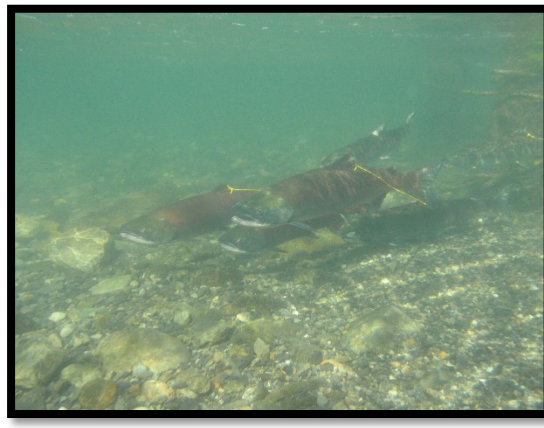
Gates Creek
Salmonid Assessment
Fall 2013
Part 2 of 2



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Executive Summary

This report presents the results of the 2013 adult component of the Gates Creek salmonid out-migration study. The data from this report are collected to compliment juvenile Sockeye (*Oncorhynchus nerka*) abundance data to be collected in the spring of 2014. The abundance, fecundity and percent spawn data from this report will be used to generate estimates of egg to fry survival for both Gates Creek and Gates Creek spawning channel in the spring of 2014.

Sockeye abundance estimates were generated using a combination of data from mechanical counters, visual surveys and video validation. Video validation indicated the Gates Creek mechanical counter overestimates Sockeye abundance by 15%. The simultaneous migration of Pink salmon (*O. gorbuscha*) at the end of the Sockeye run may have further inflated Sockeye abundance estimates in 2013. Failure of the mechanical counters into the spawning channel resulted in the 2013 abundance estimate for the spawning channel being generated solely from visual survey data.

The total estimated abundance of Sockeye returning to the Gates Creek watershed was 56829 for the fall of 2013. Of the total abundance, 43556 fish were estimated to have entered Gates Creek, and 13282 were estimated to have entered the spawning channel. Mean fecundity for females sampled from the spawning channel was 3378 (SD 519). Overall percent spawn for the watershed was estimated to be 79.6%, twice the value for 2012. A total of 5302 and 17702 females completed spawning successfully in the spawning channel and Gates Creek, respectfully. Egg deposition for Gates Creek was estimated to be 17910452 for the spawning channel and 59789345 for Gates Creek in the fall of 2013.

Challenges faced in the fall of 2013 included the failure of the spawning channel mechanical counter and the simultaneous migration of Pink salmon. An enhanced pre-season and in-season maintenance program for the counters and increased capacity building of local technician's knowledge of counter maintenance and operations is a suggested solution. As a secondary recommendation, replacement of mechanical counters with other cost effective enumeration methodologies such as resistivity counters is suggested as a solution to the mechanical counters' sensitivity to debris. Continued and expanded video validation is also recommended to allow generation of counter efficiency estimates and estimation of Pink salmon abundance in future years.

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Acknowledgements

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1.0 INTRODUCTION

Gates Creek is a major salmon bearing tributary of the Seton-Anderson Watershed and runs 12 kilometres from Gates Lake to Anderson Lake draining approximately 34,300 hectares (Komori 1997) (Figures 1 & 2). The Seton-Anderson watershed is located approximately 200km north of Vancouver in the rain shadow of the southern Coast Mountains (Anon. 2000) and contains no glaciers. Anderson Lake is connected to Seton Lake via the Portage Creek, and Seton Lake drains into the Fraser River via Seton River (Figure 1). Gates Creek supports a population of Fraser River Sockeye salmon (*Onchorynchus nerka*) that is important for First Nation, commercial and recreation fisheries, as well as smaller populations of Coho salmon (*O. kisutch*), and Pink salmon (*O. gorbushuca*).

The over 100 populations of Fraser River Sockeye are assigned into four distinct run timing groups based on the time they enter freshwater to begin their upstream migration: Early Stuart, Early Summer, Summer and Late Summer. Gates Creek Sockeye fall into the early summer run-timing group entering the Fraser River from mid-July through to mid-August. Gates Creek Sockeye along with the Portage River population form the Anderson-Seton-ES conservation unit. Fraser River Sockeye face numerous challenges during their upriver migration including recreational and commercial fisheries in the lower portion of the Fraser River and turbulent flows in the Fraser Canyon. Mean summer water temperature in the Fraser River has warmed ~2.0°C since the 1950's (Patterson et al. 2007) and is forecasted to continue to increase with climate change (Morrison et al. 2002, Ferrari et al. 2007). High temperatures have been associated with increased energetic demands, susceptibility to infection, and reduced spawning success in Pacific salmon (Lee et al. 2003, Crossin et al. 2008).

Beginning in the early 1900's Gates Creek Sockeye have been affected by several major development projects. Fraser salmon populations upstream of Hell's Gate including Gates Creek populations were heavily impacted by the slides of 1913 and 1914 (Talbot 1950, Andrew and Green 1958). In 1956, as part of the Bridge River Hydro development, a diversion dam was constructed on the Seton River 750m downstream of Seton Lake. The development, which also included a canal to a power house on the Fraser River, has had significant impacts on the Portage Creek and Gates Creek salmon stocks, through entrainment of juveniles and reduced adult escapement (Fretwell 1989, Komori 1997). In addition to these downstream impacts salmon habitat on Gates Creek has been degraded by residential and agricultural developments (Anon. 2001).

In 1968, a Sockeye specific spawning channel was constructed by the International Pacific Salmon Fisheries Commission (IPSFC) in Gates Creek 800m upstream of Anderson Lake to enhance Sockeye escapement in the Seton-Anderson watershed. The spawning channel was originally overseen by the IPSFC and Fisheries and Oceans Canada (DFO). In 1987, responsibility for channel maintenance and monitoring was turned over to the N'Quatqua First Nation with technical oversight from DFO. A gravel replacement project was undertaken in 2008 and 2009 by DFO and the BC Hydro Fish and Wildlife Compensation Program (FWCP) with the goal of increasing egg-to-fry survival in Gates Creek spawning channel (Anon. 2009). In addition to gravel replacement, changes were made to channel structure and gradient during this project (Anon. 2009). While a long standing time series of juvenile and adult abundances are available for Gates Creek spawning channel, detailed assessment of the gravel replacement activities had yet to be undertaken. Previous to this study, data regarding Sockeye egg-to-fry survival and abundance from Gates Creek had never been collected.

In 2011, the DFO scientific advisors for the Gates Creek spawning channel requested that Instream Fisheries Research Inc. (IFR) submit a study design to enumerate out-migrant Sockeye fry and coho juveniles in Gates Creek to compliment ongoing work on the Gates Creek spawning channel. A proposal including the juvenile enumeration study and complimentary Sockeye adult monitoring was submitted by the Lillooet Tribal Council (LTC) and DFO to the BC Hydro Fish and Wildlife Compensation Program. The objectives of the adult component of this study are to assess the following parameters for adult Sockeye returning to spawn in Gates Creek and the spawning channel:

- Estimate adult Sockeye abundance
- Estimate female percent spawn
- Estimate mean female fecundity
- Generate estimates of egg deposition

This report summarizes the findings of the 2013 adult component of the study.

2.0 METHODS

2.1 Loading Strategy

The Gates Creek spawning channel and Gates Creek are loaded with a known number of adults using a full channel weir and mechanical counters. Fish are excluded from Gates Creek by a full span diversion fence installed on the creek adjacent to the spawning channel out-flow (Figure 3). A second exclusion fence which houses the mechanical counters is installed in the spawning channel (Figure 2). The mechanical counters are similar to those used on subway entry gates which count a single up count as the gate is pushed past a trigger point. There are three counters on the exclusion fence with openings large enough for a single Sockeye salmon to enter at a time. Two of the gates direct fish into the spawning channel. The third gate is attached to a culvert which returns fish approximately 100m underground into Gates Creek above the diversion fence. Counter gates are lockable allowing fish to be directed into either the spawning channel or the creek based on a management strategy directed by DFO advisory staff. Ideally, the channel and creek are loaded so fish from each portion of the run are present in equal proportions in each environment.

In 2012 the DFO scientific advisory staff allowed the first ~7000 fish into Gates Creek with the postulation that early run fish are more likely be affected by pre-spawn mortality (PSM). However, pre-spawn mortality was so high in the spawning channel in 2012 this theory was not adequately assessed (Lingard et al. 2012); therefore it was decided in 2013 that the channel should again be loaded with fish from the later portion of the run. However, miscommunication between DFO scientific advisors and the N'Quatqua fisheries manager resulted in the spawning channel gates being opened on August 21st and the spawning channel being loaded entirely with fish from the early portion of the run. In addition to the miscommunication on the channel loading strategy, the gates on the 2 mechanical counters in the spawning channel malfunctioned on August 26th when the gates jammed in the open position. Loading of the channel ceased on August 27th after a live count estimated a minimum of 12000 fish in the channel (approximately 6000 fish less than in 2012 and 3000 less than in 2011). Due to the high temperatures in the Fraser River at the time there was concern returns may be low for 2013 and all fish were routed in Gates Creek for the remainder of the run to ensure spawning occurred in both habitats.

2.2 Temperature monitoring

Temperature data was collected for both the spawning channel and Gates Creek in the fall of 2013. Three sites on each Gates Creek and Gates Creek spawning channel were monitored with pairs of Onset TidbiT v2 Water Temperature Data Loggers which have an accuracy range of 0.2°C. Temperature was logged every 15 minutes from August 10th to September 25th. For analysis data was condensed to average daily temperature (°C).

Pairs of loggers were placed in the spawning channel at the upper, fifth and bottom legs. In Gates Creek the most upstream logger was placed at the Davidson's horse farm (UTM 10535385E, 5596420N), the second was placed downstream in a heavily used spawning area (UTM 10536331E, 5598092N), and the third most downstream pair was placed on river left across from the spawning channel intake (UTM 10563462E, 5599630N).

2.3 Generation of Abundance Estimates

Abundance estimates for Gates Creek and the spawning channel were generated using a combination of counter totals, visual survey data and video validation in the fall of 2013. In the spawning channel a visual survey was used to generate the total escapement for the entire channel. Visual foot surveys in Gates Creek are used to determine percent spawn and sex ratios, but do not validate the counter totals. To evaluate counter efficiency a secondary count is necessary for providing estimates of counter efficiency. In Gates Creek a combination of counter totals and video data were used to generate total abundance estimates.

2.3.1 Visual Survey Validation of Counter(s)

Spawning Channel

Visual surveys of adult Sockeye, consisting of removal and enumeration of carcasses, are conducted in the spawning channel annually. Sockeye salmon carcasses are removed from the water and placed on the channel bank. The carcasses are separated as males, females, and jacks (precocious males) prior to enumeration. Females are classified as 0%, 50% or 100% spawned, which refers to the number of eggs retained in the carcass (see section 2.4 for further discussion of percent spawn criteria). Carcasses are cut in half as they are counted and loaded into a dump truck. Generally, two people work together to process the carcasses. One technician either uses a field book or hand tally to keep count while the second technician cuts the fish. Cutting of carcasses serves to both expose the egg cavity of females which allows evaluation of percent spawn as well as prevents double counting of carcasses. The enumerated carcasses are then removed to Anderson Lake to prevent bears from becoming habituated to the channel property. Comparisons of mechanical counter generated data to channel visual enumeration data are then undertaken.

A sub sample of carcasses (180 males, 185 females, and 100 jacks) were taken from the spawning channel for biological sampling for the Pacific Salmon Commission (PSC). Fish sampled for PSC sampling are measured for standard length and post-orbital hypural length. Otiliths and scale samples are also collected for each fish.

Gates Creek

Weekly visual surveys in Gates Creek are conducted by N'Quatqua technicians on in conjunction with DFO stock assessment personnel. N'Quatqua technicians accompany DFO personnel on weekly visual surveys. Visual surveys in Gates Creek follow the same protocols for classification of percent spawn as outlined above for the spawning channel. However, in Gates Creek only a sample of individuals are enumerated from the population as it would be unfeasible to recover all carcasses in an unmanaged environment. The primary objective of visual surveys in Gates Creek above the counting fence (exclusion fence) is to obtain sex ratio and percent spawn estimates, which are later applied to the total escapement estimates obtained by the mechanical counter. Below the fence weekly visual surveys include a live count as well as carcass recovery. Peak live count plus the cumulative carcass recovery to that date are used to generate an estimate of the number of spawners in the portion of Gates Creek below the fence. The visual survey data are collected by DFO stock assessment and are released back to us as final estimates.

2.3.2 Video Validation of Counters

In 2013 video footage of fish passing through the mechanical counters was recorded. The counter totals were recorded at the start and end of each video clip. To achieve an estimate of counter efficiency, the total number of fish counted by the counter for all video segments was compared to the total number seen in all video segments combined.

Video was recorded for the counter into Gates Creek as well as the 2 counters in the spawning channel. However, counters in the spawning channel jammed open after only 5 days of loading; therefore,video validation was not done for the channel counters. On the Gates Creek counter, a total of 8.5 hours of video was recorded. Nearly half (4 hours) of the video on the creek counter was viewed twice to control for viewer error.

2.4 Classification of Female Percent Spawn

In 2011 inconsistencies were identified in survey methods employed by N'Quatqua technicians on the channel and the criteria used to estimate percent spawn of female carcasses on the creek by DFO stock assessment personnel. In an effort to eliminate these inconsistencies the N'Quatqua technicians accompanied DFO stock assessment staff during weekly Gates Creek enumeration activities in both the fall of 2012 and 2013. In general, the method of estimating female percent spawn is highly subjective and requires technicians to classify female mortalities as 0%, 50%, or 100% spawned. By DFO stock assessment definition a female Sockeye is categorized as:

- 100% spawned if only a handful of loose eggs remain in the fish (which equates to approximately 500 or less eggs).
- 50% spawned if roughly two handfuls or more loose eggs remain in the fish (greater than a few hundred eggs, but skeins not intact). *DFO advises this category to be rare among the Gates Creek Sockeye population.
- 0% spawned if there are intact skeins remaining in the fish.

To allow continuity of data collection between DFO and N'Quatqua Fisheries technicians, the above listed criteria were used for assessment of percent spawn in Sockeye females in Gates Creek and spawning channel in 2013.

2.5 Fecundity Sampling

Mean fecundity of female Sockeye was estimated using intact egg skeins from 46 un-spawned (0%) females taken from the spawning channel. All sampled individuals were natural pre-spawn mortalities. Samples were spread over the duration of the spawning period lasting from August 28th to September 19th. Post-orbital hypural (POH) lengths (cm) were taken for each fish. Total gonad weight (raw and water hardened) (g) was recorded for each female. A sub sample of 100 water hardened eggs was weighed from each fish. The sub sample weight was divided into the total gonad weight (water hardened) to arrive at the total number of eggs for each female. Full count of all eggs was carried out for 15% of the fish for verification of volume sampling technique.

2.6 Egg Retention

A total of 40 spawned females were sampled for egg retention in the spawning channel over the sampling period (September 4th to September 18th). No egg retention samples were obtained in the first week of observations as no spawned carcasses were available. Similar to fecundity sampling, when fish had more than 100 eggs, gonad weight and a sub sample of eggs was used to estimate the total number of eggs retained.

2.7 Percent Spawn and Total Egg Deposition

Percent spawn refers to the proportion effective females (100% spawned) represent of the total annual female abundance To estimate total effective females and percent spawn the total number of spawned females must be adjusted for females which only spawned partially (the 50% category). While 50% spawn is an arbitrary and subjective figure applied to a wide range of partially spawned Sockeye salmon, it was advised that standard DFO protocol for using this category in estimates of percent spawn and PSM is to split the 50% category total equally between the 0% and 100% categories (S. LePage, pers.comm.). In essence it is assumed a 50% spawned fish represents half a fully spawned fish (100%) and half an un-spawned fish (0%). The following equations were used to estimate percent spawn and pre-spawn mortality rates.

$$PS= (S+0.5*P)/ TF$$

$$PSM= (U+0.5*P)/ TF$$

Where:

PS= Percent spawn

PSM= Pre-spawn mortality

S= Spawned females (100%)

U= Un-spawned females (0%)

P= Partial spawned females

TF = Total number of females (summed 0%, 50% and 100% categories)

Egg deposition was estimated by multiplying the number of effective (100% spawned) females by the estimated mean fecundity.

$$ED= EF*MF$$

Where:

ED= Estimated egg deposition

EF= Number of effective females given by (S +0.5*P)

MF= Mean fecundity

3.0 RESULTS

3.1 Temperature Monitoring

The spawning channel was on average 0.5°C warmer than Gates Creek when data for all three sites were pooled for each spawning ground (Welch's t-test, $P < 0.01$). As water temperatures fell below 10°C the difference between the temperatures in Gates Creek and spawning channel were reduced (Figure 4). Average daily temperature across all three channel sites ranged from 7.8°C to 14.7°C over the period August 10th to September 25th. Over the same period, Gates Creek had a slightly lower temperature range of 7.6°C to 14.0°C (Table 1). The significant result in the difference between Gates Creek and the spawning channel temperatures is likely driven by the cooler temperature observed at the Davidson's horse farm loggers in Gates Creek as the mean temperature was 0.9°C cooler for this site than the loggers in the top leg of the spawning channel (Figure 4, Table 1).

In Gates Creek water temperature increased from upstream to downstream (Table 1, Figure 4). Although, the loggers at the Davidson's horse farm had an overall lower mean average daily temperature (11.1°C SD 1.1°C) than the mean average daily temperature at the logger at the channel intake (11.7°C SD 1.2°C), the difference in mean average daily temperature is less than half a degree when the 0.2°C error margin of the loggers are taken into consideration (Table 1).

In the spawning channel the mean average daily temperature between the three loggers was similar over the spawning period (Figure 4, Table 1). The only two loggers with average daily temperatures greater than the range of accuracy of the loggers were the ones in the top and bottom legs of the channel and even then the overall difference was 0.1°C (Table 1)

3.2 Video Validation

Video validation indicates the creek counter has a tendency to inflate the number of fish passing into Gates Creek by 15%. Total counts by the Gates Creek counter over the 8.5 hours of video was 820 and the total number of fish observed in all video segments was 698. For the 4 hours of video that was viewed a second time to estimate viewer efficiency there was less than a 1% difference in the number of counts observed between viewings (Table 2).

3.3 Abundance Estimates

The first Sockeye arrived at the exclusion fence on August 11th, 2013 and were directed into Gates Creek. From August 11th to September 18th a total of 48,769 fish were counted into Gates Creek. Prior to the spawning channel counters malfunctioning on August 26th, a total of 9,430 fish were counted into the channel by the counters; however, as mentioned above a live count later estimated the number of fish in the channel to be closer to 12000.

3.3.1 Spawning Channel

The total estimated abundance of the 2013 brood for Gates Creek Sockeye from visual surveys was 13282. Of the total abundance females represented 49% (6510), and males (including 700 jacks) represented 51% (6072) (Table 3).

3.3.2 Gates Creek

Visual survey data is collected and processed by DFO stock assessment staff for Gates Creek. Of DFO's total estimate (adjusted for counter efficiency for above the fence) 43927 Sockeye returned to spawn in Gates Creek (41454 above the fence and 2473 below the fence) in the fall of 2013. Of the total abundance males represented 49% (21551 (including 1687 jacks) and females represented 51% (22376). The ratio of males (including jacks) to females was 1:1.04 in fall 2013 (Table 4).

3.4 Fecundity and Egg Retention and Female Size

Mean POH length and fecundity for the females sampled for fecundity from spawning channel in 2013 were estimated to be 49.0cm (SD 3.5) and 3378 (SD 519) respectively (Table 5). The linear relationship between POH length and fecundity for Sockeye sampled from Gates Creek spawning channel in 2013 can be expressed by the equation:

$$y= 23.70x+ 2184.00\ (R^2=0.031)$$

where

y= the number of eggs, and

w= POH length in cm

This regression analysis (Figure 5) shows a weak positive relationship between egg number and POH (R^2 0.031) with 3.1% of variability in egg number being explained by POH in 2013.

Mean raw gonad weight of Gates Creek Sockeye was 356.3g with a range of 256.2g to 593.8g. The linear relations ship of raw gonad weight to POH can be explained by the equation:

$$y= 3.97x + 161.75\ (R^2=0.054)$$

where

y= raw gonad weight (g), and

w= POH length in cm

This regression (Figure 6) shows a stronger positive relationship between raw gonad weight and POH (R^2 0.054) than egg number and POH.

In 2013, mean female fecundity ranged from a minimum of 2351 to a maximum of 4767. Mean egg retention was 1694 (SD 1330) (Table 5). Egg retention ranged from a minimum of 0 to a maximum of 4715 loose eggs. Female Sockeye measured at Gates Creek spawning channel for fecundity sampling ranged in POH length from 48.8cm to 57.5cm with a mean of 49.0cm (SD 3.5) (Table 6).

Over the three years of this study 2012 had the lowest mean fecundity and smallest mean POH length (Table 5). The mean fecundity of females in 2012 (3119) was 5% lower than in 2011 (3260), and 8% lower than in 2013 (3378). Females sampled for fecundity were also smallest in 2012 (46.5cm) when compared to 2011 (48.0cm) and 2013 (49.0cm) (Table 5).

3.5 Percent Spawn and Egg Deposition

3.5.1 Spawning Channel

A total of 6510 females were loaded in the spawning channel in the fall of 2013. Female Sockeye abundance in the spawning channel was broken down into 1131 un-spawned (0%), 154 partial spawners (50%), and 5225 complete spawned (100%) (Table 7). With conversion of partial spawners to their effective female equivalents, percent spawn is estimated to be 81.5% or 5302 females in total for the spawning channel in the fall of 2013. Estimated egg deposition for the fall of 2013 was 17910452 which is twice the number of eggs deposited in 2012 (Table 8).

The distribution of 0% and 100% spawned females changed over the spawning period. Early in the run there was a greater proportion of 0% spawned female carcasses as compared to 100% carcasses (Figure 7)

3.5.2 Gates Creek

The percent spawn estimate for Gates Creek was slightly lower than the estimate for the spawning channel. Of the 22376 females estimated to have entered Gates Creek 79.1% or 17702 are estimated to have been effective spawners. Estimated egg deposition in Gates Creek was 59798345 for the fall of 2013 which is 4 times the number of eggs deposited in 2012 (Table 8).

4.0 DISCUSSION

4.1 Temperature Monitoring

Temperature data revealed a half degree difference between the spawning channel and Gates Creek in the fall of 2013. The slight difference in temperature is likely not large enough to influence biotic factors such as percent spawn. Mean daily temperatures of both Gates Creek and the spawning channel remained below the threshold for thermal stress (Servizi and Jensen 1977, Eliason et al. 2011) over the spawning period.

4.2 Counter Operations and Visual Survey/ Video Validation

Video validation showed that the Gates Creek mechanical counter to overestimates the number of fish passing through the bypass into the creek. Video footage of the creek counter shows that the mechanical counter inflates the abundance count by 15%. Further inflation of the Sockeye abundance is suspected to have occurred due to Pink salmon and smaller numbers of bull trout (*Salvelinus confluentus*) making simultaneous migrations into Gates Creek through the counter. Pink salmon were first seen on video footage on August 27th. No data was collected for Pink salmon to facilitate estimation of their total abundance. If future Pink salmon abundances resemble those experienced in 2013, it would be advantageous to devise a methodology for estimating their run size otherwise their abundance will impact the precision of Sockeye abundance and egg to fry survival estimates.

Replacement or modification of the mechanical counters may be needed in future years. Although it is unclear why the counters malfunctioned in 2013, the result of the failure was the 2013 Sockeye abundance for the spawning channel being generated solely from visual survey data. Visual surveys were found to be within 5% of the counter totals in 2012 suggesting visual surveys produce credible estimates (Lingard et al. 2012); however there is no way to validate this estimate with-out a secondary method for obtaining a count.

The design of the mechanical counter into Gates Creek appears to alter fish behavior and potentially cause physiological stress. Fish entering Gates Creek are dropped over a slide with only a few centimetres of running water. In video footage numerous fish were observed making several attempts to re-ascend the slide, but did not ascend to the point of reaching the gate and initiating additional up-counts. The inflation of the abundance estimate on the creek counter may result from fish moving the gate multiple times as they pass by. It wasn't possible to secure the camera at an angle which permitted view of the counter gate; however, the audio associated with the video segments suggests fish are moving with vigor as they pass through the counter. Additionally, the low flow of water results in fish being partially exposed to air as they fight to re-ascend the slide. Air exposure has been shown to cause stress and reduce migration success in Sockeye (Nguyen et al. 2013).

4.3 Total Sockeye Abundance

Gates Creek had favourable returns in the fall of 2013. For the period of time that DFO has kept records for Gates Creek Sockeye returns, the combined abundance estimate of 57209 (using Gates Creek data adjusted for counter efficiency) for both Gates Creek and the spawning channel is one of the highest on record for all cycles and the highest for the 1993-2009 cycle. The 2013 return was nearly 5 times the 2009 brood and 4 times the cycle average (13218) (DFO unpublished data).

4.4 Fecundity and Egg Deposition

Higher female abundance and higher rates of percent spawn resulted in higher egg deposition in 2013 over 2012 for both Gates Creek and the spawning channel. The estimates of egg deposition for Gates Creek and the spawning channel for the 2013 brood were 5 times and 2 times the egg deposition estimates for 2012, respectively. Mean fecundity was only 1% higher in 2013 over 2012; however, female escapement and lower rates of PSM resulted in a 479% increase in the number of effective females in Gates Creek in 2013.

4.5 Percent Spawn

Despite a reduced total number of female Sockeye being loaded into the spawning channel in 2013 from 2012, the number of effective females in 2013 was twice the value for 2012 due an increase in the percent spawn rate in 2013 over 2012. While 2013 was one of the highest years of percent spawn for the Gates Creek watershed (81.4% for the spawning channel and 79.1% for Gates Creek), for both spawning areas 2012 was one of the lowest years of percent spawn on record where only 27.3% of females successfully spawned in the spawning channel and 51.7% in Gates Creek.

The relative abundance of 0% spawned fish to 100% spawned fish decreased as the spawning period progressed. The data for the 2013 visual surveys in the spawning channel indicates that the proportion of 0% fish decreased as the run progressed. A similar pattern was also observed in 2012 where the majority (70%) of 0% female carcasses were recovered in the first 10 days of the spawning period (August 27th to September 5th) (Lingard et al. 2012). There does appear to be a trend for a higher proportion of early run females to be to be unsuccessful spawners which suggests best practice would be to devise a loading plan which ensures females from all parts of the run are loaded into each spawning habitat. Loading females from each portion of the run into each habitat would ensure that spawning occurs in both habitats which would help to provide insurance against stochastic events such as flooding or freezing during the fry incubation period.

In the summer of 2012 late snow melt resulted in high discharge in the Fraser River during the migration timing of the early summer run timing group (http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/index-eng.html accessed: 01/29/2014) and may have been a contributing factor to low percent spawn for Gates Creek Sockeye. While Fraser River discharge was much lower in the summer of 2013, water temperature exceeded the lethal threshold for Sockeye (>20°C) (Servizi and Jensen 1977, Elaison et al. 2011) for several weeks over the period Early Summer Sockeye were migrating upstream (http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/index-eng.html accessed: 01/29/2014). Despite high water temperatures in the Fraser (the overall estimate of 79.6% percent spawn for the Gates Creek population in 2013 was among the highest on record for the Gates population (DFO unpublished data). While direct correlations cannot be drawn from the data collected for this project the difference in percent spawn among years may indicate discharge as an important contributing factor to the high rates of pre-spawn mortality observed in 2012. The high swim speeds required to pass through river sections under elevated discharge conditions have been demonstrated to affect survival in Sockeye (Rand and Hinch 1998).

In the spawning channel the total number of females has varied year to year. Over the three years data has been collected for this study (2011 to 2013), 2012 had the highest number of females loaded into the spawning channel (9514), 2011 had the second highest (8302) and 2013 had the lowest number (6510). The year with the lowest number of females (2013) was also the year with the highest value of percent spawn. The possibility exists percent spawn in the constrained environment of the spawning channel is in part a function of female density. The 2009 modifications of the channel resulted in the removal of gates on the channel legs which prevented fish from crowding at the top of the channel. Since 2011 it has been observed that fish crowd at the top of the channel and subsequently disperse downstream.

In both 2011 and 2012 there was ~30% difference between values of percent spawn for Gates Creek and the spawning channel; however in 2013 the difference in the values decreased to ~2%. Percent spawn in the spawning channel is a direct count of all female carcasses in the channel and in Gates Creek percent spawn is an estimate generated from weekly sub-samples of available carcasses. Because of the different methods used to generate percent spawn values for each habitat, direct comparison of percent spawn between Gates Creek and the spawning channel in not advisable. However, the decrease in the difference between percent spawn values in 2013 from 2011 and 2012 suggests a change in some factor influencing spawning success. Some possible factors which may have influenced a reduction in the difference of percent spawn figures are: 1) a change in DFO staff conducting visual surveys in 2013 from 2012 and 2011 or 2) the lower density of females or Sockeye in general loaded into the spawning channel in 2013 or 3) the above mentioned lower discharge in 2013 over 2011 and 2012 4) a change in an unmeasured environmental parameter such as temperature or available spawning substrate in either Gates Creek or the spawning channel.

Two ancillary observations for the fall of 2013 were the physical appearance of the fish in the later portion of the run following the closure of the Fraser River to fishing, and fish potentially being stranded on the diversion fence. In the fall of 2013 Sockeye spawning in Gates Creek and the spawning channel appeared to have fewer signs of injury and fungal growth than in 2012 and 2011. The lasting physiological effects of fishing gear entanglement are still unclear, but there is evidence stress caused by gill net entanglement and associated handling impedes survival and upstream migration in Sockeye (Nguyen et al. 2013). The second supplementary concerning observation was of fish potentially being stranded on the diversion fence. As fish carcasses build up on the fence, live and vigorous fish appear to become stranded behind carcasses and exposed to air for prolonged periods of time (multiple minutes) likely to the point of suffocation. Several bull trout (> 60cm) were also found on the exclusion fence behind carcasses of Sockeye.

5.0 Summary and Recommendations

The objectives were largely met in the fall of 2013 for the adult component of this study:

1) A total abundance estimate (adjusted for counter efficiency) of 57209 Sockeye for the Gates Creek watershed (43927 Gates Creek and 13282 into the spawning channel) was obtained.
2) Total female abundance was estimated to be 6510 for the spawning channel and 22376 for Gates Creek.
3) Percent spawn was estimated to be 76.9% for the watershed overall (81.4% for the spawning channel and 79.1% for Gates Creek).
4) Mean female fecundity was estimated to be 3378 in the fall of 2013
5) Egg deposition for Gates Creek and the spawning channel were estimated to be 59798345 and 17910452, respectively.

In addition to the main objectives of the study, several gains were made on the project in the fall of 2013. Measurements of counter efficiency were obtained for the first time and improvements to the consistency of data collection methods achieved in 2012 were built upon. Furthermore, communication with DFO stock assessment personnel and the N'Quatqua technicians also continued to improve in the fall of 2013. Temperature data was also collected for both Gates Creek and the spawning channel which revealed a slight difference in temperature between the two habitats. Temperature monitoring should continue into the future as differences in temperature between the two habitats may relate to biotic factors such as spawning success.

The two major challenges faced in the fall of 2013 were the mechanical counter failures and the breakdown in communication between DFO advisors and N'Quatqua fisheries manager on the loading strategy. Replacement of mechanical counters with a resistivity counter is one suggested solution to the unreliability of the mechanical counters. An advantage of the resistivity counter is the absence of moving parts. Resistivity counters also do not require fish to physically move gates to initiate an up-count which may help to reduce stress on Sockeye as they enter spawning grounds. A second suggestion for preventing future failures of mechanical counters is that a structured maintenance program for the counter be developed with the local technicians which includes preventative maintenance as well as disseminating information regarding counter design enabling N'Quatqua fisheries staff to troubleshoot issues as they arise.

In addition to these two main challenges to the fall component of the Gates Creek salmonid assessment project the simultaneous migration of Pink salmon and lack of assessment program for them likely reduced the precision of the Sockeye abundance estimates in 2013. Expanded video validation could be used to generate a proportional estimate of Pink salmon in 2015.

In summary recommendations for future years of the study are to:

- Continue temperature monitoring.
- Continue video validation of counter abundance estimates and to allow estimation of Pink salmon abundance in 2015.
- Development of pre-season equipment inspection and in-season maintenance schedule for counters to reduce risk of malfunction.
- Capacity building with local N'Quatqua technicians to ensure daily maintenance of counters is completed and trouble-shooting abilities are developed.
- Consider other cost effective enumeration methodologies in the future years if concerns with mechanical counters cannot be alleviated through capacity building and enhanced maintenance schedule.
- Consider modifications to diversion fence in Gates Creek to minimize stranding of fish behind carcasses.
- Improve inter-organizational communication to prevent future miscommunication on management strategies.

Table 1. Temperature data from TidbiT v2 Water Temperature Data Loggers in Gates Creek and Gates Creek spawning channel. Temperatures were logged every 15 minutes but are summarized as mean average daily temperature, Fall 2013.

Spawning Area	Site Name	Mean average daily temperature (°C)	SD	Min	Max
Spawning Channel	Top Leg	12	1.3	7.9	14.7
	5th Leg	11.9	1.3	7.9	14.5
	Bottom Leg	11.7	1.2	7.8	14.2
Gates Creek	Davidson's Farm	11.1	1.1	7.6	13.1
	Below Log Jam	11.5	1.2	7.7	13.9
	River Left at Spawning Channel Intake	11.7	1.2	7.7	14.0

Table 2. Video validation data for mechanical counter in Gates Creek, Fall 2013.

Date	Time Start	Time End	Time Validated	Count at Start	Count at End	Counter Total	Video Total	Second Viewing Count
23-Aug-13	12:00	13:20	1:20	6657	6675	18	12	12
23-Aug-13	13:35	14:30	0:55	6680	6684	4	3	
27-Aug-13	17:00	18:50	1:50	8376	8500	124	100	98
28-Aug-13	10:30	11:15	0:45	11858	12032	174	149	
29-Aug-13	8:00	9:30	1:30	13766	14009	243	219	
29-Aug-13	11:30	12:15	0:45	14282	14330	48	39	39
04-Sep-13	8:00	9:20	1:20	32220	32429	209	176	
Total			8:25			820	698	

Table 3. Summary of Sockeye abundance estimates for Gates Creek spawning channel collected via visual surveys 2011-2013.

	2011	2012	2013
Males	6631	5882	6072
Jacks	551	1672	700
Females	8302	9514	6510
Total	**15484**	**17068**	**13282**

Table 4. Summary of adult Sockeye abundance estimates for Gates Creek 2011-2013. Abundance estimates for Gates Creek are developed using a combination of data from visual surveys and the mechanical counter.

	2011	2012	2013 before adjustment	2013 after adjustment
Males	950	4264	23141	19864
Jacks	12224	976	1968	1687
Females	25907	8336	26133	22376
Total	**39081**	**13576**	**51242**	**43927**

Table 5. Mean fecundity and post-orbital hypural (POH) length (cm) in Gates Creek spawning channel females Sockeye for 2011 - 2013.

	Sample size	Mean POH in cm (SD)	Mean Fecundity (SD)	Range of fecundity values
2011	48	48.0 (2.2)	3260 (571)	1725-4287
2012	40	46.5 (2.4)	3119 (516)	1469- 4035
2013	46	49.0 (3.5)	3378 (519)	2351- 4767

Table 6. Average egg retention and post-orbital hypural (POH) for Gates Creek Sockeye sampled from the spawning channel 2011 - 2013.

	Sample size	Mean POH in cm (SD)	Mean egg retention (SD)	Range of egg retention values
2011	64	46.1 (2.6)	68 (153)	0-896
2012	80	45.9 (2.3)	248 (391)	1-1935
2013	40	48.4 (3.4)	1694(1,330)	0-4751

Table 7. Break down of female percent spawn in Gates Creek spawning channel from visual survey data 2011 - 2013.

Percent spawn	2011		2012		2013	
	Number	% of total	Number	% of total	Number	% of total
0%	3647	43.9	6915	72.6	1131	17.3
50%	588	7.1	163	1.7	154	2.4
100%	4067	49.0	2436	25.6	5225	81.4
Total	**8302**	**100.0%**	**9514**	**100.0%**	**6510**	**100.0%**

Table 8. Estimated number of effective females, mean fecundity and egg deposition for the 2011-2013 brood years for Sockeye spawning in Gates Creek and Gates Creek spawning channel (estimates of effective females for Gates Creek were provided by DFO unpublished data).

Spawning Area	Year	Effective females	Mean Fecundity	Egg deposition
Spawning Channel	2011	4574	3260	14911240
	2012	2518	3119	7853642
	2013	5302	3378	17910452
Gates Creek	2011	21297	3260	69428220
	2012	4311	3119	13446009
	2013	17702	3378	59798345

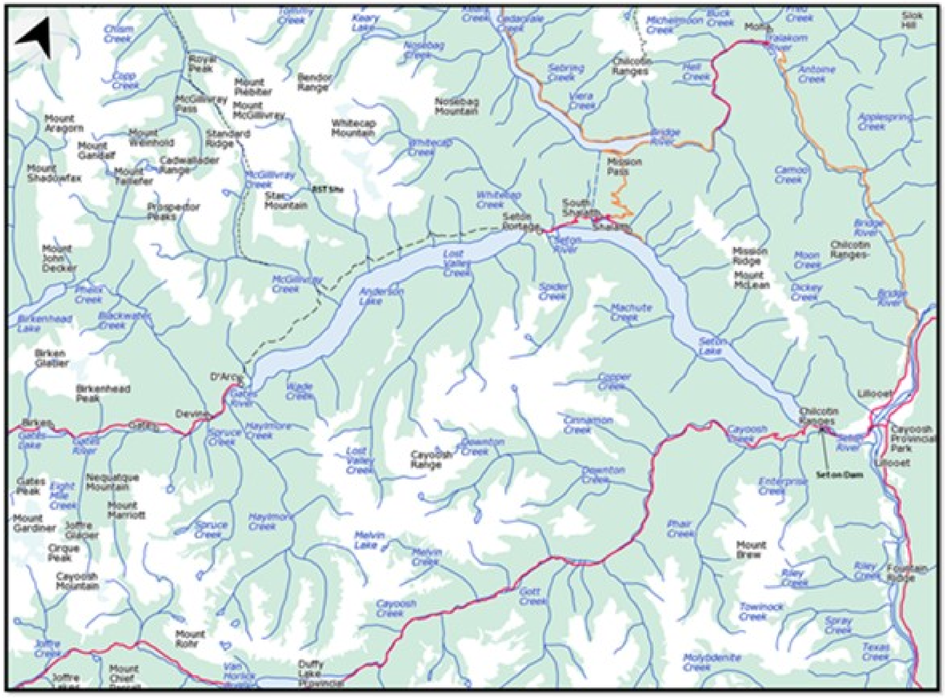

Figure 1. Overview of Seton-Anderson watershed in South Western British Columbia.

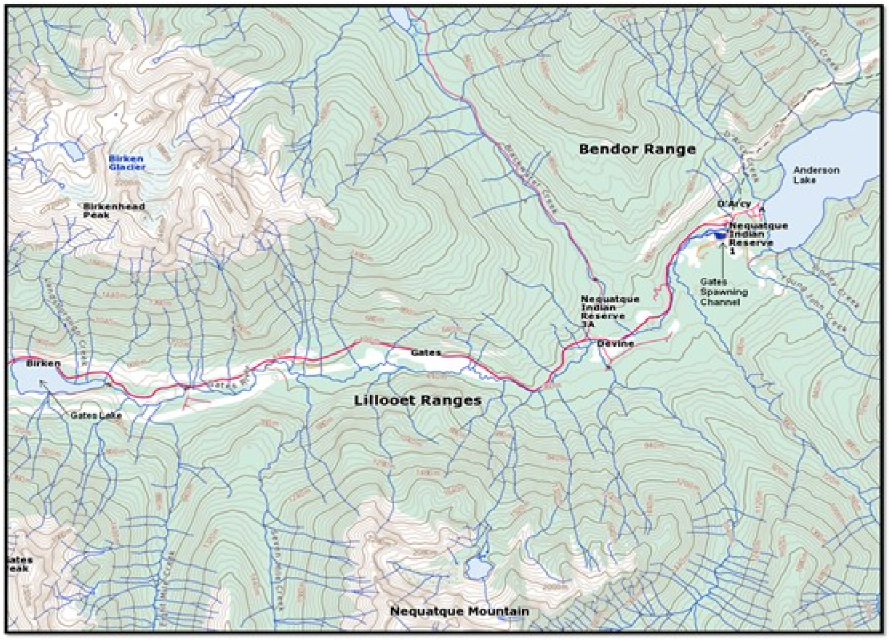

Figure 2. Map of Gates Creek and running from Gates Lake to Anderson Lake. Spawning channel is located near the confluence with Anderson Lake.

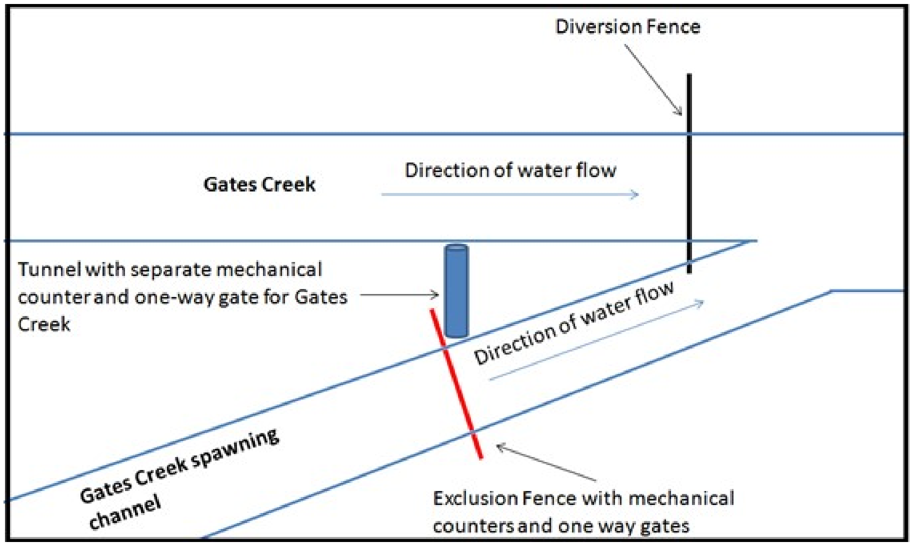

Figure 3. Schematic diagram of enumeration equipment at confluence of Gates Creek and Gates Creek spawning channel spawning channel.

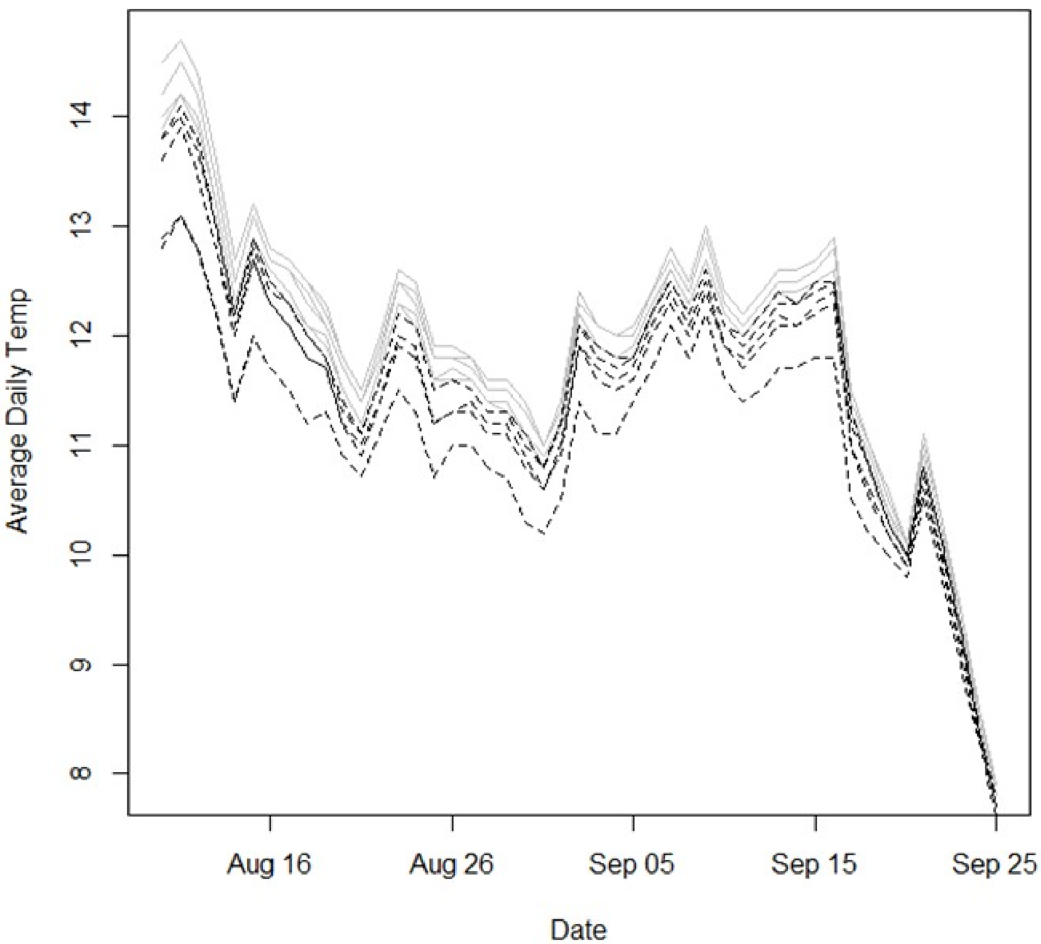

Figure 4. Average daily temperature in Gates Creek (dotted black lines) and Gates Creek spawning channel (grey lines) over the Sockeye spawning period from August 10th to September 25th, 2013.

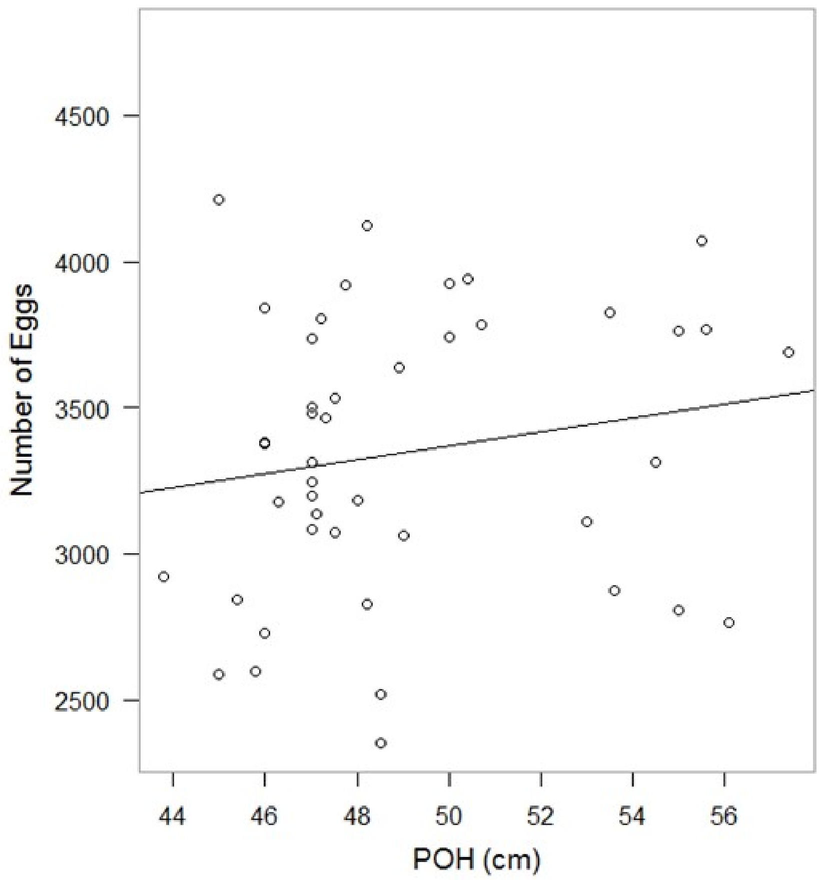

Figure 5. Scatter plot with fitted regression line (y= 23.7x+ 2184, R^2 0.031) of post-orbital hypural (POH) length (cm) and female fecundity (number of eggs) in Gates Creek Sockeye, Fall 2013. All sampled fish were taken from the Gates Creek spawning channel.

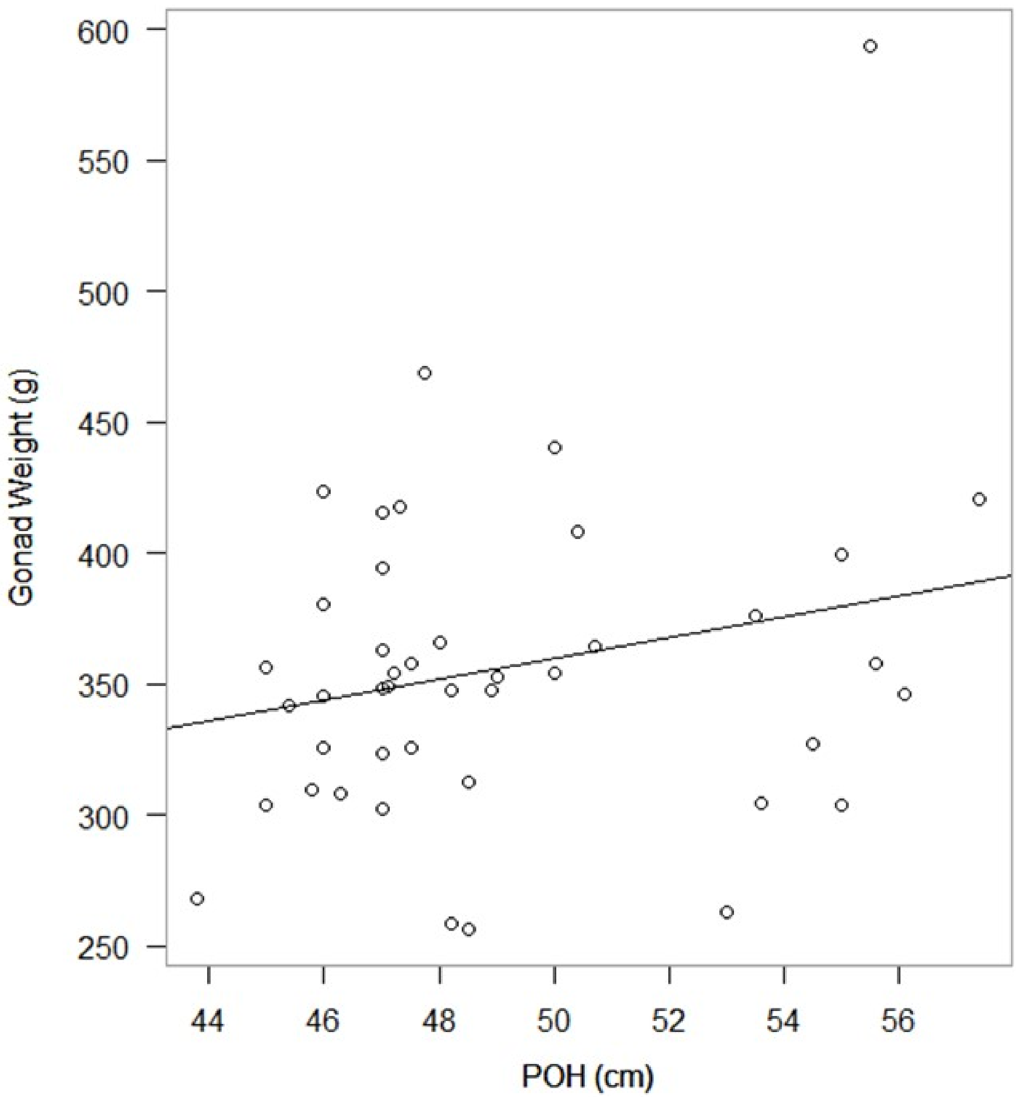

Figure 6. Scatter plot with fitted regression line (y= 3.97x+ 161.75, R^2 0.054) of post-orbital hypural (POH) length (cm) and raw gonad weight (g) in Gates Creek Sockeye, Fall 2013. All sampled fish were taken from the Gates Creek spawning channel.

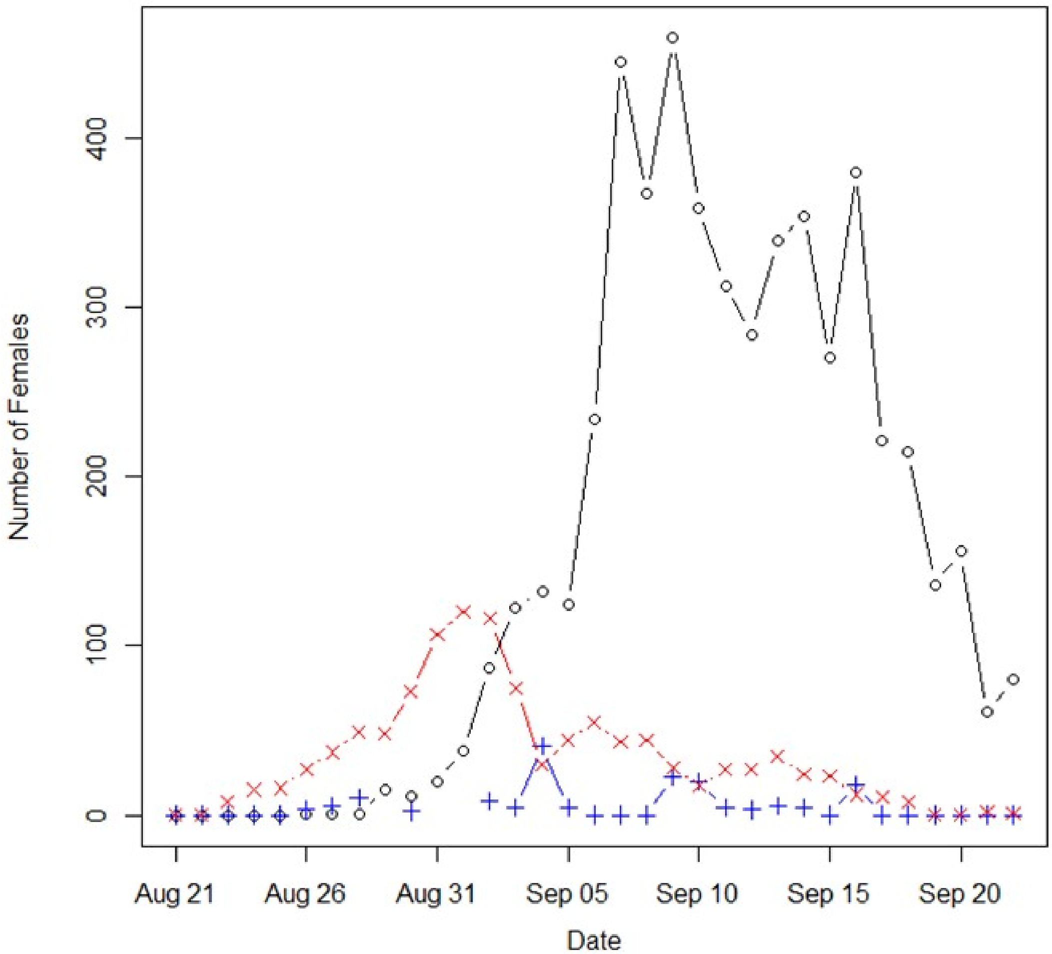

Figure 7. Distribution of female percent spawn over the fall 2013 Sockeye spawning period at Gates Creek spawning channel. Red, blue and black lines represent 0, 50 and 100% spawned females respectively.

REFERENCES

Andrew F.J. and G.H. Green. 1958. Sockeye and Pink salmon investigations at the Seton Creek hydroelectric installation. Progress Report, International Pacific Salmon Commission, New Westminster, Canada. 78 p.

Anonymous. 2000. Bridge-Coastal fish and wildlife restoration program strategic plan. 1, Bridge Coastal Restoration Program. 56 p.

Anonymous. 2001. Gates Creek assessment project. Creekside Resource Inc., Mount Currie, Canada. 35 p.

Anonymous. 2009. Rehabilitation of Sockeye spawning gravel in the Gates Creek spawning channel- year 2. Northern St'at'imc Fisheries, Lillooet, Canada. 56 p.

Crossin, G.T., S.G. Hinch, S.J. Cooke, D.W. Welch, D.A. Patterson, S.R.M. Jones, A.G. Lotto, R.A. Leggatt, M.T. Mathes, J.M. Shrimpton, G.V. Van Der Kraak, and A.P. Farrell. 2008. Exposure to high temperature influences the behavior, physiology and survival of Sockeye salmon during spawning migrations. Canadian Journal of Zoology 86(2): 127-140.

Elaison, E.J., T.D. Clark, M.J. Hague, L.M. Hanson, Z.S. Gallagher, K.M. Jefferies, M.K. Gale, D.A. Patterson, S.G. Hinch, and A.P. Farrell. 2011. Differences in thermal tolerance among Sockeye salmon populations. Science 332: 209-112.

Ferrari, M.R., J.R. Miller, and G.L. Russell. 2007. Modeling changes in summer temperature of the Fraser River during the next Century. Journal of Hydrology 342(3-4): 336-346.

Fretwell M.R. 1989. Homing behaviour of adult Sockeye salmon in repsonse to a hydroelectric diverion of homewater at Seton Creek. International Pacific Salmon Commission Bulletin 25: 38 p.

Komori, V. 1997. Strategic fisheries overview for the Bridge/ Seton habitat management area. Fraser River Action Plan, Department of Fisheries and Oceans, Vancouver, Canada. 83 p.

Lee, C.G., A.P. Farrell, A. Lotto, M.J. MacNutt, S.G. Hinch, and M.C. Healey. 2003. Effect of temperature on swimming performance and oxygen consumption in adult Sockeye (Oncorynchus nerka) and coho (O. kisutch) salmon stocks. Journal of Experiment Biology 206: 3239-3251.

Lingard, S., C. Melville and D.J.F. McCubbing. 2012. Gates Creek adult Sockeye escapement 2012. Prepared for the Lillooet Tribal Council and Department of Fisheries and Oceans, Canada, Instream Fisheries Research, Inc., North Vancouver, Canada. 20 p.

Morrison, J, M.C. Quick, and M.G.G. Foreman. 2002. Climate change in the Fraser River watershed: flow and temperature projections. Journal of Hydrology 263(1-4): 230-244.

Nguyen, V.M., E.G. Martins, D. Robichaud, G.D. Raby, M.R. Donaldson, A.G. Lotto, G.D. Willmore, D.A. Patterson, A.P. Farrell, S.G. Hinch, and S.J. Cooke. 2014. Disentangling the roles of air exposure, gill net injury, and facilitated recovery on the postcapture and release mortality and behavior of adult migratory Sockeye salmon (Oncorhynchus nerka). Freshwater. Physiological and Biochemical Zoology 87(1): 125-135.

Rand, P.S. and S.G. Hinch. 1998. Swim speeds and energy use of upriver-migrating Sockeye salmon (Oncorhynchus nerka): simulating metabolic power and assessing risk of energy depletion. Canadian Journal of Fisheries and Aquatic Science 55: 1832-1841.

Servizi, J.A. and J.O.T. Jensen. 1977. Resistance of adult Sockeye salmon to acute thermal shock. International Pacific Salmon Fisheries Commission. Progress Report 34: 1-51.

Talbot, G.B. 1950. A biological study of the effectiveness of the Hell's Gate fishways. Bulletin 3, International Pacific Salmon Commission, New Westminster, Canada. 80 p.

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