Bridge River Water Use Plan

Effectiveness of Cayoosh Flow Dilution, Dam Operation, and Fishway Passage on Delay and Survival of Upstream Migration of Salmon in the Seton-Anderson Watershed

Implementation Year 6 (2017)

Reference: BRGMON-14

Study Period: July 15th to December 31st, 2017

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Bridge-Seton Water Use Plan

Implementation Year 6 (2017):

Seton Dam Fish Counter Component

Reference: BRGMON-14

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Table of Contents

List of Tables

List of Figures

Acknowledgements

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1.0 Introduction

1.1 Background

Two populations of sockeye salmon (Gates Creek and Portage Creek) have spawning grounds located upstream of BC Hydro's Seton Dam on the Seton River. Upstream-migrating adult salmon must navigate flows in the Seton Dam tailrace to locate and enter the Seton Dam fishway, before ascending the fishway and continuing their migration. Water discharges at Seton Dam during the migration period are intended to maximize upstream adult salmon migration success by providing strong attractive flows for salmon to more-readily locate the fishway entrance. However, neither the effectiveness of the attractive flows for maximizing fish passage at Seton Dam, nor the potential upstream effects of strong attractive flows on post-passage survival, have been evaluated. Therefore, a key objective of the BRGMON-14 monitoring program is to determine if water discharge operations at Seton Dam affect adult salmon passage at or upstream of the dam, and if so, determine what configuration of flows from the siphons at Seton Dam may mitigate any salmon migration issues.

Studies in 2013 identified high water velocities in the Seton Dam tailrace as a potential barrier to Gates Creek sockeye salmon (GCSK) entrance into the Seton Dam fishway (Casselman et al. 2014). Release of water immediately adjacent to the fishway created high water velocities downstream of the fishway entrance. While these high-water velocities provided effective attractive flows that assisted GCSK in locating the fishway entrance, 2013 studies found GCSK were required to expend high amounts of energy to pass the high-water velocities and reach the fishway (as measured through implanted accelerometer tags). Further, GCSK that expended the greatest amounts of energy were found to have decreased post-dam passage survival to spawning grounds.

To determine if reducing water velocities downstream of the fishway would benefit GCSK, an alternative flow release configuration was tested at Seton Dam in 2014 and 2016. Water releases from Seton Dam were changed from the 'routine' flow scenario – releasing water immediately adjacent to the fishway – to an 'alternative' scenario – that released water away from the fishway entrance. The goal of this change was to reduce water velocities downstream of the fishway entrance while maintaining discharge near-constant and within the WUP-mandated hydrograph. Within each study year, flows were alternated between the 'routine' and 'alternative' scenarios during the migratory period for GCSK. GCSK were tagged, released, and their migration to spawning grounds tracked during each flow scenario. In-river flow monitoring was used to measure water velocities downstream of the fishway. Flow monitoring results confirmed water velocities downstream of the fishway entrance were reduced under the alternative flow scenario. Tagging studies found that GCSK had equal success entering the fishway under the routine and alternative flow scenarios, but the time GCSK delayed in the Seton Dam tailrace prior to entering the fishway was longer under the alternative scenario. However, post-passage survival of GCSK to spawning grounds was 15-20% greater for fish that passed Seton Dam during the alternative flow scenario.

Although trials in 2014 and 2016 suggested a positive effect on GCSK, the alternative scenario at Seton Dam has yet to be implemented and tested for the entire six-week duration of the GCSK migration period. Trials of the scenario in 2014 and 2016 were for one week and two weeks, respectively, and occurred near the peak of GCSK migration. As a result, the change in overall GCSK survival to spawning grounds has not been estimated. In addition, baseline post-passage survival data under constant, routine conditions has not been collected as routine flow scenario discharge is normally decreased at the midpoint of the GCSK migration period as part of the Seton Dam WUP hydrograph. Further, water temperature conditions in 2014 and 2016 were near the optimal temperatures for GCSK migration, likely minimizing any potential effect of the observed increase in GCSK delay in the Seton Dam tailrace under the alternative flow scenario. It is unknown if increased GCSK survival would still be observed if elevated water temperatures occurred during the alternative flow scenario. As migration water temperatures can be reasonably expected to warm under future climate scenarios, it is important to continue monitoring the effectiveness of the alternative flow scenario.

An addendum (addendum 2) was submitted to the Comptroller of Water Rights (CWR) by BC Hydro in the fall of 2017 to further monitor the passage survival at Seton Dam based on the 2014 and 2016 trials. The addendum was approved and 2017 was year 6 of the study year, but year 1 (of 2) under addendum 2 for the fish counter component. The Seton Counter component will be monitored annually (as required) until the end of 2020 when a final report synthesizing the four years (2017-2020) of monitoring will be submitted.

1.2 Management Questions

Two management questions from the original Terms of Reference will be addressed in this monitor:

> 3) Does the operation of Seton Dam and fishway affect salmon passage upstream of Seton Dam?
>
> 3a) What changes to the fishway or operation may mitigate salmon migration issues at Seton Dam?

1.3 Summary of Hypotheses

To effectively answer the management questions the following new null hypotheses was formulated:

> H9O: Gates Creek sockeye salmon survival from Seton Dam to spawning grounds is equal under the routine and alternative flow scenarios.

2.0 Methods

2.1 Objectives and Scope

The objective of this study is to provide an estimate of the population-level survival of GCSK from Seton Dam (Figure 1) to the spawning grounds following passage of Seton Dam during the routine flow scenario. These studies will act as a control for future years where the alternative flow scenario will be tested.

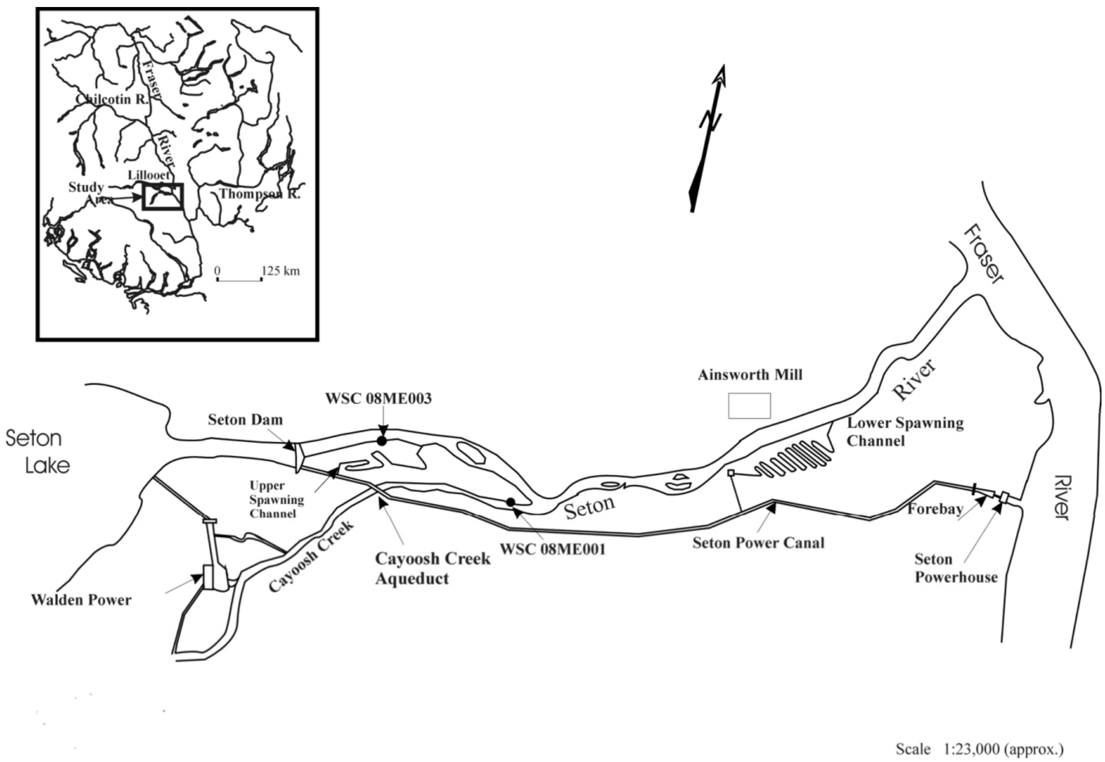

Figure 1. Seton River Study Area.

2.2 Monitoring Approach

This report covers the first year of a proposed four-year extension to the BRGMON-14 monitoring program.

The approach to this study involves three parts: operation of resistivity counter and video validation equipment at Seton Dam, validation of resistivity counter data using video validation analysis that will result in an estimate of fish passing Seton Dam and a post passage survival estimate of GCSK utilizing a statistical comparison of counter and spawning ground estimates. The approach to each of these tasks is described below:

2.2.1 Seton Dam Resistivity Counter

The Seton dam is located approximately 0.5km downstream of Seton Lake. The resistivity counter and video equipment was installed at the top of the Seton Dam fishway and operational by July 29, 2017 (Figure 1). The equipment consists of 8 tube sensors, 2- four channel Logie 2100c resistivity electronic fish counters (Aquantic Ltd., Scotland, UK) and 8 video cameras and recording each of the sensors. The counter was operational until Dec 15, 2017. Remote communication via cell phone was used to ensure the ongoing operation of the counter. Periodic on-site visits were completed when remote communication indicated issues with counter function as well as every (2-3 weeks) to ensure all equipment was functioning properly and for counter maintenance. Counter data was downloaded either remotely or onsite weekly at minimum and more frequently if fish numbers were large. Video data was recorded to hard drives until November 23, 2017. All data will be available as per the data standards established by BC Hydro and the requirements of the BRGMON-14 TOR.

Detailed fish counter operation is summarized in the Year 1 report (Casselman et al. 2013). Briefly, the counter operates by detecting a change in electrical resistance when fish swim through a sensor tube (Figure 2; Figure 3). The change in resistance is measured by the counter and an internal algorithm is used to determine if a fish passed through the counter in the upstream or downstream direction or if the fish entered the sensor unit but failed to pass. For detections meeting the appropriate criteria, the date and time, conductivity, channel, direction (upstream or downstream), and peak signal size (PSS) are recorded. The PSS is a function of fish size, position in the sensor tube, electrode sensitivity, river conductivity, and bulk resistance (background resistance caused by flowing water). Minimum thresholds for detection were set (PSS of 40 out of 127) to eliminate resistance noise caused by air bubbles from the water surface or debris passing through the sensor tubes. Automatic re-calibrations of the sensor were programmed to occur every 30 min to compensate for changes in environmental conductivity.

In 2016, some counter issues were identified, two of the eight channels were not operating properly and had very poor accuracy. It was determined that there was some wiring issues. In early July of 2017, we conducted a detailed assessment of the electrical wiring for the tube sensors. Some faulty connections were identified and repaired. It was also identified that some of the electrical wire that is being used is not appropriate and the issue may arise again. It is recommended that one of the tube sensors be re-wired to help prevent future counter accuracy issues.

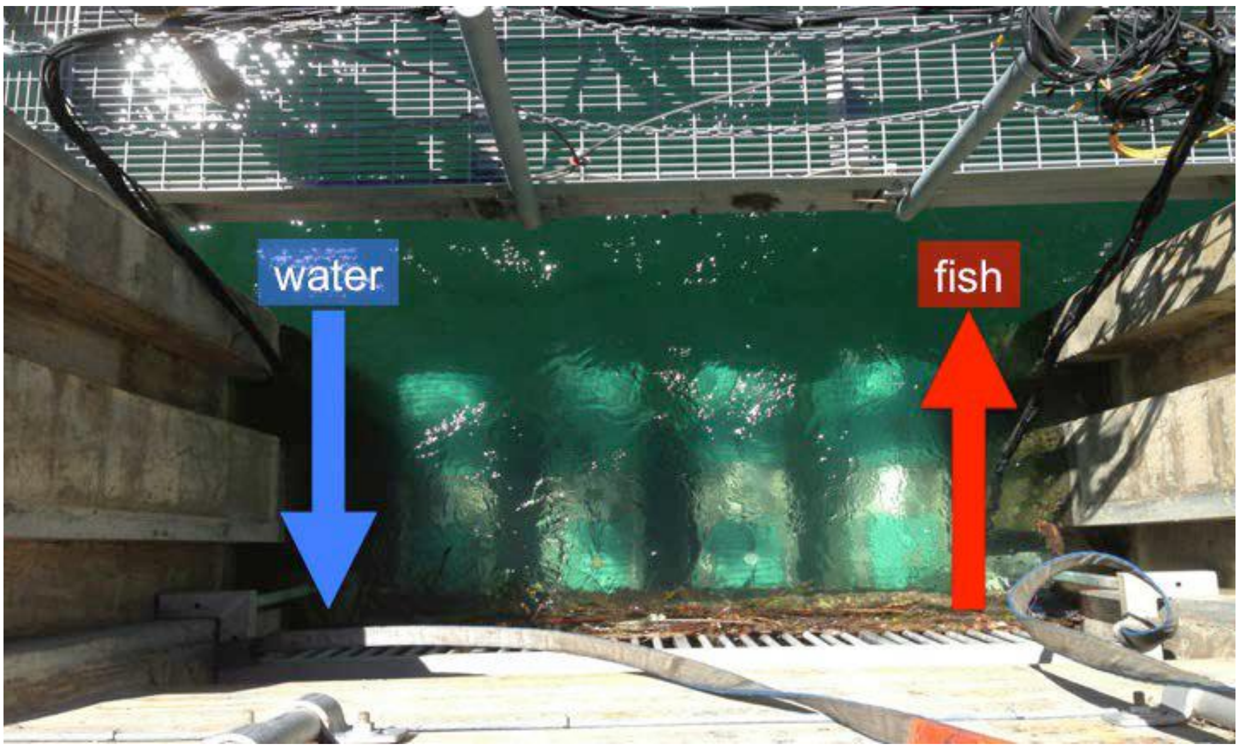

Figure 2. Overhead view of the resistivity counter sensor tubes installed at the exit of the Seton Dam fishway. Water flow and fish migration directions are indicated.

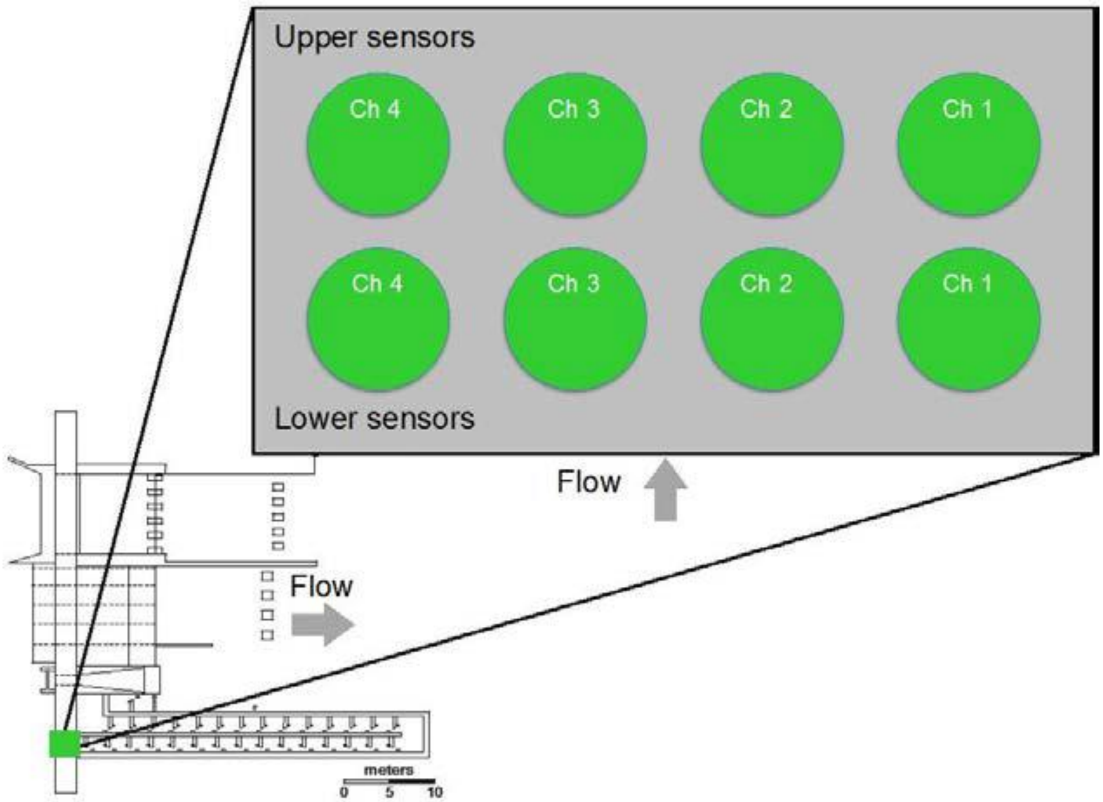

Figure 3. Schematic of the fish counter located at the exit of the Seton Dam fishway. The upper and lower sensors were monitored by two, four channel resistivity counters.

2.2.2 Video Monitoring

Digital underwater video cameras were attached to the upstream end of each counter tube. This allowed for all eight tubes to be validated even when turbidity was high. Video was recorded from 01 August to 23 November and was saved to a digital-video recorder at 30 frames per second. Each camera also has a light to aid nighttime viewing, which allows for improved species identification at night.

2.2.3 Resistivity Counter Data Analysis

For GCSK, video recordings of fish passage were used to validate the counter detections and estimate the accuracy of each sensor tube. Recordings of fish passing through the counter were matched with the counter detections to determine the proportion of detections that were correctly recorded (accuracy). For each tube, 6 randomly–selected 20 min segments of video data were reviewed from every day between 01 August and 12 September. Validation data was pooled for each sensor, resulting in a single accuracy for each sensor tube. The ratio of Gates Creek sockeye salmon to other species was also estimated using video validation and incorporated into abundance estimates using the average ratio of Gates Creek sockeye salmon to other species for each tube.

Counter accuracy (A) was calculated from the number of false positives (counter indicates a fish but one did not pass through the sensor); false negatives (counter does not indicate a fish but video indicates a fish passed through the sensor), and true positives (counter correctly identifies fish moving through the sensor):

Equation (1)

$$A = \frac{TP}{TP + FP + FN}$$

where TP is the number of true positives, FP is the number of false positives, and FN is the number of false negatives. Counter accuracy was broken down by counter tube/channel.

Abundance estimates are calculated by summing the daily net up counts (after accounting for species ratios) over the upstream migration period for Gates Creek Sockeye. Net up counts are calculated as follows:

Equation (2)

$$E = \sum_{t=1}^{k} \frac{U_t - D_t}{q}$$

where, U_t is the total number of upstream detection classified as fish by the counter, D_t is the corresponding number of downstream detections, and q is the counter accuracy. In 2017 k is the day when the Gates Creek migration is assumed to be complete, based on the visual assessment of the data and historical data. All fish observed after September 10 are assumed to be Pink Salmon followed by Portage Creek Sockeye.

2.2.4 Post Passage Analysis

To estimate the 2017 post-passage mortality of GCSK between the Seton Dam and the Gates Creek spawning grounds we used a Bayesian framework that integrated data from multiple stages of the spawning migration:

- Number of GCSK at the top of the Seton Dam fishway (source: BRGMON-14 resistivity counter)
- Escapement at Gates Creek spawning grounds (source: Fisheries and Oceans Stock Assessment)
- Catch from First Nation subsistence fishery in Portage Creek (source: Fisheries Observer Data)
- Survival of pit-tagged subset detected at Seton Dam and subsequently detected at Gates Creek (source: UBC Tagging Data – Scott Hinch pers. comm.)

These data were used to model the probability of GCSK surviving to the spawning grounds following passage through Seton Dam.

Model:

The number of fish that passed through the dam and survived to the spawning grounds can be calculated as:

$$n_{s,t} = s \cdot n_{f,t} - h_{p,t}$$

where $n_{s,t}$ is the true number of fish on the spawning ground in year t, $n_{f,t}$ is the true number of fish passing the fishway in year t, $h_{p,t}$ is the number of fish harvested at Portage Creek in year t, and s is the survival probability between the fishway and spawning grounds (for all years). The number of fish returning to the spawning grounds ($n_{s,t}$) was assumed to follow a binomial distribution with parameters $n_{f,t}$ and s:

$$n_{s,t} \sim Binomial(n_{f,t}, s) - h_{p,t}$$

The parameters $n_{f,t}$ and $n_{s,t}$ represent the **true** number of fish above the fishway and at the spawning grounds, respectively. We used incorporated Poisson-distributed error into the **estimated** (observed) number of fish using:

$$y_{f,t} \sim Poisson(n_{f,t})$$
$$y_{s,t} \sim Poisson(n_{s,t})$$

where $y_{s,t}$ is the estimated number of fish at the spawning grounds in year t, and $y_{f,t}$ is the estimated number of sockeye passing the fishway in year t. The Poisson error structure assumes that the observation variance equals the true abundances. Other error structures accommodating variances larger than the true abundances could be used if necessary, or if values of precision are available for the count data.

The survival probability (s) was modelled as a Bernoulli trial incorporating observed data from a subset of pit-tagged sockeye detected at the Seton Dam and at the outflow of Anderson Lake:

$$d_i \sim Bernoulli(s)$$

where d_i is a binary variable indicating whether a pit-tagged fish successfully reached the spawning grounds (assuming 100% detection efficiency at pit antennas in the dam and at the spawning grounds). Using this method, survival is not modelled as a year-specific parameter, which allows limited tagging data to inform survival in years when tagging did not occur (provided that adequate years of pit-tagging data are available for each treatment type).

For this analysis we used 2017 data only, however, in future years the survival model could be expanded to include additional years of abundance/catch data and tagging data. A key deliverable of the post-passage analysis is to determine the effect of water release treatments on survival from the Seton Dam to the spawning grounds. Survival in year t would then be modelled as a function of water release treatment (i.e., routine vs. alternative) using a logistic regression. Tagging data would be required for each water treatment type:

$$logit(s_t) = \alpha + \beta \cdot x_{treatment}$$

3.0 Results

Abundance and run timing estimates were generated for Gates Creek sockeye salmon using an electronic fish counter at Seton Dam.

3.1 Video and Signal Validation

Review of 88 h of video data between 01 August and 16 September recorded 1,815 fish passing upstream through the counter sensor tubes of which 1,272 were Gates Creek sockeye salmon (Figure 4). Video validation confirmed the upstream detection accuracy for all the eight sensor tubes was 78-92%.

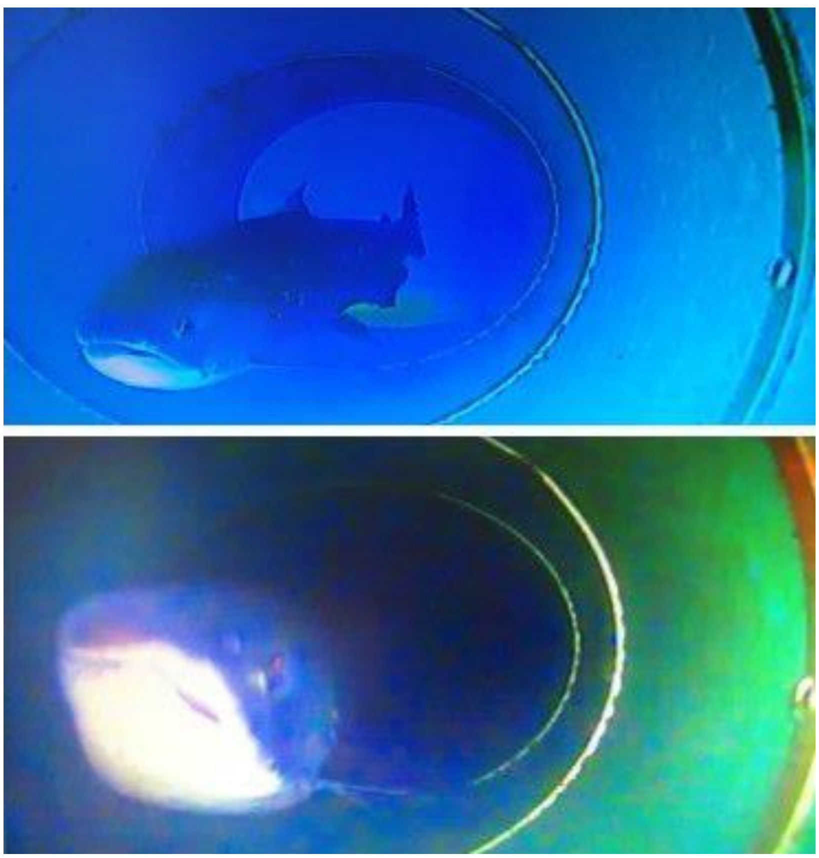

Figure 4. Video validation images from the Seton Dam fish counter of sockeye salmon migrating through the counter tubes in daytime (top) and nighttime (bottom).

Table 1. Summary of counter accuracy for each counter channel.

Counter	Channel	Accuracy
Top	1	85%
Top	2	90%
Top	3	82%
Top	4	78%
Bottom	1	87%
Bottom	2	92%
Bottom	3	91%
Bottom	4	85%

3.2 Gates Creek Sockeye Salmon Abundance

An estimated 18,977 Gates Creek Sockeye Salmon passed through the Seton Dam between 25 July and 10 September based on a counter accuracy at the Seton Dam of ~80% (Figure 5). An exact date for the end of Gates Creek sockeye salmon migration was difficult to determine with the fish counter due to the presence of Pink Salmon and Gates Creek and Portage Creek populations that cannot be visually discriminated. However, the daily migration numbers through Seton Dam decreased between 02 and 10 September, suggesting the Gates Creek sockeye salmon migration ended near this date. The total abundance estimate for Gates Creek sockeye salmon is relatively insensitive to the selection of an end date for the Gates Creek run because of the low numbers of sockeye migrating in mid-September when the migration of Gates Creek and Portage Creek sockeye salmon overlaps. Species ratio calculated through video validation indicate that the majority of fish (>75%) that migrated past the counter after 07 September were Pink Salmon.

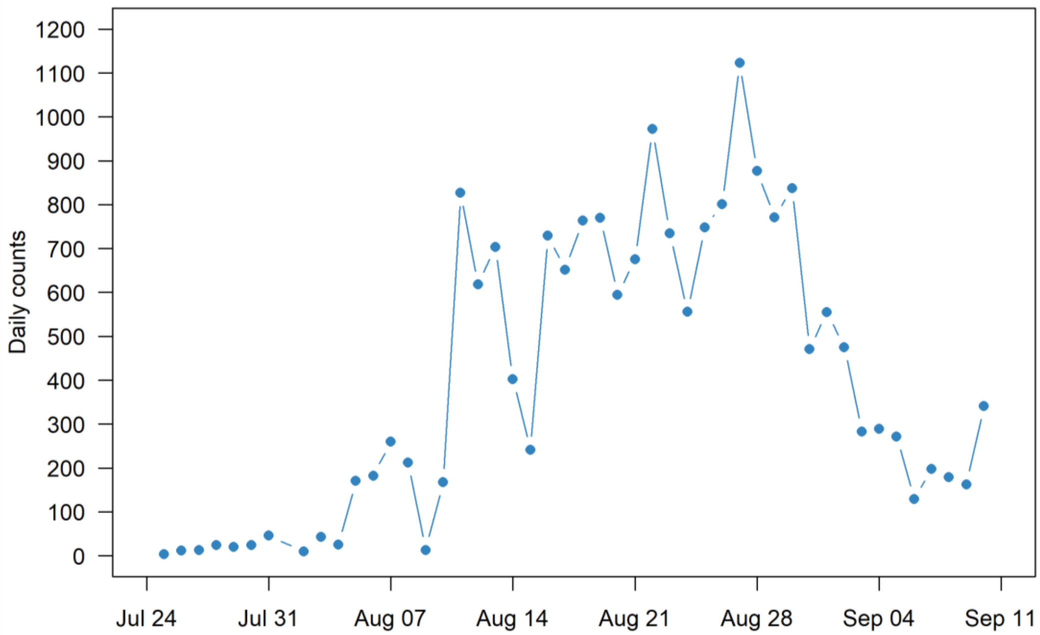

Figure 5. Daily abundance of fish migrating through the Seton Dam fishway between 25 July and 10 September 2017.

3.3 Post Passage Survival

The Bayesian model was implemented in JAGS (Plummer 2003) and R Project (R Core Team, 2017) using the package "jagsUI" (Kellner 2017). We used uninformative priors on s and $n_{s,t}$. Three mcmc chains of 10,000 iterations in length were used, with a burn-in period of 5,000 iterations. Convergence was assessed using traceplots of posteriors on $n_{s,t}$, $n_{f,t}$, and s.

The data inputs for the model (Table 2) were collected from different sources as described in section 2.2.4. There are no estimates of uncertainty available for the data sources presented in Table 2, although counter accuracy at the Seton Dam was assumed to be high (~80%). The Gates Creek estimate was based on low precision visual surveys, where surveys may range from weekly coverage to single surveys, in the creek mainstem (4,561 individuals) and a mechanical counter or visual counts in the spawning channel (2,479 individuals) (DFO, 2017). The PIT-tagged subset of sockeye salmon used to calculate survival consisted of 124 individuals that were tagged downstream of the dam throughout the period of August 9 to August 21, 2017.

Table 2. Input data for Bayesian Model

Data	2017 Value
Number of GCSK at top of the Seton Dam fishway	18,977
Escapement at Gates Creek spawning grounds	7,041
Catch from First Nation subsistence fishery in Portage Creek	642
Survival of pit-tagged subset detected at Seton Dam and subsequently detected at Gates Creek (detected at Gates Creek / total tags released)	0.766

Prior and posterior distributions are shown in Figure 6. Posterior mean values of $n_{s,t}$ and $n_{f,t}$ closely fit the data, while the mean estimated survival (0.39) was substantially lower than survival from the pit-tagged subset (0.77). These results are unsurprising given the uninformative priors used and the large discrepancy between the number of fish observed above the Seton Dam fishway and the DFO escapement estimate at Gates Creek (Table 2). This discrepancy is likely because the fish PIT tagged in 2017 were not representative of the population enumerated at the Seton Dam counter and at Gates Creek. PIT-tagged fish were of high condition and were known to be Gates Creek sockeye (strays from other stocks are also present during the migration and may not be PIT tagged), which likely resulted in a higher rate of survival relative to that of the total population (observed by the resistivity counter). To resolve this discrepancy, the Bayesian model requires PIT-tagging data from a representative subset of the population being enumerated by the counter (i.e., the whole migration) under both the current and alternative flow scenarios. Without these data, the Bayesian post-passage survival model cannot be used to inform the effect of flow treatment on post-passage survival due to the difference in survival for the entire population and high condition Gates Creek Sockeye salmon highlighted in this analysis.

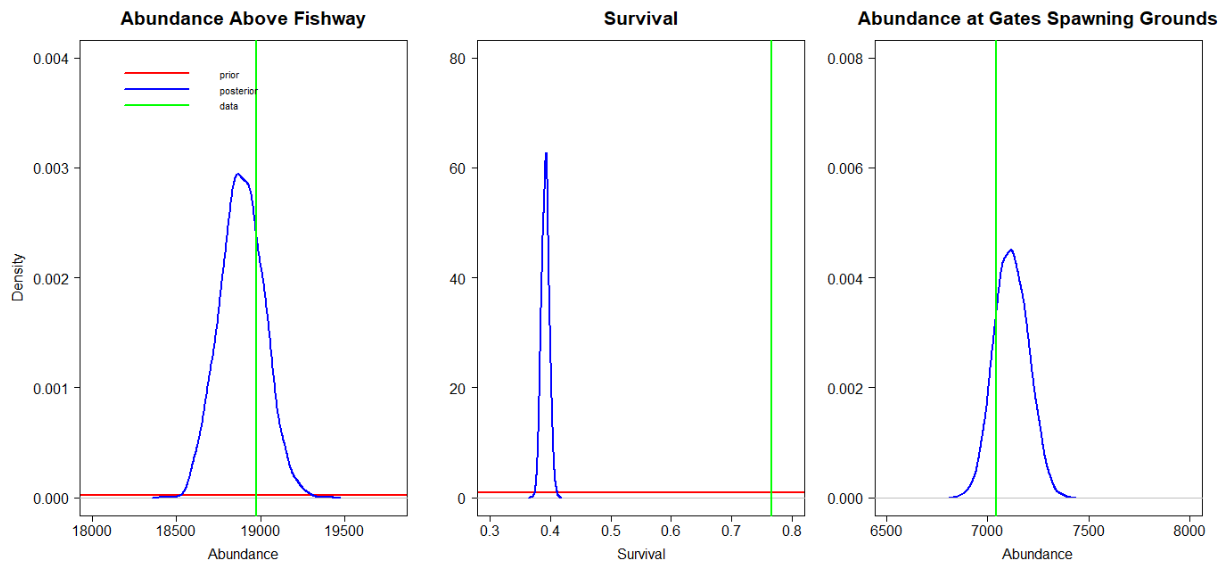

Figure 6. Bayesian prior and posterior distributions and observed data for post-passage analysis of GCSK mortality between Seton Dam and the Gates Creek spawning ground.

Summary

The fish counters in the Seton River fishway provided data on the abundance of fish migration through the counter. These data were used to calculate estimates of abundance for Gates Creek Sockeye. It was estimated that 18,977 Gates Creek Sockeye, migrated past the counters between 25 July and 10 September.

This year's data quality was qualitatively deemed to be high with abundance estimates having lower uncertainty (Accuracies > 78%). Counter operations for 2017 were successful, but electrical wiring updates are recommended. One of the counter tube sensors was not wired with the appropriate wire and was producing high amounts of erroneous data. To fix this problem a new wire (three conductor 16AWG) will need to be pulled from the junction box at the gantry (on dam) to the battery room where the counters are located.

This analysis should be considered a preliminary example of how the Bayesian framework can inform the effect of Seton Dam flow treatments (routine and alternative) on post-passage survival of Gates Creek sockeye salmon. There are several points to consider when applying this model to the management questions:

- The Bayesian model framework presented here requires representative PIT-tagging data from each treatment being assessed.
- The current PIT-tagging data are insufficient to determine the effect of flow treatment using the Bayesian framework presented here because the PIT tagging data do not adequately represent the migrating population and there are too few years of PIT-tagging data to include flow treatment in the logistic regression outlined in section 2.2.4. Straying rates can vary between years and have the potential to significantly affect the numbers of fish observed by the counter and what is observed at the Gates Creek spawning grounds (Bett et al. 2017). Strays may be less likely to make the full migration to Gates Creek, but this can be confirmed with PIT tag data.

- The effect of flow treatment cannot be determined using counter and escapement estimates alone due to the coarse (low precision) nature of Gates Creek escapement estimates. The effect of the alternative flow treatment (15-20% increase in survival) may be less than the relative uncertainty in the Gates Creek escapement estimate.
- A benefit of the Bayesian framework is that PIT-tagging data is not required for each year included in the model (years with PIT-tagging data can inform years without data); however, PIT-tagging years must be representative of environmental conditions from all years. For example, in a year with abnormally high river temperatures, additional PIT-tagging data should be collected to separate the effect of flow treatment and temperature.

BC Hydro is considering implementing the alternative flow scenario beginning in 2019 in-light of previous research from BRGMON-14 indicating that the alternative flows increase sockeye post-passage survival (Casselman et al. 2013). There is still uncertainty regarding the effects of flow treatment and environmental conditions on post-passage survival, particularly regarding the combined effects of high temperature and flows through Seton Dam, and this analysis suggests that counter and escapement data alone will not be sufficient (low power) to detect the effect of flow scenario on post-passage survival. The Bayesian post-passage analysis could be used to determine the effect of flow treatment on survival of Sockeye salmon to Gates Creek following passage through Seton Dam; however, additional years of PIT-tagging data (in addition to counter and escapement estimates) are required to better inform the model and address straying and sampling concerns.

References

Bett, N. N, Hinch, S. G, Burnett, N. J, Donaldson, M. R, & Naman, S. M. (2017). Causes and Consequences of Straying into Small Populations of Pacific Salmon. *Fisheries, 42*(4), 220-230.

Casselman, M.T., Burnett, N.J., Bett, N.N., Middleton, C.T., Martins, E.G., Braun, D.C., McCubbing, D., and Hinch, S.G. 2013. BRGMON-14 Effectiveness of Cayoosh Flow Dilution, Dam Operation, and Fishway Passage on Delay and Survival of Upstream Migration of Salmon in the Seton-Anderson Watershed. Annual Report – 2013. Report prepared for St'át'imc Government Services and BC Hydro. The University of British Columbia, Vancouver, BC. 66 p. + 2 Apps.

Casselman, M.T., Burnett, N.J., Bett, N.N., McCubbing, D., and Hinch, S.G. 2013. BRGMON-14 Effectiveness of Cayoosh Flow Dilution, Dam Operation, and Fishway Passage on Delay and Survival of Upstream Migration of Salmon in the Seton-Anderson Watershed. Annual Report – 2012. Report prepared for St'át'imc Government Services and BC Hydro. The University of British Columbia, Vancouver, BC. 60 p. + 9 Apps

Kellner, K. 2017. jagsUI: A wrapper around rjags to streamline JAGS analysis. R package version 1.4.9. http://CRAN.R-project.org/package=jagsUI

Plummer, M. 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling, proceedings fo the 3rd international Workshop on Distributed Statistical Computing (DSC 2003), March 20-22, Vienna, Austria.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation