacts of WUP CC recommended minimum flow release targets on Lower Jones Creek fish productivity. Specifically, in the fall of 2005 new minimum flow targets were implemented requiring a release of 1.1 m^3/s from September 15 to November 30 to help improve spawning conditions and incubation/rearing flows of 0.6 m^3/s for the remainder of year. The fish productivity monitoring program was focused on the following central management question as stated in the fish productivity monitoring Terms of Reference (BC Hydro 2004):

> *Will the operational changes recommended in the Wahleach Water Use Plan result in increased productivity for anadromous and resident populations in lower Jones Creek as predicted from the flow-habitat relationships generated from the empirical study?*

The goal of this report was to summarize the data collected during the fall adult escapement period for Pink, Chum and Coho salmon, as well as the salmon fry outmigration data gathered from March – May 2014. The implications of these results with respect to the management question are discussed.

Adult escapement data was collected for Pink, Chum and Coho salmon from September 5, 2013 to December 15, 2013. Other factors were examined such as; flow, water temperature, substrate, water quality and channel morphology in an effort to determine which most influenced spawning success and egg-to-fry survival. For the 2013 survey period, the escapement estimate for adult Pink Salmon was 6071. For Chum Salmon, escapement for the 2013 survey period was 376, and for Coho Salmon escapement it was estimated at 3 individuals.

A total of 22,897 pink fry were captured during the trapping period, which translated to an out-migration population estimate of 129,498. A total of 6447 chum fry were captured during the trapping period, which translated to an out-migration population estimate of 23,802. These results are the largest capture and population estimates for Pink and Chum salmon fry to date. The egg-to-fry survival estimate for Pink Salmon was 3.11% and for Chum Salmon the results were the highest survival estimate yet at 5.70%. This compares to a post-WUP mean 2.38% for Pink Salmon and 2.33% for Chum Salmon.

Results of the 2013/14 study work appear to confirm that for Pink and Chum salmon, there have been productivity improvements in their respective populations. The outcome for Coho Salmon remains uncertain, but the data do suggest a possible positive effect. No steelhead trout were encountered during this monitoring study, but this was expected given the fall and early spring timing windows of the survey period. The degree to which these study outcomes match expectations derived from flow-habitat models remains unresolved, as such an assessment was considered outside the scope of this monitoring report.

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1.0 INTRODUCTION

The Wahleach Water Use Plan (WUP) was submitted to the Provincial Comptroller of Water Rights in December of 2004 and later implemented by BC Hydro in January of 2005. One of the key outcomes of the WUP process was the provision for a minimum flow release of 1.1 m^3/s in Lower Jones Creek from September 15 to November 30, and 0.6 m^3/s for the rest of the year as conditions allow. This change in minimum flow was expected to significantly increase anadromous salmonid production in the creek. To determine if this indeed would occur, a fish productivity monitoring program was included as part of the WUP. Specifically, this program was to monitor annual escapement and egg-to-fry survival of Pink and Chum salmon in the anadromous section of Lower Jones Creek over a 5 year period starting in the fall of 2005. This program was extended another 4 years in 2010 to capture an additional two years of Pink Salmon escapement data as they only spawn in odd years. Additional Chum Salmon escapement data were collected in those years as well.

Coho Salmon and Steelhead Trout escapement and smolt production were also included in this monitoring program. Because these fish were only present in very low numbers, analysis regarding egg to fry survival estimates was not possible. Thus only between-year comparisons in escapement is presented.

The anadromous section of Jones Creek consists of the lower 1.2 km of creek between its confluence with the Fraser River upstream to the cascade above the Laidlaw Road Bridge, which is a barrier to upstream fish passage. (Figure 1). In addition to the seven years of escapement and egg-to-fry survival data, there were also four years of baseline data gathered prior to WUP implementation (from 1999 - 2004) for comparison. This report summarizes the findings of the last year of Pink Salmon escapement monitoring in 2013 and provides a preliminary comparison with past data.

The goal of the monitoring program is address the following management questions as outlined in the fish productivity monitoring Terms of Reference (BC Hydro 2004):

> *Will the operational changes recommended in the Wahleach Water Use Plan result in increased productivity for anadromous and resident populations in lower Jones Creek as predicted from the flow-habitat relationships generated from the empirical study?*

Secondary questions relating to the key management question are:

a) Is salmon fry survival improved through the operational changes recommended in the WAH WUP?

b) Is juvenile steelhead productivity improved through the operational changes recommended in the WAH WUP?

With respect to management questions above, the objectives of the fish productivity monitoring study for the last two years of study (i.e., post review) were identified as follows:

Adult Escapement:

1. To provide an accurate estimate of returning adults to Lower Jones Creek in odd years.
2. To determine the distribution and density of spawning salmon within Lower Jones Creek in odd years.
3. To monitor stream discharge and document the effects of the variable discharge on channel morphology and the potential implications to spawning success.
4. To monitor water quality and water temperature to determine if these factors may influence spawning success.

Fry Outmigration:

1. To provide estimates of out-migrating pink and chum fry from Lower Jones Creek in odd years.
2. To provide estimates of egg-to-fry survival in odd years based on egg deposition data derived from each year's escapement and total fry out-migration estimates.

1.1 Site Description

Jones Creek is located 30 km west of Hope, British Columbia. The Wahleach Dam is located on Jones Creek approximately 8.5 km upstream of its confluence with the Fraser River. The Wahleach Dam impounds Jones (Wahleach) Lake Reservoir which receives water from the Upper Jones Creek and a number of other local inflow sources. The reservoir provides flow to the Wahleach Generating Station (WAH GS) which is located on the Fraser River downstream of the Jones Creek confluence (Figure 1). Lower Jones Creek flows are provided mainly from tributary inflow and surficial runoff from areas downstream of the Wahleach Dam, although additional flows can be provided via a siphon from the Wahleach Reservoir as well as through a water diversion structure at Boulder Creek. Both of these sources are used by BC Hydro to meet the lower Jones Creek minimum flow targets during low flow periods.

The Lower Jones Creek area is characterized as a highly mobile gravel fan which is unstable and prone to regular shifts in channel location (Hartman, G.F. and M. Miles. 1997). In addition, significant amounts of fine materials are mobilized from upstream areas and are deposited in the lower Jones Creek area. This leads to gravel compaction and channel instability. The channel instability and stream bed scour are thought to be major factors in low egg-to-fry survival in Lower Jones Creek.

An artificial spawning channel for Pink and Chum salmon was constructed at the lower end of Jones Creek in 1953-54 (Figure 2). Pink and Chum salmon fry out-migration studies conducted between 1954-1981 during the operation of the spawning channel, estimated mean annual chum fry production at 71,100 (range 1,700 to 253,600) while odd-year Pink Salmon fry production from the channel was estimated at 747,000 (range 145,000 to 1,500,000). The average egg-to-fry survival for Chum Salmon over the same period was estimated to be 34.6% (range 13.5% to 85.0%) while the average for Pink Salmon was 37.7% (range 8.5% to 79.1%) (Fraser and Fedorenko 1983). The spawning channel was decommissioned after it was

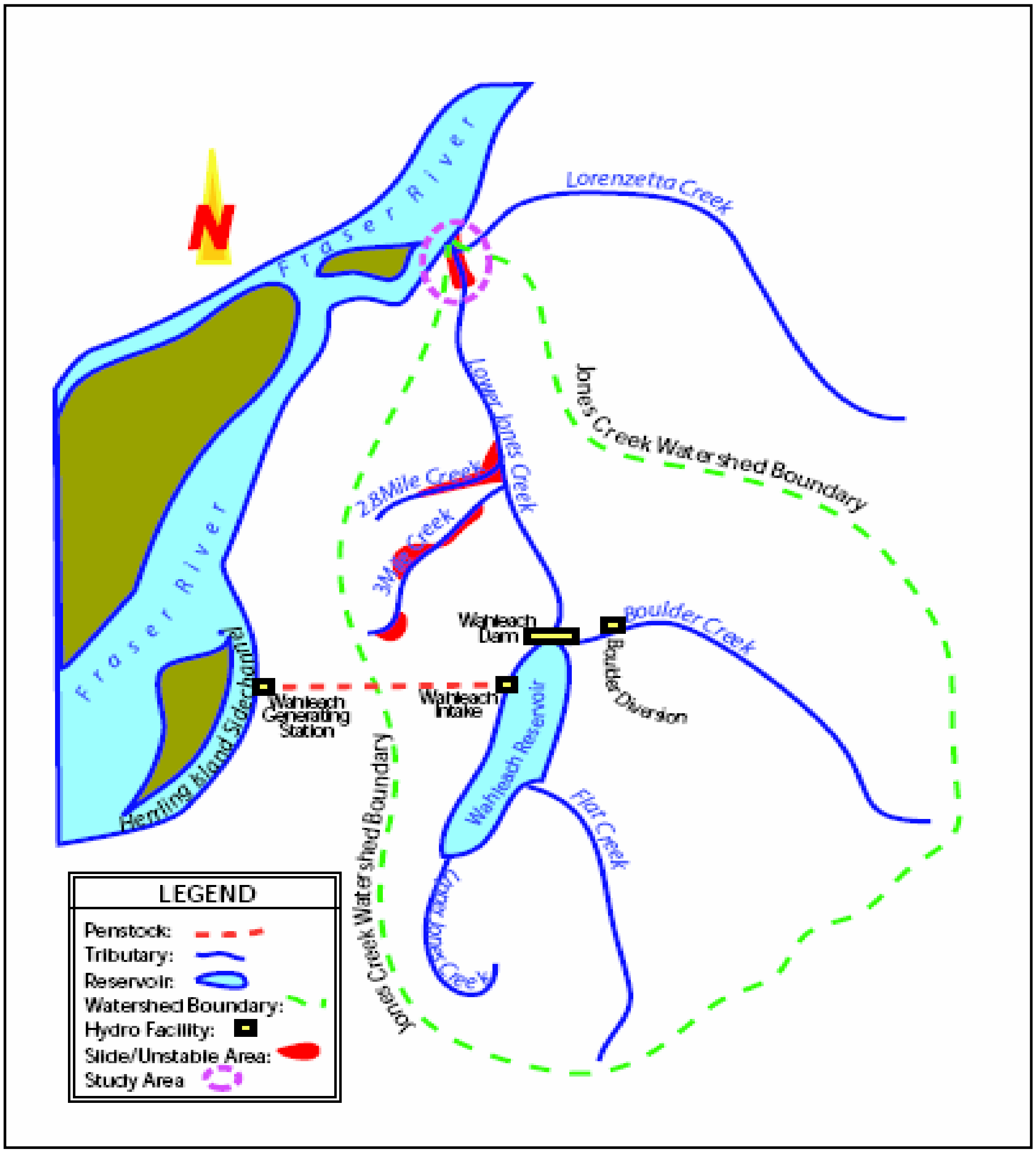

Figure 1. Schematic diagram showing the location of the general study area on Lower Jones Creek relative to the the Waleach Dam and other key features in the area

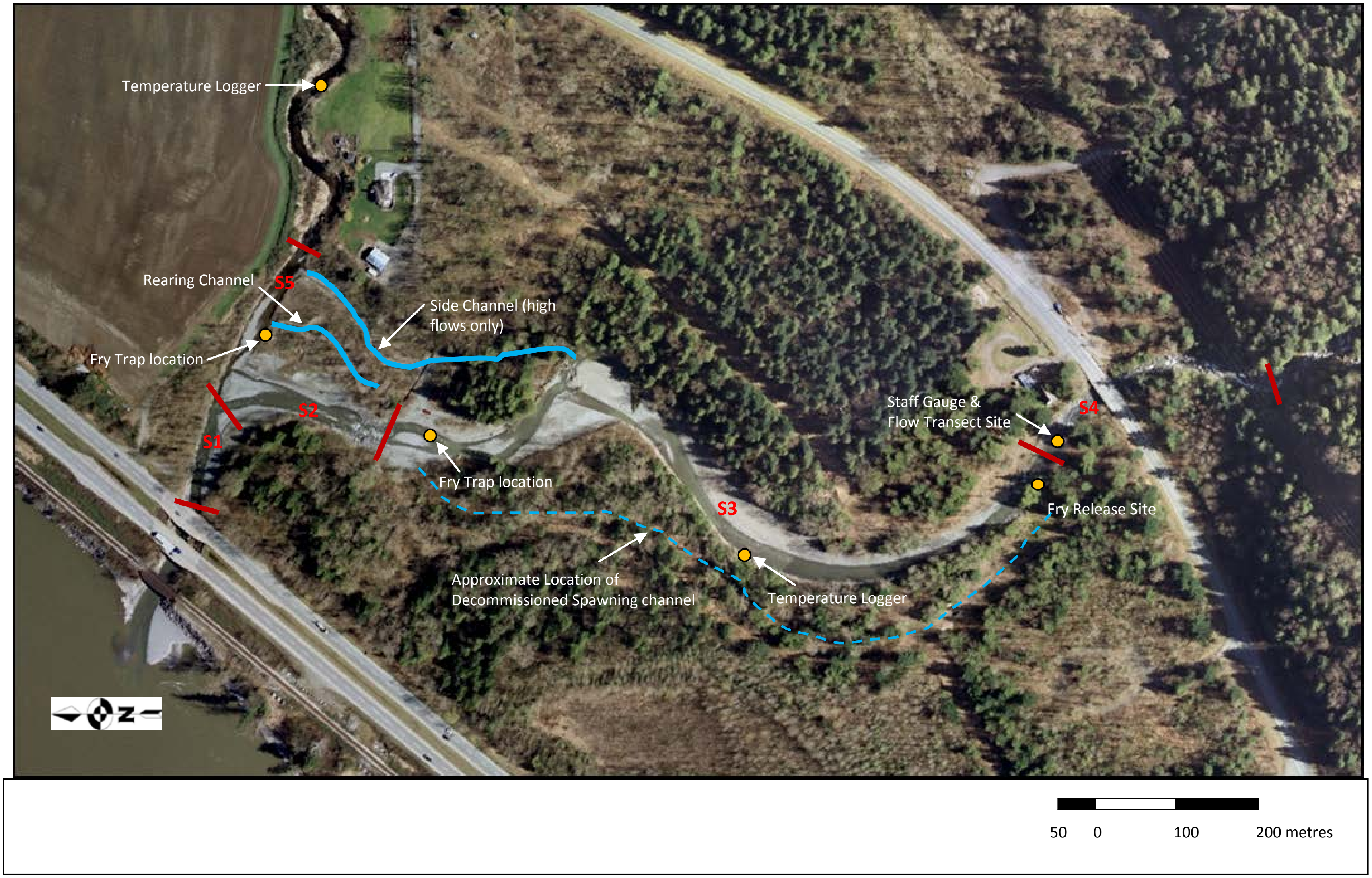

Figure 2. **Lower Jones Creek study area**

severely damaged by two landslides in 1993 and 1995. Historical information regarding spawning in Jones Creek prior to spawning channel construction is summarized in Hartman and Miles (1997).

A large bin-wall weir, located 300 m upstream of the Fraser River was constructed to divert returning spawners into the artificial spawning channel during its operation. The diversion weir remained in place after the channel was decommissioned and prohibited fish passage into upstream areas until 1998, when a small channel was excavated around the downstream diversion dam. This allowed fish to access an additional 650 m of linear habitat (or approximately 6000 m^2 of spawning habitat) in Lower Jones Creek to the location of the upstream weir which was constructed to provide intake water for the spawning channel. Both of the weirs were removed by BC Hydro in August 2004 (Newbury Hydraulics, 2004), extending access to the remaining accessible anadromous habitat in Lower Jones Creek (an additional 500-600 m^2 of spawning habitat, identified as Section 4 in this report, see Figure 2).
The study area includes the lower 1.2 km of Jones Creek from its confluence with the Fraser River to the natural barrier to anadromous fish located just above the Laidlaw Road Bridge (Figure 2). The study area also includes a portion Lorenzetta Creek which is a low gradient tributary to Jones Creek with slough-type characteristics in most areas. Coho Salmon also spawn in the lower area but utilize intermittent spawning habitat in upstream areas. Most of Lorenzetta Creek provides good rearing habitat for Coho and resident trout species.

2.0 METHODS

2.1. Adult Enumeration

Ground surveys were undertaken by a crew of two people walking in an upstream direction. The survey was started at the Fraser River confluence and extended up to the barrier to fish migration. Lower Jones Creek was divided into 4 sections (Figure 2) and counts were maintained separately for each section. The four survey sections were:

- Section 1: Fraser River confluence to Lorenzetta Confluence (80m)
- Section 2: Lorenzetta confluence to boulder riffle (110m)
- Section 3: Boulder riffle to hydrometric station (565m)
- Section 4: Hydrometric station to barrier (180m)

The lower section Lorenzetta Creek, from its confluence with Lower Jones Creek to the DFO spawning platform approximately 190 m upstream (Section 5) was also surveyed.

Each crew member walked on opposite sides of the creek and remained in continuous communication with each other to ensure as many fish were observed as possible. This also helped avoid duplicate counts of individual fish. Fish were identified to species and live fish were counted as either holding or actively spawning. Carcasses were identified to species, enumerated and placed above the high water mark to avoid double counting. Counts were conducted once or twice weekly from September 5, 2013 to December 15, 2013.

Ground surveys were only completed if water clarity, and hence observer efficiency, was deemed suitable to warrant a high likelihood of counting most of the spawners in the survey area. If conditions for a good count were not suitable, the ground survey was postponed to another day, thus ensuring a relatively consistent observer efficiency over the course of the survey period and across all years. It is important to note that the same observers carried out all survey work. This also ensured consistency over time. From the work of Decker et al 2011, observer efficiency was assumed to be 0.78 (i.e., the survey crew was able to detect on average 78% of the spawners within the survey area) for Pink Salmon and 0.76 for Chum Salmon.

Section 5 (Lorenzetta Creek) was extended by 500-800m on a several occasions during the Coho migration and spawning period to confirm their presence/absence in this river system and establish the extent of system usage. This also helped improve the total count data for Coho Salmon in the entire Lower Jones Creek watershed and to determine general patterns of distribution of these in-migrating fish.

2.2 Adult Enumeration Data Analysis and Escapement Estimates

Escapement estimates were derived from the repeat spawner count data using the Maximum likelihood Area-Under the Curve (L-AUC) estimation method (Hilborn *et al.* 1999). The method consists of three components. First, a process model was used to predict the number of fish present on each day of the run over the course of the spawning period. This includes a departure schedule based on the total escapement, parametric relationships simulating arrival timing and survey life. Second, an observation model was used to predict the number of fish counted on each survey based on the predicted numbers present in the survey area from the process model. Included in this calculation was the effect of observer efficiency. The third component was a statistical model that assessed the agreement between predicted and observed survey count data through a goodness of fit metric.

2.2.1 Process Model

The process model was used to estimate the proportion of the total escapement present on each day of the spawning period. This was done by estimating a series of run timing parameters that describe the cumulative proportion of spawners that arrive and depart on each model day in the survey area. The proportion of the total escapement entering the survey area on day 't' (PA_t) of the run was predicted by using the beta distribution,

$$PA_t = \phi_t^{\tau-1}(1-\phi_t)^{\beta-1} \qquad \text{Eq. 1}$$

where, τ and β are shape parameters of the beta distribution and ϕ_t represents the proportion of the run for day *i*, ranging from 0 to 1, on the assumed first (*t* = 1) and last (*t* = *T*) day, respectively. The τ coefficient determines the precision of run timing; with smaller values representing a low and constant rate of arrival over the duration of the run, and larger values representing a shorter and more concentrated arrival timing. The maximum length of the spawning period for Chum and Pink salmon was constrained to 66 days (September 1- November 5) and 92 days (September 5- December 5), respectively. The *β* coefficient was calculated from estimates of the peak arrival day (μ) and the precision of arrival timing, using the following equation:

$$\beta = \frac{\tau - 1}{\frac{\mu}{T}} + 2 - \tau \qquad \text{Eq. 2}$$

For Pacific salmon, survey life (the number of days a fish spends in the survey area) is normally longer for fish that arrive earlier in the spawning period (Perrin and Irvine 1990; Su *et al.* 2001). Survey life was modeled such that it varied with day of entry into the spawning area, but did not vary among years. Survey life was predicted using a decaying exponential relationship,

$$SL_t = \lambda_c e^{-\lambda_s t} \qquad \text{Eq. 3}$$

where SL_t is the mean survey life of a fish entering on day *t*, λ_c is the maximum mean survey life, and λ_s is the slope of the relationship. The mean departure day for a fish arriving on day *t* was simply computed as $d_t = t + SL_t$. The λ_c, coefficients were set to 24 and 18 days for Pink and Chum salmon respectively from measurements taken in Coquitlam River (Decker *et al.* 2011). Corresponding λ_s coefficients were set to 0.018 and 0.006, also from observations in Coquitlam River.

The proportion of fish that arrived on day *t* and departed on day *tt* ($PAD_{t,tt}$) were predicted from a normal distribution function with mean d_t and standard deviation σ_t,

$$PAD_{t,tt} \sim \text{Normal}(tt, d_t, \sigma_t)^{1} \qquad \text{Eq. 4}$$

It was assumed that error around the date of entry-mean survey life relationship is lognormally distributed, thus $\sigma_t = \lambda_v * SL_t$, where λ_v is the coefficient of variation (CV) in mean survey life. PAD values were standardized so that proportions across all departure days for each arrival day summed to 1; that is, all fish were assumed to be out the survey area by the last day of the run. The CV was assumed to be 0.65 for both salmonid species based on data collected in Coquitlam River (Decker et al. 2011). Because fish cannot depart before they arrive, $PAD_{t,tt} = 0$ for day tt < t. The proportion of fish departing on each day (PD_t) was computed from,

$$PD_t = \sum_t PA_t * PAD_{t,tt} \qquad \text{Eq. 5}$$

[1] The term "~" denotes that the value to the left of the term is a random variable sampled from the probability distribution defined on the right

Note that departure timing depends on both arrival timing and the survey life relationship that defined PAD. Finally, the number of fish present in the survey area on each day (U_t) was computed as the product of the total escapement (E) and the difference between the cumulative arrivals and departures on that day:

$$U_t = E\left[\int_1^t PA - \int_1^t PD\right] \qquad \text{Eq. 6}$$

The difference between the cumulative values of *PA* and *PD* on any date represented the proportion of the total run that was present in the survey area.

2.2.2 Observation Model

The observation model was used to simulate the outcomes of a spawner count survey on a given survey date by assuming that the survey count data arise from an over-dispersed Poisson distribution. The over dispersion aspect of the distribution accounted for the extra variation associated with the nonrandom distribution of fish on any survey date (e.g., clumping):

$$n_t \sim Poisson(N_t \theta_t e^{\varepsilon_t}) \qquad \text{Eq. 7}$$

where, n_t is the total number of fish counted on day t, $N_t = U_t$ derived from the process model above, θ_t is an estimate of the survey-specific observer efficiency (i.e., an uncorrected guess of detection probability made by the surveyor), and ε_t is a survey-specific deviate used to account for over-dispersion in the count data (McCarthy 2007, Royle and Dorazio 2008)). ε_t was drawn from a normal distribution with a mean of 0 and a precision of τ (i.e., $\varepsilon_t \sim$ Normal(0, τ)). This equation is often referred to as the likelihood component of the model because it describes the likelihood of the data given the parameter values.

2.2.3 Maximum Likelihood Estimation

The MLE process is the statistical component of the L-AUC method where estimates of escapement (E) and the beta distribution shape parameters α and β are obtained. The maximum likelihood values for each parameter were jointly determined through a systematic trial and error procedure with the goal of minimizing the difference between predicted and observed survey counts. The procedure relied on a penalized likelihood function that assumed a Poisson error distribution for the count data to track maximum likelihood. In calculating the negative log-likelihood function, observer efficiency was assumed to be a constant value of 0.78 and 0.76 for Pick and Chum salmon respectively.

Because observer efficiency was kept constant for all analyses, uncertainty in escapement estimates could not be fully quantified (English *et al.* 1992). Thus escapement estimates were not reported with 95% confidence limits.

2.3 Channel Morphology and Spawner Density

Channel morphology was monitored during all post-WUP study years. Channel width measurements were taken at a number of established transect locations in each study section. Multiplying the average wetted channel width by the length of the section allowed us to estimate wetted area for each study section. This assessment was completed a minimum of five times over each spawning and incubation period. The average total area by section during the spawning period was used to estimate spawner density. This procedure also allowed us to determine if channels were shifting location or if wetted area was changing over time. Although the channel measurements were influenced by different flows on each measurement day, this procedure allowed a rough assessment of spawning area availability over time and channel shifting. The wetted area calculations were also used to estimate spawner density within each study section. Spawner density was calculated by applying the percent distribution of total live counts in each section to the estimate of total escapement for each species. This was considered a better approach than calculating escapement estimates for each section due to the uncertainty in fish movement between surveys during the spawning period. Other environmental information collected during each of the surveys included:

- Staff gauge reading and discharge measurements at the upstream weir (Discharge was directly measured with a flow-transect)
- Water visibility/clarity was visually estimated and recorded as an observer efficiency during each ground survey.
- Current weather conditions were recorded.
- Hourly water temperature was collected continuously at two locations (Jones Creek at the upstream weir and Lorenzetta Creek) with Onset TidBit thermistors.

Additional fluvial geomorphologic data was collected in odd (Pink) years by Northwest Hydraulic Consultants (NHC 2008, 2010). This data were used to explore the potential impact of channel migration, scour and sedimentation on fish productivity.

2.4 Fry Trapping

Annual fry trapping was undertaken using a modified fyke-net and live-box downstream migrant trap. This work was completed under a DFO scientific fish collection permit (License No. XR 40 2012). The trap consisted of a 6mm mesh fyke-net with 7 m wing panels funneling to a 1 m^2 opening at the cod end (See Appendix 6 for trap images). Additional panels were added or removed during the course of the studies to improve trap efficiency when possible or to prevent damage to the trap during high flow events. The net panels were anchored to the substrate using 5/8 inch rebar secured via cedar bracing poles. The cod end funneled to an 8 inch diameter PVC pipe attached by two stainless steel pipe clamps. The 7.4 m PVC pipe discharged directly into a 0.75 x 1.4 x 1.0 m welded aluminum live-box.

A mesh baffle served to reduce turbulence in the box and also provided the fry with separation from predators that may have also been captured. Fry trapping was not possible at the furthest downstream extent of Lower Jones Creek due to inundation of Fraser River waters, which typically occurs about half way through the outmigration period. To avoid inundation of the trap, it was installed at the downstream end of Section 3 (Figure 2) at a level higher than the Fraser River local flood elevation.

A single-trap configuration was used and efficiencies under all trap configurations were tested with mark-recapture tests. The trap was fished continually for the entire migration period with the exception of 5 days when high water levels damaged the traps or clogged the intake. The traps were cleaned of debris several times daily. Fish were generally counted once in the morning and again at the end of the day.

All efforts were made to keep the traps fishing as efficiently as possible, with slight adjustments sometimes necessary to ensure that maximum efficiency was maintained. An additional trap was employed in Lorenzetta Creek to capture additional fry for use in the mark-recapture tests at the Jones Creek trap if insufficient numbers were available. This trap was similar in design to Lower Jones. It employed the same PVC pipe, though shorter in length (4.5 m) and with a cod end opening of only 0.5 m^2. The wings were also smaller, extending only 5m from the conduit opening. This trap operated from the middle of March to when the Fraser River inundated the area (April 20 this year). Mark-recapture experiments were not undertaken on Lorenzetta Creek because it was not possible to operate the trap for the entire outmigration period. It was also outside of the influence of the Jones Creek flow regime. No fry from Lorenzetta were used in mark-recapture tests in 2014 as sufficient numbers were available from Lower Jones Creek.

Fry were transferred from the traps to plastic buckets and moved streamside for processing. Fry were identified to species and enumerated while ensuring that marked fry were identified and enumerated separately. Unmarked fry were often held in covered 20 L buckets until they were required for a mark-recapture test. All adults and smolts captured were transferred to buckets, measured and immediately released downstream.

In 2014, 11 marked releases were undertaken during the out-migration to determine catch efficiencies. Fry were marked by immersion in a dilute solution of Bismarck Brown Y dye (concentration 1:100,000) for approximately 90 minutes. Marked fish were held for a minimum of 4 hours prior to release to ensure survival and good condition. The condition of all batches of marked fry was assessed before being released and those dead or moribund were removed from the calculation. Fry were released between 19:00 and 22:00 hours, at a location approximately 600 m upstream of the trap (Figure 2). Fry were released at dusk or in the dark to mimic natural emergence and migration behavior and to provide maximum cover from predators during migration.

2.5 Fry Population Estimates

Numbers of chum and pink smolts passing the downstream trapping site were estimated using a maximum likelihood (ML) model developed by Darroch (1961) and modified by Plante (1990) for stratified, mark-recapture data. Smolts captured at downstream traps in either Jones Creek or Lorenzetta Creek, marked with Bismark Brown Y dye, and then released upstream of the Jones Creek trap (Figure 2), constituted "marked populations", and smolts recovered at the Jones Creek trap represented the "recovery sample". With stratified mark-recapture methodology, both the marking and recovery samples were stratified. All smolt population estimates and 95% confidence intervals were computed from the collected, mark-recapture data using the software package, Stratified Population Analysis System (SPAS) (http//www.cs.umanitoba.ca/~popan/). A description of the ML estimator and the use of the SPAS software is provided by Arnason *et al.* (1996).

The number of marking and recovery periods was set to equal the number of marked batches released. The midpoint for each recovery period was defined as the date when the mark group was released. It was necessary to pool strata (mark and recovery periods) to avoid small sample and numeric problems that may prevent the maximum likelihood iterations from converging. When pooling strata, we followed the recommendations of Arnason *et al.* (1996). If numbers of marked and recaptured smolts in the majority of strata were too low to use the stratified estimator, data from all marking and recovery periods were pooled and the standard, pooled Petersen estimator for unstratified data were used (see Arnason *et al.* 1996 and for a discussion of the problems associated with pooling sparse data).

The stratified mark-recapture model used to estimate fry abundance allows for the proportion of marked fish and trapping efficiency to vary over time, but assumes the population is closed (i.e., the trapping period overlaps the entire migration period) and that capture efficiency is equal for marked and unmarked fish. The number of pink and chum fry captured at the beginning and end of the trapping period was either zero or very low relative to numbers captured during the peak of migration, suggesting that the assumption of population closure was reasonably well met. We assumed 100% mark retention and 0% marking-induced mortality, but we did not attempt to evaluate this. As noted earlier, to minimize the effect of marking induced mortality, all dead or moribund fish were removed prior to release. With respect to the assumption of equal capture efficiency for marked and unmarked fry, we assumed marking did not change CE at the trap, but we did not test this directly. Due to a lack of chum fry available for mark release, CE estimates for pink fry were used as a proxy for the chum fry population estimate.

Fry have been taken from Lorenzetta Creek in most years to augment fry numbers from Jones Creek for the mark-recapture tests, however, in 2014 this was not required as there were sufficient numbers of fry captured in Lower Jones Creek to provide for all mark recapture tests.

2.6 Egg-to-fry survival

For egg-to-fry survival estimates, we divided total fry production by the potential egg deposition for each species. Potential egg deposition was calculated by simply multiplying the number of females spawning above the trap site by their fecundity. The number of females was estimated for the escapement data assuming a 1:1 sex ratio. Fecundity estimates were obtained from Banford and Baily (1979) where an average fecundity of 1,600 eggs per female was assumed for Pink Salmon and 2,765 eggs per female for Chum Salmon.

3.0 RESULTS - ADULT ESCAPEMENT

3.1 Pink Salmon Adult Escapement

The first observation of Pink Salmon was on September 5, 2013 when 10 fish were observed (Table 1). Numbers increased throughout September until the peak count of 4651 adult Pink Salmon was observed on September 26, 2013. The last observation of Pink Salmon was on October 21, 2013 when a total of 16 fish were counted. Carcass recovery was completed during each of the field surveys. Excluding Lorenzetta, a total of 1244 carcasses (586 male, 658 female) were recovered throughout the escapement period (Appendix A). The peak carcass count of 346 occurred on Sept 21, 2013, which was 5 days prior to the peak live count. The peak count in Lorenzetta was 247 adults on September 26, 2013.

Table 1 Daily adult pink observations in Lower Jones and Lorenzetta Creek by survey date and section.

	Lower Jones Creek				Jones	Lorenzetta
Date	**S1**	**S2**	**S3**	**S4**	**Total**	**S5**
5-Sep-13	0	3	7	0	10	0
11-Sep-13	12	17	322	89	440	6
18-Sep-13	106	215	2065	271	2657	49
21-Sep-13	86	147	2766	369	3368	37
26-Sep-13	96	364	3664	527	4651	247
1-Oct-13	27	143	1493	311	1974	230
9-Oct-13	10	31	493	48	582	107
13-Oct-13	9	97	233	28	367	37
16-Oct-13	7	36	107	3	153	12
21-Oct-13	1	4	10	1	16	3
Distribution	**2.5%**	**7.4%**	**78.5%**	**11.6%**	**100%**	

The estimate of total escapement excluded the counts from Lorenzetta since those fish were not directly affected by the flow regime in Jones Creek. Applying the day specific counts to the model described above (Section 2.2) resulted in an escapement estimate of 6071 Pink Salmon.

This assumed a maximum survey life of 24 days, a slope of survey life relationship of 0.018, a CV = 0.65, and a mean observer efficiency of 0.78 (Decker *et al.* 2011). The escapement estimate of 6071 pink salmon was the third highest since surveys were first started by BC hydro in 1999 (Figure 9).

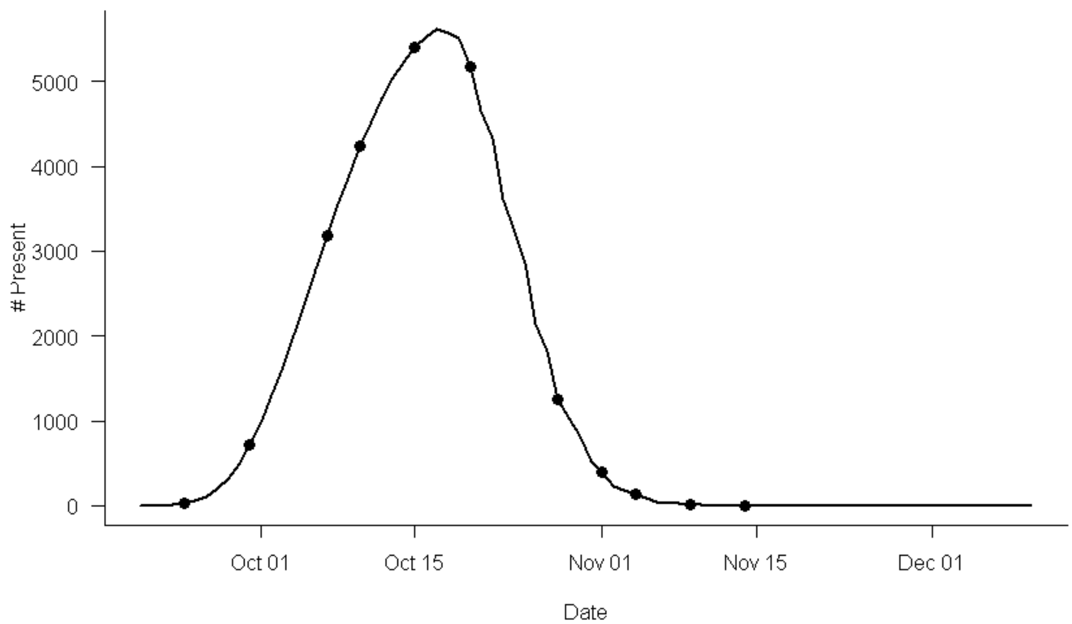

Figure 3 Example of L-AUC model output of 2013 pink salmon arrival and departure timing, predicted numbers present and observer counts expanded by observer efficiency.

The majority of Pink Salmon spawning activity (81.3%) occurred in Section S3, which holds approximately 75% of all the available spawning area in Lower Jones Creek, (Table 7 & 2). Sections S4 (11.6%) and S2 (7.4%) had the next highest concentration of activity (Table 2). This pattern of Pink Salmon spawner distribution was similar to that seen in previous years with the exception of one anomalous year in 2005. This brood year also had unusually low escapement for Lower Jones Creek, which likely influenced spawning distribution.

An index of adult spawning density in Lower Jones Creek was calculated in two ways. This first was in terms of Total Density (TD), which was calculated by applying the section specific percent spawner distribution in Table 2 to the estimate of total escapement (6071 pink), and then comparing it to the average area of available section specific spawning habitat throughout the escapement period (Table 7). The second index provided a Maximum Instantaneous Density (MID), which was calculated as the peak count divided by total area at peak count. Within Lower Jones Creek, Section S4 had the highest spawner density with a TD of 1.08 fish/m^2 and MID of 0.81 (Table 3). The total density for the entire Lower Jones Creek survey area was

0.57 fish/m^2. Table 3 showed that the pink spawning concentration by Section in 2013 was typical of past surveys since the start of the monitoring program in 2005.

Table 2 Pink spawning distribution by section and escapement 1999-2013. Sections S1 and S2 were combined from 2001-2004, Section S4 was made accessible in 2004. Percentages in S5 are presented for information only and reflect the share of total adult spawners *if*, S5 counts were included with Lower Jones escapement. n/a = not accessible, n/s = not surveyed

Year	S1	S2	S3	S4	S5 (Lor)	Esc. Est.
1999				n/a	n/s	1380
2001	15%		85%	n/a	n/s	4432
2003	10%		90%	n/a	n/s	2489
2005	4.5%	15.4%	27.7%	52.4%	*(26.7%)*	212
2007	0.8%	3.3%	78.2%	17.7%	*(1.8%)*	3167
2009	0.6%	4.2%	85.0%	10.0%	*(2.2%)*	7820
2011	1.7%	8.4%	81.3%	8.6%	*(1.6%)*	7569
2013	2.5%	7.4%	78.5%	11.6%	*(4.9%)*	6071
Post WUP Mean	**1.5%**	**6.2%**	**80.9%**	**11.3%**		

Table 3 Lower Jones Creek adult pink spawning density by section 2013. Total Density (TD) is the escapement estimate/average area m^2. Maximum instantaneous density (MID) is the peak count/ area m^2 at peak count.

Lower Jones Creek Pink										
Year	s1		s2		s3		s4		Total Creek	
	TD	MID	TD	MID	TD	MID	TD	MID	TD	MID
2005	0.01	0.01	0.04	0.02	0.01	0.01	0.27	0.19	0.04	0.03
2007	0.03	0.02	0.11	0.05	0.30	0.21	0.89	0.61	0.29	0.17
2009	0.13	0.14	0.43	0.31	1.05	0.79	1.45	0.89	0.96	0.74
2011	0.16	0.12	0.85	0.54	0.96	0.66	1.22	0.85	0.89	0.67
2013	0.12	0.08	0.39	0.31	0.64	0.49	1.08	0.81	0.57	0.44
Mean	0.09	0.07	0.36	0.27	0.59	0.43	0.98	0.67	0.55	0.40

3.2 Chum Salmon Adult Escapement

The first observation of Chum Salmon was on September 18, 2013 when 3 fish were observed (Table 4). Numbers continued to increase slowly throughout October until a peak count was observed on October 21, 2013 with a total of 186 adult chum. One Chum Salmon was observed in Lower Jones Creek on December 9, 2013 and none were observed on subsequent surveys.

Carcass recovery was minimal as a grand total of only 43 were recovered; 21 male and 22 female. Lorenzetta Creek was accessible to chum salmon during the entire escapement period. The peak count in Section S5 was 29 chum adults on October 21, 2013.

Table 4 Daily chum observations by section. Distribution by percent is calculated using Lower Jones Creek numbers only.

	Lower Jones Creek				Jones
Date	**S1**	**S2**	**S3**	**S4**	**Total**
18-Sep-13	0	0	2	1	3
21-Sep-13	1	2	6	1	10
26-Sep-13	2	1	13	2	18
1-Oct-13	0	2	2	0	4
9-Oct-13	3	4	7	4	18
13-Oct-13	0	3	53	5	61
16-Oct-13	2	10	104	9	125
21-Oct-13	6	13	167	0	186
26-Oct-13	4	11	122	3	140
31-Oct-13	5	11	95	3	114
4-Nov-13	4	11	72	3	90
8-Nov-13	2	13	56	2	73
15-Nov-13	3	7	17	4	31
22-Nov-13	0	3	11	3	17
28-Nov-13	0	1	5	0	6
4-Dec-13	0	0	2	1	3
9-Dec-13	0	0	1	0	1
15-Dec-13	0	0	0	0	0
	32	92	735	41	900
Distribution	**3.6%**	**10.2%**	**81.7%**	**4.6%**	**100.0%**

The estimate of total escapement excluded the counts from Lorenzetta since those fish were not directly affected by the flow regime in Jones Creek. Applying the day specific counts to the model described above (Section 2.2) resulted in an escapement estimate of 376 Chum Salmon. This assumed a maximum survey life of 18 days, a slope of survey life relationship of 0.006, a CV = 0.65, and a mean observer efficiency of 0.76 (Decker *et al.* 2011).

The majority of chum spawning activity (81.7%) was observed in Section S3, which holds approximately 75-80% of all the available spawning area in Lower Jones Creek, (Table 7 & 5). Section S2 (10.2%) had the next highest level of activity, while Section S4 had the lowest at 4.6% (Table 5). The pattern of Chum Salmon spawning distribution, though more variable than Pink Salmon, was also typical of patterns seen in past surveys (Tables 5).

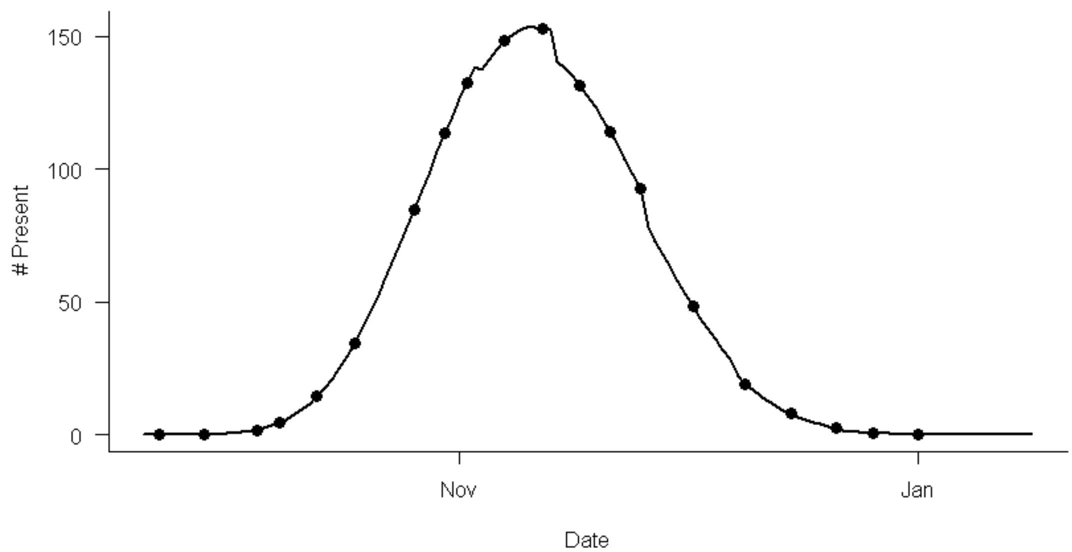

Figure 4. **Example of L-AUC model output. 2013 chum salmon arrival and departure timing, predicted numbers present and observer counts expanded by observer efficiency.**

Table 5 **Chum spawning distribution by section 2001-2013. Section 1 and 2 were combined from 2001-2004, section 4 was made accessible in 2004.**

Year	S1	S2	S3	S4	S5	Esc. Est.
1999				n/a	n/s	989
2001	11%		89%	n/a	n/s	182
2003	18%		82%	n/a	n/s	555
2004	67%		32%	1%	n/s	571
2005	6.2%	31.0%	27.4%	35.4%	*(36.9%)*	104
2006	4.6%	9.6%	64.8%	21.1%	*(3.9%)*	1311
2007	3.8%	15.6%	65.6%	15.0%	*(39.3%)*	124
2008	70.5%	2.3%	16.6%	4.9%	*(10.2%)*	543
2009	3.8%	4.9%	70.1%	21.1%	*(4.3%)*	423
2010	n/a	n/a	n/a	n/a	n/a	5
2011	4.0%	19.3%	58.7%	18.0%	*(28.6%)*	92
2013	3.6%	10.2%	81.7%	4.6%	*(10.6%)*	549
Post WUP Mean	**14.5%**	**9.4%**	**60.6%**	**15.5%**		

An index of adult spawning density in Lower Jones Creek (Table 6) was calculated by applying the percent distribution for each section to the estimate of total escapement (376 chum), and comparing it to the average area of available spawning habitat throughout the escapement period (Table 7). For chum Section 3 had the highest spawner density with 0.06 fish/m^2 (Table 6). The density for all of the Lower Jones Creek survey area was 0.04 fish/m^2.

Table 6 **Chum salmon spawning density by section in Lower Jones Creek 2005-2013. Values shown are Total density (TD) which is the escapement estimate/average area m^2.**

Lower Jones Creek Chum					
Year	s1	s2	s3	s4	Total
2005	0.01	0.03	0.00	0.08	0.03
2006	0.08	0.09	0.10	0.44	0.18
2007	0.01	0.02	0.01	0.03	0.02
2008	0.43	0.02	0.01	0.05	0.13
2009	0.03	0.03	0.05	0.16	0.07
2011	0.01	0.02	0.01	0.03	0.02
2013	0.01	0.03	0.06	0.03	0.04
Mean	0.08	0.03	0.03	0.12	0.07

3.3 Coho Salmon Adult Escapement

Adult Coho Salmon were observed spawning in Lower Jones Creek on three occasions; all in section S4. Three were observed on November 4, 2013 constructing redds, another was observed on November 8, and another two individuals were observed November 15. In addition, three confirmed Coho Salmon redds were found in Lower Jones Creek. A maximum count of 19 Coho Salmon were observed upstream in Lorenzetta Creek, outside the Jones Creek survey area (on two occasions, Nov 15 & 28, 2013).

3.4 Temperature Monitoring

Over the course of the active spawning period for Pink and Chum salmon (September 1 – December 15, 2013), mean daily water temperature ranged from a high of 18.7°C (September 2, 2013) to a low of 0.0°C (December 6-10, 2013). Figure 6 shows the daily max, min and mean temperature for the entire survey period. The average daily mean temperature for Pink Salmon during their spawning period (September 5 – October 21, 2013) was 11.9°C (with a maximum of 18.4°C and a minimum 7.0°C). For Chum Salmon the average daily mean temperature during the spawning period (September 18 – December 9, 2013) was 7.2°C (with a maximum of 14.8°C and a minimum of 0.0°C).

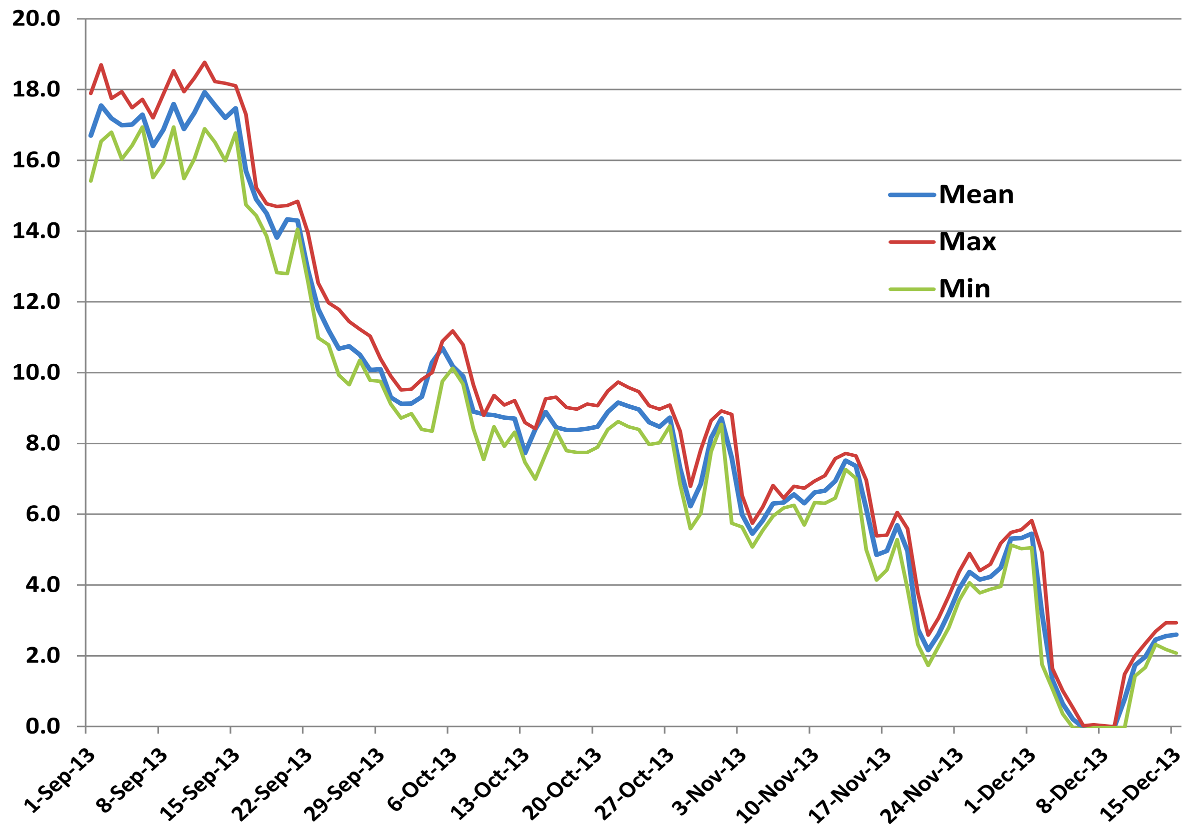

Figure 5 Lower Jones Creek daily temperature during escapement period, September 1 – December 15, 2013.

3.5 Flow and Channel Morphology

Detectable channel shifts affecting an active spawning area in Lower Jones Creek was observed in Section S2 at the peak of Pink Salmon spawning. Following high inflow from September 28-October 1, 2013, this entire section was dramatically altered. Figures 7 and 8 visually demonstrate the dramatic change in creek morphology following the high flow event, which had a maximum instantaneous flow of approximately 16.3 m^3/s. As the images show, the entire area was significantly widened and deepened, increasing from an average channel width of 6.10 metres prior to the high flow, to 11.50 metres after (Table 7). The available wetted area for spawning also increased, growing from 549m^2 to 1035m^2 in this section. The photos show evidence of a large area of recent (Summer 2013) fluvial deposits completely washed away, removing gravel and fines deposition up to a depth of 1.5 metres in some places along this channel.

Pink Salmon spawning was active at this time, and it is assumed that any redds constructed in this area prior to September 26 were washed away. In the last survey prior to the channel shifting (Sept 21, 2013), a total of 147 pink salmon were counted in Section S2. Following the

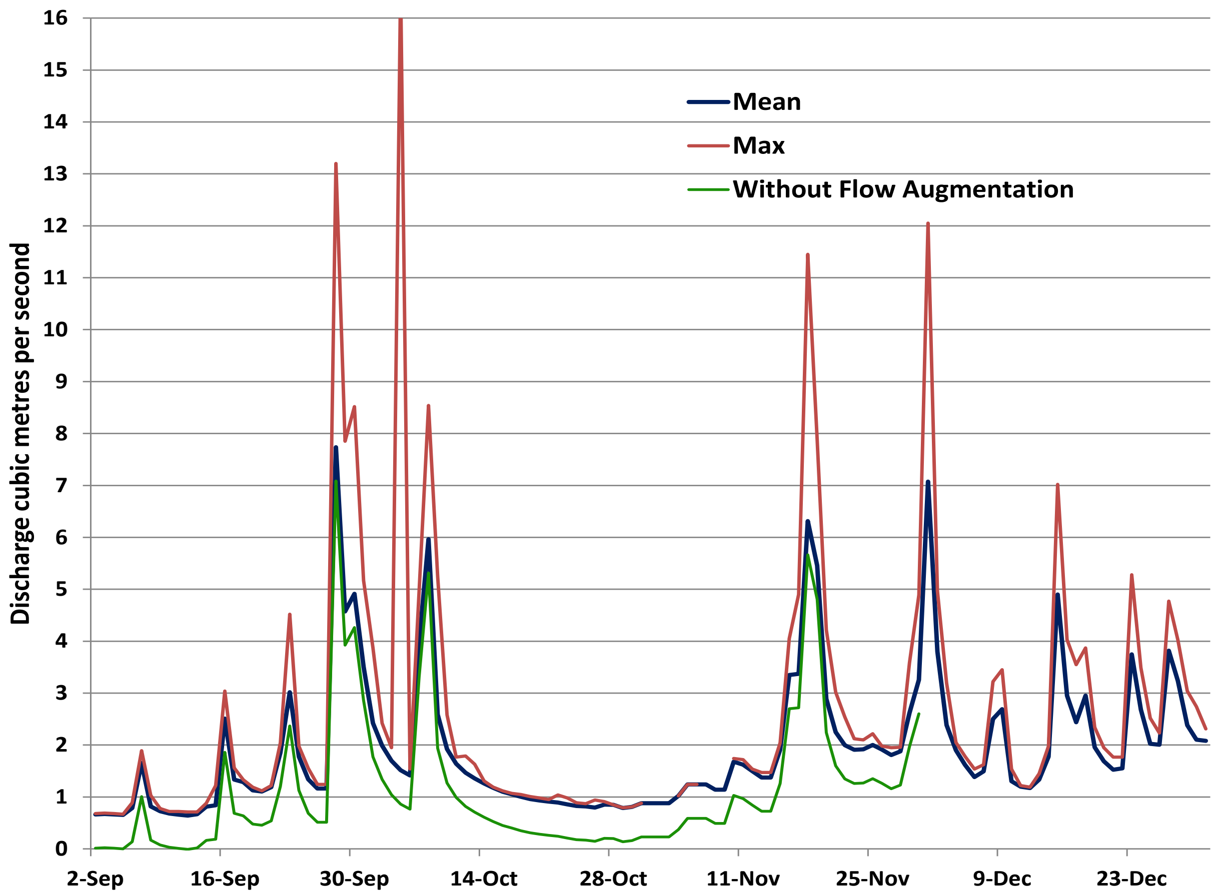

Figure 6 **Lower Jones Creek hydrograph for the pink and chum spawning period Sept 1-Dec 31, 2013**

channel shift, a peak of 364 pink salmon were observed on Sept, 26, 2013 (Table 1). The greatly expanded area of available spawning habitat was used extensively by pink salmon.

BC Hydro is required to deliver a minimum of 1.1 m^3/s to Lower Jones Creek throughout the Pink and Chum salmon spawning period (September 15 to November 30). For a two week period from October 19-November 3, 2013, discharge in Lower Jones Creek was below compliance. Despite using all available sources of flow augmentation within the watershed (Boulder Creek diversion and the siphon from Wahleach Lake), the estimated discharge fell to between 0.78 - 1.04 m^3/s during this period. The timing of this low flow event occurred after Pink Salmon spawning had finished, and during peak Chum Salmon spawning and migration. The presence of adult Chum Salmon during this time indicated that the lower flow did not hinder spawning or migration into any of the survey areas in Lower Jones Creek.

Without the augmented flow from Boulder Creek and the WAH siphon, discharge in Lower Jones Creek would have fallen to nearly zero during the first two weeks of September when Pink Salmon adult were migrating into the system. At the end of October and early November during peak Chum Salmon spawning, flow would have been between 0.11 m^3/s and 0.25 m^3/s without the addition of inputs from WAH Dam and Boulder Creek (Figure 6).

Table 7 Lower Jones Creek average wetted width (ww) and available spawning area by reach 2013

Date	18-Sep		13-Oct		26-Oct		15-Dec	
Stage	0.47m		0.475m		0.42		0.69	
Flow	1.33cms		1.60cms		0.94cms		4.14cms	
Reach	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2
S-1	14.80	1110	17.43	1308	17.27	1295	15.33	1150
S-2	6.10	549	11.50	1035	11.57	1041	15.53	1398
S3-1	11.93	1133	12.35	1173	12.18	1157	17.38	1651
S3-2	7.73	1701	10.63	2339	10.33	2273	14.10	3102
S3-3	12.94	3947	12.84	3916	12.60	3843	14.98	4569
S4	14.37	647	14.53	654	14.33	645	15.77	710
Total		**9086**		**10425**		**10254**		**12579**
Spawnable Area		**7951**		**9122**		**8972**		**11007**

Figure 7. Section 2, Sept 18, 2013, average channel width 6.10 metres, area 549m^2. Observe the expansive area of recently deposited fluvial sediment along the right bank of the Creek.

Figure 8. Section 2, October 13, 2013, following high flows. Note the majority of the fluvial material has been washed away and the channel greatly widened as well as deepened. Average channel width now 11.50 metres, total area 1035m2 (at equivalent discharge).

4.0 DISCUSSION

4.1 Pink Salmon Escapement

The adult Pink Salmon estimate of 6071 represents the third consecutive brood year of strong escapement in Lower Jones Creek. The 2013 estimate surpassed the mean post WUP value of 4968 and was the third highest estimate on record (Figure 9). Pink Salmon migration and spawning timing was typical of the pattern seen in previous years with the first entrants to the system arriving in the first week of September, and peak spawning occurring a few weeks later. The peak count timing of September 26, 2013 was typical for the system. The last Pink Salmon spawners were observed on October 21, 2013, which was also typical of the end-of-run timing for Lower Jones Creek (Appendix A).

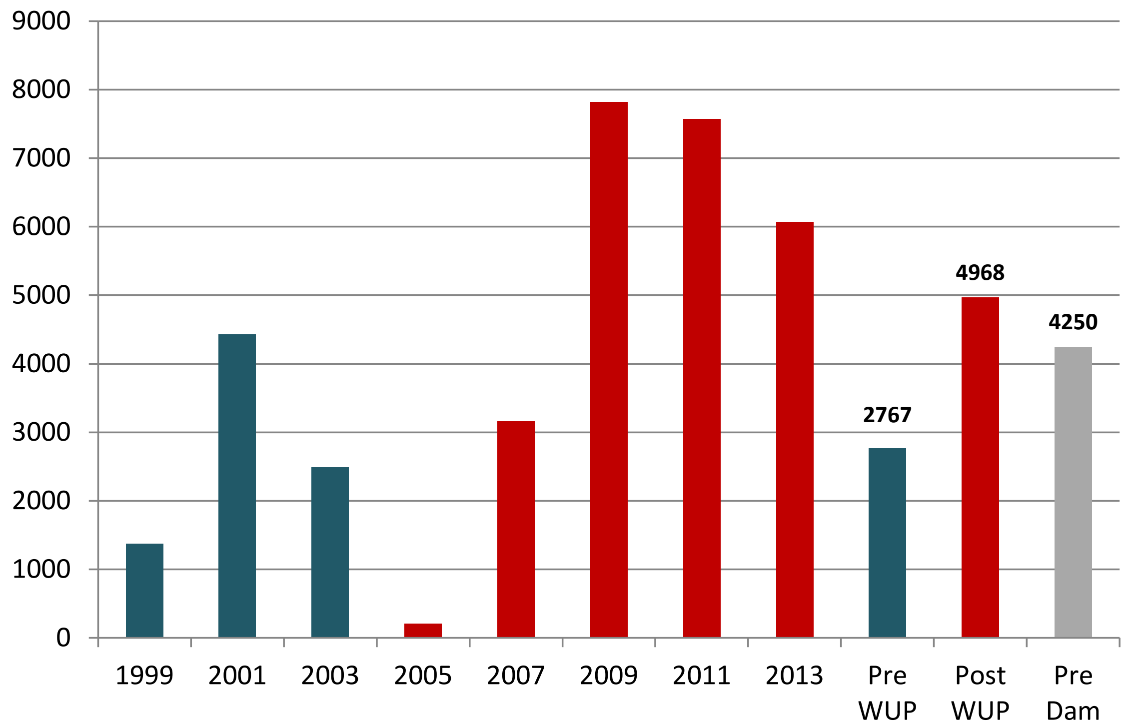

Figure 9 **Lower Jones Creek yearly estimates of adult pink escapement including pre and post WUP mean escapement.**

The heavy concentration of spawners in Sections S4 (1.08 per m^2) and S3 (0.64 per m^2) was observed in all survey years for Pink Salmon. Despite the high number of Pink Salmon spawners, redd density was more than 30% lower compared to the years 2009 and 2011 (Table 3). The reduction in spawner density may have had the potential to improve egg-fry survival, as demonstrated in (McNeil 1964, Fukushima et. al, 1998). “Redd superimposition leading to spawning failure is a concern in water courses where spawning density is high”. The heavy densities of the two previous brood years was thought to have negatively impacted reproductive success due to redd superimposition (Greenbank, Macnair 2010, 2012).

Heard (1975) noted that instantaneous densities (defined as “the density of spawners on the spawning ground at any given time”) of over .80 spawners/m^2 can influence spawning behavior and potentially lead to redd superimposition. The maximum instantaneous density (MID) for Section S4 exceeded this threshold during the past three consecutive broods (Table 3). These results, coupled with field observations that have recorded signs of egg wash in Section S4, supports the possibility that redd superimposition may be an issue in these sections. Section S4 has supported between 8.6% and 11.6% of total spawning activity in the previous three brood years for Pink Salmon.

4.2 Chum Salmon Escapement

The adult Chum Salmon escapement estimate of 376 fish was near the mean estimate for the Post-WUP period (Figure 10). Chum Salmon migration and spawning timing was typical of patterns seen in previous years with the first entrants to the system arriving in mid to late September (September 18, 2013) and peak spawning occurring approximately a month later (October 21, 2013). The last Chum Salmon spawners were observed on December 9, 2013, which was the latest end-of-run timing yet observed in Lower Jones Creek. The pattern of Chum Salmon spawning distribution was typical of Lower Jones Creek, with the majority (75.7%) of all fish spawning in Sections S3 and S4 (Table 5).

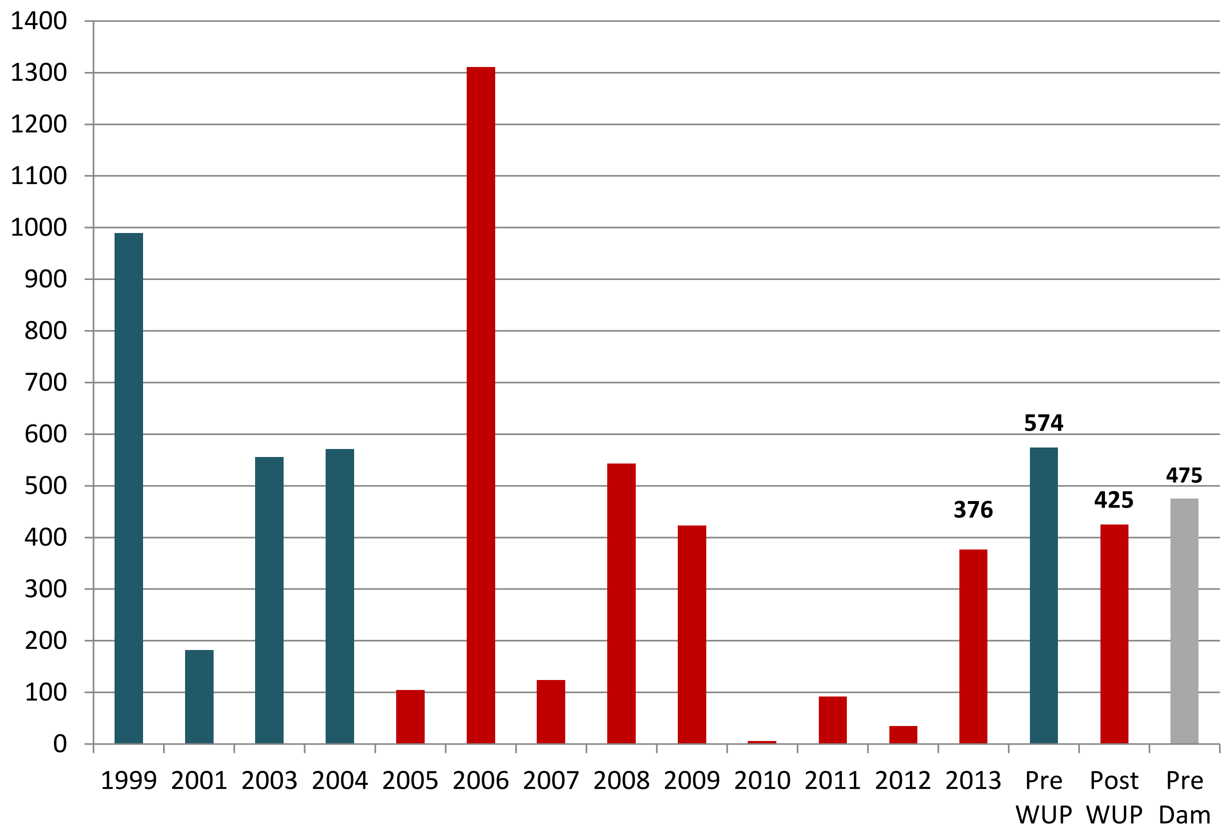

Figure 10. Lower Jones Creek yearly estimates of adult chum escapement including pre and post-WUP mean escapement.

4.3 Coho Salmon Escapement

Coho Salmon escapement to Lower Jones Creek continued to be very limited. Active spawning was observed on November 4, 8 and 15, 2013. Three adult Coho Salmon were observed spawning on November 4, 2013, one was observed on November 8 and two more on November 15. All individuals in Lower Jones Creek were observed in Section S4. This was only the second time that Coho Salmon redds have been observed in Lower Jones Creek. The time previous was in 2005 (Table 8). Coho Salmon have been observed in neighboring Lorenzetta Creek every year surveyed with the exception of 2009. Movement of Coho Salmon from Lorenzetta to Lower Jones may explain the appearance of fry in Lower Jones Creek in years when no adults were observed.

Table 8 Coho observations Lower Jones and Lorenzetta Creek 1999-2013. Spawning was witnessed in Lower Jones Creek in 2005 and 2013. Spawning was observed in Lorenzetta in all years where coho were seen.

Brood Year	Lower Jones Ck	Lorenzetta Ck
1999	0	n/a
2001	0	n/a
2003	0	n/a
2004	0	9
2005	2	13
2006	0	11
2007	2	13
2008	2	5
2009	0	0
2011	2	19
2013	3	21

4.4 Flow and Channel Morphology

The high flow in Lower Jones Creek at the end of September likely had an impact on the success of spawning Pink Salmon adults in Section S2. Assuming that all redds in this section were lost, the peak count (prior to the channel shifting) of 364 Pink Salmon on September 26 was indicative of an overall impact. However, the actual impact can only be speculated upon, as the number of redds created in this section and number of fish in this section that were spawning as opposed to migrating through were unknown and precluded an accurate assessment of loss. The impact of losing the spawn of 364 fish was likely significant considering that this represents 6% of the total escapement estimate of 6071. This phenomenon was also observed during the 2011 and 2009 brood years and was likely a regular occurrence considering the loose, un-compacted gravel substrate that is deposited in this section each spring during the Fraser River freshet.

5.0 RESULTS - FRY OUTMIGRATION

5.1 Fry Outmigration

Of the 74 trapping days completed on Lower Jones Creek (March 18 – May 31, 2014), a total of 2 days were lost due to high flows resulting in a total of 72 operational trapping days. The trap remained fishing in the same location and configuration in Reach 3 for the entire duration of the study. Pink and/or Chum salmon fry were captured on 71 of the 72 days that the trap was operating. Pink Salmon were captured on 65 of 72 and Chum Salmon 67 of 72 operational trapping days.

A total of 6 fish species were captured in Lower Jones Creek, with Pink Salmon fry representing 77.82% of all fish captured (Table 9). Chum Salmon fry comprised the next largest proportion of the catch at 21.9%. Together, salmonids comprised virtually 100% of the total catch in Lower Jones Creek (Table 9). The total catch of 22,897 Pink Salmon fry was the largest amount of fry captured since this project was initiated in 1999, (Appendix A). The 65 days of capture also represented the second most protracted out-migration period yet observed for Pink Salmon fry. Over the previous 8 survey years the mean out-migration period for was 57 days, with the longest trapping period being 71 days in 2012.

Table 9. Species composition of fish captured in Lower Jones Creek, 2014.

Jones Creek			
Common Name	**Taxonomic Name**	**Total Catch**	**% Composition**
Salmonids			
Pink Salmon	*Oncorhynchus gorbuscha*	22897	77.8%
Chum Salmon	*Oncorhynchus keta*	6446	21.9%
Coho Salmon (Age 0)	*Oncorhynchus kisutch*	79	0.3%
Coho smolt	*Oncorhynchus kisutch*	1	<0.1%
Rainbow Trout	*Oncorhynchus mykiss*	2	<0.1%
Non-salmonids			
Sculpins	*Cottus (sp)*	8	<0.1%
Longnose Dace	*Rhinichthys cataractae*	4	<0.1%
Total		**29437**	

The first Pink Salmon fry was captured on March 19 and the last on May 2. The peak single day count occurred on April 4 with a capture of 1315 fry. This is the second largest single day total catch for Lower Jones Creek. The first Chum Salmon fry was captured on March 31 and the last on May 31. The peak single day count was on April 30 with a catch of 458 Chum Salmon fry. The March 21 date for the first capture of Chum Salmon fry was the earliest yet; the previous earliest first capture date was March 23 in 2012 and 2006.

Table 10. Species composition of fish captured in Lorenzetta Creek, 2014.

Lorenzetta Creek			
Common Name	**Taxonomic Name**	**Total Catch**	**% Composition**
Salmonids			
Pink Salmon	*Oncorhynchus gorbuscha*	6574	82.5%
Chum Salmon	*Oncorhynchus keta*	1110	13.9%
Coho Salmon (Age 0)	*Oncorhynchus kisutch*	0	0.0%
Coho Salmon (Age 1+)	*Oncorhynchus kisutch*	125	1.6%
Rainbow Trout	*Oncorhynchus mykiss*	12	0.2%
Cutthroat Trout	*Oncorhynchus clarki*	0	0.0%
Non-salmonids			
Lamprey	*lampreta (sp)*	44	0.6%
Northern Pike Minnow	*Ptycheilus oregonesis*	6	0.1%
Sculpin	*Cottus (sp)*	96	1.2%
Total		**7967**	

The trap on Lorenzetta Creek operated for a total of 28 days from March 26 to April 22, 2014. There were 6 trapping days lost due to high flow for a total of 22 operational days. A total of 8 fish species were captured in Lorenzetta Creek, with Pink Salmon fry representing 82.5%% of all fish captured (Table 10). Chum Salmon fry represented the next largest capture group at 1110 or 13.9% of the total catch. No Coho Salmon fry were captured in Lorenzetta Creek, despite active spawning observed in Lorenzetti Creek. Their absence was likely due to the fact that the trap was pulled before the last week in April which is when Coho Salmon fry typically begin to emerge in Lorenzetta Creek.

A total of eleven mark-recapture tests were carried out on Lower Jones Creek throughout the migration period, nine for Pink Salmon and six for Chum Salmon. Capture efficiencies for Pink Salmon fry ranged from a low of 0.06 to a high of 0.40; the pooled efficiency was 0.25. For Chum Salmon, capture efficiency ranged from a low of 0.18 to a high of 0.37 with a pooled efficiency of 0.28 (Tables 11 & 12). Mark-recaptures were performed at early, peak and late out-migration times, and at a variety of flows from a low of 1.24 m^3s to a high of 3.02 m^3/s.

For the third consecutive year, fry capture results indicated that successful Coho Salmon spawning did occur in Lower Jones Creek during the 2013 brood year. Coho Salmon fry have been captured in Lower Jones Creek during the 2004, 2005, 2010, 2012 and 2014 out-migration trapping programs (Appendix A). Adult Coho Salmon have been observed in Lower Jones Creek in the 2004, 2007, 2009 and 2013 brood years.

Table 11. Pink salmon fry mark recapture results Lower Jones Creek 2014.

Date	Marked	Recaptured	Capture Efficiency	Staff Gauge
30-Mar	500	30	0.06	0.48
8-Apr	1000	379	0.38	0.51
10-Apr	1000	178	0.18	0.52
15-Apr	1000	136	0.14	0.45
18-Apr	1000	147	0.15	0.58
22-Apr	1000	167	0.17	0.51
28-Apr	1000	396	0.40	0.54
8-May	1000	301	0.30	0.52
13-May	1000	355	0.36	0.49
Pooled Total	**8500**	**2089**	**0.25**	

Table 12 Chum salmon fry mark recapture results Lower Jones Creek 2014

Date	Marked	Recaptured	Capture Efficiency	Staff Gauge
22-Apr	500	88	0.18	0.51
28-Apr	400	96	0.24	0.54
8-May	1000	283	0.28	0.52
13-May	1000	288	0.29	0.49
18-May	1000	369	0.37	0.49
26-May	1000	245	0.25	0.52
Pooled Total	**4900**	**1369**	**0.28**	

5.2 Egg-to-fry Survival Estimates

Pink Salmon escapement to Lower Jones Creek was estimated to be 6071 fish in 2013, of which 86% (5221 fish) spawned upstream of the trap site. Assuming a male to female ratio of 1:1, the number of effective females was estimated to be 2610. An average fecundity of 1600 eggs per female was assumed to calculate potential egg deposition (PED) since no direct estimates of Pink or Chum salmon fecundity in Jones Creek are available. The PED (effective females x average fecundity) was estimated at 4,176,000 eggs upstream of the trap location. Based on the total out-migrating population estimate of 129,498 pink fry, the egg-to-fry survival rate for lower Jones Creek was determined to be 3.10 %, (Table 13 & 14). This result was the second highest egg-to-fry survival estimate for Pink Salmon fry on record. Average post WUP mean egg-to-fry survival was 2.42%.

Table 13. Lower Jones Creek Fry Production with upper and lower confidence limits

	Brood Year	Number mark groups	*N*	lower 95% CI	upper 95% CI	CI (± *N* as %)
Chum	1999	3	5,049	2,105	7,992	58%
	2003	3	1,901	960	2,843	50%
	2004	4	1,027	598	1,456	42%
	2005	5	1,055	828	1,282	22%
	2006	5	16,733	13,535	19,930	19%
	2007	8		too few fish		
	2008	5	1,567	1,071	2,062	32%
	2009	10	16,711	15,293	18,130	8%
	2011	11*	2,301	2,003	2,599	13%
	2013	6	24,750	22,853	26,647	7.7
Pink	1999	3	7,160	3,928	10,392	45%
	2003	3	5,702	3,575	7,829	37%
	2005	5	3,570	2,884	4,257	19%
	2007	8	86,442	56,744	116,140	34%
	2009	12	39,315	37,240	41,390	5%
	2011	11	119,249	110,905	127,593	7%
	2013	9	129,498	116,680	142,316	10%

Chum Salmon escapement to Lower Jones Creek was estimated to be 376 in 2013. It was estimated that 79.4% of the chum (299 fish) spawned upstream of the trap site and with a 1:1 male to female ratio, the number of effective females was determined to be 149 individuals. Assuming an average fecundity of 2765 eggs per Chum Salmon female, the PED (effective females x average fecundity) was estimated at 411,985 eggs upstream of the trap location. Based on a total out-migrating population estimate of 24,750 Chum Salmon fry, the egg-to-fry survival rate for Lower Jones Creek was determined to be 6.01%. (Tables 13 & 14). This result represented the highest yet egg-to-fry survival for Chum Salmon since surveys began, and was also greater than any result for Pink Salmon fry. The highest egg-to-fry survival prior to the 2013 brood year was in 2009 with a Chum Salmon fry survival estimate of 3.13%. The post-WUP mean survival for Chum Salmon fry was 2.39% (Table 14).

Table 14. Lower Jones Creek fry population and egg-to-fry estimates for chum and pink salmon. There was no population estimate 2007 due to low chum escapement and fry capture.

	Chum			Pink		
Brood Year	Fry Capture	Pop. Est	Egg-to-Fry	Fry Capture	Pop. Est	Egg-to-Fry
1999	170	5,049	0.37%	396	7,160	0.36%
2003	164	1,901	0.30%	470	5,702	0.32%
2004	108	1,027	0.39%			
2005	161	1,055	1.17%	493	3,570	2.56%
2006	1,572	16,733	1.07%			
2007		0	n/a	5,377	86,442	3.54%
2008	231	1,567	0.97%			
2009	3,965	16,711	3.13%	9,085	39,315	0.66%
2011	368	2,301	1.98%	20,149	119,249	2.24%
2013	6,447	24,750	6.01%	22,897	129,498	3.10%
Pre WUP Mean	147	2,659	0.35%	433	6,431	0.34%
Post WUP Mean	2,124	9,017	2.39%	11,600	75,615	2.42%

5.3 Flow and Channel Stability

As described in Section 3.5, a channel change affecting spawning area in Section S2 of Lower Jones Creek was observed at the time of peak of Pink Salmon spawning. It was assumed that any redds constructed in this area prior to September 26 were washed away. However, this section was downstream of the fry traps so any loss of redds and/or incubating eggs did not impact the fry outmigration results presented here. Additional channel morphology surveys carried out during the outmigration trapping period did not indicate any notable disturbance to redd areas or any lateral channel movement that could have impacted emerging fry (Table 15).

Table 15. Lower Jones Creek average wetted width (ww) and available spawning area by reach Sept 2013-April 2014

Date	18-Sep		13-Oct		26-Oct		15-Dec		18-Mar		15-Apr	
Stage	0.47m		0.475m		0.42		0.69		0.54		0.48	
Flow	1.33cms		1.60cms		0.94cms		4.14cms		2.29		1.35	
Reach	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2	Avg WW(m)	Reach area m^2
S-1	14.80	1110	17.43	1308	17.27	1295	15.33	1150	15.15	1106	14.82	1164
S-2	6.10	549	11.50	1035	11.57	1041	15.53	1398	15.04	1362	14.66	1306
S3-1	11.93	1133	12.35	1173	12.18	1157	17.38	1651	16.26	1488	15.79	1343
S3-2	7.73	1701	10.63	2339	10.33	2273	14.10	3102	14.92	2668	14.80	2577
S3-3	12.94	3947	12.84	3916	12.60	3843	14.98	4569	14.04	4127	13.79	3881
S4	14.37	647	14.53	654	14.33	645	15.77	710	14.71	684	14.50	649
Total		**9086**		**10425**		**10254**		**12579**		**11435**		**10920**
Spawnable Area		**7951**		**9122**		**8972**		**11007**		**10006**		**9555**

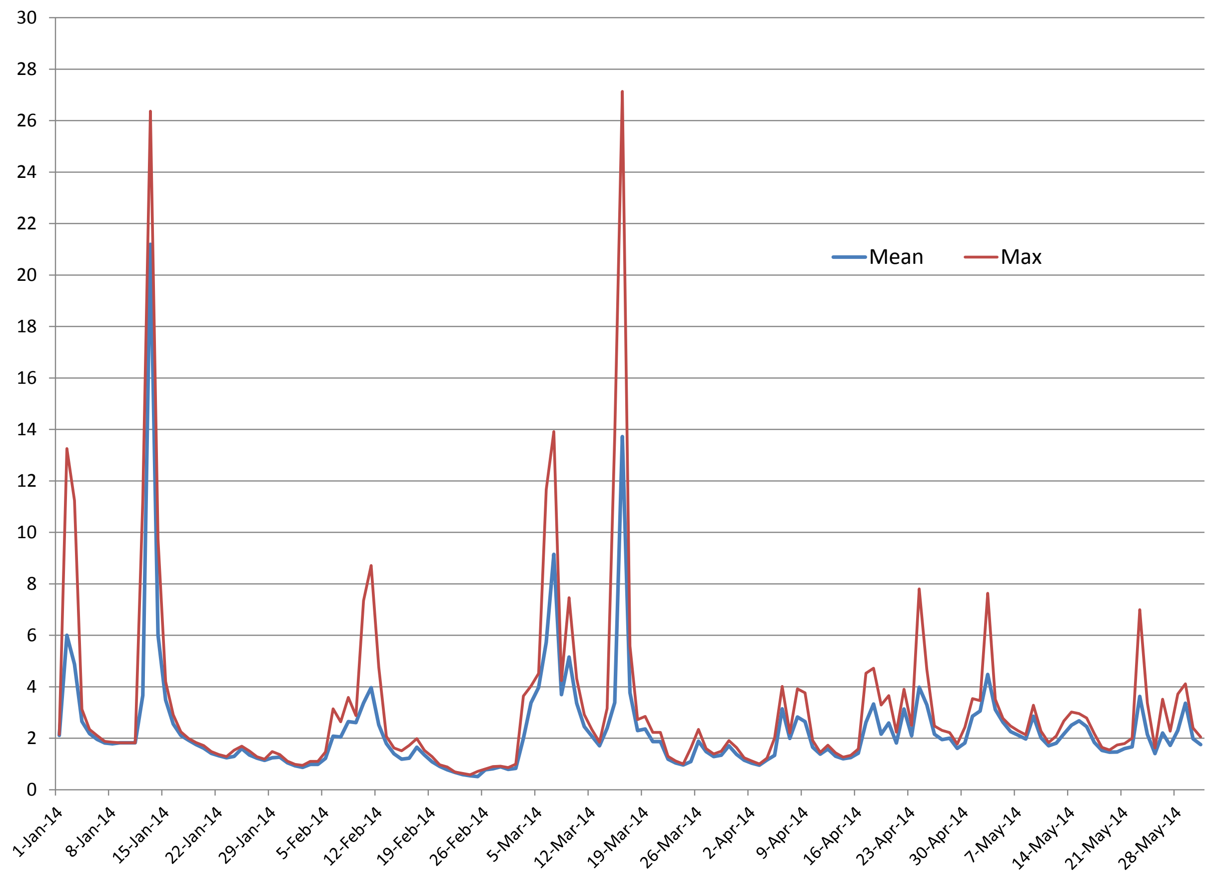

Figure 11. **Daily mean Lower Jones Creek Discharge January 2014 - June 2014. The peak instantaneous discharge occurred March 16, 2014 with an estimate of 27.1 m^3/s.**

5.4 Water Temperature and Accumulated Thermal Units

Mean daily water temperature and accumulated thermal units (ATUs) from September 15, 2013 (start of Pink Salmon spawning) to May 31, 2014 (end of emergence) are shown in Figure 6. ATU for the duration of the trapping program for Pink Salmon ranged from 899 to 1368 (ATU calculated from the beginning of active Pink Salmon spawning, September 15, 2011). The predicted peak emergence period for Pink Salmon fry using the range 800-1100 ATU was from January 26 to April 27, 2014. This did not match the observed peak that was between March 25 and May 2.

For Chum Salmon fry, which used ATU calculated from the beginning of active Chum Salmon spawning (October 1, 2013), predicted peak emergence (using the same range 800-1100 ATU) was from April 10 to May 22, 2014. This corresponded well to the observed emergence pattern for Chum Salmon fry, which ran from April 14 to May 25, 2014. During the incubation period, water column temperatures ranged from a high of 15.7°C to 0.0°C and averaged 5.4°C. This temperature range was considered ideal for salmonid incubation (Pauley, 1988).

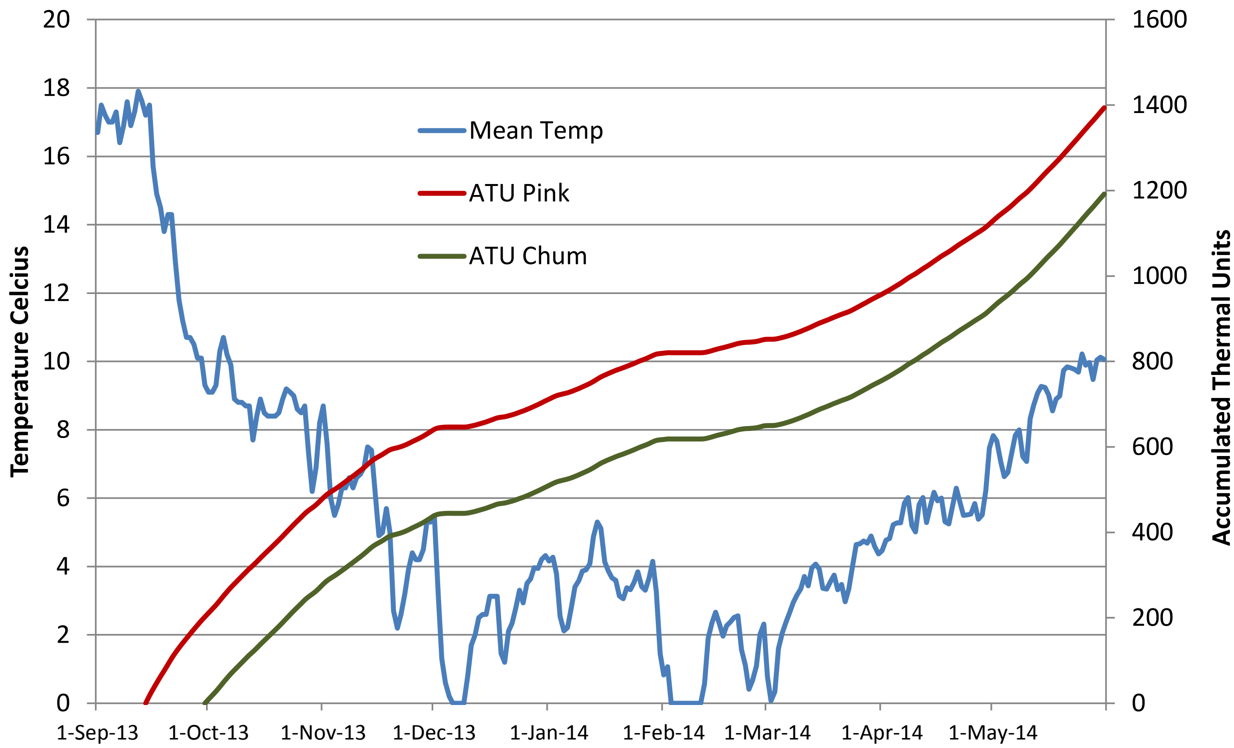

Figure 12. **Lower Jones Creek Temperature and Accumulated Thermal Units September 2013-May 2014**

6.0 GENERAL DISCUSSION

In 2014 egg-to-fry survival for Pink Salmon fry was typical of past observations. It was estimated to be 3.11% and was the second highest yet recorded. It was also above the Post-WUP mean of 2.42%. The egg-to-fry survival estimate for Chum Salmon fry was the highest yet observed for either species at 6.00%, which is over twice the post-WUP mean of 2.39%. Egg-to-fry survival in the post-WUP period has been greater than the pre-WUP estimates in every year examined to date for both species. In general, post-WUP egg-to-fry survival estimates were nearly seven times greater than the pre-WUP estimates (based on pre-WUP rates of 0.35% and 0.34% for Pink and Chum salmon respectively).

Although egg-to-fry survival and total fry production has increased post WUP, survival estimates were still low relative to salmonid enhancement program bio-standards for Pink and Chum salmon in the Lower Fraser River (6% and 9% respectively), as well as other values reported for Pink Salmon populations in 18 other natural, non-regulated streams (mean: 7.4%; ±1 standard deviation: 3.2%-17.0%; Bradford 1995, Appendix C).

Potential issues that may have impact egg-to-fry survival in Lower Jones Creek include the following four factors:

1. **Low flow hindering spawning and creek access.**

   This issue was addressed in 2005 with the introduction of the new flow regime minimum flow requirement of 1.1 m^3/s from September 15 to November 30 and 0.6 m^3/s during the rest of the year. The minimum flow appears to have successfully addressed adult spawning access issues and availability of water for spawning and incubation. All evidence indicates that no stream or spawning accessibility issues exist under the WAH WUP minimum flow requirement.

2. **High flow events causing scour and channel movement.**

   High magnitude flows leading to bed scour and channel shift during the spawning and incubation periods in Lower Jones Creek were observed in most years. Direct evidence of lost spawning habitat was documented in the 2003, 2006, 2008, 2009, 2011 and 2013 brood years. However, the 2003 brood year was the only year with significant loss of spawning habitat in Section S3, which is the most heavily used area of Lower Jones Creek. All other high flow events causing identifiable and significant changes to spawning habitat have only occurred in Section S2, which on average accommodates 6.2% of Pink Salmon and 9.0% of Chum Salmon spawning activity and typically makes up 5-10% of the available spawning habitat in Lower Jones Creek. Section S2 is a highly mobile gravel fan composed of loose material that is easily activated during high flow events. Judging from data collected since 2003, bed scour and channel movement appear to be a chronic problem in this area. The impact of this on fish productivity in Lower Jones Creek has not been directly measured due to the fact that this section lies downstream of the trapping area.

3. **Density dependent factors, eg. redd superimposition.**

   Data collected on the potential impact of redd superimposition on egg-to-fry survival in Lower Jones Creek suggests that it is not a major issue. High spawner density leading to the potential negative impacts of redd superimposition appears to be a problem only with Pink Salmon, and only in some years, (2009 & 2011 to date), and only in Section S4.

4. **Poor substrate quality due to high density of fines.**

   The first three impacts listed above are variable events depending on: magnitude of flow during spawning and incubation periods and the number of returning salmon. Both are only notable in some years, whereas poor substrate quality appears to be a constant factor. Substrate quality was not analyzed in our assessment, though NHC has reported sedimentation related to the accumulation of fines throughout the 2005-2010 period at several of their transect locations. Concentrations of fines in excess of 25% have been regularly recorded at monitoring stations located in the high density spawning areas of Lower Jones Creek (Section S3). The impact of sedimentation, (ie. fine sediment < 10 mm) in spawning gravels has been shown to decrease survival of salmonid eggs to emergence in many studies (Bjornn and Reiser, 1991; Everest *et al.*, 1987; Greig *et al.*, 2005, 200, Jensen et. al., 2009). The impacts of these high concentrations of fine material can be severe. For example, findings in Jensen et. al. (2009) indicated that at concentrations of fines (defined in their study as grain size of less than 0.85 mm) greater than 10%, threshold effects were observed and embryo survival dropped rapidly. This 10% threshold was surpassed in all years examined by NHC in most transects (NHC, 2006, 2008, 2010).

6.0 CONCLUSIONS AND RECOMMENDATIONS

Within the context of Lower Jones Creek, the 2014 out-migration of Pink and Chum salmon fry appears to have been reasonably productive for the system based on our observations to date. The record Chum and Pink salmon fry population estimates were encouraging, as was the increase in the mean survival rate. The fact that Coho Salmon were again found to have successfully spawned and their eggs incubated in Lower Jones Creek was equally positive. Although egg-to-fry survival has improved for both Chum and Pink Salmon post WUP, egg-to-fry survival continues to be near the low end of typical rates in coastal streams. This is likely a product of the watershed's natural characteristics which include unstable slopes upstream of the anadromous reach. These slopes create sediment issues for the lower sections of Jones Creek, and in turn potentially impact incubation success. Despite this fact, based on the evidence to date, the results suggest that fish productivity has improved in general for anadromous salmon due to the operational changes prescribed for Lower Jones Creek. This outcome directly addresses the first of the two secondary management questions:

a) *Is salmon fry survival improved through the operational changes recommended in the WAH WUP?*

Both Pink and Chum salmon fry typically have little residence time in their natal stream once they have emerged from the gravel substrate. Thus, for these two species, fry survival overall appears to have improved. For salmonids with longer instream residence times such as Coho Salmon, there are indications of improved survival, however it is unclear whether this is the result of broader population trends in the area, including the in-migration of fry from Lorenzetta Creek. The present study results would require a more comprehensive analysis, incorporating the outcomes of other relevant studies, as well as the data of past study work in the watershed, to address the primary and secondary management questions. Such a meta-analysis was considered beyond the scope of the present study.

No steelhead trout were encountered in the present study, which was not surprising given that the survey timing windows was geared towards the fall salmonid spawners and early fry out-migrants. As a result, this study did not contribute new information regarding the second management question:

b) *Is juvenile steelhead productivity improved through the operational changes recommended in the WAH WUP?*

The key management question as outlined in the fish productivity monitoring Terms of Reference (TOR) is:

> *Will the operational changes recommended in the Wahleach Water Use Plan result in increased productivity for anadromous and resident populations in lower Jones Creek as predicted from the flow-habitat relationships generated from the empirical study?*

Results of the 2013/14 study work appear to confirm that for Pink and Chum salmon, there have been productivity improvements in their respective populations. The outcome for Coho Salmon remains uncertain, but the data do suggest a possible positive effect. The degree to which these study outcomes match expectations derived from flow-habitat models remains unresolved, as such an assessment was considered outside the scope of this monitoring report.

It should be noted that a recent study by Holtz and Cox (2008) was able to demonstrate that temporal trend-detection in escapement data was not as robust when using MLE methods to solve AUC calculations as either peak count data or more 'traditional' (i.e., trapezoidal) AUC methods. It would appear that in some cases, the MLE can "over correct" escapement data, confounding trend detection. Whether this may have been the case for the present study is uncertain. There are also new techniques that can be employed to add confidence limits to AUC escapement estimates (Millar *et al.* 2012). Adding confidence limits to the escapement estimate would in turn add statistical rigor to the comparison of pre and post WUP escapement and egg-to-fry survival estimates, though this may not necessarily change conclusions. Any future study work should consider incorporating these study outcomes in their analysis of repeat count data.

We recommend that a meta-analysis of all data related to salmonid productivity in Lower Jones Creek be carried out in order to fully address the primary and secondary management questions listed above with rigor. This would include a re-examination of how the AUC escapement estimates were calculated with the goal of adding confidence limits to all past estimates.

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Appendix A List of Chum and Pink Escapement estimates 1999-2011 and species list of all trap captures in Lower Jones Creek 2000, 2004-2014.

Pink Salmon Escapement

Date	1999	Date	2001	Date	2003	Date	2005	Date	2007	Date	2009	Date	2011
			0	sept. 5	0			Sept. 9	11	Sept. 5	3	4-Sep	0
		Sept. 11	1	sept. 11	4	14-Sep	20	Sept. 12	11	Sept. 9	10	8-Sep	3
		Sept. 18	49	sept. 18	32	19-Sep	21	Sept. 17	583	Sept. 14	69	14-Sep	695
		Sept. 23	863	sept. 21	156	22-Sep	11	Sept. 18	875	Sept. 18	484	18-Sep	3561
Oct. 5	1125	Oct. 1	3662	sept. 25	523	27-Sep	10	Sept. 21	1098	Sept. 24	4854	24-Sep	5946
Oct. 12	1261	Oct. 9	1193	sept. 29	1603	3-Oct	115	Sept. 23	1292	Sept. 29	5824	30-Sep	5757
Oct. 13	46	Oct. 15	521	Oct. 1	1989	6-Oct	135	Sept. 25	1438	Oct. 3	2772	4-Oct	3744
Oct. 20	559	Oct. 22	21	Oct. 2	1561	11-Oct	97	Sept. 27	1752	Oct. 8	977	8-Oct	1828
Oct. 29	0	Oct. 29	0	Oct. 6	1114	21-Oct	39	Oct. 5	758	Oct. 13	224	13-Oct	303
				Oct. 9	290	25-Oct	5	Oct. 10	279	Oct. 19	33	18-Oct	72
				Oct. 16	3			Oct. 14	169	Oct. 24	2	23-Oct	26
	1380		**4432**		**2489**		**212**		**3167**		**7820**		**7569**

Escapement Estimates		
	1999-2004	**2767**
	2005-2011	**4692**

Chum Salmon Escapement

Date	1999	Date	2001	Date	2003	Date	2004	Date	2005	Date	2006	Date	2007
		Sept. 11	0	sept. 11	0			14-Sep	1				
		Sept. 18	4	sept. 18	1			19-Sep	0			Sept. 23	1
		Sept. 23	3	sept. 21	4			22-Sep	5	25-Sep	50	Sept. 25	2
Oct. 5	375	Oct. 1	32	sept. 25	2	Oct. 3	3	27-Sep	4	29-Sep	60	Sept. 27	10
Oct. 12	223	Oct. 9	43	sept. 29	25	Oct. 8	25	3-Oct	2	6-Oct	97	Oct. 5	14
Oct. 13	19	Oct. 15	76	Oct. 1	21	Oct. 12	47	6-Oct	14	13-Oct	276	Oct. 10	12
Oct. 20	239	Oct. 22	16	Oct. 2	33	Oct. 19	89	11-Oct	28	16-Oct	399	Oct. 14	23
Oct. 29	46	Oct. 29	9	Oct. 6	110	Oct. 24	107	21-Oct	37	22-Oct	504	Oct. 20	42
Nov. 4	13	Nov. 6	0	Oct. 9	196	Oct. 30	102	25-Oct	16	27-Oct	209	Oct. 23	37
Nov. 10	12			Oct. 16	38	Nov. 6	72	28-Oct	0	2-Nov	219	Oct. 30	13
Nov. 18	5			Oct. 27	70	Nov. 10	82	3-Nov	4	9-Nov	57	Nov. 5	10
Nov. 24	2			Nov. 4	45	Nov. 16	124	9-Nov	2	16-Nov	21	Nov. 8	4
Dec. 1	0			Nov. 12	13	Nov. 22	47			22-Nov	12	Nov. 15	0
				Nov. 23	27	Nov. 27	14					Nov. 21	0
				Nov. 27	4	Dec. 3	3						
	989		**182**		**555**		**571**		**104**		**1311**		**124**

Escapement Estimates		
	1999-2004	**372**
	2005-2011	**574**

Chum Salmon Escapement

Date	2008	Date	2009	Date	2010	Date	2011
						14-Sep	0
Sept. 22	7	24-Sep	24	Sept. 27	0	18-Sep	1
Sept. 27	50	29-Sep	17	Oct. 8	0	24-Sep	3
Oct. 1	94	3-Oct	61	16-Oct	2	30-Sep	2
Oct. 6	132	8-Oct	124	25-Oct	5	4-Oct	4
Oct. 8	123	13-Oct	110	2-Nov	2	8-Oct	7
Oct. 12	114	19-Oct	138	22-Nov	0	13-Oct	6
Oct. 19	78	24-Oct	99			18-Oct	24
Oct. 22	99	2-Nov	42			23-Oct	34
Oct. 27	20	11-Nov	11			27-Oct	38
Oct. 30	21	14-Nov	3			2-Nov	53
Nov. 2	21	20-Nov	0			9-Nov	20
Nov. 9	15					18-Nov	12
Nov. 16	7					25-Nov	6
Nov. 18	2					5-Dec	0
	543		**423**		**5**		**92**

Lower Jones Creek — 2000-2014

Common Name	Taxonomic Name	2014	2012	2010	2009	2008	2007	2006	2005	2004	2000	Total	% Comp
Salmonids													
Pink Salmon	*Oncorhynchus gorbuscha*	22897	20149	9105		5377		493		470	396	35990	83.0%
Chum Salmon	*Oncorhynchus keta*	6446	368	3965	231	11	1556	161	108	164	170	6734	15.5%
Coho Salmon (smolt)	*Oncorhynchus kisutch*	1		2		4	2	1	15	3		27	0.1%
Coho Salmon (fry)	*Oncorhynchus kisutch*	79	6	164					15	2		187	0.4%
Rainbow Trout	*Oncorhynchus mykiss*	2	1	3	2	24	23	14	6	23	19	115	0.3%
Non-salmonids													
Sculpins	*Cottus (sp)*	8	2	2	8	128	61	3	63			267	0.6%
Longnose Dace	*Rhinichthys cataractae*	4		2	1	3	5		3	1	1	16	0.0%
Bridgelip Sucker	*Catostomus columbianus*					2	2		1			5	<0.01%
Peamouth Chub	*Mylcheilus caurinus*					1						1	<0.01%
Mountain Whitefish	*Prosopium williamsoni*	1				1	2					3	<0.01%
Lamprey	*Lampetra sp.*						8					8	<0.01%
Northern Pike Minnow	*Ptycheilus oregonesis*						4				1	5	<0.01%
Threespine Stickleback	*Gasterosteus aculeatus*						2			2	3	7	<0.01%
	Total	**29438**	**20526**	**13243**	**242**	**5551**	**1665**	**672**	**211**	**665**	**590**	**43365**	**100%**

Lorenzetta Creek — 2000-2014

Common Name	Taxonomic Name	2014	2012	2010	2009	2008	2007	2006	2005	Total	% Comp
Salmonids											
Pink Salmon	*Oncorhynchus gorbuscha*	6547	1843	7288		5327		3702		18160	48.6%
Chum Salmon	*Oncorhynchus keta*	1110		4674	2061	1034	7	3022	309	11107	29.7%
Coho Salmon (smolt)	*Oncorhynchus kisutch*	123	351	63	123	75	101	154		867	2.3%
Coho Salmon (fry)	*Oncorhynchus kisutch*			5897						5897	15.8%
Rainbow Trout	*Oncorhynchus mykiss*	4	9	13	21	29	14	40	2	128	0.3%
Cutthroat Trout	*Oncorhynchus clarki clarki*		1			1		2		4	<0.01%
Dolly Varden	*Salvelinus malma*			1		1				2	<0.01%
Non-salmonids											
Sculpins	*Cottus (sp)*	37	85	217	41	79	35	164	17	638	1.7%
Longnose Dace	*Rhinichthys cataractae*							2		2	<0.01%
Bridgelip Sucker	*Catostomus columbianus*							1		1	<0.01%
Mountain Whitfish	*Prosopium williamsoni*				2			3		5	<0.01%
Lamprey	*Lampetra sp.*	18	19	102	53	97	25	259		555	1.5%
Northern Pike Minnow	*Ptycheilus oregonesis*	1		4	1	8				13	<0.01%
Threespine Stickleback	*Gasterosteus aculeatus*					1		1		2	<0.01%
	Total	**7840**	**2308**	**18259**	**2302**	**6652**	**182**	**7350**	**328**	**37381**	**100%**

Appendix B Lower Jones Creek trap at varying flow levels.

Figure 13. Lower Jones Creek Trap March 26, 2014 discharge at approximately 1.85 m^3/s.

Figure 14. Lower Jones Creek Trap April 26, 2014 discharge at approximately 7.5 m^3/s..

Appendix C Comparison of egg-to-fry survival for selected coastal streams and Jones fry raw capture data.

Pink Salmon, *Oncorynchus gorbuscha*

Egg- Fry survival rates		**Egg - Fry**	**Egg - Fry**	
Population	**years of data**	**Mean Survival**	**Std Dev. Survival**	**Reference**
McClinton Cr	6	14.40%	6.9-23.88	Prichard 1948
Nile Ck	3	13.40%	0.4-32.3	Wickett 1962
Morrison Cr.	2	7.83%	0.68	
Nile Ck	5	7.75%	4.79	Wickett 1951
Hooknose Creek	14	6.96%	2.67	Parker 1962
Vedder R	5	6.91%	0.98	Chapman 1970
Harrison R.	5	6.42%	1.77	IPSFC 1967
Lyutoga R	7	6.39%	2.56	
Lesnaya R	7	6.26%	2.18	Kanid'yev et al. 1970
Lakelse Lk.	8	6.20%	1.20	Harding 1970
Fraser R.	15	6.01%	1.14	Pac. Sal. Comm. 1988
Hooknose Cr.	10	5.60%	0.9-16.5	Hunter 1959
McLinton Cr.	6	5.52%	1.31	Neave 1953
Auke Cr.	11	4.30%	0.2-12.3	Taylor 1983
Unweighted Average		**7.43%**		

Chum Salmon, *Oncorynchus keta*

Egg- Fry survival rates		**Egg - Fry**	**Egg - Fry**	
Population	**years of data**	**Mean Survival**	**Std Dev. Survival**	**Reference**
Qualikum	10	26.69%	8.90%	
Disappearance Cr. Alaska	2	12.80%		Wright (1964)
Qualicum R.	4	12.11%	3.44%	Fraser et al. 1983
Big Qualicum R.,, BC	4	11.20%		Lister and Walker (1966)
Barnes Ck.	4	10.63%	3.08%	Fedorenko and Bailey 1980
Minter Cr., Wash.	10	9.10%		
Hooknose Ck.	14	7.64%	2.91%	Parker 1962
Nile Ck.	4	6.51%	1.29%	
Inch Ck	4	4.54%	1.15%	Fedorenko and Bailey 1980
Nile Ck.	6	1.12%	0.46%	Wickett 1952
Unweighted Average		**10.23%**		

Jones Creek 2014

Date	Day	Pink	Chum	Coho fry	coho 1+	RT	Dace	Cot	CTF
19-Mar	wed	0	0						
20-Mar	thu	2	0						1
21-Mar	fri	7	2						0
22-Mar	sat	22	0						1
23-Mar	sun	58	0					2	0
24-Mar	mon	64	3						1
25-Mar	tue	215	7						2
26-Mar	wed	365	12						3
27-Mar	thu	277	8					1	1
28-Mar	fri	185	2						1
29-Mar	sat	424	6						0
30-Mar	sun	152	4						2
31-Mar	mon	213	4						1
1-Apr	tue	506	2						0
2-Apr	wed	619	0						1
3-Apr	thu	827	2						0
4-Apr	fri	1315	5						2
5-Apr	sat	518	7						0
6-Apr	sun	1087	9						5
7-Apr	mon	478	13						1
8-Apr	tue	784	25						4
9-Apr	wed	742	23					1	2
10-Apr	thu	262	9						2
11-Apr	fri	1149	7						0
12-Apr	sat	926	27						2
13-Apr	sun	853	30						1
14-Apr	mon	1123	41						2
15-Apr	tue	586	55						5
16-Apr	wed	641	49						1
17-Apr	thu	1276	88						0
18-Apr	fri	911	60						2
19-Apr	sat	191	7	4					1
20-Apr	sun	671	12	0					2
21-Apr	mon	398	17	0					0
22-Apr	tue	267	11	1					2
23-Apr	wed	325	9	0					2
24-Apr	thu	159	29	0					1
25-Apr	fri	n/a	n/a	n/a	n/a			n/a	n/a
26-Apr	sat	116	20	2					0
27-Apr	sun	279	18	0				1	1
28-Apr	mon	519	193	1					2
29-Apr	tue	702	265	0					1
30-Apr	wed	991	458	1					1
1-May	thu	280	364	23					0
2-May	fri	275	156	2					0
3-May	sat	n/a	n/a	n/a	n/a			n/a	n/a
4-May	sun	59	22	0					4
5-May	mon	159	189	2					2
6-May	tue	169	396	11				1	1
7-May	wed	141	104	2					2
8-May	thu	98	144	1					0
9-May	fri	169	611	4					4
10-May	sat	81	277	2					1
11-May	sun	68	314	2					2
12-May	mon	30	223	3	1				2
13-May	tue	38	182	5					6
14-May	wed	23	207	3					2
15-May	thu	14	71	0					2
16-May	fri	4	34	2			1		2
17-May	sat	18	117	1				1	14
18-May	sun	21	371	4		2	1		5
19-May	mon	11	215	1					8
20-May	tue	6	273	0				1	6
21-May	wed	14	135	2					9
22-May	thu	8	149	0			2		9
23-May	fri	2	102	0					3
24-May	sat	3	85	0					4
25-May	sun	1	131	0					7
26-May	mon	0	12	0					6
27-May	tue	0	6	0					4
28-May	wed	0	8	0					3
29-May	thu	0	1	0					2
30-May	fri	0	5	0					2
31-May	sat	0	3	0					4
	Total	**22897**	**6446**	**79**	**1**	**2**	**4**	**8**	**172**

Lorenzetti 2014

Date	Pink	Cm	Coho fry	coho 1+
26-Mar	58	1	0	7
27-Mar	31	1	0	5
28-Mar	27	7	0	3
29-Mar	97	7	0	1
30-Mar	73	22	0	1
31-Mar	118	13	0	11
1-Apr	194	21	0	6
2-Apr	386	44	0	4
3-Apr	870	39	0	7
4-Apr	466	71	0	13
5-Apr	775	88	0	11
6-Apr	326	14	0	9
7-Apr	401	20	0	11
8-Apr	177	22	0	2
9-Apr	390	39	0	4
10-Apr	n/a			
11-Apr	n/a			
12-Apr	n/a			
13-Apr	n/a			
14-Apr	n/a			
15-Apr	804	157	0	3
16-Apr	625	199	0	9
17-Apr	413	92	0	9
18-Apr	207	163	0	7
19-Apr	n/a			
20-Apr	n/a			
21-Apr	136	90	0	2
22-Apr	n/a			
	6574	**1110**	**0**	**125**