Bridge River Project 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 7

Reference: BRGMON-14

2018 Seton Dam Fish Counter Component

Study Period: July 15, 2018 to September 31, 2018

Daniel Ramos-Espinoza, Annika Putt, Michael Chung and Carson White

InStream Fisheries Research Inc.
Unit 215 – 2323 Boundary Rd.,
Vancouver, BC.
V5M 4V8

St'át'imc Eco-Resources
10 Scotchman Rd.
PO Box 2218
Lillooet, BC
V0K 1V0

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Bridge-Seton Water Use Plan

Implementation Year 7 (2018):

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Daniel Ramos-Espinoza, Annika Putt, Michael Chung and Carson White

Prepared for:
St'át'imc Eco-Resources Ltd.
10 Scotchman Road
PO Box 2218
Lillooet, BC V0K 1V0

Prepared by:
InStream Fisheries Research Inc.
Unit 215 – 2323 Boundary Road
Vancouver, BC V5M 4V8

Executive Summary

High water velocities in the Seton Dam tailrace were identified as a potential barrier to Gates Creek sockeye salmon (GCSK) entering the Seton Dam fishway. An alternative flow release configuration was tested at the Seton Dam in 2014 and 2016 to determine if reduced water velocities downstream of the fishway would result in increased GCSK post-passage survival. Flow scenario trials indicated the alternative flow regime resulted in a 10-20% increase in post-passage survival relative to the routine scenario. These findings were preliminary as trials did not span the full migration and the effects of environmental conditions such as water temperature could not be separated from flow effects. A TOR addendum in 2017 facilitated four additional years of data collection (under the Seton Dam Fish Counter Component) to further evaluate the alternative regime.

The Seton Dam Fish Counter Component has two main components. The first is to operate a resistivity counter at the exit of the Seton Dam fishway to enumerate GCSK as they migrate through Seton Dam en-route to Gates Creek. The second component is to compile GCSK migration data and model population-level survival of GCSK from the Seton Dam to Gates Creek. This model will help determine the effect on post-passage survival of the routine vs alternative flow scenarios.

The Seton Dam resistivity counter was successfully operated in 2017 and 2018 with average accuracies >80%. In both years, the GCSK migration occurred between approximately July 10 and September 10. In 2017, an estimated 18,977 GCSK migrated through Seton Dam, while in 2018 the estimated abundance was 11,858 fish.

Data from 2017 and 2018 (routine regime) were analysed using a Bayesian survival model that incorporated abundance at the Seton Dam fishway, escapement at Gates Creek, catch in Portage Creek, and survival to Gates Creek of a subset of fish tagged below Seton Dam. The Bayesian model predicted a population-level survival of 38% from the Seton Dam fishway to Gates Creek in both 2017 and 2018. Large discrepancies within the data (i.e., ‘missing’ or ‘surplus’ fish between the fishway and Gates Creek) suggest that more comprehensive input data are required to accurately determine population-level survival and answer the management questions. Most importantly, tagging data are needed from a representative subsample of the sockeye migration for both the routine and alternative scenarios, and the precision of the escapement estimate at Gates Creek must be improved for the model to be able to detect a 10-20% change in survival.

Status of BRGMON-14 Task 7 (Seton Dam fish counter component) management questions

Objectives	**Management Questions**	**Management Hypotheses**	**Status**
To determine the effectiveness of current dam operations for ensuring uninterrupted migration into Seton River and past Seton Dam to spawning ground.	3) Does the operation of Seton Dam and fishway affect salmon passage upstream of Seton Dam? *And* 3a) What changes to the fishway or operation may mitigate salmon migration issues at Seton Dam?	H_{09}: Gates Creek sockeye salmon survival from Seton Dam to spawning grounds is equal under the routine and alternative flow scenarios.	In progress. Flow scenario trials in 2014 and 2016 indicated the alternative flow regime may increase post-passage survival by 10-20% relative to the routine scenario; however, trials did not span the full migration and the effects of environmental conditions such as water temperature could not be separated from flow effects. Data from 2017 and 2018 (routine regime) were analysed using a Bayesian survival model that incorporated abundance at the Seton Dam fishway, escapement at Gates Creek, catch in Portage Creek, and survival to Gates Creek of a subset of fish tagged below Seton Dam. Preliminary results show a relatively low (38%) probability of survivorship to spawning grounds and suggest the Bayesian model may help to estimate the difference in survival between the routine and alternative flow regimes; however, to increase accuracy, more comprehensive input data are required. Tagging data are required from a representative subsample of the sockeye migration for both the routine and alternative scenarios, and the precision of the escapement estimate at Gates Creek must be improved for the model to be able to detect a 10-20% change in survival (the change in survival predicted by preliminary trials in 2016).

Table of Contents

List of Tables

List of Figures

Acknowledgements

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1.0. Introduction

1.1 Background

The Seton Dam is located 4 km upstream of the confluence of the Seton and Fraser Rivers near Lillooet, British Columbia. Gates Creek and Portage Creek sockeye salmon spawn upstream of the Seton Dam. During their upstream migration, salmon must navigate flows in the tailrace of the Seton Dam to locate and enter the Seton Dam fishway. Discharges at the Seton Dam during the migration period are intended to maximize upstream migration success by providing strong attractive flows that help salmon efficiently locate the fishway entrance; however, the effectiveness of the attractive flows and the effects of attractive flows on post-passage survival have not been assessed. The primary objectives of this monitoring program are to determine whether discharge operations at Seton Dam affect adult salmon passage at or upstream of the dam and determine the configuration of siphon flows at the Seton Dam that best mitigates salmon migration issues.

High water velocities in the Seton Dam tailrace were identified as a potential barrier to Gates Creek sockeye salmon (GCSK) entering the Seton Dam fishway (Casselman et al. 2013). Water releases immediately adjacent to the fishway created high water velocities downstream of the fishway entrance. Attractive flows from high water velocities assisted GCSK in quickly locating the fishway entrance; however, accelerometer tag data suggested increased energy expenditures were required to enter the fishway. GCSK that expended high amounts of energy to enter the fishway had decreased post-passage survival to spawning grounds (Casselman et al. 2014).

An alternative flow release configuration was tested at the Seton Dam once in 2014 and twice in 2016 to determine if reduced water velocities downstream of the fishway would result in increased GCSK post-passage survival (Harrower et al. 2018; Casselman et al. 2016). Water releases were changed from the ‘routine’ flow scenario – releasing water immediately adjacent to the fishway – to an ‘alternative’ scenario – releasing water away from the fishway entrance. Within each study year, the routine and alternative scenarios were alternated during the GCSK migratory period. A subset of GCSK were tagged during each scenario and tracked to the spawning grounds at Gates Creek. Tagging data indicated that GCSK had equal success entering the fishway under the routine and alternative scenarios. Under the alternative scenario, GCSK spent more time in the Seton Dam tailrace prior to entering the fishway; however, post-passage survival to the spawning grounds was 10-20% higher under the alternative scenario.

Preliminary trials in 2014 and 2016 suggested the alternative flow scenario may have a positive effect on post-passage survival of GCSK, but conclusions were uncertain due to several study limitations. First, the trials occurred over 1- to 2-week periods, and the alternative scenario has not been implemented over an entire migration period. Also, the effect of water temperature on post-passage survival has not been assessed for either flow scenario. Under the alternative scenario, fish delay longer in the Seton Dam tailrace prior to entering the fishway. GCSK experiencing the alternative flow scenario in high water temperature years would therefor be exposed to extended high temperatures relative to the routine scenario, possibly reducing post-passage survival. Seton River water temperatures are expected to warm under future climate scenarios, and it is important to monitor the effectiveness of both flow scenarios under variable river conditions.

An addendum to BRGMON-14 (addendum 2) was approved in 2017 to further monitor the post-passage survival of GCSK to the spawning grounds at Gates Creek (BC Hydro 2017). The operation of the Seton Dam fish counter in 2018 represented Year 7 of the original WUP and Year 2 of the addendum. The Seton fish counter will be operated annually (as required) to 2020, after which a four-year synthesis (2017-2020) will be completed. Operations in 2017 and 2018 followed the routine flow scenario, while the alternative scenario will be used in 2019 and 2020.

1.2 Management Questions and Hypotheses

One management question (and one sub-question) from the original Terms of Reference (TOR) will be addressed by 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?

A null hypothesis was formulated to answer management questions 3 and 3a:

> H_{09}: 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 Monitoring Approach

The objective of this monitor is to provide a population-level survival estimate of GCSK to the Gates Creek spawning grounds following passage through Seton Dam under the routine flow scenario. Results will provide baseline data for future comparisons with the alternative flow scenario.

There are three components to this monitor:

1. operation of a resistivity counter at the Seton Dam during the GCSK migration period;
2. enumeration of GCSK passage through the Seton Dam using resistivity counter data validated using video validation techniques; and
3. post passage survival estimation using abundance from the Seton Dam fish counter, abundance at the spawning grounds, and tagging data from a subset of GCSK.

2.2 Water Temperature Data

We compared water temperatures in the Seton River and in the lower Fraser River at Hope between 2017 and 2018 to determine if environmental conditions experienced by migrating GCSK were different between the two years. Average daily water temperature data for the Upper Seton River (~100 m downstream of Seton Dam) were obtained from BRGMON-09 (collected via Onset Tidbit Water Temperature Data Loggers). Average daily water temperatures in the lower Fraser River at Hope (08MF040) were obtained from Environment Canada (Lynne Campo, pers. comm.).

2.3 Resistivity Counter Operation

A resistivity counter was operated at the exit of the Seton Dam fishway from July 12 to September 10, 2018. The counter consisted of eight tube sensors, two four-channel Logie 2100c resistivity electronic fish counters (Aquantic Ltd., Scotland, UK), and eight video cameras (one camera per tube sensor). Resistivity counters were downloaded weekly (at minimum) by remote communication or by experienced technicians. All data are available as per the data standards established by BC Hydro and the requirements of the BRGMON-14 TOR.

A detailed description of the operation of the Seton Dam fish counter can be found in the BRGMON-14 Year 1 report (Casselman et al. 2013). Briefly, when a fish swims through the resistivity sensor tube, the counter measures a change in electrical resistance (Figure 2; Figure 3). An internal algorithm is then used to determine if a fish passed through the counter, or if a fish entered the sensor unit but failed to pass through. For each detection, the counter records the date and time, water conductivity, channel, direction of movement (upstream or downstream), and peak signal size between 0 and 127 (PSS). 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). A minimum PSS threshold of 40 was used at the Seton Dam fish counter to eliminate resistance noise caused by surface air bubbles or debris passing through the sensor tubes (i.e., detection events with PSS < 40 were ignored by the counter).

During counter installation in July of 2017, a detailed assessment of the electrical wiring for the tube sensors identified several faulty connections and inappropriate wiring characteristics. These issues caused excess noise on the counter and could potentially affect counter accuracy. Faulty connections were repaired in 2017, but we recommended that one of the tube sensors be re-wired to improve counter accuracy. Recommended repairs were completed in early July 2018, when BC Hydro electricians replaced the wire connecting the counter to the tube sensor.

Video monitoring equipment consisted of digital video cameras attached to the upstream end of each counter tube (one camera per tube). Video data were collected from August 1 to September 10, 2018 and saved to a Digital Video Recorder (DVR) at 30 frames per second. Each camera was lit by an underwater LED light to aid in species identification (Figure 3).

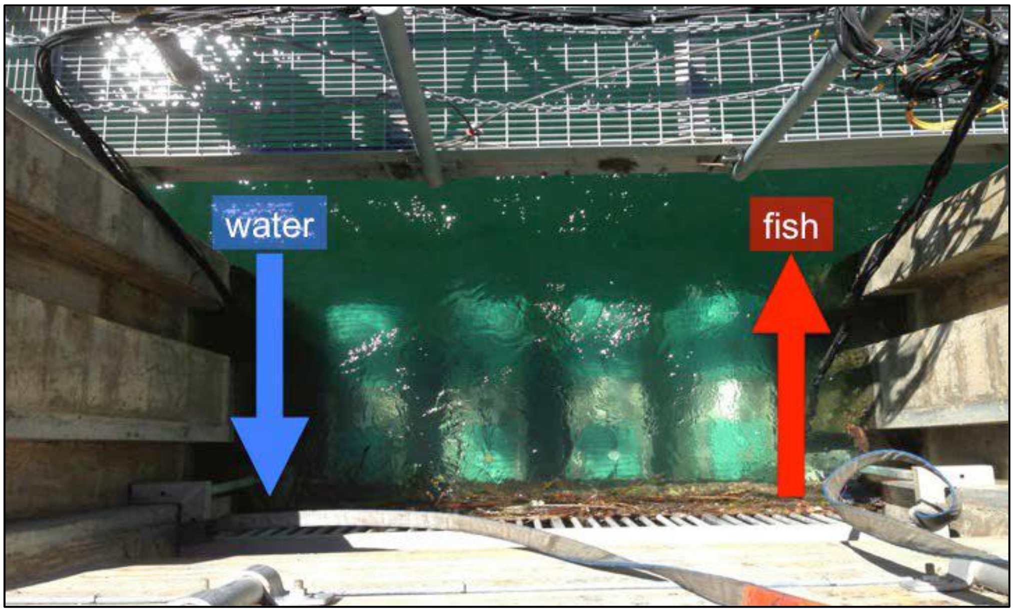

Figure 1. Overhead view of the resistivity counter sensor tubes installed at the exit of the Seton Dam fishway. Water flow and fish migration directions are indicated.

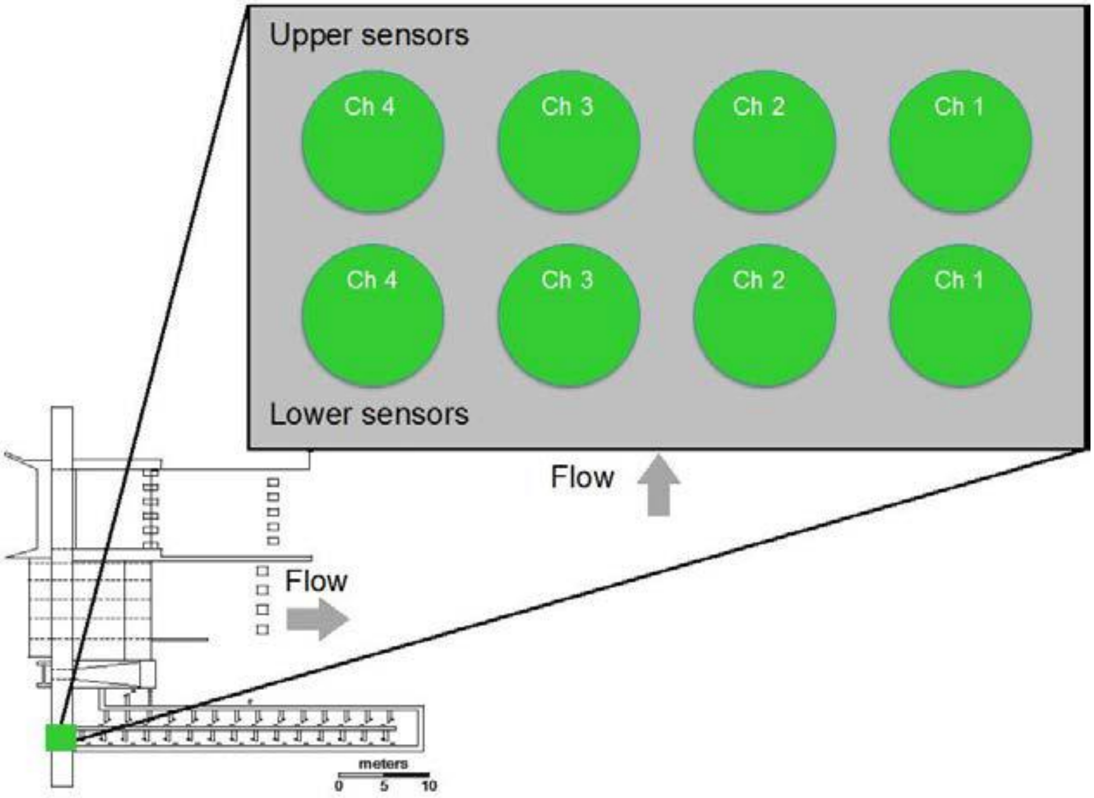

Figure 2. Schematic of the fish counter located at the exit of the Seton Dam fishway. The upper and lower sensors were monitored by two, four channel resistivity counters.

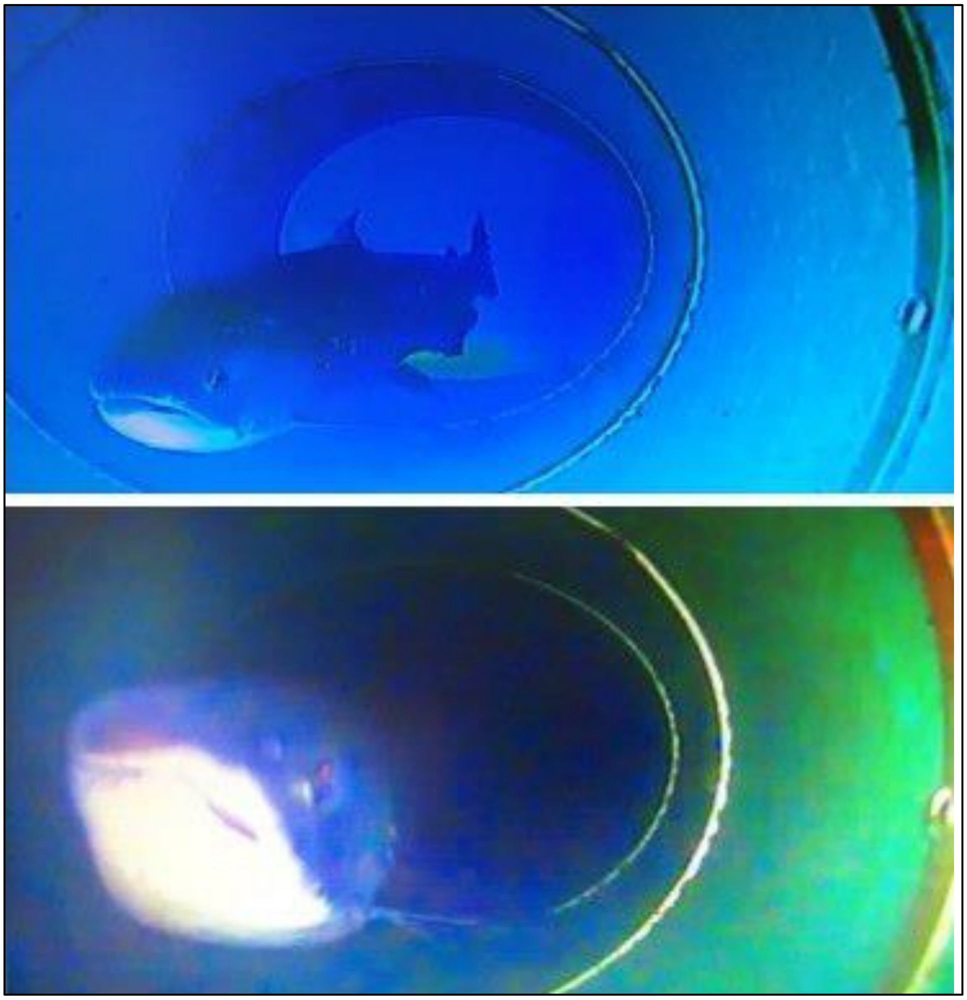

Figure 3. Example video validation images from the Seton Dam fish counter showing sockeye salmon migrating through the counter tubes in daytime (top) and nighttime (bottom).

2.4 Resistivity Counter Validation and Enumeration

Raw counter data were validated using the video record to determine tube-specific counter accuracies and estimate the number of GCSK that passed through Seton Dam. For each tube, six randomly-selected 20-minute video segments were reviewed daily from August 1 to September 12.

Counter accuracy (A) was calculated for each sensor tube:

Equation 1 $$A = \frac{TP}{TP + FP + FN}$$

Where FP is the number of false positives (counter indicates a fish but one did not pass through the sensor), FN is the number of false negatives (counter does not indicate a fish but video indicates a fish passed through the sensor), and TP is the number of true positives (counter correctly identifies fish moving through the sensor). Abundance of GCSK through the Seton Dam fishway (E) was calculated using Equation 2:

Equation 2

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

where, U_t is the total number of upstream detections, D_t is the total number of downstream detections, $U_t - D_t$ is the net up counts (accounting for species ratio is the counter accuracy), A is the counter accuracy, and k is the final day of the Gates Creek migration period (September 10 in 2018). The abundance estimate for Gates Creek sockeye salmon is relatively insensitive to the selection of k because the GCSK and Portage Creek sockeye migrations typically have very little overlap.

The resistivity counter and video system were not fully operational for four days during the GCSK migration (August 14 to 17, 2018), and the 2018 counter abundance estimate therefore underestimated the true abundance. We modelled the GCSK migration using a normal probability density function using accuracy-corrected daily counts from the resistivity counter. Specifically, we estimated the mean, standard deviation, and a scale parameter, which transformed the probabilities into daily counts. We used a least-squares fitting method that minimized the sum of squares between the observed and predicted counts, and the final parameter estimates were used to predict the daily abundance of GCSK migrating through the Seton Dam fishway.

2.5 Post-Passage Survival Analysis

We used a Bayesian modelling framework to estimate the post-passage survival of GCSK through the Seton Dam to the spawning grounds at Gates Creek. The Bayesian framework incorporated data from multiple stages of the spawning migration:

1. Abundance of GCSK at the exit of the Seton Dam fishway (resistivity counter estimate).
2. Escapement from Gates Creek spawning grounds (Department of Fisheries and Oceans stock assessment estimate).
3. Catch numbers from the First Nation subsistence fishery in Portage Creek (from fisheries observer data).

4. Survival from Seton Dam to Gates Creek of tagged subset of GCSK (from Scott Hinch, University of British Columbia).

The number of GCSK that passed through the Seton Dam and survived to the spawning grounds can be calculated as:

Equation 3
$$n_{s,t} = s_t \cdot n_{f,t} - h_{p,t}$$

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_t is the survival probability between the fishway and spawning grounds in year t. 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_t:

Equation 4
$$n_{s,t} \sim Binomial\left(n_{f,t}, \mathrm{s}_t\right) - h_{p,t}$$

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 incorporated Poisson-distributed error into the **estimated** (observed) number of fish:

Equation 5
$$y_{f,t} \sim Poisson\left(n_{f,t}\right)$$

Equation 6
$$y_{s,t} \sim Poisson\left(n_{s,t}\right)$$

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_t) 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:

Equation 7 $$d_i \sim Bernoulli(s_i)$$

where d_i is a binary variable indicating whether a pit-tagged fish *i* successfully reached the spawning grounds (assuming 100% detection efficiency at pit antennas in the dam and at the spawning grounds). A key deliverable of the post-passage analysis is to determine the effect of water release treatment on survival from the Seton Dam to the spawning grounds. Survival for each flow scenario (i.e., routine vs. alternative) is modelled using a logistic regression (requiring tagging data from each water treatment type):

Equation 8 $$logit(s_x) = \alpha + \beta \cdot x_{treatment}$$

We do not have data from two different flow scenarios as monitoring in 2017 and 2018 both occurred under the routine scenario. We replaced $x_{treatment}$ in Equation 8 with x_{year} to estimate the difference in survival between the two monitoring years and to test the ability of the model to detect a difference between two states.

All Bayesian modelling was performed using JAGS (Plummer 2003) and R Project (R Core Team, 2017) using the package “jagsUI” (Kellner 2017). Uninformative priors were used for α, β, and $n_{s,t}$. The model was implemented using three mcmc chains of 10,000 iterations, with a burn-in period of 5,000 iterations. Convergence was assessed using traceplots of posteriors on $n_{s,t}$, $n_{f,t}$, and α and β from the logit survival model.

3.0 Results

3.1 Water Temperature Data

GCSK are part of the early summer migration run timing, which enters the Fraser River from early July to the end of August (Patterson et al., 2007). Peak migration of GCSK into the Fraser River occurs during the first week of August (Patterson et al., 2007), while peak migration through Seton Dam occurs during the second week of August (see Section 3.3). From August 1 to 7 in the Fraser River at Hope, average water temperature was 18.4°C in 2017 and 19.9°C in 2018 (Figure 4). From August 7 to 17 in the upper Seton River, average water temperature was 18.0°C in 2017 and 19.0°C in 2018

(Figure 4[1]). These data tentatively suggest that GCSK experienced warmer water temperatures during their upstream migration in 2018 relative to 2017.

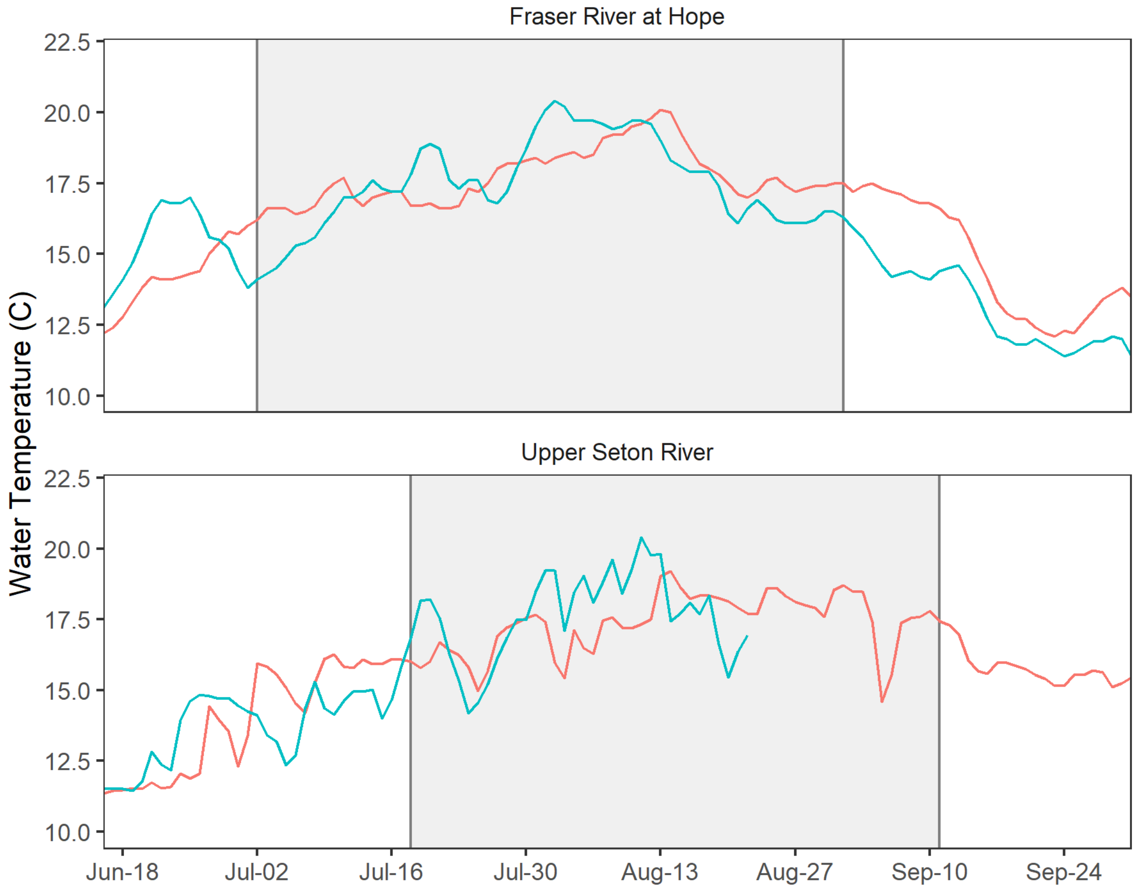

Figure 4 Average daily water temperatures (2017 in red and 2018 in blue) for the Fraser River at Hope (lower Fraser River) and for the upper Seton River (~100 m downstream of Seton Dam). Upper Seton River temperature data for August 21 onwards were unavailable at reporting due to high flows inhibiting logger downloads. Grey shaded areas represent migration timing of GCSK. In the Fraser River at Hope GCSK migrate approximately from July 1 to August 31, while the migration past Seton Dam in the upper Seton River occurs from July 17 to September 10.

3.2 Resistivity Counter Validation

A total of 888 hours of video data were recorded between August 1 and September 10, 2018, of which ~15% (138 hours) was validated (six 20-minute segments per day per channel). During video

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[1] Water temperature data are not yet available for August 21 onward as high flows prevented recovery of temperature loggers in the upper Seton River in the spring of 2019.

validation, 545 GCSK, 1 Chinook Salmon, 2 Coho Salmon, and 7 fish of unknown species were enumerated passing upstream through the Seton Dam fishway. Video validation indicated the upstream detection accuracy for all sensor tubes was 67-97% (avg 83%; Table 1).

Table 1 Sensor-specific accuracy for up-migrating GCSK at the Seton Dam fishway in 2018.

Counter	Channel/ Sensor Tube	Accuracy %
Top	1	97
Top	2	93
Top	3	88
Top	4	71
Bottom	1	67
Bottom	2	87
Bottom	3	91
Bottom	4	71

3.3 Resistivity Counter Abundance Estimate

The GCSK migration occurred between July 17 and September 10, 2018. An estimated 10,292 GCSK passed through the Seton Dam between assuming an overall counter accuracy 83% (Figure 5); however, the counter was not fully operational between August 14 and 17. We modelled GCSK daily up counts using a normal probability density function to account for missing data (Figure 6). The normal probability function estimated that 11,858 GCSK migrated through the Seton Dam in 2018.

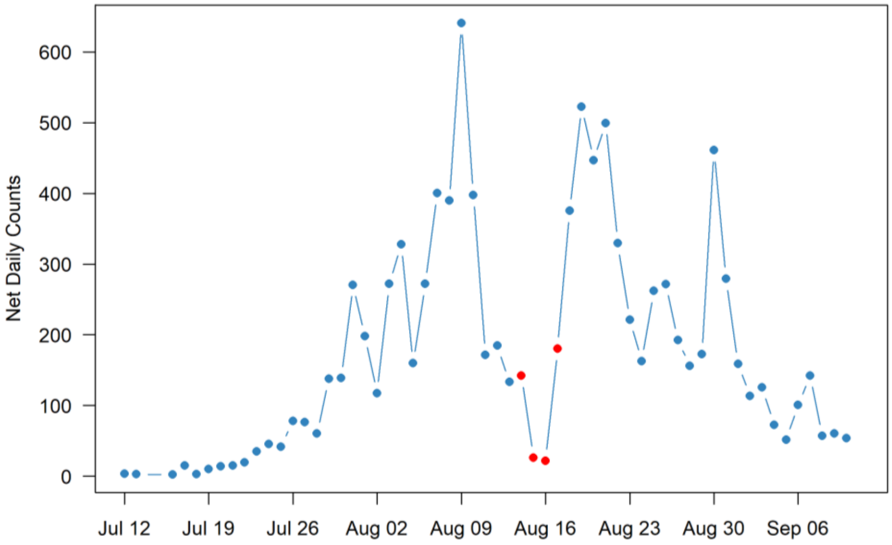

Figure 5. Daily abundance of fish migrating through the Seton Dam fishway between July 12 and September 10, 2018. Red points represent dates where the resistivity counters were not fully operational (counts during these dates are likely underestimates).

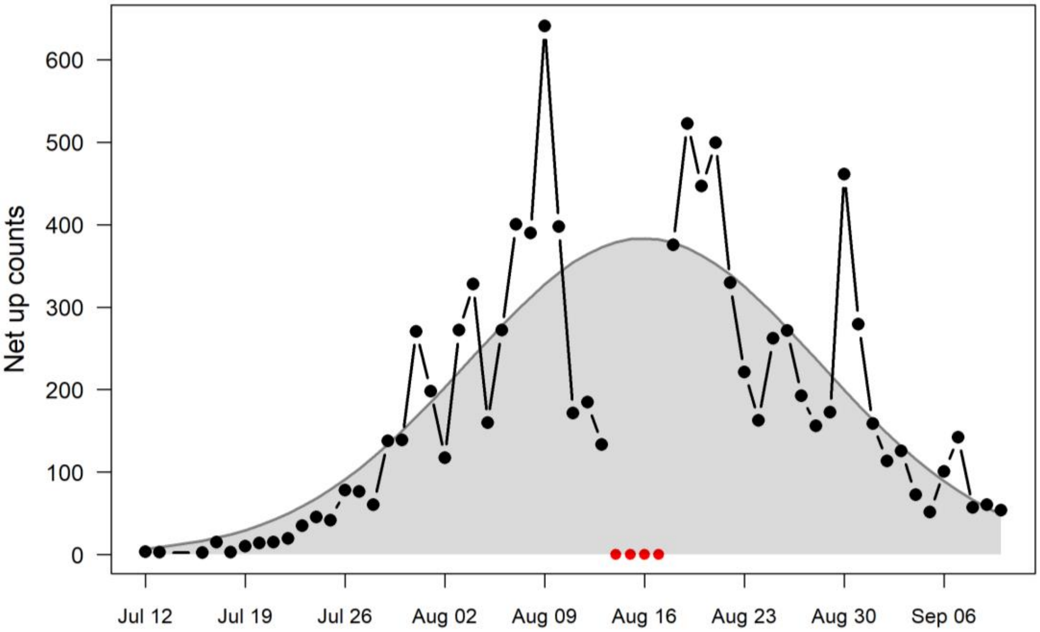

Figure 6. Net daily up counts through the Seton Dam resistivity counter modelled using a normal probability density function. Dates in red were removed from the analysis because the counter was not fully operational, and counts on those days underestimated the true count.

3.4 Post Passage Survival Analysis

Input data for the Bayesian post-passage survival analysis are presented in Table 2, but we were unable to obtain confidence limits for the data sources. Mean accuracy at the Seton Dam resistivity counter was 86% in 2017 and 83% in 2018, indicating that abundance estimates for the exit of the Seton Dam fishway were relatively accurate. The catch estimate at Portage Creek was also accurate, as data were collected daily by a local fisheries observer who was present during each capture event (K. Terry, Pers. Comm.). The escapement estimate at Gates Creek was less accurate: the mainstem count was generated by a weekly visual survey method with an adjustment factor of 1.8 (Welch et al. 2011), and the spawning channel was enumerated using a dead pitch count (DFO 2018, 2017). The survival of the tagged subset was composed of two parts: detection by a PIT antenna in the Seton Dam fishway, and detection by a second PIT antenna at Gates Creek. We assume the accuracy of the survival estimate for the tagged subset was relatively high because detection efficiency at the dam and at Gates Creek were both approximately 100%.

Using uninformative priors, Bayesian posterior estimates demonstrated a relatively close fit to input data for the abundance at the exit of the Seton Dam fishway and Gates Creek escapement abundance (Table 3, Figure 7). In contrast, posterior estimates for population survival in 2017 and 2018 did not closely fit survival calculated for the tagged subsets in either year. This model behaviour is expected given the uninformative priors and the large discrepancy between the input data in Table 2. Simple mass balance calculations for both years (and particularly 2017) show that the data in Table 2 cannot account for the change in abundance between the Seton Dam fishway and Gates Creek. To account for ‘missing’ or ‘surplus’ fish, the Bayesian model estimates the most probable population-level survival given the uninformative prior distribution.

The posterior distributions for the slope and intercept of the logit survival model (α and β_{2018}; Table 3) can be used to inform the difference in survival between the two years (or flow scenarios). The population-level survival odds were 0.62 (e^{α}) in 2017 and 0.61 ($e^{\alpha+\beta_{2018}}$) in 2018, suggesting that the odds of survival in 2017 were 1.01 times greater than in 2018 (i.e., odds of survival were nearly identical between the two years).

Table 2. Input data for the Bayesian survival model of GCSK from Seton Dam to Gates Creek.

Description	2017	2018
Abundance of GCSK at top of the Seton Dam fishway	18,977	11,858
Escapement at Gates Creek spawning grounds (mainstem and spawning channel combined)	7,041 ms: 4,561 sc: 2,479	4,338 ms: 2,578 sc: 1,760
Catch from First Nation subsistence fishery in Portage Creek	642	24
Survival of tagged subset detected at Seton Dam and subsequently detected at Gates Creek (# at Gates Creek/total tags released)	0.77 n = 124 tagged Aug 9-21	0.26 n = 62 tagged Aug 3-11

Table 3. Bayesian parameter estimates with mean, standard deviation, and 95% confidence intervals. n_f is the true abundance at the top of the fishway, n_s is the true abundance at the Gates Creek spawning grounds, *s* is population-level survival, and α and β are intercept and slope parameters for the logistic survival model.

Parameter	Mean	SD	2.5%	95%
$n_{f,2017}$	19,001.69	133.64	18,748.72	19,271.28
$n_{f,2018}$	11,792.14	107.01	11,587.16	12,015.18
$n_{s,2017}$	7,021.18	85.04	6,862.98	7,191.08
$n_{s,2018}$	4,409.71	65.69	4,282.98	4,538.00
α	-0.48	0.03	-0.54	-0.42
β_{2018}	-0.01	0.04	-0.10	0.07
s_{2017}	0.38	0.01	0.37	0.40
s_{2018}	0.38	0.01	0.36	0.39

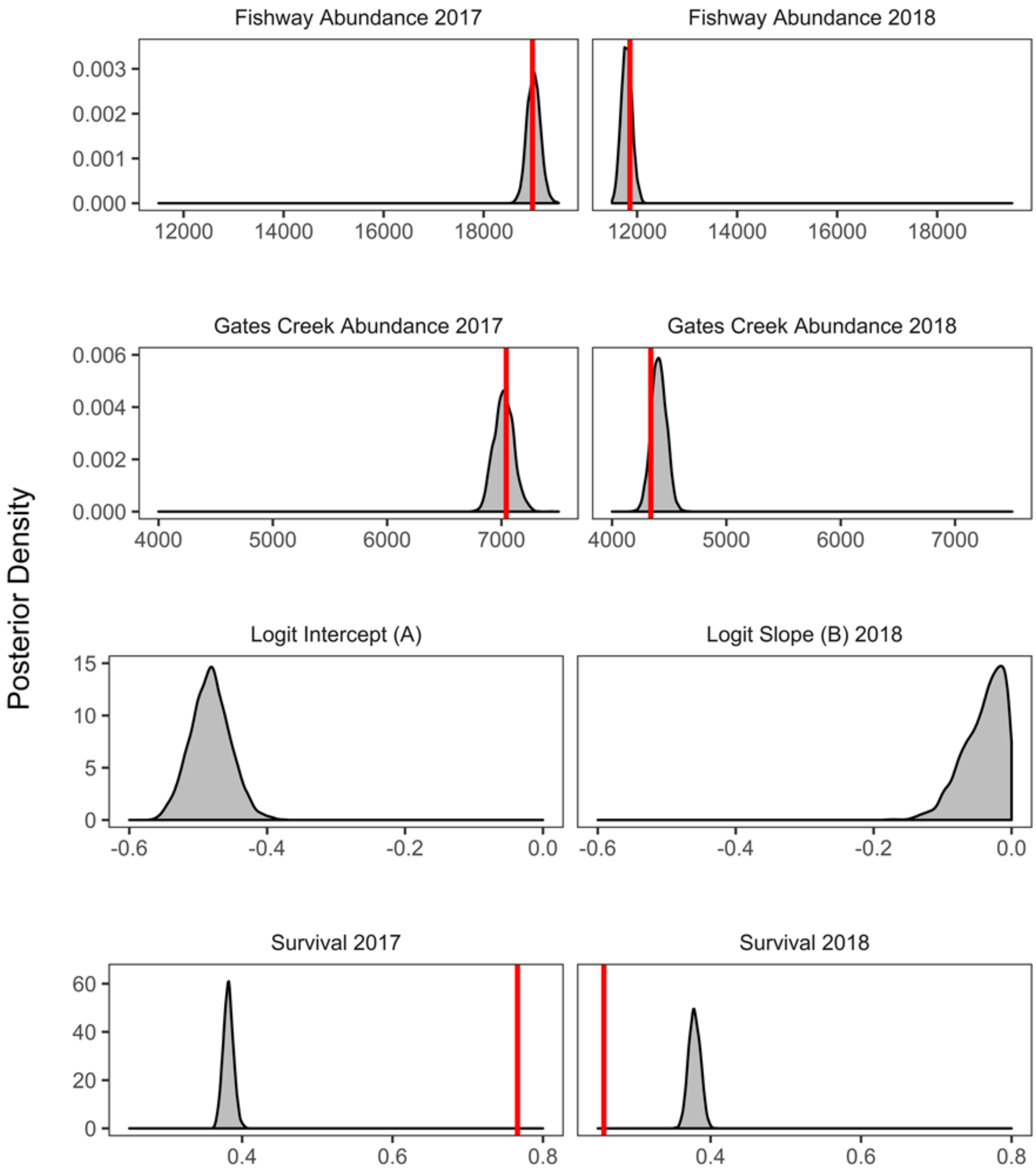

Figure 7. Bayesian posterior distributions (polygons) and observed data (red lines) for post-passage survival of GCSK from Seton Dam to the Gates Creek spawning ground.

4.0 Discussion

This monitor aims to determine whether the operation of Seton Dam and fishway affect salmon passage upstream of Seton Dam, and what changes to the fishway or operation may mitigate salmon migration issues at Seton Dam (management questions 3 and 3a). Preliminary results from 2016 suggest that the alternative flow regime does not significantly change attraction efficiency of GCSK migrating through Seton Dam, and may increase post-passage survival to Gates Creek by 10-20% (Harrower et al. 2018). In light of these findings, BC Hydro is considering implementing the alternative flow scenario beginning in 2019; however, 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.

Resistivity counters in the Seton Dam fishway were used to estimate the abundance of GCSK that migrated through the Seton Dam. In 2017, 18,977 GCSK migrated through the Seton Dam, while in 2018 the abundance was 11,858. Approximate migration timing for GCSK in both years was July 20 to September 10. Accuracy of the counter was high, averaging 86% in 2017 and 83% in 2018.

The Bayesian survival model predicted population-level survival in 2017 and 2018 to be 38%; however, the utility of the Bayesian survival analysis was hampered by discrepancies in the input data, particularly in 2017. Simple mass balance calculations using the input values in Table 2 suggest that the input data do not fully explain the dynamics of the GCSK migration. There are several possible explanations for the discrepancies between abundance at the top of the fishway and escapement at Gates Creek: strays from other stocks were present during the migration, precision of the Gates Creek escapement estimate was low, and the tagged subset of GCSK used to inform population-level survival was not representative of the whole migration.

The subset of fish tagged below the Seton Dam (used to inform population-level survival in the model) was composed of high-condition fish known to be Gates Creek sockeye (Laura Elmer, pers comm.). This subset does not accurately represent the migration as it does not account for fish of low and average condition. Survival of the tagged subset is likely higher than survival of the full migration. In 2017, the survival of the tagged subset was 77% (concurrent with survival from previous years: 70-85%; Casselman et al. 2016; Harrower et al. 2018), but the Bayesian model estimated the true survival to be 38% based on abundance data from the Seton Dam fishway and escapement at Gates Creek. The discrepancy between survival of the tagged subset (26%) and the predicted survival (38%) was lower in 2018; however, the tagged fish were of high condition and may not have represented survival of the population. To accurately represent population-level survival and inform the Bayesian survival model, the tagged subset must be representative of the entire run (i.e., all condition fish distributed across the migration period).

The presence of strays from other stocks (e.g., Chilko and Stellako) migrating with GCSK may also have contributed to discrepancies between abundance at the top of the fishway and at Gates Creek. Although straying is often temporary (i.e., straying salmon return downstream and continue towards their natal stream; Bett et al. 2017), straying is assumed to be permanent once salmon have migrated up the Seton Dam fishway (entrainment back through Seton Dam is rare). Strays that migrate through Seton Dam may fail to reach Gates Creek (but may spawn elsewhere), attempt to spawn at Gates Creek, or fail to spawn entirely, and likely have a different rate of post-passage survival than GCSK. Straying rates vary between years and can significantly affect the numbers of fish observed by the counter and at Gates Creek (Bett et al. 2017). A subset of the Seton River salmon migration was assessed for straying in 2012, and 36% of fish sampled were determined to be strays (Bett et al. 2017). Random tagging of the entire migration can account for strays in survival estimates; however, only fish confirmed to be GCSK were tagged in 2017 and 2018 and the survival rate of strays is therefor unknown.

The discrepancy between abundance at the Seton Counter and abundance at Gates Creek may also be due to the low precision of the Gates Creek escapement estimate. Gates Creek is assessed using low-precision visual survey methods, and the escapement estimate is generated by applying an index of 1.8 to peak count values (Welch et al. 2011). The index value was developed using historic data and has been calibrated on streams throughout the Fraser River region but is not specific to Gates Creek. Calibration indices can vary with stream size, turbidity, substrate colour, woody debris coverage, population abundance, and survey frequency. Although the precision of the escapement assessment is unknown, calibration data suggest estimates in small tributaries including Gates Creek are biased low (Welch et al. 2011). Post-passage survival of GCSK under the alternative flow scenario was estimated to be 10-20% greater than that under the routine scenario. The uncertainty in the Gates Creek escapement estimate is likely greater than 10-20% (Welch et al. 2011), which will make it challenging to detect the effect on survival of a change in flow scenario (Harrower et al. 2018).

A major strength of the Bayesian framework is that tagging data are not necessarily required for each year being modelled. Years with tagging data can inform years without data, provided that the environmental conditions in the river (e.g., flow scenario and water temperature) are comparable between years. Calibrating the model with adequate tagging data would require several years for each flow treatment, plus tagging in subsequent years with anomalous conditions (e.g., high temperature years, flow variations, etc). Differences between input data in 2017 and 2018 highlight the need to monitor survival using tagging studies. Despite experiencing the same flow scenario in both years, the survival of the tagged subset was low in 2018 (26%) relative to 2017 (77%). Water temperatures from the lower Fraser River at Hope and from the Seton River suggest GCSK experienced warmer temperatures during their upstream migration in 2018 relative to 2017. High water temperatures (relative to historic averages) have been shown to increase en-route mortality and pre-spawn mortality in Fraser River Sockeye Salmon (Martins et al. 2012). Warmer temperatures in 2018 (relative to 2017) may have affected survival of the tagged subset of GCSK, highlighting the importance of obtaining tagging data in contrasting water temperature years. The effects of temperature and other environmental variables must be considered when assessing the effect of different flow scenarios on post-passage survival.

The Bayesian post-passage analysis could be used to answer the management questions by determining to what degree the alternative flow regime affects post-passage survival; however, accurate and representative data are required to inform the model and address straying and sampling concerns. The Bayesian model requires tagging data from a representative subset of the whole migration (i.e., not just high condition fish) under both the current and alternative flow scenarios, and a more accurate estimate of escapement from Gates Creek. Without the required high-quality data inputs, the Bayesian post-passage survival model cannot be used to inform the effect of flow treatment on post-passage survival, making it difficult to address the uncertainties identified through the previous survival studies regarding the effectiveness of the alternative operations under variable environmental conditions.

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