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 1

Reference: BRGMON#14

Study Period: 2012 Annual Data Report

University of British Columbia
Instream Fisheries Research

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April 2013

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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

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Cover photo: Gastric implantation of an acoustic accelerometer transmitter in an adult sockeye salmon.

EXECUTIVE SUMMARY

Operation of Seton Dam has required BC Hydro adopt mitigation measures to minimize the effect of dam operations on adult salmon migration in the Seton-Anderson watershed. Seton Dam discharges are managed to aid salmon migration up the Seton River and encourage salmon to enter and ascend the Seton Dam fishway. Additional measures are taken during the migration periods for Gates Creek and Portage Creek sockeye to prevent Cayoosh Creek from diluting the Seton River and disrupting salmon migration to the Seton-Fraser River confluence.

Mitigation measures were incorporated in the Bridge River Power Development Water Use Plan completed in 2011. However, the effectiveness of mitigation measures has not been fully evaluated. The Consultative Committee recommended the implementation of the BRGMON-14 adult fish passage monitoring program to evaluate current mitigation measures. The key objectives of the monitoring program are:

1. To determine the effectiveness of current dam operations for ensuring uninterrupted migration into Seton River and past Seton Dam to spawning grounds.
2. To evaluate the sensitivity of the salmon populations to variations in the level of Cayoosh dilution in the Seton River.

Investigations in 2012 were limited to the Seton Dam and associated downstream waterways. Water chemistry sites were established and a previously installed fish counter at Seton Dam was modified to improve detection efficiency. Fish passage studies began in mid-August and compared different telemetry methods for assessing fish passage at Seton Dam. Olfactory sensitivity trials were also carried out to test the olfactory response of salmon to Cayoosh Creek dilution.

Results in 2012 were focused on water chemistry, fish enumeration and fish passage. Although Gates Creek sockeye were targeted for collection, a high proportion of stray sockeye reduced the sample size of some study groups.

Key findings from 2012 include:

- The Seton River and Cayoosh Creek displayed differences in water chemistry that became more distinct during the salmon migration period.
- Modifications to the fish counter increased the detection efficiency to 99%.
- Escapement estimates in 2012 were 26,179 Gates Creek sockeye, up to 1,269 Chinook salmon, and up to 2,005 Portage Creek sockeye.
- Acoustic accelerometer transmitters were determined to be the best method for detailed fish passage assessment at Seton Dam.
- Attraction efficiency to the fishway entrance was low (69%) and appeared to be strongly influenced by radial gate openings at Seton Dam.
- Fishway passage efficiency was considered high (89%).

Data from 2012 will be incorporated with data from future years to develop a model to analyze fish passage at Seton Dam. Recommendations for 2013 include further refining fish counter validation and detection methods, the installation of a fish weir to improve fish collection, implementing a method to identify stray sockeye, and monitoring fish passage at Seton Dam during specific operating conditions.

BRGMON-14 STATUS of OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES after Year 1

Objectives	Management Questions	Management Hypotheses	Year 1 (2012) Status
To determine the effectiveness of current dam operations for ensuring uninterrupted migration into Seton River and past Seton Dam to spawning grounds. *And* To evaluate the sensitivity of the salmon populations to variations in the level of Cayoosh Creek dilution in the Seton River.	Are the Cayoosh flow dilution requirements for Seton River derived by the IPSFC effective for mitigating delays in migrations of Gates and Portage Creek sockeye salmon populations? *And* How sensitive is Gates and Portage Creek sockeye migration behaviour to variations in the Cayoosh dilution rate?	H_{O1}: Gates Creek sockeye upstream migration is not significantly delayed when the Cayoosh Creek dilution exceeds 20%.	Gates Creek sockeye passage rates at Seton Dam and olfactory sensitivity results can be analyzed for changes with the dilution ratio. Further data are required and will be collected in Year 2 to Year 4. Methods in Section 2.2 & 2.4 Results in Section 3.2 & 3.5 Discussion in Section 4.2 & 4.5
		H_{O2}: Portage Creek sockeye upstream migration is not significantly delayed when the Cayoosh Creek dilution exceeds 10%.	Fish passage rates at Seton Dam can be analyzed for changes with the dilution ratio. Further data are required and will be collected in Year 2 to Year 4. Methods in Section 2.2 Results in Section 3.2 Discussion in Section 4.2
		H_{O3}: There is not a predictable relationship between flow dilution and the delay of upstream migrations of Gates Creek sockeye.	Gates Creek sockeye passage rates at Seton Dam and olfactory sensitivity results can be analyzed for changes with the dilution ratio. Further data are required and will be collected in Year 2 to Year 4. Methods in Section 2.2 & 2.4 Results in Section 3.2 & 3.5 Discussion in Section 4.2 & 4.5 & 4.6
		H_{O4}: There is not a predictable relationship between flow dilution and the delay of upstream migrations of Portage Creek sockeye.	Fish passage rates at Seton Dam can analyzed for changes with the dilution ratio. Further data are required and will be collected in Year 2 to Year 4. Methods in Section 2.2 Results in Section 3.2 Discussion in Section 4.2 & 4.6

Objectives	Management Questions	Management Hypotheses	Year 1 (2012) Status
To determine the effectiveness of current dam operations for ensuring uninterrupted migration into Seton River and past Seton Dam to spawning grounds. *And* To evaluate the sensitivity of the salmon populations to variations in the level of Cayoosh Creek dilution in the Seton River.	What are the effects of Seton powerhouse operation on the upstream migration of other salmon populations (pink, Chinook, coho) migrating to the Seton-Anderson watershed?	H_{O5}: There is significant delay of pink salmon at the Seton Powerhouse under the normal operating procedure.	This hypothesis was not tested in Year 1. Studies will begin in Year 2.
		H_{O6}: There is significant delay of Chinook salmon at the Seton Powerhouse under the normal operating procedure.	This hypothesis was not tested in Year 1. Studies will begin in Year 2.
		H_{O7}: There is significant delay of coho salmon at the Seton Powerhouse under the normal operating procedure.	This hypothesis was not tested in Year 1. Studies will begin in Year 2.
To determine the effectiveness of current dam operations for ensuring uninterrupted migration into Seton River and past Seton Dam to spawning grounds.	Does 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?	H_{O8}: Operation of Seton Dam and fishway does not affect attraction to the fishway.	Attraction efficiency of Gates Creek sockeye was 69% in Year 1. Additional data are required and will be collected in Year 2 to Year 4. Hypothesis cannot be rejected at this time. Methods in Section 2.3 Results in Section 3.4 Discussion in Section 4.4 & 4.6
		H_{O9}: Operation of the Seton Dam and fishway does not affect passage efficiency at the fishway.	Passage efficiency of Gates Creek sockeye was 89% in Year 1. Additional data are required and will be collected in Year 2 to Year 4. Hypothesis cannot be rejected at this time. Methods in Section 2.3 Results in Section 3.4 Discussion in Section 4.4 & 4.6

Keywords: Pacific salmon, *Oncorhynchus* spp., Seton River, Seton Dam, migration, fish passage, olfaction, acoustic accelerometer.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The Bridge River Power Development Water Use Plan (WUP) was developed for BC Hydro`s operations in the Bridge River Basin and includes the Seton Dam and associated infrastructure in the Seton-Anderson watershed (BC Hydro 2011). Five Pacific salmon species migrate through the Seton-Anderson watershed including two genetically-distinct populations of sockeye salmon (*Oncorhynchus nerka*), coho salmon (*O. kisutch*), Chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha*), and steelhead trout (*O. mykiss*) (BC Hydro 2000). The primary spawning grounds for salmon, with the exception of pink salmon, are upstream of the Seton Dam. To access spawning areas, adult salmon migrating up the Fraser River must pass the Seton Generating Station tailrace, enter the Seton River, negotiate the Seton Dam tailrace, and locate and ascend the Seton Dam fishway. Recommendations within the WUP by the Consultative Committee included the implementation of an adult fish passage monitoring program in the Seton-Anderson watershed to identify factors impeding the successful upstream migration of salmon through this migration route. Specifically, the Consultative Committee recommended the monitoring program address uncertainties in the effects of current Seton Dam and fishway operations on salmon passage and uncertainties in the effects of Seton River dilution by Cayoosh Creek on salmon migration.

Sockeye salmon passage through the Seton Dam fishway was recently examined in 2005 (Pon et al. 2006; Pon et al. 2009a, Pon et al. 2009b). A follow-up investigation in 2007 also monitored sockeye fishway passage as well as migration from the Seton Generating Station tailrace to spawning grounds above Seton Dam (Roscoe and Hinch 2008; Roscoe et al. 2010; Roscoe et al. 2011). Several impediments to salmon migration were identified in these studies including high discharge in Seton River that hindered upstream migration and complex flow patterns in the Seton Dam tailrace that delayed migration and reduced fishway attraction efficiency. These impediments resulted in the majority of observed sockeye salmon migration failure downstream of Seton Dam (Roscoe and Hinch 2008). Upstream migratory failure was also observed as post-passage mortality in Seton Lake and Anderson Lake with physiological indicators in failed migrants suggestive of increased stress. Post-passage mortality was also significantly higher for females than males. Fishway passage efficiency was high in both study years.

Absent from previous investigations was a comprehensive analysis of the influence of discharge and tailrace flow patterns on salmon passage success at Seton Dam. Although a fish counter has historically been operated at the exit of the Seton Dam fishway, the low efficiency of the counter has not allowed Seton Dam operating conditions to be effectively correlated with fish passage success. The studies in 2005 and 2007 provided some insight, but salmon passage could only be examined under five operating conditions and detailed information on Seton Dam water release patterns and associated flow conditions was not collected. In addition, the 2005 and 2007 investigations also primarily focused on sockeye salmon. Needed is a multi-year investigation of Seton River and Seton Dam fish passage to capture a range of discharge and flow conditions associated with Seton Dam operations. In addition, fish counter enumeration efficiency must be improved and a thorough assessment of how discharge and flow patterns at Seton Dam influence delay and fishway attraction for all salmon species is required. Operating conditions at Seton Dam can then be correlated with migratory success, post-passage survival, and environmental variables to identify factors impeding salmon migration and formulate mitigation measures.

Target dilution ratios for Cayoosh Creek flow to total Seton River flow are a component of the current WUP. Current targets were adopted from findings of the International Pacific Salmon Fisheries Commission on stock-specific water preference behaviour exhibited by migratory Gates Creek and Portage Creek sockeye salmon (Fretwell 1989). Dilution targets for the Seton River are <20% Cayoosh Creek flow from 20 July to 31 August for Gates sockeye and <10% Cayoosh Creek flow from 28 September to 15 November for Portage sockeye (BC Hydro 2011). Maintaining target dilutions during sockeye migration is intended to reduce sockeye delay in the Seton Generating Station tailrace and encourage upstream migration to the Seton-Fraser River confluence. The target dilution ratios and the apparent reduction in migratory delay are based on behavioural experiments and telemetry performed in the early 1980's. Neither the water preference behaviour of sockeye salmon nor the effectiveness of current dilution targets have been fully evaluated since the adoption and implementation of the target ratios. Recent studies have shown a high level of sockeye migration failure can still occur at target dilution levels (Hinch and Roscoe 2008). Further, it is not fully known how target dilution ratios influence the migratory behaviour of other salmon species, although pink salmon appear less sensitive to changes in the dilution ratio (Fretwell 1989). The target dilution ratios and their effect on salmon migration will be assessed in this monitoring program.

The current BRGMON-14 monitoring program is a 5-year investigation that will provide a comprehensive assessment of how Seton River dilution, Seton Dam operations, and environmental variables interact with the behaviour and physiology of salmon to affect upstream migration in the Seton-Anderson watershed. Data collected in this program will build upon previous studies while incorporating new technologies to enhance monitoring. The University of British Columbia (UBC) will carry out physical parameter monitoring, use telemetry to assess fish passage at the Seton Generating Station, in the Seton River, and at Seton Dam, and conduct olfaction experiments. Instream Fisheries Research Inc. will conduct fish passage enumeration at the Seton Dam fishway using an electronic fish counter and video monitoring. Ultimately, this program will make recommendations to St'át'imc Government Services and BC Hydro on operational modifications to the hydroelectric facilities within the Seton-Anderson watershed to improve salmon passage. This report summarizes Year 1 of the BRGMON-14 monitoring program that evaluated fish passage monitoring technologies at Seton Dam, gathered initial data on fish passage success at Seton Dam, and performed experiments to test the sensitivity of salmon olfactory ability to dilution.

1.1 Scope and Objectives

The objectives of the BRGMON-14 monitoring program are:

1. To determine the effectiveness of current dam operations for ensuring uninterrupted migration into Seton River and past Seton Dam to spawning grounds.
2. To evaluate the sensitivity of the salmon populations to variations in the level of Cayoosh dilution in Seton River.
3. To identify operating strategies that will mitigate delays in upstream migration without conflicting with other water use goals for environmental protection, flood risk, and power production in the Bridge Seton generating system.

1.2 Management Questions

The management questions of this monitoring program will achieve the program objectives by addressing specific uncertainties in the current operational requirements at Seton Dam and how these operations impact all salmon species migrating in the Seton-Anderson watershed. Uncertainty within the WUP operational requirements exist because Seton River dilution ratios were derived from studies that were limited to sockeye salmon and have not been re-evaluated. Further, fish passage at Seton Dam requires more detailed investigation. Therefore, the management questions of this monitoring program are:

1.1 Are the Cayoosh flow dilution requirements for Seton River derived by the IPSFC effective for mitigating delays in migrations of Gates and Portage Creek sockeye salmon populations?

1.2 How sensitive is Gates and Portage Creek sockeye migration behaviour to variations in the Cayoosh dilution rate?

2.1 What are the effects of Seton powerhouse operation on the upstream migration of other salmon populations (pink, Chinook, coho) migrating to the Seton-Anderson watershed?

3.1 Does the operation of Seton Dam and fishway affect salmon passage upstream of Seton Dam?

3.2 What changes to the fishway or operation may mitigate salmon migration issues at Seton Dam?

1.3 Management Hypotheses

Although previous investigations indicate that the target dilution ratios are necessary to mitigate delay of upstream migrating Gates Creek and Portage Creek sockeye salmon populations, confirmation of this operation requirement is central to the BRGMON-14 monitoring program and will address Management Question 1.1. The null (no effect) hypotheses to be tested for the effect of Cayoosh Creek dilution on the two sockeye salmon populations are:

H_{O1}: Gates Creek sockeye upstream migration is not significantly delayed when the Cayoosh Creek dilution rate exceeds 20%.

H_{O2}: Portage Creek sockeye upstream migration is not significantly delayed when the Cayoosh Creek dilution rate exceeds 10%.

Testing these hypotheses will require monitoring sockeye salmon migration at different dilution ratios. Operating conditions during the 5-year monitoring program period should provide sufficient variation in dilution levels to accept or reject these hypotheses.

Variations in the dilution ratio necessitate a secondary set of hypotheses to test the sensitivity of Gates Creek and Portage Creek sockeye migration behaviour and address Management Question 1.2. The null hypotheses are:

H_{O3}: There is not a predictable relationship between flow dilution and the delay of upstream migrations of Gates Creek sockeye.

H_{O4}: There is not a predictable relationship between flow dilution and the delay of upstream migrations of Portage Creek sockeye.

To date, investigations have focused on sockeye salmon because of their abundance in the Seton-Anderson watershed and high cultural and economic value. It has not been determined if discharge at the Seton Generating Station delay pink, Chinook, or coho salmon migrating to the Seton River. Management Question 2.1 will be addressed by testing the following hypotheses:

H_{O5}: There is significant delay of pink salmon at the Seton Powerhouse under the normal operating procedure.

H_{O6}: There is significant delay of Chinook salmon at the Seton Powerhouse under the normal operating procedure.

H_{O7}: There is significant delay of coho salmon at the Seton Powerhouse under the normal operating procedure.

The following hypotheses are related to Seton Dam and fishway operations and will address Management Questions 3.1 and 3.2:

H_{O8}: Operation of Seton Dam and fishway does not affect attraction to the fishway.

H_{O9}: Operation of the Seton Dam and fishway does not affect passage efficiency at the fishway.

In Year 1 of the BRGMON-14 monitoring program hypotheses H_{O8} and H_{O9} were addressed and data collected to evaluate hypotheses H_{O1} to H_{O4}. All hypotheses will continue to be assessed in future years. Testing of the remaining hypotheses will begin in Year 2.

1.4 Study Area

The study area for the BRGMON-14 monitoring program encompasses the salmon migration route within the Seton-Anderson watershed from the Seton Generating Station on the Fraser River to the Gates Creek spawning grounds upstream of Anderson Lake (Figure 1-1).

For Year 1, study of salmon migration was limited to the lower portion of the migration route including Seton Dam, the Seton River, a section of the Fraser River, and Cayoosh Creek (Figure 1-2). Sampling of physical parameters occurred in the Year 1 study area and at upstream sites (Figure 1-1; Figure 1-3).

Study of salmon passage was carried out at Seton Dam located 4.4 km upstream from the Fraser River (Figure 1-2; Figure 1-4). Seton Dam is a 76.5 m long by 13.7 m high concrete structure consisting of a radial gate spillway, five siphon spillways, a fish water release gate, and fishway (Figure 1-5). The fishway entrance is located at the southern bank of the Seton Dam adjacent to the fish water release gate. For Year 1, telemetry receivers were installed downstream of Seton Dam, in the Seton Dam tailrace and fishway, and upstream of Seton Dam. The receivers upstream and downstream of Seton Dam defined the upper and lower boundaries of the fish passage study area. The release site for tagged fish was on the south bank of Seton River ~350 m downstream of Seton Dam. Manual telemetry tracking extended the study area downstream to the Seton Generating Station on the Fraser River.

For studies of salmon olfactory sensitivity, salmon holding sites were located on the northern bank of the Seton River downstream of Seton Dam and in Cayoosh Creek downstream of the Walden North Generating Station (Figure 1-4).

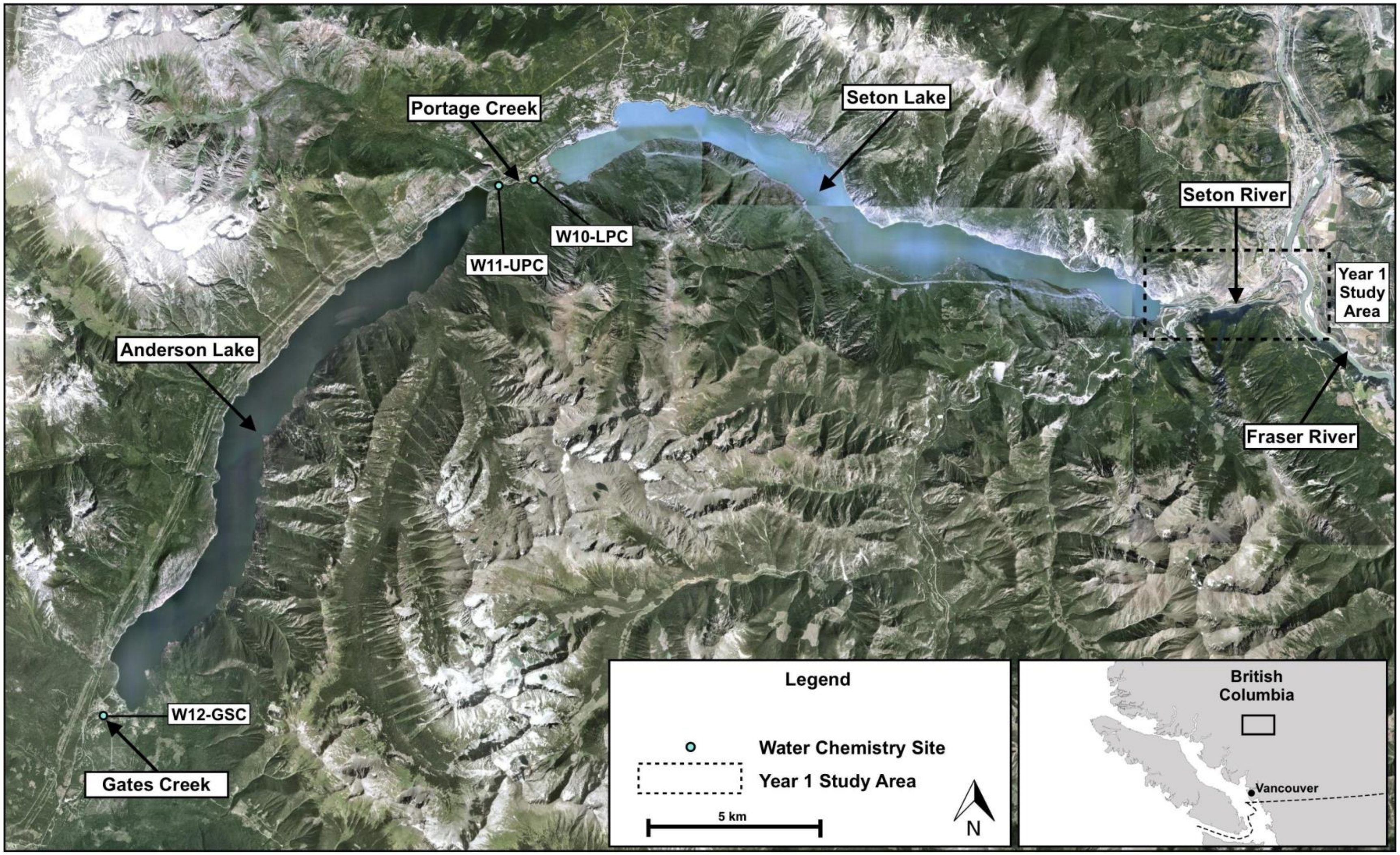

Figure 1-1: **Study area for the BRGMON-14 monitoring program and location of water chemistry sites outside the Year 1 study area**

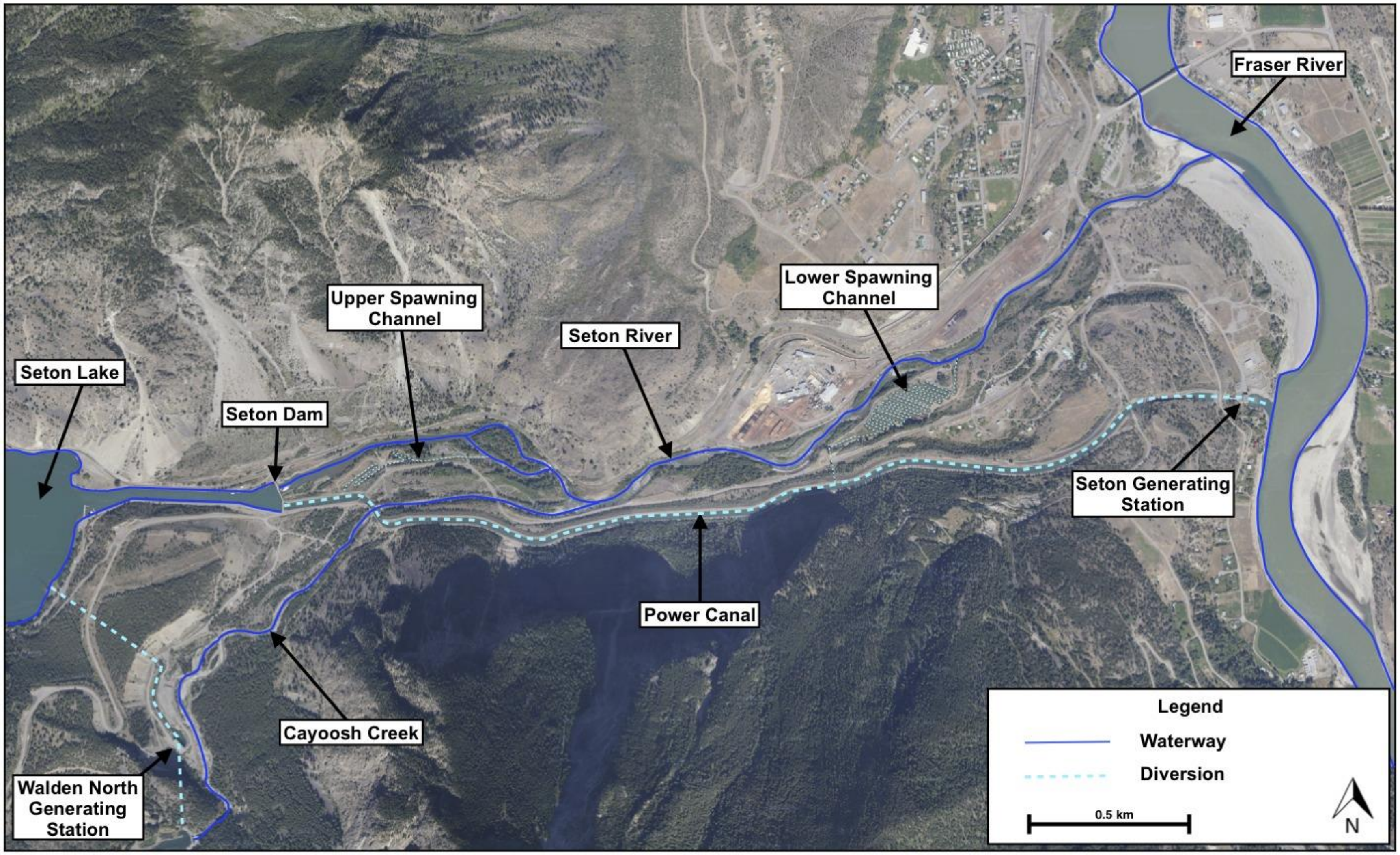

Figure 1-2: Study area for Year 1 (2012) of the BRGMON-14 monitoring program

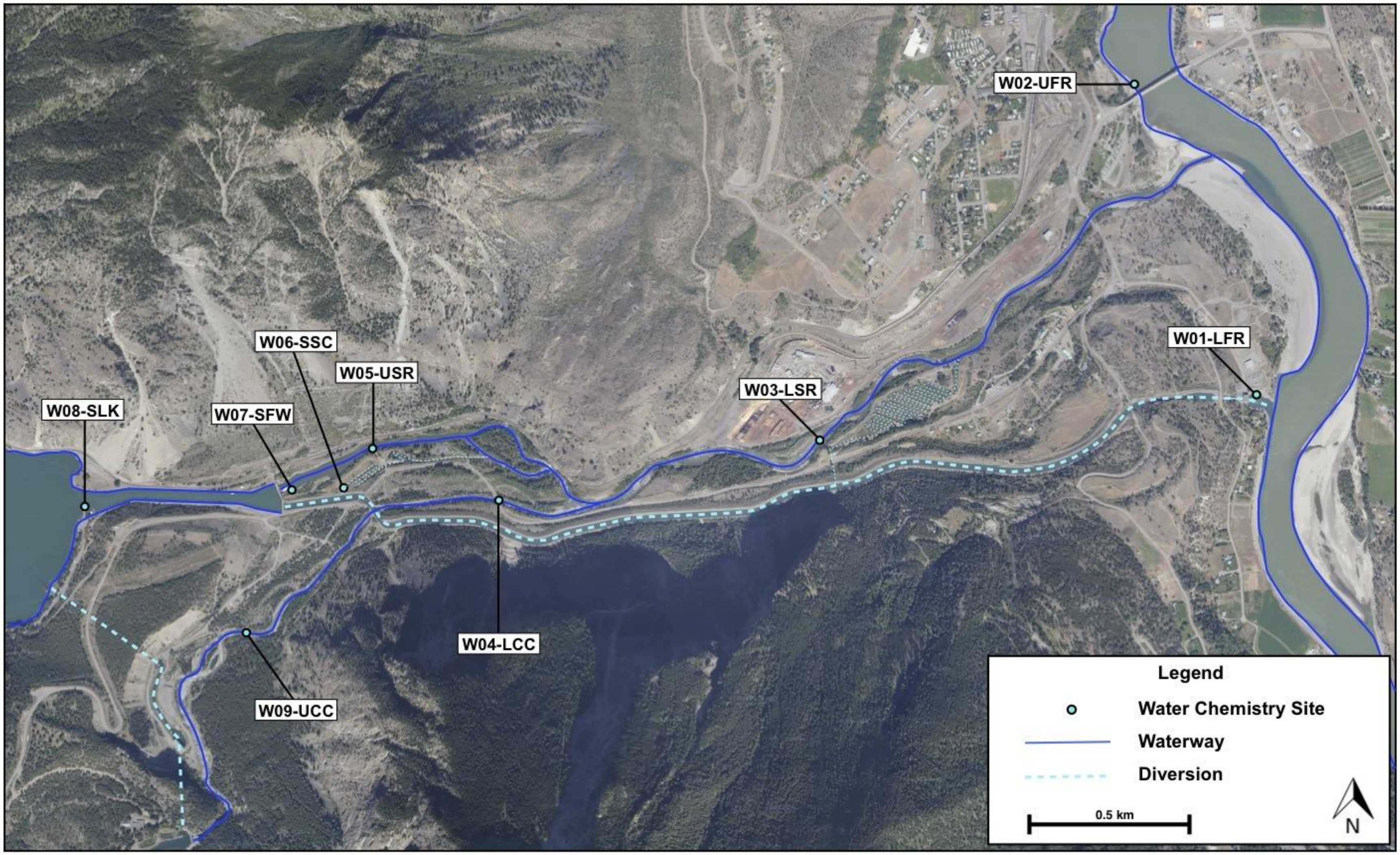

Figure 1-3: **Water chemistry sites within the Year 1 (2012) study area**

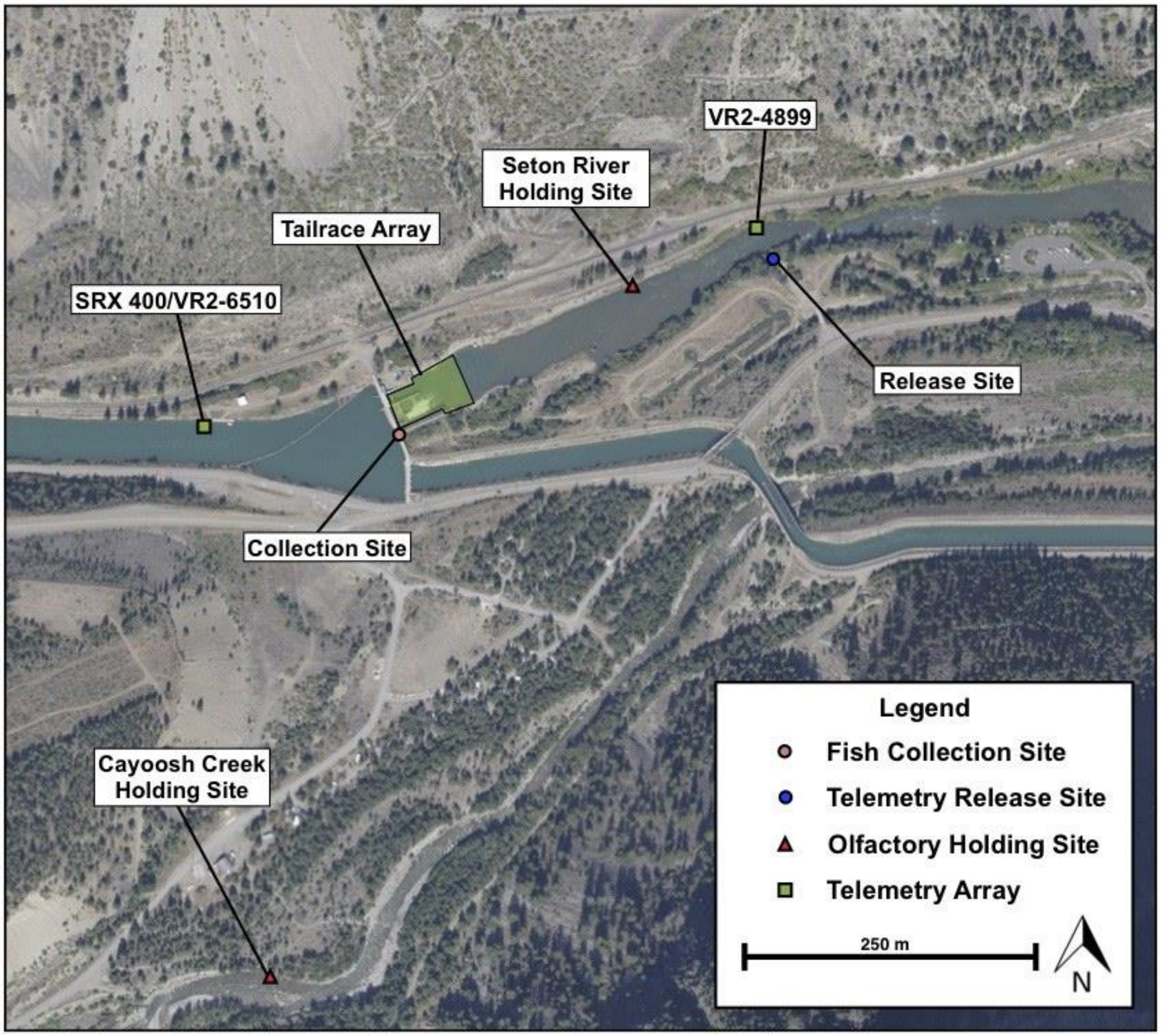

Figure 1-4: **Fish passage study area and holding sites for olfactory sensitivity trials. The tailrace array of six VR2 receivers at Seton Dam is outlined**

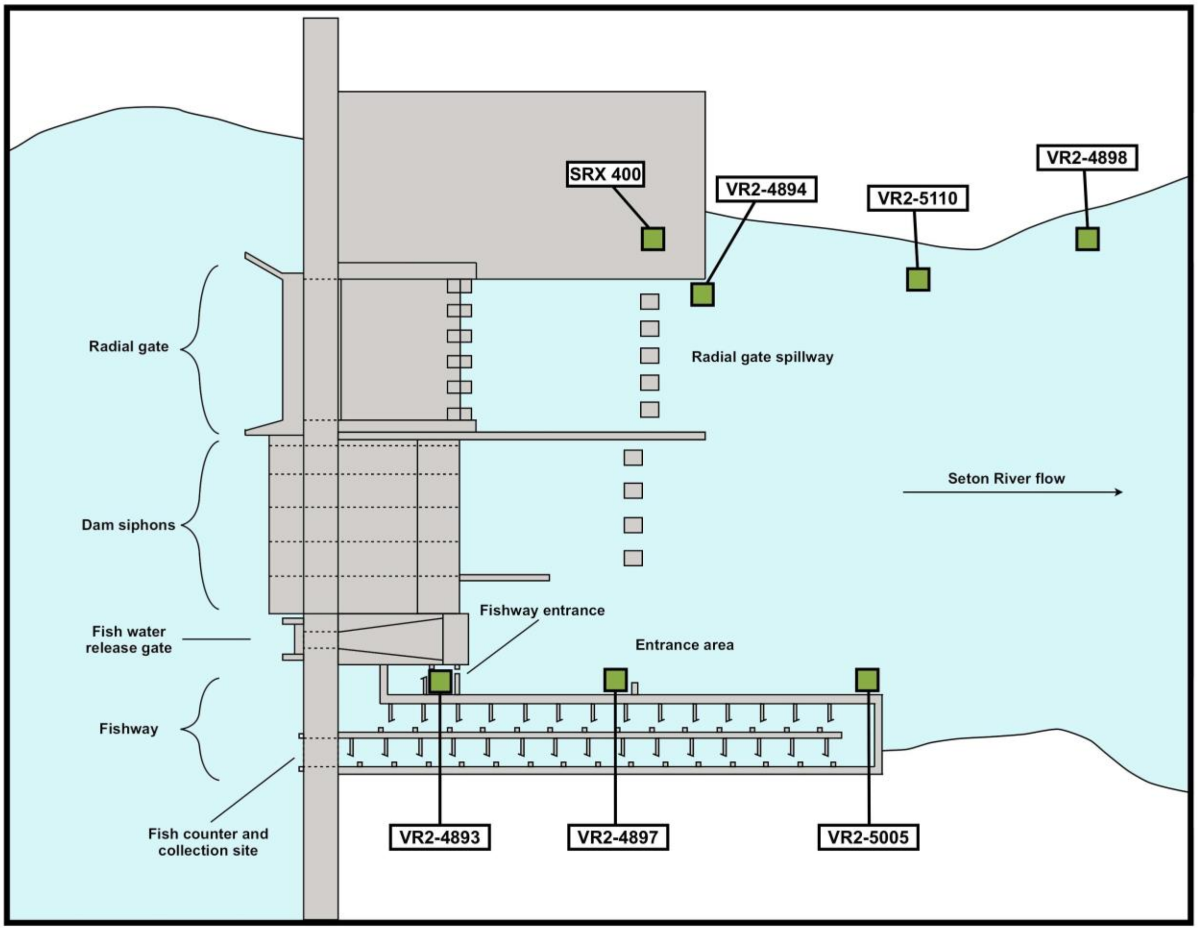

Figure 1-5: **Schematic of Seton Dam and fishway showing conveyance structures (left) and locations of acoustic receivers (VR2), the radio receiver (SRX 400), fish collection site, and fish counter**

2.0 METHODS

All methods involving animals were approved by the University of British Columbia Animal Care Committee (AUP A11-0215-002).

2.1 Physical Parameters

Various physical parameters important to fish passage and migratory behaviour were monitored as part of the BRGMON-14 monitoring program. Following the collection of further data on fish passage in Year 2 to Year 4, these parameters will be modeled with salmon migration data to determine their impact on migratory success.

2.1.1 Discharge and Dilution Ratio

Discharge and dilution ratio data for the Seton River, Cayoosh Creek, and Seton Dam, and Seton Generating Station were obtained from BC Hydro. BC Hydro discharge and dilution ratios were based on the daily average of hourly discharges recorded by Water Survey of Canada (WSC) gauging stations on Cayoosh Creek (No. 08ME002) and Seton River above Cayoosh Creek (No. 08ME003). Hourly discharge data for Seton Dam were obtained for each dam conveyance structure. The daily dilution ratio for the Seton River was calculated by BC Hydro using the daily average discharge of each location in the following equation:

$$\text{Dilution Ratio (\%)} = \frac{\text{Cayoosh Creek}}{(\text{Cayoosh Creek} + \text{Seton River} + \text{Spawning Channels})}$$

2.1.2 Water Temperature

Water temperature data in Year 1 were collected using temperature loggers and spot temperature readings from multiple monitoring sites (Figure 1-1; Figure 1-3; Table 2-1). TidbiT v2 water temperature loggers (± 0.2°C accuracy) (Onset Computer Corporation Inc., Bourne, Massachusetts, USA) were installed in the Seton Dam fishway and at the intake to the lower Seton River spawning channel. Water temperature was also recorded in the Fraser River at the Seton Generating Station tailrace using the same method. UBC installed loggers at the fishway and the Seton Generating Station while Fisheries and Oceans Canada installed the logger in the lower Seton River. Fisheries and Oceans Canada also installed a logger in Cayoosh Creek. Unfortunately, loggers in Cayoosh Creek and the fishway were lost prior to any data being collected. Three additional loggers were installed outside the Year 1 study area in upper and lower Portage Creek and the Gates Creek spawning channel. Supplemental temperature data were collected from spot measures taken at the same time as specific conductivity. An attempt was made to download the temperature loggers in the fall of 2012 but was unsuccessful. Another download will be attempted in the spring of 2013. Therefore, Year 1 temperature logger data will be presented in the Year 2 report. Only supplemental temperature data collected from spot readings are presented for Year 1.

Additional water temperature data were obtained from the Fraser River to estimate the thermal experience of Gates Creek and Portage Creek sockeye salmon prior to entering the Seton River. Water temperature data were obtained from Fisheries and Oceans Canada for the monitoring station at Qualark Creek (10 U 613935 5488072). The Qualark Creek monitoring station was used because it is located approximately equal distance from the mouth of the Fraser River and Seton River. Temperatures at Qualark Creek were judged to be representative of average thermal regime encountered by sockeye during their upstream migration. Entry dates and run duration for Gates Creek and Portage Creek sockeye were determined using migration data from Hague and Patterson (2009).

Table 2-1: Geographic locations of water chemistry sites within the BRGMON-14 study area for temperature loggers, spot temperature readings, specific conductivity (SC) measurements, and amino acid (AA) water sampling

Site	UTM Coordinates	Parameters Measured and Samples Collected
W01-LFR	10 U 576031 5613993	Temperature logger; Temperature; SC
W02-UFR	10 U 575582 5615178	Temperature; SC; AA (Aug 4)
W03-LSR	10 U 574353 5613777	Temperature logger; Temperature; SC; AA (Aug 4 & 20)
W04-LCC	10 U 573114 5613546	Temperature; SC; AA (Aug 4 & 20)
W05-USR	10 U 572601 5613736	Temperature; SC; AA (Aug 4 & 20)
W06-SSC	10 U 572485 5613585	SC
W07-SFW	10 U 572288 5613575	Temperature logger (lost)
W08-SLK	10 U 571492 5613499	Temperature; SC; AA (Aug 4)
W09-UCC	10 U 572134 5613034	Temperature logger (lost); Temperature
W10-LPC	10 U 550618 5617562	Temperature logger; SC
W11-UPC	10 U 549717 5617329	Temperature logger; SC
W12-GSC	10 U 536474 5599626	Temperature logger

2.1.3 Water Chemistry

Measurements of specific conductivity (SC) and water samples for dissolved free amino acids (DFAA) analysis were collected to compare the water chemistry of the Seton-Anderson and Cayoosh Creek watersheds. Specific conductivity can be used as a general indicator of water chemistry (Fretwell 1989) and is an important consideration given that dilution ratio targets are fixed during the Gates Creek and Portage Creek migration periods. Amino acids are also an important migratory cue for salmon (Udea 2011).

Both specific conductivity and amino acid sampling occurred in the Year 1 study area whereas sites outside the Year 1 study area were only monitored for specific conductivity (Table 2-1). Specific conductivity (µS/cm) was measured using a YSI Pro30 (YSI Inc., Yellow Springs, Ohio, USA). Water samples for DFAA analysis were filtered through a 0.45 µm polyethersulfone membrane filter into 1 L acid-washed Nalgene high-density polyethylene bottles and frozen at -20ºC within 1 h of sampling.

Laboratory analysis of DFAA is still in progress and will be reported in Year 2. Analysis will follow the methods outlined in Hawkins et al. (2006).

2.2 Fish Passage Enumeration

Estimates of fish passage through Seton Dam have historically been generated with a resistivity fish counter installed at the exit of the Seton Dam fishway (Figure 1-5). The configuration of the current fish counter was known to have poor detection efficiency and underestimate fish passage (Pon et al. 2006). For Year 1 of the BRGMON-14 monitoring program, the existing fish counter was modified in an attempt to increase counter efficiency and improve fish passage estimates.

2.2.1 Resistivity Counter

In July 2012, the fish counter at Seton Dam was removed and replaced with a new monitoring apparatus. A Logie 2100c resistivity electronic fish counter (Aquantic Ltd., Scotland, UK) was installed in combination with eight, 1.2 m long by 0.3 m diameter plastic sensor tubes installed at the fishway exit (Figure 2-1). Each sensor tube contained paired 12 mm stainless steel electrode rings spaced 0.3 m apart. Sensor tubes were mounted into an aluminum separation grid that was installed in the stop-log channel at the upper end of the final fishway holding bay. Four tubes were placed in a horizontal row across the base of the separation grid with a second row of four tubes placed in the same configuration approximately 20 cm below the surface of the water. The separation grid prevented fish from exiting the fishway by any means other than through the sensor tubes. This apparatus doubled the sensor capacity of the previous fish counter that used four sensor tubes close to the fishway floor. Fish enumeration began 25 July 2012 and ended 15 November 2012.

Fish swimming through the sensor tubes caused a change in electrical resistance that was detected by the fish counter. For detections exceeding a minimum threshold, the date and time, conductivity, channel, direction (upstream or downstream), and peak signal size (PSS) were recorded. The PSS is a function of fish size, fish swimming distance from the sensors, electrode sensitivity, river conductivity, and bulk resistance (background resistance caused by flowing water). Peak signal size readings can be used to estimate the species composition of enumerated fish populations by correlating PSS with visual species identifications. Minimum thresholds for detection were set (PSS of 40 out of 127) to eliminate resistance noise caused by air bubbles from the lake 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. Detections were saved to one of four channels on the fish counter. Due to technical limitations at the study site, it was only possible to use one resistivity counter rather than the two proposed in the Terms of Reference. Sensor tubes were paired within each vertical column such that fish swimming through either the upper or lower tube were detected on the same channel. The limitation of this approach is that two fish swimming through the upper and lower sensors simultaneously could not be differentiated. A minimum time of 0.5 s between fish passing through sensors on the same detection channel was required to differentiate between fish. All detections were saved on the fish counter and downloaded at the conclusion of the study period.

2.2.2 Video Monitoring

Digital underwater video cameras (VCULED, Visiontech) were attached to the upstream ends of one column of counting tubes to record fish movements and evaluate counter efficiency. Both cameras monitored a single column of sensor tubes with one camera installed to monitor the upper sensor tube at the water surface and a second camera installed to monitor the lower sensor tube. Video was recorded periodically between 9 August and 15 August 2012 and was saved to a digital-video recorder (Capture DVR400) at 15 frames per second. Technical limitations prevented simultaneous video recording from the two cameras. Despite the use of infra-red illumination with each camera only day-time recording of fish passage was possible.

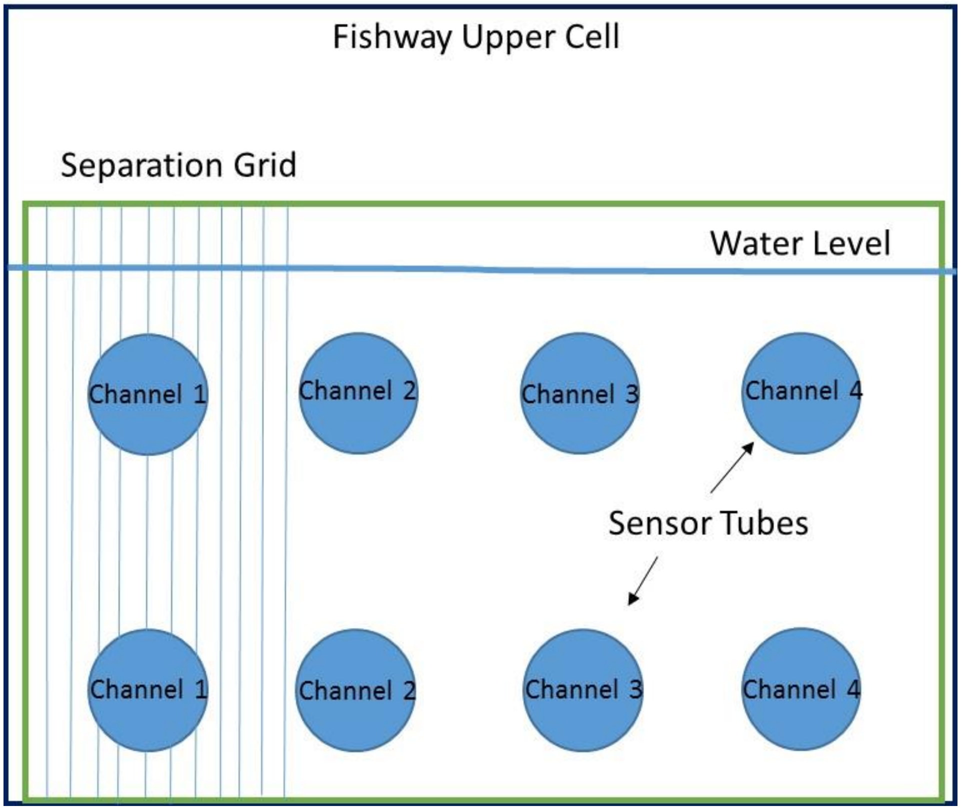

Figure 2-1: Schematic of fish counter located at the exit of the Seton Dam fishway. A separation grid forces fish to swim through one of the eight sensor tubes in order to exit the fishway

2.2.3 Data Analysis

Fish passage estimates in 2012 were based on methods used on the Deadman River in 1999 through 2002 (McCubbing and Ignace 2000). Estimates were performed as follows. First, detection errors due to debris or air entrapment – apparent as increased detections on a multiple channels in a short time frame - were removed from the data set. Second, a frequency histogram of PSS values was generated to differentiate sockeye salmon from larger co-migrating Chinook salmon. Third, daily counts of fish upstream and downstream migration were examined to identify potential increases in fallback of spawned fish (kelts). Finally, a value for the net number of upstream movements was determined for sockeye, coho, and Chinook salmon based on PSS distributions, temporal migratory patterns, and video data.

The total upstream escapement (E) for each species (size class) of fish was estimated using the equation:

$$E = \sum_{t=0}^{k}\left(\frac{U_t}{q_{up}} - \frac{D_t}{q_{down}}\right) + \sum_{t=k}^{\infty}\left(\frac{U_t}{q_{up}}\right)$$

where U_t is the total number of daily upstream detections classified as fish by the counter algorithm, D_t is the corresponding number of daily downstream detections, q_{up} is the detection efficiency of upstream moving fish and q_{down} is the detection efficiency of downstream moving fish, both of which were assessed independently using video validation. The parameter k is the day that kelts began migrating downstream and is determined by examining the pattern of upstream and downstream detections over the study period. The occurrence of downstream detections was low throughout the study period, but detections that were recorded most likely related to cycling of un-spawned fish. All downstream detections were subtracted from upstream detections to provide an estimate of net upstream fish passage.

Counter efficiency was calculated independently for upstream and downstream fish movements by comparing video observations and counter detections. Briefly, video recording were analyzed to identify all upstream and downstream complete passage events along with direction of fish movement, fish species (if possible), and fish size evaluated as small (<20cm), medium (20-70cm), and large (>70cm). Multiple fish events, when two or more fish passed through one tube simultaneously, or partial passage events, were taken into account. Counter efficiency (q_{up}, q_{down}) was calculated as the number of fish movements detected on the counter divided by the number observed on the video, for each direction of movement:

$$q_{up} = \frac{U_c}{U_v} \quad \text{and} \quad q_{down} = \frac{D_c}{D_v}$$

where U_c and D_c are the total upstream or downstream fish movements detected on the counter and U_v and D_v are the total upstream or downstream fish movements observed on the video recording. However, because video observation of fish movements could only be recorded from one sensor tube camera within a detection channel, fish passage detections without a corresponding video observation were possible. Analyzing counter detections and video observations independently would produce an over-estimate of counter efficiency. To account for this, video observation data were compared with the time-synchronized counter records and fish counter detections without a corresponding video observation were ignored.

Counter estimates are reported as total net daily fish passage for each species during the sampling period.

2.3 Fish Passage at Seton Dam

Previous studies in 2005 and 2007 used either radio telemetry (Pon et al. 2006) or acoustic telemetry (Roscoe and Hinch 2008) to monitor fish passage at Seton Dam. While these studies identified fishway attraction as an impediment to fish passage, they were unable to identify the specific factors within the Seton Dam tailrace that reduced attraction efficiency. Year 1 of the BRGMON-14 monitoring program tested the suitability of new accelerometer technologies for improving fish passage assessment at Seton Dam while collecting data on fish passage success. Results from the Year 1 monitoring program will build upon the 2005 and 2007 studies.

2.3.1 Fish Collection and Tagging

Between 17 August and 28 August 2012 upstream migrating adult sockeye (n=41) were individually captured via dip net in the last pool of the fishway at the top of Seton Dam as in previous years (Figure 1-5). Contracting issues delayed the start of fish capture and fish collection began approximately one week after the peak sockeye migration. Fish capture and tagging occurred each day during this period, except for 26 August when no fish were caught. Fish were captured opportunistically but a maximum of six fish were tagged per day. The daily limit was set in order to achieve a representative sample of the salmon population over a range of discharge conditions and permit more accurate tracking of tagged fish. No pink, Chinook or coho salmon were captured in Year 1.

Three treatments groups were used to determine if fish passage assessment at Seton Dam would be best studied using radio telemetry paired with accelerometer loggers or acoustic accelerometer transmitters. The size of the accelerometer logger required external attachment. Therefore, the following combinations of tags were applied: 1) An internal radio transmitter and external accelerometer logger (tagging group A); 2) An internal acoustic accelerometer and external radio transmitter (tagging group B); and 3) An internal acoustic accelerometer (tagging group C). Since data logging accelerometers do not remotely transmit data to an external receiver, they were paired with a radio transmitter to track fish and attempt recovery of the accelerometer logger and data. Internal acoustic accelerometers were used in combination with an external radio transmitter to provide a comparable treatment for fish tagged with an external accelerometer. Pairing acoustic and radio transmitters also allowed the detections of each telemetry method to be compared. The third group, tagged with internal acoustic transmitters alone, served as a control to evaluate the potential impacts of externally attached tags on fish passage and activity. Detailed specifications for applied tags are listed in Table 2-2.

Table 2-2: Manufacturer specifications for telemetry transmitters. Dimensions are provided as length (L), width (W), height (H), and diameter (D)

Tag Type (Manufacturer)	Model	Dimensions	Mass (g)	Logging Frequency (Hz) and Sample Period (s)
Accelerometer Logger (Gulf Coast Data Concepts, Waveland, Mississippi, USA)	X8M-3	54 mm L 31 mm W 16 mm H	34.0 g	12 Hz / Continuous
Radio Transmitter (Sigma Eight Inc., Newmarket, Ontario, Canada)	Pisces 5	43 mm L 16 mm D	15.2 g	-
Accelerometer Transmitter (AMIRIX Systems Inc., Halifax, Nova Scotia, Canada)	V9AP-2x	43 mm L 9 mm D	6.1 g	10 Hz / 10 s
Accelerometer Transmitter (AMIRIX Systems Inc., Halifax, Nova Scotia, Canada)	V13A-1x	42 mm L 13 mm D	12.2 g	10 Hz / 10 s

Fish were individually captured at the top of the fishway and immediately transferred to a watered V-shaped holding trough for tagging and sampling. Fish were manually restrained during processing. Anaesthesia was not used in order to minimize handling and duration of the tagging procedure. Internal radio and acoustic tags were implanted gastrically by placing the tag in the mouth of the fish and using a plastic plunger to insert the tag into the stomach. Accelerometer data loggers were too large for gastric implantation, necessitating their attachment externally. External tags were enclosed within a custom-made cylindrical plastic housing and attached posterior to the dorsal fin using metal wiring inserted through the dorsal musculature in a manner similar to Petersen disks. The housing increased the weight of all external tags by 28.0 g (in air). The fish was then sampled for DNA via an adipose fin clip, fork length was measured, sex was estimated from secondary sexual characteristics, and an estimate of somatic lipid concentration was made following methods in Crossin and Hinch (2005) using a fish Fatmeter (FM 692 Fish Fatmeter, Distell, West Lothian, Scotland, UK). A basic injury assessment was performed to note any physical deformities or external injuries on fish and any injuries were categorized as disease, a result of a fisheries capture event, a result of a predator event, a physical injury of unknown origin, or if a recent cranial injury, assumed to be a result of attempted passage at the Seton Generating Station. The total time to tag the fish and collect all samples was no more than two minutes. Tagged fish were temporarily held in a 1000 L transport tank for a maximum of 0.75 h while the remaining fish for that day were tagged. All fish tagged on one day were transported together to the release site and released simultaneously.

As a primary goal of Year 1 telemetry studies was to evaluate the suitability of accelerometers for assessing fish passage at Seton Dam, fish were released close to the dam to maximize the possibility of fish entering the Seton Dam tailrace and attempting passage. Fish were released from the southern bank of the Seton River ~350 m downstream of Seton Dam (Figure 1-4).

2.3.2 Telemetry

Fish movements were monitored with radio or acoustic telemetry from 17 August to 02 September 2012.

Manual radio tracking was performed using a portable Lotek SRX 400 receiver (Lotek Wireless Inc., Newmarket, Ontario, Canada) and a 3-element Yagi hand-held antenna. Manual tracking of radio tagged fish began immediately upon release in order to record initial migration behaviour and determine if fish swam upstream to Seton Dam or downstream and out of the study area. Fish observed to migrate upstream were tracked on foot from the south shore of the Seton River. Upon fish reaching Seton Dam, an attempt was made to track fish movements within the tailrace. Unfortunately, fish could not be continuously tracked within the tailrace due to radio interference from Seton Dam discharge. Therefore, fine-scale measurements of fish location within the tailrace were not recorded using manual radio telemetry. Regardless, manual tracking continued for the remainder of the day or until all fish detected within the tailrace successfully ascended the fishway or fell-back downstream and out of the study area. On subsequent days, manual tracking was performed any time fish were not being tagged and staff available.

Radio-tagged fish with an accelerometer logger that ascended the fishway were manually tracked during ascent and recapture was attempted at the fishway exit. The goal of recapture was to recover the accelerometer logger data. Only one fish was successfully recaptured but the accelerometer data were corrupted. Manual tracking was not performed above the telemetry stations at the upper study site boundary. To monitor fallback of fish downstream of the study area, daily manual tracking was performed along the Seton River between the release site and Fraser River confluence and along the Fraser River between the Seton River confluence and the Seton Generating Station. Tracking occurred at access points within each river section. Manual tracking of fish tagged with acoustic transmitters was not performed.

Stationary acoustic and radio telemetry receivers were deployed throughout the study area to remotely capture telemetry and accelerometer data (Figure 1-4; Figure 1-5). A total of eight Vemco VR2 underwater acoustic receivers (AMIRIX Systems Inc., Halifax, Nova Scotia, Canada) and two SRX 400 radio receivers were installed.

The VR2 receivers were capable of recording simultaneous time-stamped detection and acceleration data whereas the SRX 400 receivers only recorded detection data. For the VR2s, one receiver was installed at the release site, six were installed in the Seton Dam tailrace including three downstream of the radial gate spillway and three near the fishway entrance, and one receiver was installed ~200 m upstream of Seton Dam at the Seton Lake boathouse. The Seton Dam tailrace was considered the area of the Seton River from the base of the Seton Dam to the most downstream acoustic receiver. Within the tailrace, acoustic receivers were secured to sandbags with zip-ties, lowered into the water column with rope, and allowed to rest on the riverbed. The receivers at the boathouse and release site defined the upstream and downstream receiver arrays for fish passage assessment at Seton Dam. All six acoustic receivers installed with the Seton Dam tailrace were considered as a single tailrace array. For the tailrace array, it is important to note that VR2 detection capacity decreases in turbulent water. While turbulence was not a concern for receivers located at the release site or upstream of Seton Dam, the receivers in the tailrace were expected to have significantly reduced detection ability due to dam discharges. To compensate for this, VR2 receivers were installed at regularly spaced intervals within the tailrace. A side benefit of reduced detection capacity is that fish must be in close proximity to a VR2 receiver to be detected, resulting in increased precision when estimating fish location within the tailrace. For radio receivers, one SRX 400 was installed at Seton Dam on the concrete platform adjacent to the radial gate spillway. A single 5-element Yagi antenna was positioned to detect fish in the tailrace. A second radio receiver was installed at the boathouse with the antenna positioned downstream to detect fish leaving the top of the fishway. Data from the VR2 receivers were retrieved at the conclusion of the study while radio receiver data were downloaded every two to three days.

2.3.3 Data Analysis

Estimates of lipid concentration were used to estimate the gross somatic energy density (GSE) of fish. The GSE ($MJ \cdot kg^{-1}$) for sockeye salmon was estimated using the methods outlined in Crossin and Hinch (2005) and calculated using the equation:

$$GSE = 1.7338 \cdot \left[\frac{\ln(F_1) + \ln(F_2)}{2} \right] + 5.4886$$

where F_1 and F_2 are the lipid concentration estimates from two body locales in percent (%). Adipose fin samples were sent to the Fisheries and Oceans Canada Pacific Biological Station (Nanaimo, British Columbia, Canada) for DNA stock identification (Beacham et al. 2005). Stock IDs revealed that of the 41 Fraser River sockeye salmon tagged in the study, 26 were from the Gates Creek stock, 8 were from the Chilko River stock, and 7 were from the Stellako River stock. Only data from Gates Creek sockeye were used for fish passage analysis.

Radio and acoustic detection data were subject to a quality assurance process to remove detection errors and calculate detection efficiencies. For fish tagged with acoustic and radio transmitters, data from each of the telemetry methods were cross-checked to confirm temporal agreement of the detection methods. Manual radio-tracking data were also compared with stationary radio receivers to confirm data agreement. Radio telemetry detection errors were filtered and removed from the data set. Detection efficiency – the proportion of fish known to pass a receiver that were detected - was calculated for the acoustic arrays at the upper and lower study site boundaries, for the radio receiver at Seton Dam, and together for all acoustic receivers in the Seton Dam tailrace. Acoustic receivers within the Seton Dam tailrace were considered a single array because of the low detection range of individual receivers and because fish could approach the fishway entrance from multiple routes.

Telemetry data from fish that reached Seton Dam were used to calculate the following passage parameters: entrance delay (h), attraction efficiency (%), fallback delay (h), passage efficiency (%), overall delay (h), and overall success (%). Entrance delay was only calculated for fish that entered the fishway and was the time fish spent in the tailrace prior to fishway entrance. For fish that reached Seton Dam but failed to either enter or ascend the fishway, fallback delay was calculated as the time difference between the first and last detection in the tailrace. Attraction efficiency was calculated as the percentage of fish that reached Seton Dam and were detected either in the fishway entrance or at the upper study site boundary, as some fish entered the fishway without being detected. Passage efficiency was calculated as the percentage of fish that were detected at the upper boundary and not subsequently detected on any of the downstream arrays, confirming successful migration into Seton Lake. Fish that were recaptured in the fishway were considered to have successfully entered Seton Lake. Overall delay was calculated to incorporate all time fish spent navigating the Seton Dam tailrace and fishway and was the time between first detection in the tailrace and fishway exit. Finally, overall success was the proportion of all fish that reached Seton Dam and successfully entered Seton Lake.

Accelerometry data from fish tagged with acoustic accelerometer transmitters were used to calculate instantaneous swimming speeds for individual sockeye salmon. Transmitters sampled acceleration ($m \cdot s^{-2}$) in three axes (X, Y, Z) for a period of 10 s with a sampling frequency of 10 Hz. Following the sampling period, the transmitter internally calculated the root mean square (RMS) acceleration using the equation:

$$m \cdot s^{-2} = \sqrt{X^2 + Y^2 + Z^2}$$

averaged over time. The RMS acceleration was then transmitted after a 13-17 s processing delay. If a fish was in the vicinity of a VR2 receiver, the RMS acceleration was recorded along with the transmitter ID and the date and time of detection. The maximum detectable RMS acceleration value was 4.9 $m \cdot s^{-2}$. Fish swimming speeds were calculated from RMS acceleration values using the relationships described in Wilson et al. (2013) who calibrated RMS acceleration with the swimming speed of adult sockeye salmon (Figure 2-2). Swimming speed in body lengths per second ($BL \cdot s^{-1}$) was calculated using the equation:

$$BL \cdot s^{-1} = (0.625a - 0.0357 l_b) + 2.556$$

where a is the RMS acceleration and l_b is the fork length of the fish in centimetres.

Based on data from Gates Creek sockeye swimming activity in Lee et al. (2003), all swimming speeds below 1.66 $BL \cdot s^{-1}$ were considered to be aerobic swimming activity, swimming speeds greater than 1.66 $BL \cdot s^{-1}$ were considered to have required fish to initiate some burst swimming activity, and any detections exceeding 2.08 $BL \cdot s^{-1}$ were considered fully-bursting anaerobic swimming activity. Activity data were then correlated with spatial data from telemetry stations detections to estimate fish swimming activity in different areas of the Seton Dam tailrace under different discharge conditions.

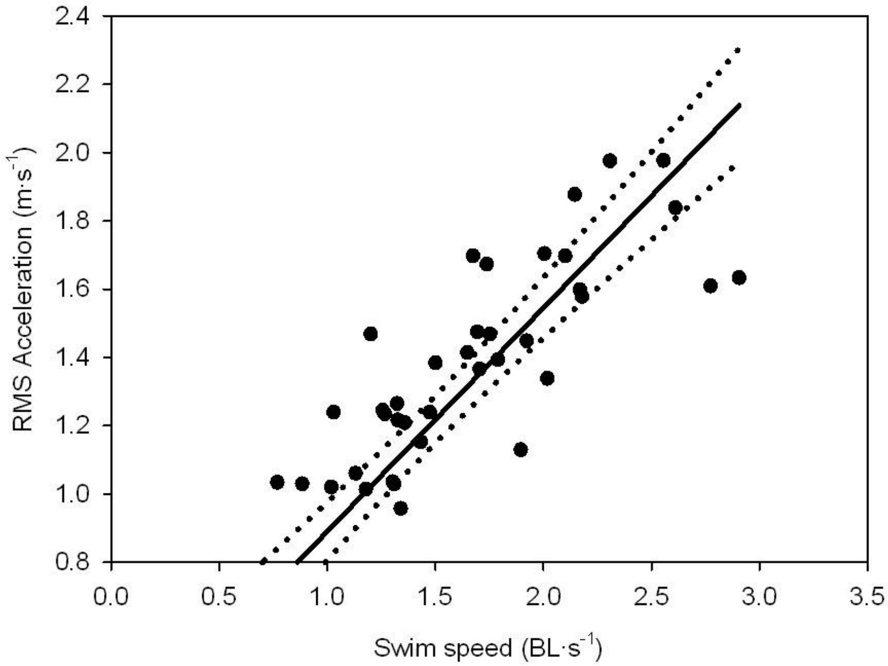

Figure 2-2: Data from Wilson et al. (2013) showing the relationship of RMS acceleration obtained from acoustic accelerometer transmitters and the swimming speed of sockeye salmon

Sampling data from fish collected for telemetry and olfactory studies were pooled for statistical analysis and comparison amongst stocks (see Section 2.4). Telemetry and acceleration data management and analysis was carried out in Excel. Fish passage metrics were compared amongst tagging groups and discharges using the statistical methods stated in text. Significance was assessed as $p<0.05$ for all tests. Statistical analyses were performed using SigmaPlot 11 (San Jose, California, USA).

2.4 Salmon Olfactory Sensitivity

The olfactory sensitivity of Gates Creek sockeye salmon was assessed by examining changes in olfactory gene expression. For background, juvenile salmon imprint on chemical compounds in their natal water and are attracted to these compounds during the adult spawning migration (Hasler and Scholz 1983). Salmon detect these chemical compounds with olfactory rosettes located in the nares (nostrils). Chemical compounds bind to specific olfactory receptors on the rosette surface triggering a signal cascade that is processed by the olfactory bulb and brain. The sensitivity of salmon to different chemical cues is dependent upon the quantity and type of olfactory receptors expressed by the cells on the rosette surface (Johnstone et al. 2011). The expression of different olfactory receptors is a product of gene expression, the conversion of DNA into RNA and RNA into the proteins that ultimately form the receptors. Increases in olfactory gene expression have been linked to exposure to imprinted chemical compounds and an increase in the olfactory sensitivity of fish (Harden et al. 2006). As a result, the olfactory sensitivity of salmon can be assessed by analyzing changes in the gene expression of the olfactory rosette, olfactory bulb, and brain tissue of salmon.

Experiments were designed to test if the olfactory sensitivity of Gates Creek sockeye is altered by exposure to Cayoosh Creek dilution or stress during upstream migration. Exposure to Cayoosh Creek dilution could impair the olfactory ability of migrating sockeye salmon by temporarily or permanently altering olfactory gene expression and thereby reducing the ability of migrating sockeye to detect natal Seton River water. Similarly, olfactory gene expression may be sensitive to stress (Carruth et al. 2002) and increased stress during migration could affect salmon olfactory ability.

2.4.1 Fish Collection and Study Sites

Between 17 August and 28 August 2012 upstream migrating adult sockeye (*n*=113) were individually captured via dip net in the last pool of the fishway at the top of Seton Dam. Fish were either immediately sampled or transferred to a 1000 L holding tank and transported in groups of 12 to two in-river holding sites. Holding sites were located on the north bank of the Seton River ~300 m downstream of Seton Dam and in Cayoosh Creek just downstream of the Walden North Generating Station (Figure 1-4). Four additional fish were opportunistically collected at the Cayoosh Creek holding site for sampling.

2.4.2 Olfactory Sensitivity Trials

A summary of the experimental holding design used for olfactory sensitivity trials can be found in Table 2-3. As a control for the olfactory sensitivity trials, a group of fish was collected and immediately sampled (see Section 2.4.3).

Table 2-3: Summary of the holding locations, holding period, and treatments for sockeye salmon olfactory sensitivity trials in the Seton River and Cayoosh Creek

Group	n	Initial Location	Holding Period	Treatment	Second Location	Holding Period
1A	12	Seton River	24 h	Stress	-	-
1B	13	Seton River	24 h	-	-	-
2A	11	Cayoosh Creek	24 h	Stress	-	-
2B	10	Cayoosh Creek	24 h	-	-	-
3A	8	Cayoosh Creek	24 h	Stress+Transport	Seton River	24 h
3B	10	Cayoosh Creek	24 h	Transport	Seton River	24 h
4A	9	Seton River	24 h	Stress+Transport	Seton River	24 h
4B	10	Seton River	24 h	Transport	Seton River	24 h
Control	24	Fishway	-	-	-	-
Cayoosh	4	Cayoosh Creek	-	-	-	-

Fish collected from the fishway were initially held for 24 h in either Seton River (Groups 1 and 4) or Cayoosh Creek (Groups 2 and 3). At each holding site, fish were held in individual flow-through isolation chambers made from PVC pipe measuring 6” in diameter and 28” in length (Figure 2-3). Ends of the chambers were covered with mesh to permit flow-through and the chambers secured to the streambed using re-bar.

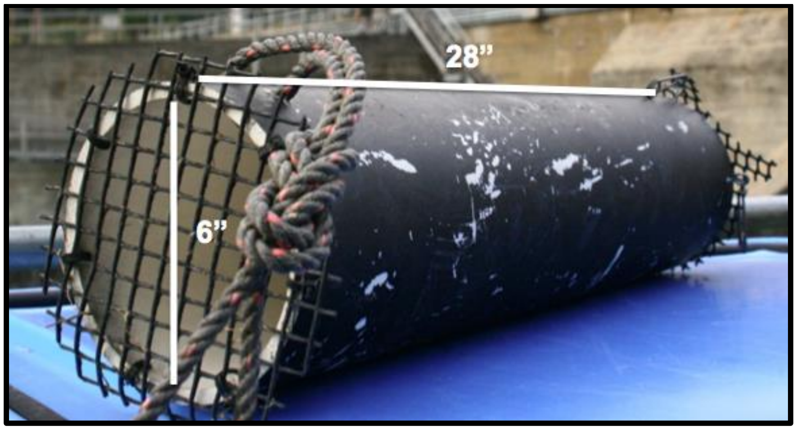

Figure 2-3: Isolation chamber used to hold fish in Seton River and Cayoosh Creek during olfactory sensitivity trials. Chamber dimensions are indicated on the figure

Fish were held in Cayoosh Creek to test the maximum effect of Cayoosh Creek dilution on olfactory gene expression. For comparison, a group of fish was held in Seton River above the Cayoosh Creek confluence. By holding fish in Cayoosh Creek and the Seton River above the Cayoosh Creek confluence, fish experienced dilution ratios of 100% and 0%, respectively. Holding fish in this manner permitted the strongest comparison of gene expression changes between groups. Practical limitations prevented holding fish at intermediate Cayoosh Creek dilution ratios.

During the initial 24 h holding period, half the fish in each treatment group received two stress events. Sockeye migrating to and within the Seton-Anderson watershed are known to encounter stressful conditions at multiple migration points. Sockeye can encounter elevated Fraser River temperatures during upstream migration (Young et al. 2006, Crossin et al. 2008), are known to attempt passage at the Seton Generating Station (Fretwell 1989), and exhibit physiological indication of stress following Seton Dam and fishway passage (Pon et al. 2009a). Stress events were applied to simulate the physiological condition of fish after encountering these challenging conditions during migration. Since sockeye may encounter multiple stressors in close succession, stress events were applied twice to maintain an extended period of high stress levels. Stress events were applied within the holding chambers and consisted of 60 s of holding or touching the tail of the fish followed by 20 s of air exposure. Touching the tail of the fish elicited burst swimming behaviour that fish would be expected to use when attempting passage at the Seton Generating Station or approaching the Seton Dam fishway entrance. Air exposure ensured that the stress event resulted in anaerobic metabolism to simulate the maximum potential exertion by fish.

Following the initial 24 h holding period and stress events, a sub-set of fish from each treatment group in Cayoosh Creek was transported and held for an additional 24 h in Seton River. It was predicted that fish exposed to 100% Cayoosh Creek dilution would demonstrate reduced olfactory gene expression due to the absence of natal stream chemical cues. Reintroducing fish to Seton River would test if fish could rapidly increase olfactory gene expression levels and therefore regain olfactory ability and continue migration. Fish were transported within the isolation chambers and care was taken to minimize stress during transport. However, to control for the possible effects of re-location stress, two of the treatment groups initially held in Seton River experienced transportation, but were simply returned to their initial holding location in Seton River.

2.4.3 Fish Sampling

All treatment fish were sampled at the end of the holding trials while control fish were sampled immediately upon capture at the top of the fishway. Blood samples were taken to analyze blood plasma for indices of stress. Fish were sacrificed by cerebral concussion and blood samples immediately withdrawn via a caudal puncture with a 22G needle into heparinized Vacutainers (Houston 1990). Vucutainers were then centrifuged to separate blood plasma and the plasma samples frozen in liquid nitrogen for 1-3 weeks. Olfactory bulbs and rosettes and brain tissues were then dissected from the cranial cavity and the tissue fixed in vials with RNA Later®. Samples were frozen at -20°C for 1-3 weeks. Both plasma and tissue samples were later transferred to a -80°C freezer for storage until laboratory analysis. Fish were also sampled for weight (pre-dissection), fork length, sex via visual confirmation of male or female gonads, and GSE.

2.4.4 Gene Expression

Initial tissue gene expression analysis was carried out in the Molecular Genetics Laboratory at the Pacific Biological Station (Nanaimo, British Columbia, Canada). A quantitative measure of RNA expression was generated for each collected tissue using the real-time PCR (qPCR) protocol outlined by Miller et al. (2011). In brief, tissue was homogenized in RNA isolation reagent and pipetted into Mag-MAX™-96 for Microarrays Kit 96 well plates (Ambion Inc, Austin, TX, USA). Extraction of RNA was carried out with a Biomek FXP (Beckman-Coulter Inc, Mississauga, Ontario, Canada) using no-spin procedures (Ambion Inc. 2010). Satisfactory RNA yield and purity was confirmed using spectrometry and solutions stored at -80°C until qPCR could be carried out.

Due to laboratory capacity limits, final tissue gene expression procedures and analysis are still in progress. Complimentary-DNA (cDNA) will be synthesized from RNA using Superscript VILO Master Mix (Life Technologies Inc., Burlington, Ontario, Canada) following the manufacturer's instructions (Invitrogen 2008). Olfactory genes will be targeted for amplification using the primers listed in Appendix II. A total of 31 olfactory gene primers are to be tested for binding to genes present on the cDNA strands. For primers that successfully bind, DNA will be amplified using Specific Target Amplification qPCR with a BioMark™ System (Fluidigm, San Francisco, California, USA) using a modified version of the manufacturer's instructions (Appendix I).

2.4.5 Data Analysis

Stock ID procedures and GSE calculations are the same as those outlined in Section 2.3.3. Stock IDs revealed that of the 113 fish collected for olfactory trials, 71 were from the Gates Creek stock, 18 were from the Chilko River stock, 13 were from the Stellako River stock, and 9 were from the Tachie River stock. The stock ID for two fish could not be determined. Blood plasma samples were sent for analysis to the Fisheries and Oceans Canada Center for Aquaculture and Environmental Research (West Vancouver, British Columbia Canada). Blood plasma analysis is still in progress and will be presented in the Year 2 report. Gene expression analysis will be performed on all fish and the analysis methods and results will be included in the report for Year 2.

3.0 RESULTS

3.1 Physical Parameters

3.1.1 Discharge and Dilution

In the 2012 study period, total Seton River discharge into the Fraser River peaked at 166 $m^3 \cdot s^{-1}$ on 18 July and then decreased for most of the remaining study period (Figure 3-1). Peak discharge from the Seton River on 18 July coincided with peak Cayoosh Creek discharge and temporary increases in total Cayoosh Creek discharge in early August and from September through December. Discharge from Seton Dam comprised the majority of total Seton River flow. The spawning channel siphons remained open with a constant discharge throughout the study period.

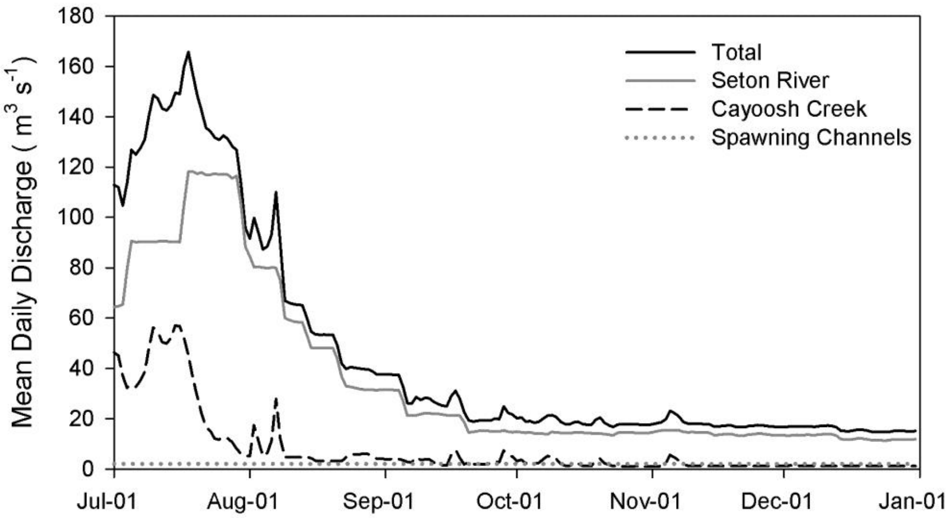

Figure 3-1: Total combined discharge of the Seton River in 2012 from the upper Seton River, Cayoosh Creek and spawning channels (BC Hydro data)

The dilution ratio of Cayoosh Creek discharge to total Seton River discharge was highly variable throughout the study period (Figure 3-2). Initially, high Cayoosh Creek discharges increased the dilution ratio in mid-July to greater than 30%. However, increased discharge from Seton Dam decreased the dilution ratio to the <20% target dilution ratio for Gates Creek sockeye migration. As a result, the target dilution ratio was exceeded for 1-day during the 43-day Gates Creek sockeye migration period. Temporary increases in Cayoosh Creek flow from September to November caused increases in the dilution ratio that exceeded the <10% target dilution ratio for Portage Creek sockeye migration. From 28 September to 15 November, the target dilution was exceeded for 24 of 49 days (49%). Following the target ratio period for Portage Creek sockeye salmon migration the dilution ratio remained below 10%.

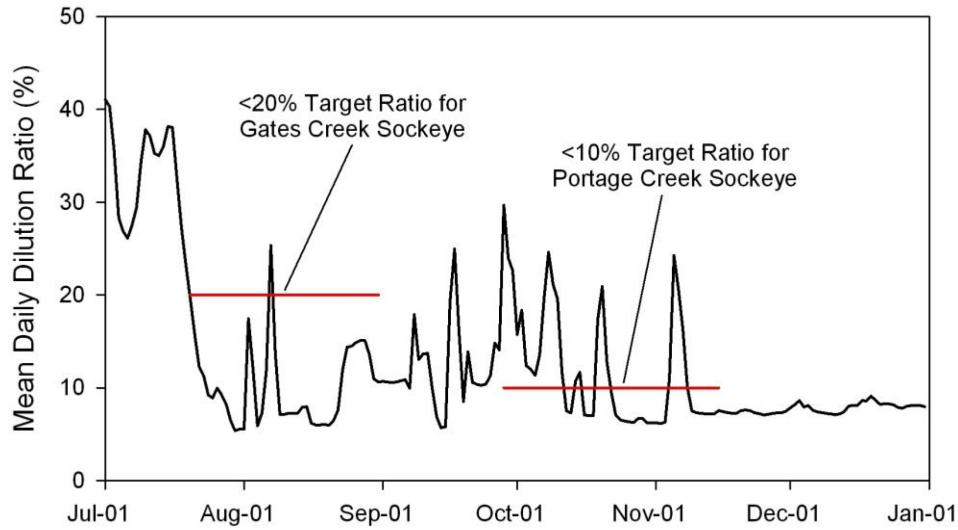

Figure 3-2: **Daily mean dilution ratio of the Seton River in 2012 (BC Hydro data). Current Water Use Plan target dilution ratios for Gates Creek and Portage Creek sockeye migration are shown in red (BC Hydro 2011)**

Operational adjustments at Seton Dam decreased total discharge from a maximum in late-July to target flow levels by mid-September (Figure 3-3). Decreases in total discharge were achieved through reductions in dam siphon discharge, temporary radial gate openings, and short-term reductions in fish water gate discharge. Radial gate openings occurred on 30 July, 08 August, and 21 August. During telemetry studies from 17 August to 02 September, three operating conditions were present at Seton Dam: a discharge of approximately 48 $m^3 \cdot s^{-1}$ primarily via the dam siphons; variable discharge during the operational change on 21 August when the radial gate was temporarily opened, discharge from the dam siphons reduced, and discharge from the fish water gate increased; and a discharge of approximately 35 $m^3 \cdot s^{-1}$ following radial gate closure. Seton Dam fishway discharge remained constant during the study period.

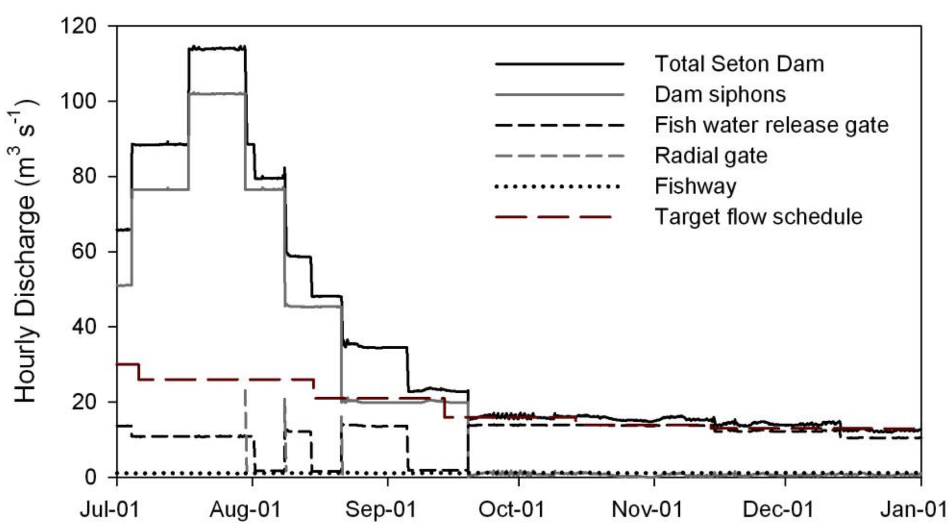

Figure 3-3: **Total hourly discharge for the Seton Dam and each Seton Dam conveyance structure in 2012 (BC Hydro data). The target flow schedule for Seton Dam is shown in red (BC Hydro 2011)**

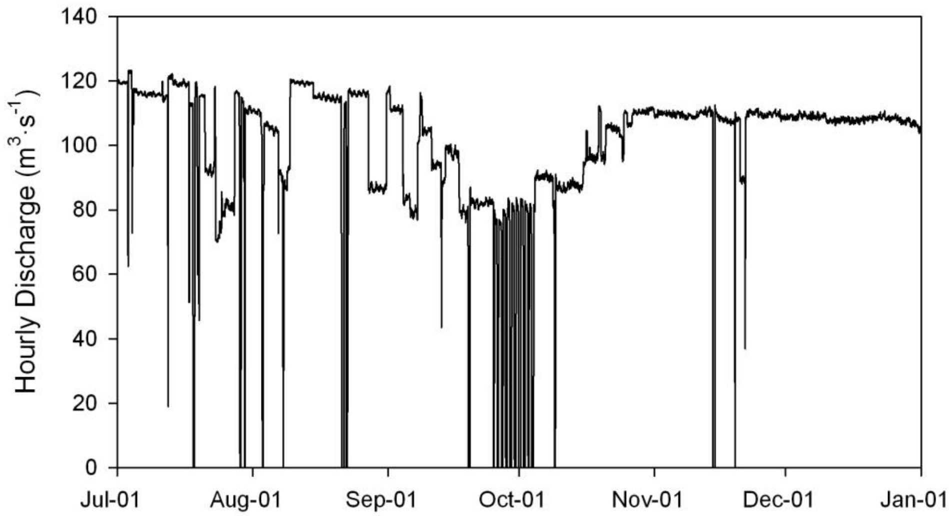

Figure 3-4: **Hourly discharge of the Seton Generating Station into the Fraser River in 2012 (BC Hydro data)**

Discharge from the Seton Generating Station on the Fraser River was maintained above 80 $m^3 \cdot s^{-1}$ for the majority of the study period (Figure 3-4). Discharge was interspersed with brief shut down periods lasting up to approximately 12 h.

3.1.2 Water Temperature

During the estimated upstream migration of Gates Creek and Portage Creek sockeye salmon past Qualark Creek, Daily mean water temperature of the Fraser River ranged from 15.5°C to 19.4°C for Gates Creek sockeye and 14.7°C to 19.4°C for Portage Creek sockeye (Figure 3-5).

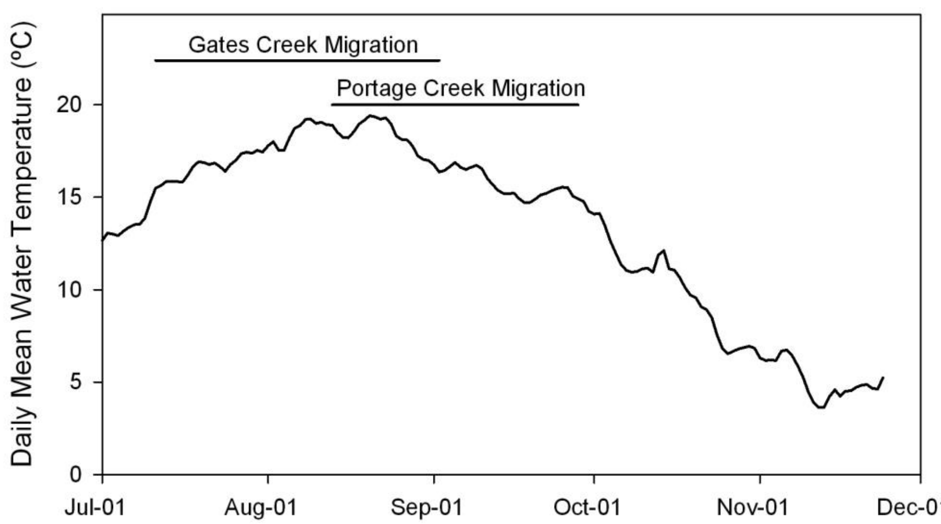

Figure 3-5: **Daily mean water temperature of the Fraser River at Qualark Creek in 2012. The duration of Gates Creek and Portage Creek sockeye migration past Qualark Creek is shown. Migration timing was estimated based on Fraser River entry timing and run duration data in Hague and Patterson (2009) and adjusted (+7 d) to the location of Qualark Creek**

Migration timing of Gates Creek and Portage Creek sockeye past Qualark Creek on the Fraser River was estimated from historic Fraser River entry timing, run duration, and migration rates in Hague and Patterson (2009). Mean historic peak entry dates for Gates Creek (31 July) and Portage Creek (29 August) sockeye into the Fraser River were offset by seven days to account for the approximately 110 km migration from the Fraser River mouth to Hope and through Hell's Gate to Qualark Creek. The mid-point of the historic run duration for Gates Creek (53 days) and Portage Creek (46 days) was centered on the modified peak Qualark Creek migration date to provide an estimate of timing for Gates Creek and Portage Creek sockeye passing Qualark Creek.

Water temperatures at Qualark Creek peaked in the latter half of the Gates Creek sockeye migration. The average temperature upstream migrating Gates Creek sockeye salmon would have experienced in the Fraser River was approximately 17-18°C. For Portage Creek sockeye salmon, water temperature in the lower Fraser River was near maximum at the estimated date of river entry. During the Portage Creek migration, Fraser River water temperature reached a summer maximum of 19.4°C but then decreased with the exception of a minor temperature increase near the end of the Portage Creek migration. The average temperature of the Fraser River during the Portage Creek sockeye salmon migration was approximately 17°C.

Water temperature at sites in the study area reached a maximum in August and then decreased until temperature monitoring ended in mid-October (Figure 3-6; Appendix III). Differences in water temperature were greatest between the sites receiving water from Seton Lake and the upper Fraser River and Cayoosh Creek. The temperature of the lower Fraser River at the Seton Generating Station tailrace was approximately 2°C less than the temperature of the upper Fraser River during the majority of August. Although this temperature difference was less apparent later in the season, water temperatures remained approximately 1°C lower at the Seton Generating Station site until mid-September. Temperatures within the tailrace began to exceed the temperature of the upper Fraser River in late-September.

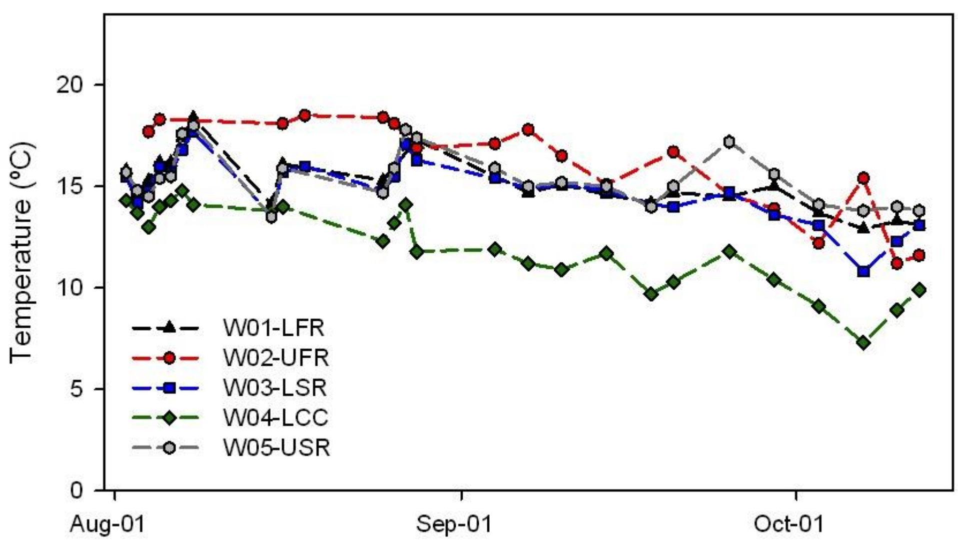

Figure 3-6: Spot water temperature readings at water chemistry sites in the Year 1 study area from 02 August to 12 October 2012

Cayoosh Creek routinely displayed the lowest temperatures within the Year 1 study area. Compared to the upper and lower Seton River, Cayoosh Creek was approximately 1-4°C colder in August and 3-6°C in October. On average, Cayoosh Creek was 3°C colder than the Seton River during the study period. Temperature data from monitoring sites outside the Year 1 study area are presented in Appendix III.

3.1.3 Water Chemistry

In 2012, the specific conductivity in Cayoosh Creek gradually increased during the study period whereas the specific conductivity in the upper Seton River decreased slightly, and the lower Seton River and lower Fraser River remained relatively constant. (Figure 3-7).

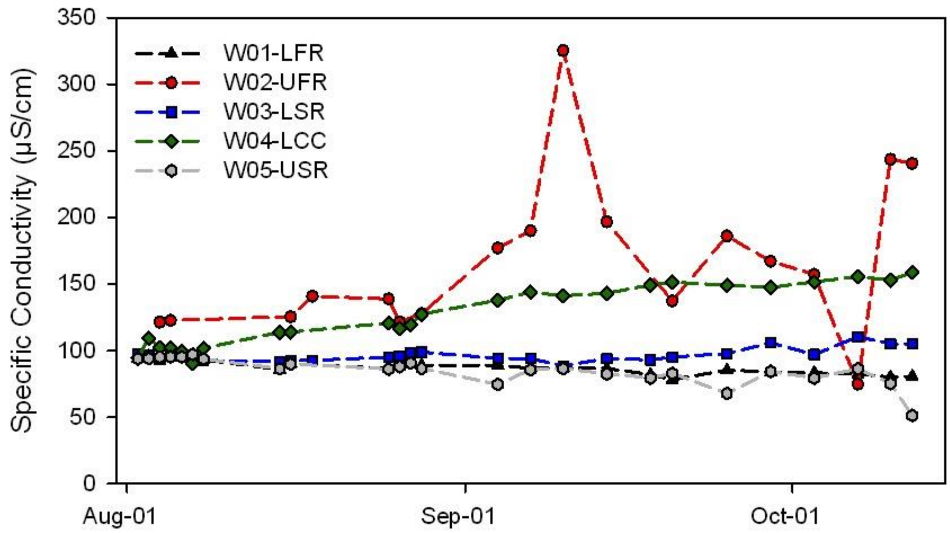

Figure 3-7: Specific conductivity readings at water chemistry sites in the Year 1 study area from 02 August to 12 October 2012

Specific conductivity in Cayoosh Creek increased from approximately 100 µS/cm in early-August to over 150 µS/cm in mid-October. During the same period, changes in the lower Seton River and the lower Fraser River were also observed, but were of lesser magnitude than those in Cayoosh Creek. Specific conductivity in the lower Seton River increased from 95 µS/cm to 105 µS/cm and paralleled the increase in Cayoosh Creek, whereas the lower Fraser River displayed a minor decrease in specific conductivity of approximately 15 µS/cm. Specific conductivity in the upper Seton River also decreased, although there was greater variation than observed at the lower Fraser River site in the Seton Generating Station tailrace, despite the two sites sharing the same water source. Specific conductivity of the upper Fraser River was greater and more highly varied than all other sites, ranging from 121.4 µS/cm to 325.4 µS/cm.

Differences in the specific conductivity between Cayoosh Creek and the upper Seton River, the two water sources used for olfactory sensitivity trials (Section 3.4), were apparent during both the Gates Creek and Portage Creek sockeye target dilution periods (Figure 3-8).

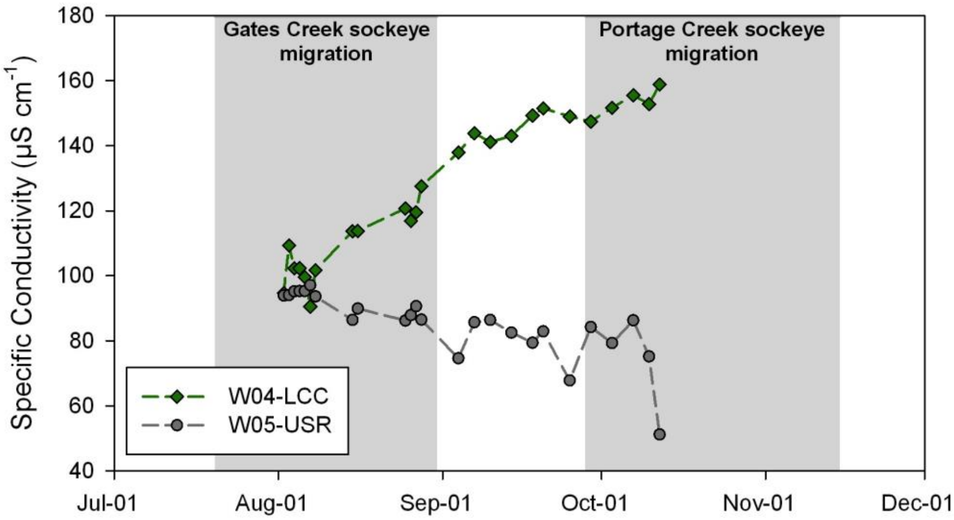

Figure 3-8: Specific conductivity readings from lower Cayoosh Creek (W04-LCC) and the upper Seton River (W05-USR) water chemistry sites during the migration period for Gates Creek and Portage Creek sockeye

During the target dilution ratio period for Gates Creek sockeye, the mean ± S.D. specific conductivity in lower Cayoosh Creek (108.7 ± 11.1 µS/cm) was significantly greater (paired t-test: t=-4.169, d.f.=12, p<0.001) than that of the upper Seton River (91.7 ± 3.9 µS/cm) with a mean ± S.D. difference of 17.0 ± 14.7 µS/cm between the two sites. During the Portage Creek target dilution ratio period, the specific conductivity of upper Seton River (75.2 ± 14.1 µS/cm) and lower Cayoosh Creek (153.2 ± 4.3 µS/cm) were also significantly different (paired t-test: t=10.052, d.f.=4, p<0.001). However, the difference between the two sites (78.0 ± 17.4 µS/cm) was greater than during the Gates Creek migration period. These preliminary results indicate that differences in water chemistry exist better the Seton River and Cayoosh Creek and that the differences are not constant while salmon are migrating through the Seton-Anderson watershed.

Laboratory analysis of DFAA is in progress and the results will be reported in Year 2.

3.2 Fish Passage Enumeration

3.2.1 Signal and Video Validation

A high frequency of counter enumeration errors was recorded on fish counter sensor channels 3 and 4. Up counts of fish represented only 2% and 0.1% of total recorded detections on channels 3 and 4, respectively, while up counts represented 79% and 82% of total detections on channels 1 and 2, respectively. Examination of the graphical trace data collected during operations indicated electrical shorting and non-typical trace data on channel 3 and 4 compared to the typical patterns observed on channel 1 and 2 (Appendix V). However, the pattern of daily events recorded was similar in periodicity to sensor channels 1 and 2 (Appendix VI). In the absence of video records for the channel 3 and 4 sensor tubes due to limited cable connections for video data collection and site access issues, it was assumed that the percentage of up counts on channels 3 and 4 should have been similar to channels 1 and 2. To correct for detection errors on sensor channels 3 and 4, daily up counts for both channels were summed and multiplied by a factor of 0.81, the average ratio of up counts to total detections on channels 1 and 2. This provided a corrected up count for channels 3 and 4 combined.

Fish counter enumeration data from 25 July to 31 August 2012 was verified using a sub-set of video data recorded from the camera mounted on the channel 1 sensor tube. From 14 August 2012 at 14:43 to 15 August 2012 at 20:11 a total of 377 upstream migrating sockeye salmon were observed on video recordings of which 374 were correctly assigned as an up count (99% efficiency). Eight char were also observed on video recordings of which two passed entirely through the sensor tube. Neither of the char were enumerated by the counter as a up count. Chinook salmon were not observed on video recordings. No night video data were available as the infra-red light used did not provide sufficient illumination for camera recording.

Kelt migration was not observed at the Seton Dam fish counter in 2012. Kelt migration was not expected given the fish counter is separated from Gates Creek and the Portage River by Seton Lake and Anderson Lake.

3.2.2 Gates Creek Sockeye

Past annual migrations of Gates Creek sockeye salmon through the Seton Dam fishway have typically occurred from mid-July through the end of August. Therefore, the period of 15 July to 31 August 2012 was used to define the migration period for Gates Creek sockeye and would encompass the majority of Gates Creek migration. Although Gates Creek sockeye would likely dominate fish counter data during this period, detection of co-migrating Chinook salmon was possible.

Peak signal size analysis of detections during the Gates Creek sockeye migration found the PSS for up counts was 92 ± 18 (mean ± S.D.; *n*=19,996) and 75 ± 24 (mean ± S.D.; *n*=1,282) for down counts. The up count PSS distribution was skewed towards high PSS value and also bi-modal (Figure 3-9) with an increased frequency of detection at a PSS of 81-90 and a second peak at a PSS of 127, the maximum detectable signal size. The down count PSS distribution was also skewed towards high PSS values but displayed a tri-modal distribution with the largest detection frequency occurring at a PSS of 61-70 with smaller peaks at 91-100 and 127. In total, 9.3% of up counts were recorded with a PSS of less than 70 whereas 55.2% of down counts had a PSS less than 70.

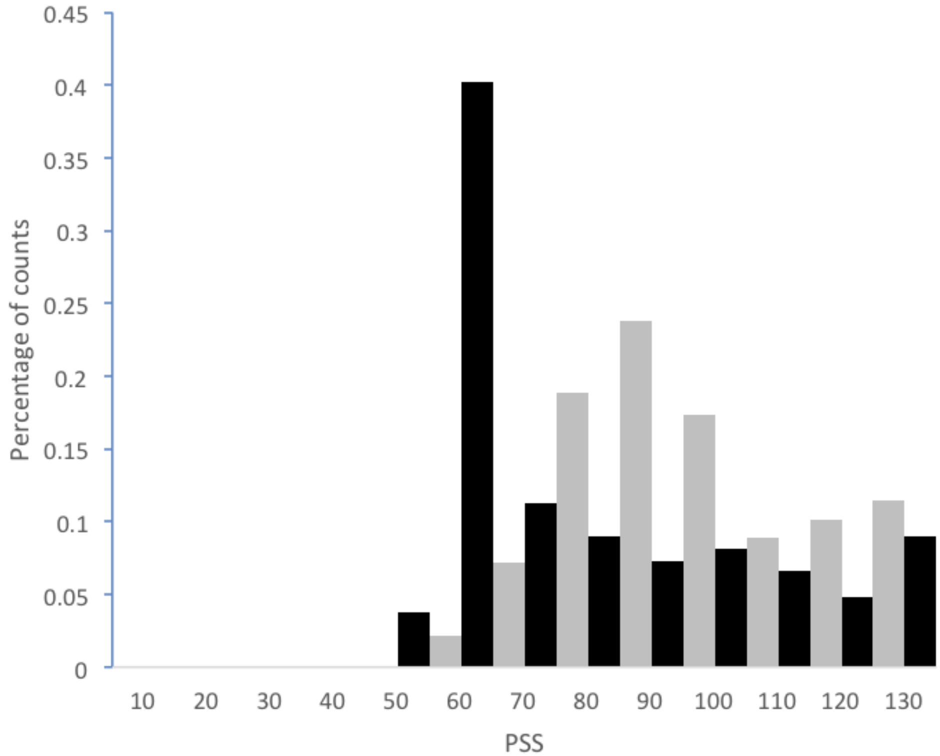

Figure 3-9: Peak signal size histogram of up counts (black bars) and down counts (grey bars) for fish enumerated at the Seton Dam fishway between 15 July and 31 August 2012

The increased detection of lower PSS value in down counts likely resulted from fish other than sockeye. Smaller bodied char and trout were observed on video data recording and may have passed through the sensor tubes. Given that the fish counter should estimate fish size equally regardless of direction of travel, the majority of down counts were likely not generated by sockeye salmon. For 2012, it was assumed that 50% of down counts were associated with small fish other than sockeye salmon. These counts were not removed from the net upstream salmon migration totals. The remaining 50% of fish were assumed to be pre-spawn sockeye salmon holding around the sensor tubes, as observed on video data recordings, and were removed from the upstream escapement total.

Based on above corrections for channel 3 and 4 detection errors, counter efficiency, and down counts, the total estimated salmon escapement between 15 July and 31 August 2012 was 26,179 fish. Five days of increased net upstream migration were observed on 07 August, 12 August, 19 August, 24 August, and 27 August (Figure 3-10). Migration peaked on 12 August with a net upstream migration of 2,793 fish. Of the total escapement in 2012, 10% had passed through the Seton Dam fishway by 07 August, 50% by 13 August, and 90% by 24 August (Figure 3-11).

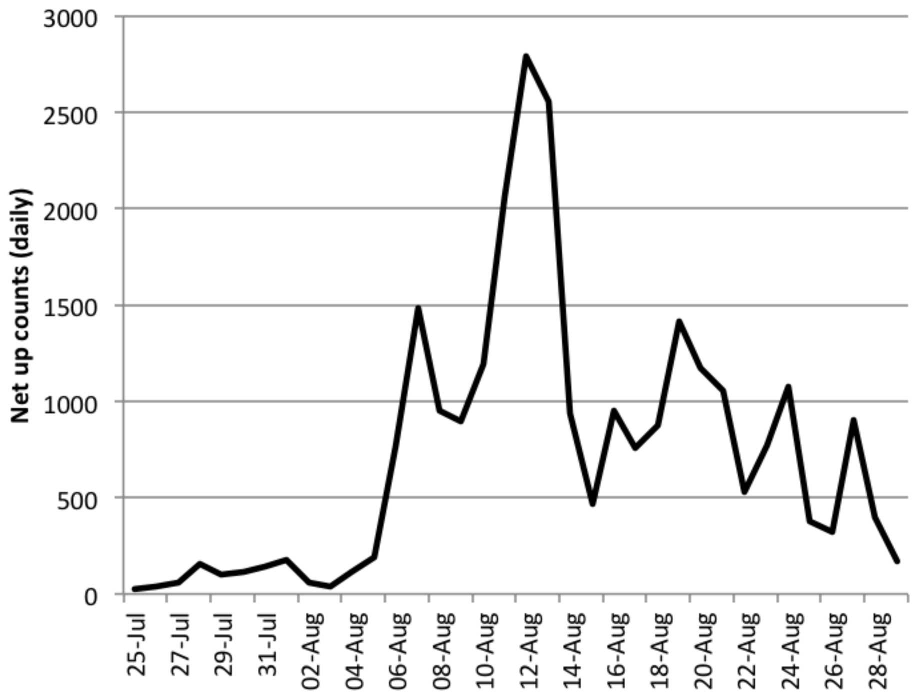

Figure 3-10: **Net daily total up counts of salmon enumerated at the Seton Dam fishway between 15 July and 31 August 2012**

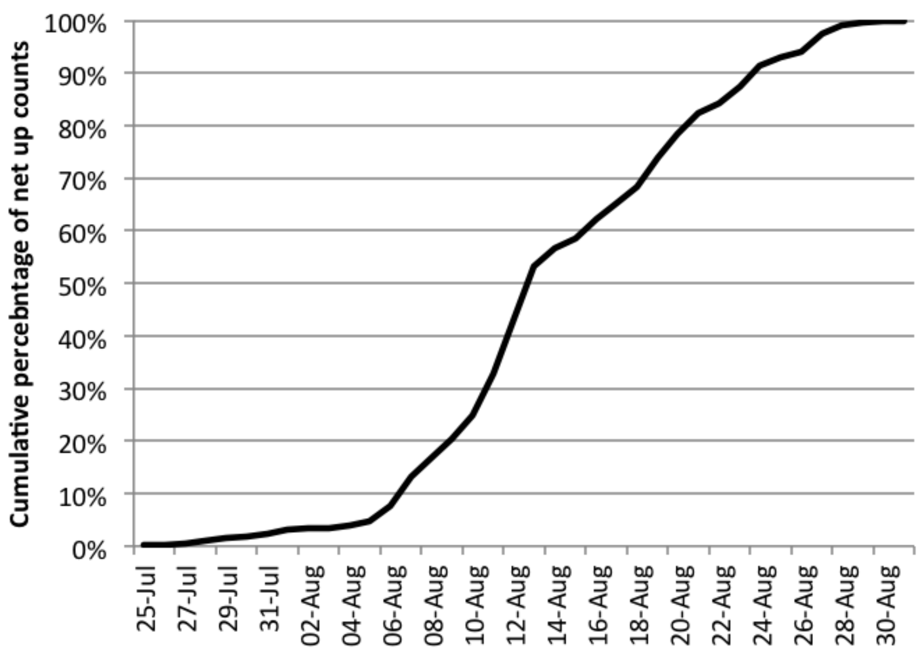

Figure 3-11: **Cumulative net upstream migration of salmon enumerated at the Seton Dam fishway between 15 July and 31 August 2012**

3.2.3 Chinook Salmon

No Chinook salmon were observed on the video data recording from 10 August, 14 August or 15 August. Data were restricted in 2012 due to dam access, equipment availability and budget constraints. Of the 26,179 up counts recorded from 15 July to 31 August 2012, 1,269 were recorded as the maximum PSS value (127) and could have been generated by larger-bodied Chinook salmon. However, without validated video evidence these detections cannot be confirmed as Chinook salmon. Further, 0.34% of validated sockeye salmon detections were recorded as the maximum PSS value. Therefore, although total Chinook salmon escapement for 2012 has not been estimated at this time, the final escapement estimate of Chinook salmon in 2012 will not exceed 1,269 fish.

3.2.4 Portage Creek Sockeye

Portage Creek sockeye salmon as well as late summer and fall Chinook salmon and coho salmon are all known to migrate through the Seton Dam fishway after 01 September. The precise migration timing of each species is poorly described and their migration timing may overlap. In 2012, video data recording was not performed during this time period. Therefore, PSS data and migration timing are the only available indicators of potential species proportions.

Between 01 September and 15 November 2012 a total of 2,005 fish were recorded at the Seton Dam fishway (Figure 3-12). The lowest daily net upstream migration occurred on 02 September with two fish enumerated. Prior to 02 September, 336 fish were enumerated passing through the fishway and were likely Portage Creek sockeye, Chinook salmon, and possibly late Gates Creek sockeye salmon. From 19 September to 15 November 2012 a total of 1,663 fish were enumerated. A distinct increase in daily net upstream migration was observed after 19 September that peaked on 28 September. After the date, the number of net upstream migrations steadily declined to less than five per day by mid-November.

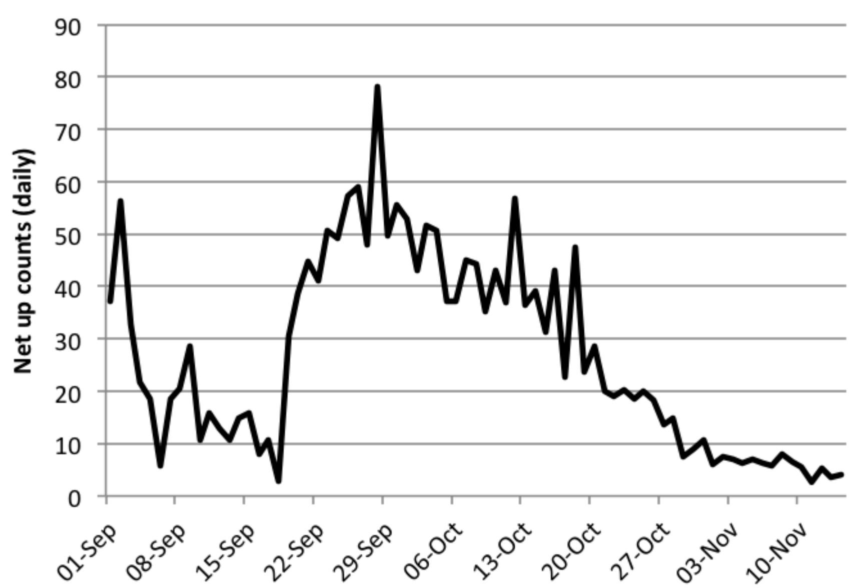

Figure 3-12: Net daily total up counts of salmon enumerated at the Seton Dam fishway between 01 September and 15 November 2012

3.3 Sampling

3.3.1 Sockeye Salmon

Stock identification DNA analysis revealed that 63% of the 154 sockeye salmon collected in the fishway during Year 1 were Gates Creek sockeye (Table 3-1; Appendix VII). The remaining 37% (*n*=57) of collected sockeye salmon were Chilko River, Stellako River or Tachie River stocks. The stock ID of two fish could not be determined due to contaminated DNA samples and these fish were not used for further analysis. Except for the final collection day, stray sockeye were captured in the fishway each day from 17 August to 27 August 2012, indicating stray sockeye were migrating through Seton Dam throughout the collection period. Further, all fish collection occurred at the top of Seton Dam at the fishway exit indicating that stray sockeye had successfully located the fishway entrance and ascended the fishway.

Table 3-1: Stock ID of Fraser River sockeye collected for telemetry and olfactory sensitivity trials and the sampling results for each identified stock

Stock ID	Fish Collected (*n*)	Sex (M/F)	Fork Length (cm)	Mass (Kg)	GSE ($MJ·kg^{-1}$)
Gates Creek	97	21 M / 76 F	56.6 ± 5.7	1.92 ± 0.31	6.6 ± 0.8
Chilko River	26	6 M / 20 F	56.1 ± 2.1	1.79 ± 0.34	8.4 ± 0.9*
Stellako River	20	7 M / 13 F	55.4 ± 1.7	1.74 ± 0.35	8.3 ± 1.2*
Tachie River	9	2 M / 7 F	54.5 ± 3.4	1.79 ± 0.36	7.9 ± 0.9*
Unknown	2	1 M / 1 F	57.7 / 55.0	2.27 / 1.73	9.0 / 7.7

Note: All values are presented as mean ± S.D. Mass is based on a subset of fish for each of Gates Creek (*n*=71), Chilko River (*n*=18) and Stellako River (*n*=13). A (*) indicates a significant difference from the Gates Creek value. Gross somatic energy (GSE) was estimated using Fatmeter readings.

Estimates of gross somatic energy density differed between stocks and was significantly higher in all stray sockeye populations than Gates Creek sockeye (ANOVA on Ranks: H=77.278, d.f.=3, $p<0.001$). The mean estimated GSE of all stray sockeye (8.3 ± 1.0 MJ Kg^{-1}) was 26% greater than Gates Creek sockeye. Estimates of GSE ranged from 2.9% to 8.4% for Gates Creek sockeye and from 4.9% to 11.2% for stray sockeye. However, 90% of Gates Creek sockeye had a GSE less than 7.4%, whereas 90% of stray sockeye had a GSE exceeding 7.2%, indicating minimal overlap of GSE for Gates Creek and stray sockeye (Figure 3-13).

Given that Gates Creek sockeye are to be specifically targeted for collection and experimentation, GSE estimates may provide a method of quickly identifying Gates Creek sockeye from stray sockeye. Calculations of GSE could be quickly performed in the field upon lipid concentration measurement using the Fatmeter. This would provide a rapid, non-invasive method of identifying Gates Creek sockeye.

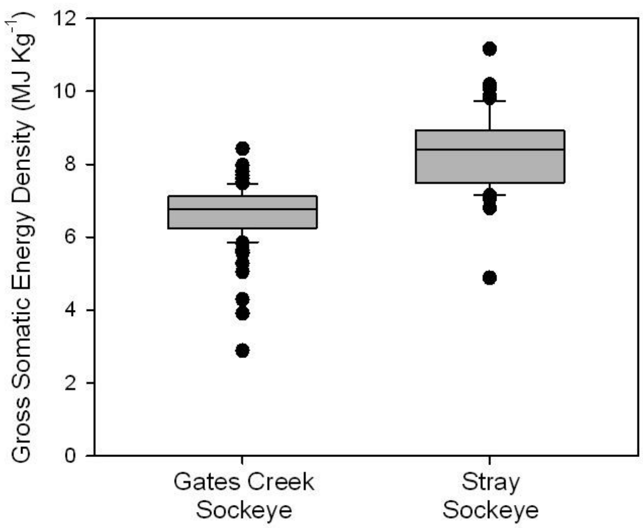

Figure 3-13: Box plots of the estimated gross somatic energy density of Gates Creek and stray sockeye salmon. Upper and lower whiskers show the 90th and 10th percentiles. The upper, lower and middle box boundaries show the 75th and 25th percentiles and median

Female sockeye salmon made up 78% of the Gates Creek sockeye that were collected (Table 3-2). Female sockeye were not targeted for collection so the high proportion of females is probably a reflection of the run composition during the collection period. For sampling, males were found to have a significantly longer fork length (Mann-Whitney Rank Sum: T=1597.5, p<0.001) and larger mass (t-test: t=-4.069, d.f.=69, p<0.001) although the estimated GSE did not differ between sexes.

Table 3-2: Sampling results of male and female Gates Creek sockeye salmon collected in 2012

Sex	Fish Collected (*n*)	Fork Length (cm)	Mass (Kg)	GSE ($MJ \cdot kg^{-1}$)
Male	21	59.1 ± 1.7*	2.19 ± 0.35*	6.3 ± 1.1
Female	76	55.9 ± 6.2	1.85 ± 0.27	6.7 ± 0.7

Note: All value are presented as mean ± S.D. Mass is based on a subset of fish for males (*n*=14) and females (*n*=57). A (*) indicates a significant difference. Gross somatic energy (GSE) was estimated using Fatmeter readings.

3.3.2 Injury Monitoring

Injury monitoring in 2012 was a basic assessment of external physical injuries. This assessment limited the application of injury monitoring to a determination of injury prevalence amongst the fish that were sampled. A more comprehensive fish condition protocol will be performed in future years.

A total of 41 physical injury observations were made on 33 of 97 Gates Creek sockeye for an overall injury prevalence of 34% (Table 3-3; Appendix VII). Five fish displayed injuries from multiple categories. Disease and cranial injuries made up the greatest proportion of injuries observed. Fungus was the primary disease observed on sockeye and accounted for 14 of the 17 disease observations. All cranial injuries were related to eye injuries with four sockeye displaying opaque eyes that were judged to severely impair vision and one sockeye that was entirely missing one eye.

The three remaining eye injuries were judged to be less severe. Three of the instances of fisheries capture injuries were apparent as net scarring that was consistent with entanglement in gill or seine nets. The remaining five injuries were attributed to recreational angling because of wounds judged to be from fishing hooks or hooks still present in the mouth of fish. The remaining instances of injury were comprised of natural injuries such as sea lice scars, injuries of unknown origin, and once instance of an injury that was judged to be a result of a bite from a predator.

Table 3-3: Summary of physical injuries recorded on Gates Creek sockeye (*n*=97) collected in 2012

Injury Category	# Observations	Prevalence
Cranial Injury	8	8%
Fisheries Capture Injury	8	8%
Predator Injury	1	1%
Disease	17	18%
Natural	4	4%
Unknown	2	3%

Cranial injuries were assumed to be the result of attempted upstream migration at the Seton Generating Station on the Fraser River. Previous studies have observed Gates Creek sockeye salmon attempting migration at the Seton Generating Station (Fretwell 1989). Since injury monitoring was only carried out at the time of fish collection, no direct observations of attempted migration at the Seton Generating Station were made in 2012. However, the relatively low prevalence of cranial injuries suggests that attempted migration at the Seton Generation Station was low in 2012.

At this time, the physical condition of fish cannot be linked to migration behaviour. Study of migration in 2012 was limited to the Seton Dam and fishway with only Gates Creek sockeye used to assess fish passage at Seton Dam (Section 3.4). There was no significant difference in number of injuries observed on fish that successfully ascended Seton Dam (0.88 injuries per fish, n=16) compared to fish that were unsuccessful (0.60 injuries per fish, n=10) (Kruskal-Wallis rank sum test: χ^2=0.6523, d.f.=1, p=0.4193). Future studies will continue to assess the link between migration success and physical condition.

3.4 Fish Passage at Seton Dam

3.4.1 Tagging Comparison

Tagging groups were compared to assess for potential effects of tagging on fish passage and activity while also comparing the suitability of each tagging method for evaluating fish passage and activity at Seton Dam. Of the 41 sockeye salmon tagged, 26 were Gates Creek sockeye salmon (63%) while the remaining 15 sockeye (Chilko River: n=8; Stellako River, n=7) were strays from other systems. Stray sockeye were not used to assess tagging methods and were excluded from fish passage assessments because only one stray sockeye approached Seton Dam and re-ascended the fishway and all remaining strays immediately exited the study area upon release. A total of 6 accelerometer loggers, 11 radio transmitters, and 9 accelerometer transmitters were applied to stray sockeye salmon. Gates Creek sockeye were tagged with a total of 10 accelerometer loggers, 18 radio transmitters, and 16 acoustic accelerometer transmitters.

Physical characteristics did not differ between the tagging groups used to assess fish passage at Seton Dam (Table 3-4). No differences were found in fork length or GSE. Proportionally, more females were tagged in each tagging group, reflecting the higher prevalence of females captured for this study. Fish were not weighed during tagging so tag burden was estimated for each tagging group using the mean mass of males and females in Table 3-2. For males and females, respectively, the estimated tag burden in each tagging group was 3.5% and 4.2% for tagging group A, 2.5% and 3.0% for tagging group B, and 0.6% and 0.7% for tagging group C. All tag burdens were within the generally accepted range for adult salmon (Cooke et al. 2012) and fish with external tags in tagging groups A and B demonstrated equal swimming ability to fish in tagging group C with internal tags (see below).

Table 3-4: The number of Gates Creek sockeye per tagging group and sampling results for each tagging group

Tagging Group	Fish Tagged (*n*)	Sex (M/F)	Fork Length (cm)	GSE ($MJ \cdot kg^{-1}$)
A. Internal Radio / External Accelerometer Logger	10	3 M / 7 F	56.4 ± 2.6	5.8 ± 1.1
B. Internal Acoustic Accelerometer / External Radio	8	3 M / 5 F	57.5 ± 1.8	6.6 ± 0.7
C. Internal Acoustic Accelerometer	8	1 M / 7 F	57.1 ± 1.9	6.7 ± 0.6

Note: Fork length and GSE (gross somatic energy) are mean ± S.D. GSE was estimated using Fatmeter readings.

Releases for each tagging group occurred over a period of 4 to 12 days (Table 3-5). Originally, releases had occurred over a broader period of time but removal of stray sockeye from analysis reduced this period. Regardless, the range of discharge conditions experienced by fish upon release was similar for all tagging groups.

Table 3-5: Summary of release river conditions and initial activity and migratory behaviour for each tagging group of Gates Creek sockeye

Tagging Group	Release Dates	Discharge ($m^3 \cdot s^{-1}$)	Swimming Speed (BL s^{-1})	Dam Approach (h)
A. Internal Radio / External Accelerometer Logger	20 Aug - 25 Aug	34.9 to 48.1	-	0.9 ± 0.5
B. Internal Acoustic Accelerometer / External Radio	17 Aug - 28 Aug	34.5 to 48.2	1.37 ± 0.21 (*n*=3)	1.6 ± 24.9
C. Internal Acoustic Accelerometer	21 Aug - 24 Aug	35.4 to 47.9	1.38 ± 0.11 (*n*=5)	1.3 ± 0.8

Note: Discharge is based on hourly Seton Dam discharge data (BC Hydro data). Dam approach times are median ± S.D. Swimming speed is mean ± S.D. based on acoustic accelerometer detections at the downstream telemetry array.

Manual radio tracking, visual observations, and acoustic data indicated that fish either briefly held in the vicinity of the release site or immediately began migrating upstream in groups to Seton Dam along the southern bank of the Seton River. This behaviour was consistent with previous observations of tagged fish (Pon et al. 2006).

Detection efficiency was 56% at the downstream acoustic array resulting in limited activity data for fish swimming in the Seton River. For security reasons, the downstream acoustic receiver was installed on the river bank opposite to the release site and this limited detection efficiency. The swimming speed of tagging groups was compared at the release site rather than Seton Dam due to the variable discharge conditions within the Seton Dam tailrace. At the release site, the swimming speed of fish did not differ between tagging group B fish with an external and internal transmitter and tagging group C fish with only an internal transmitter (Wilcoxon rank sum test: W=9.5, d.f.=1 p=0.65) (Table 3-5) indicating that the external attachment of transmitters did not impact fish swimming performance. Further, all fish approached Seton Dam and were detected in the Seton Dam tailrace within 0.48 h to 3.26 h of release with the exception of one fish from tagging group B. The median time for fish to migrate from the release site to Seton Dam did not differ between tagging groups (ANOVA on Ranks: H=4.611, d.f.=2, p=0.1). The single fish from tagging group B that did not initially migrate upstream was tracked with manual radio telemetry to the Cayoosh Creek confluence where the fish held for approximately 3 days before migrating upstream to the Seton Dam tailrace. Eventually, this fish failed to ascend the Seton Dam fishway.

At Seton Dam, attraction efficiency differed between tagging groups by as much as 60% (Table 3-6). This difference was probably the result of different discharge conditions experienced by fish in the tailrace, although the low sample size of each tagging group also likely contributed to the observed differences in attraction efficiency. Tagging group A displayed the lowest attraction efficiency, but confirming fishway entrance was difficult for this tagging group because of radio interference from Seton Dam (see below). For tagging group A, fish were only considered to have entered the fishway if detected on the boathouse receiver, likely producing an under-estimate of attraction efficiency. Further, tagging group A had the highest proportion of fish present in the tailrace during the 21 August radial gate opening. All fish present in the tailrace during the radial gate opening failed to locate the fishway entrance (see Section 3.4.2). In contrast, fish in tagging group B entered the tailrace after the radial gate opening and all fish located the fishway entrance.

The time for fish to enter the fishway varied both within and between tagging groups and ranged from 0.5 h to 114.7 h for all fish. Entrance delay did not differ between groups (ANOVA on ranks: H=0.537, d.f.=2, p=0.765). Passage efficiency was high across all tagging groups, indicating that upon entering the Seton Dam fishway, fish performance was equal regardless of tagging group.

Table 3-6: Summary of the tailrace conditions experienced and the passage success at Seton Dam of each tagging group of Gates Creek sockeye

Tagging Group	Discharge Experience	Attraction Efficiency	Entrance Delay	Passage Efficiency	Overall Success
A. Internal Radio / External Accelerometer Logger	High (*n*=1) Radial Gate (*n*=3) Low (*n*=6)	40% (4 of 10)	19.1 ± 19.2 h	100% (4 of 4)	40% (4 of 10)
B. Internal Acoustic Accelerometer / External Radio	High (*n*=3) Low (*n*=5)	100% (8 of 8)	2.1 ± 39.3 h	75% (6 of 8)	75% (6 of 8)
C. Internal Acoustic Accelerometer	Radial Gate (*n*=2) Low (*n*=6)	75% (6 of 8)	6.9 ± 20.4 h	100% (6 of 6)	75% (6 of 8)

Note: Discharge experience is the flow condition in the tailrace; High = 48 $m^3 \cdot s^{-1}$ prior to 21 August; Radial Gate refers to the 21 August radial gate opening; Low = 35 $m^3 \cdot s^{-1}$ after 21 August. Passage metrics were calculated using pooled data from all discharges experienced. Delay times are median ± S.D.

Although fish arrival and exit at the Seton Dam tailrace could be determined by both radio and acoustic telemetry, fish movements and activity within the Seton Dam tailrace could only be quantified for fish with acoustic transmitters. Fish from group B were detected by both radio and acoustic fixed receivers in the tailrace within 0.03 h to 0.85 h. On average, first detections of fish by both technologies were separated by 0.3 ± 0.3 h (median ± S.D.; n=8) indicating a good agreement of fish arrival time at the Seton Dam tailrace. Detection efficiency of both telemetry methods was high, with fixed radio and acoustic telemetry detecting 94% and 100% of fish in the tailrace, respectively. Therefore, both radio and acoustic telemetry are suitable for monitoring fish migration to Seton Dam. However, upon fish entering the tailrace, movement profiles could not be generated using manual radio tracking due to signal interference from Seton Dam discharge that prevented proper transmitter tag identification. Further, only four of the ten fish tagged with radio transmitters and accelerometer loggers entered the fishway and only one fish was recaptured before exiting the fishway. Unfortunately, data on the single recovered accelerometer logger was found to be corrupt. In comparison, acoustic receivers recorded 9,886 unique acceleration detections on five of the six receivers within the tailrace (Table 3-7). No fish were detected on VR2-5005, likely due to the high surrounding turbulence created by discharge from the dam siphons and fish water release gate. Receivers on the north bank of the Seton River detected acoustic transmitters more frequently due to lower levels of turbulence but also because of fish holding patterns in the tailrace (see Section 3.4.3).

Detection efficiencies at the upstream telemetry array were 94% for acoustic telemetry (17 of 18 fish detected) and 86% for radio telemetry (6 of 7 fish detected). Detection efficiencies were expected to be high for both telemetry methods at the upstream array due to calm water and lack of interference from Seton Dam discharge.

Table 3-7: The number of detections for each acoustic VR2 receiver in the Seton Dam tailrace and an observational rating of turbulence in the surrounding water

Receiver	Turbulence	Total Detections
VR2-4898	Low	619
VR2-5110	Low	1,999
VR2-4894	Low	7,180
VR2-4893	High	75
VR2-4897	High	13
VR2-5005	High	0

Overall, while the movement and activity data collected by the acoustic accelerometer transmitters was not continuous within the tailrace, the quality and quantity of telemetry data met or exceeded those collected using radio telemetry. In addition, the future use of smaller, internally implantable acoustic accelerometers would minimize any potential tagging effects on fish, although no apparent effects were observed with the Gates Creek sockeye monitored in 2012. Therefore, acoustic accelerometers are the technology best suited for supporting investigations into salmon migration behaviour at the Seton Dam and fishway and are recommended for use in future study years.

3.4.2 Among year passage comparison

Given that dam approach time, swimming speed, and passage efficiency did not differ among tagging groups, Gates Creek sockeye from all groups were pooled to examine fish passage and activity in the Seton Dam tailrace. In addition, since the telemetry methods in this study mirrored those of previous assessments in 2005 (Pon et al. 2006) and 2007 (Roscoe and Hinch 2008) results from 2012 were compared with the overall results of these previous studies. Data from 2005 and 2007 will be further incorporated into future analyses upon additional data collection in the current monitoring program. For 2012 specifically, fish migration behaviour and success was assessed under different tailrace discharge conditions.

The discharge conditions in 2012 were higher than in 2005, but similar to conditions in 2007 (Table 3-8). Fish in each of the 2007 and 2012 study years experienced initial discharges that were lowered to 35 $m^3 \cdot s^{-1}$ following temporary opening of the radial gate. Compared to 2005, fish in 2012 experienced discharges two to three times greater. However, despite some differences in discharge conditions from previous years, the mean entrance delay of fish in the Seton Dam tailrace in 2012 was similar to 2005 and 2007.

Table 3-8: Among year comparison of passage conditions and success at Seton Dam for Gates Creek sockeye tagged in 2005, 2007 and 2012

Variable	2005[a]	2007[b]	2012
Attraction Efficiency	77% (23 of 30)	86% (44 of 51)	69% (18 of 26)
Mean Entrance Delay	18.0 ± 4.7 h	16.3 ± 3.1 h	18.8 ± 6.8 h
Delay Range	-	0.5 – 92.6 h	0.5 – 114.7 h
Passage Efficiency	100% (23 of 23)	93% (41 of 44)	89% (16 of 18)
Overall Success	77% (23 of 30)	80% (41 of 51)	62% (16 of 26)

Note: Mean entrance delay is mean ± S.E. to match previously reported values. Data were obtained from [a]Pon et al. (2006) and [b]Roscoe et al. (2008). Fish passage was assessed in 2005 at discharges of 15.8 $m^3 \cdot s^{-1}$, 12.7 $m^3 \cdot s^{-1}$, and 11.0 $m^3 \cdot s^{-1}$; in 2007 at discharges of 60.0 $m^3 \cdot s^{-1}$ and 35.0 $m^3 \cdot s^{-1}$; and in 2012 at 48.0 $m^3 \cdot s^{-1}$, 35.0 $m^3 \cdot s^{-1}$, and at a radial gate opening.

Fish passage success at Seton Dam in 2012 was lower than reported in previous years, but was not significantly different (Table 3-8). Attraction efficiency in 2012 was 8% lower than 2005 and 17% lower than 2007. However, the proportion of fish that entered the fishway in each year did not differ (chi-square test: χ^2=3.259, d.f.=2, p=0.2), although the statistical power was low (0.332). Passage efficiency in 2012 was nearly 90% and approximated the efficiency observed in 2005 and 2007. Overall success also did not differ between years (chi-square test: χ^2=3.324, d.f.=2, p=0.19) but the comparison was again limited by statistical power (0.338). Trends within the 2012 results mirrored those of previous years where passage efficiency exceeded attraction efficiency. As a result, the overall passage success of fish in 2012 was driven primarily by attraction efficiency and the ability of fish to locate and enter the fishway rather than the ability of fish to ascend the fishway. Additional tagging and the use of PIT tags in future years will be important to increasing sample sizes to better detect differences in fish passage success at Seton Dam.

Table 3-9: Summary of Gates Creek sockeye salmon passage at Seton Dam under the three discharge conditions in 2012

Variable	High Discharge (48 $m^3 \cdot s^{-1}$)	Radial Gate Opening (Variable Discharge)	Low Discharge (35 $m^3 \cdot s^{-1}$)
Attraction Efficiency	75% (3 of 4)	0% (0 of 5)	88% (15 of 17)
Mean Entrance Delay	1.8 ± 0.2 h	-	22.2 ± 7.9 h
Median Entrance Delay	1.9 ± 0.4 h	-	8.8 ± 30.5 h
Entrance Delay Range	1.3 – 2.1 h	-	0.5 – 114.7 h
Fallback Rate	25% (1 of 4)	100% (5 of 5)	12% (2 of 17)
Mean Fallback Delay	2.6 h	11.0 ± 6.7 h	55.5 h
Median Fallback Delay	-	7.1 ± 15.0 h	-
Fallback Delay Range	-	1.1 – 37.1 h	2.4 h / 116.8 h
Passage Efficiency	100% (3 of 3)	-	87% (13 of 15)
Overall Success	75% (3 of 4)	0% (0 of 5)	76% (13 of 17)
Mean Overall Delay	3.2 ± 0.7 h	-	17.4 ± 4.8 h
Median Overall Delay	3.1 ± 1.1 h	-	9.2 ± 17.4 h
Overall Delay Range	2.1 – 4.3 h	-	0.75 – 52.2 h

Note: Mean delay times are mean ± S.E. Median delay times are presented as median ± S.D.

In 2012, the greatest differences in attraction efficiency occurred between high and low discharges and radial gate openings (Table 3-9). Of the 21 fish that entered the tailrace under high or low discharges, 18 fish entered the fishway for an attraction efficiency of 86%. In contrast, no fish that entered the tailrace during the radial gate opening entered the fishway and all fish were observed to fallback from the tailrace. This result suggests that the flow conditions during radial gate openings prevented fish from either locating or entering the fishway. However, it is important to note that only five fish experienced the radial gate opening and this sample size may have contributed to the disproportionately low attraction efficiency. However, high discharge was also experienced by a relatively small number of fish (n=4) and in contrast to the radial gate opening, the attraction efficiency during high discharge was comparable to that observed in previous study years.

Entrance delay in 2012 was greatest under low discharge conditions but was also highly variable (Table 3-9). In comparison, the entrance delay at high discharge was lower and less variable, but the sample size was also reduced (n=3). Of the 15 fish that delayed during the low discharge period prior to fishway entrance, eight delayed for less than 12 hours, three delayed for 12-24 hours, and four delayed for greater than 24 hours. Entrance delays for the two fish that entered but did not ascend the fishway under low discharge were 2.1 h and 114.7 h. A similar delay range was seen for fish that did not enter the fishway under low discharge (Table 3-9). All fish that entered the tailrace during the radial gate opening were observed to fallback out of the tailrace. For the 16 fish that successful passed Seton Dam, the overall delay between when fish entered the tailrace and exited the fishway was 14.7 ± 16.6 h (mean ± S.D.).Taken together, these results suggest that delay by fish in the tailrace may not have impacts on passage success as fish that delayed for a brief or extended period were capable of entering and ascending the fishway. Future data collection and relationship modeling will help determine if delay and passage success are linked.

3.4.3 Fish Activity

Fish movements and activity within the tailrace was limited to Gates Creek sockeye tagged with acoustic accelerometer transmitters (*n*=16). Since acoustic activity was only recorded when a transmission was detected on a receiver, the proportion of activity recorded varied with the holding patterns of individual fish (Table 3-10; Appendix IX). On average, receivers recorded 10.3% of fish activity in the tailrace.

Table 3-10: The proportion of Gates Creek sockeye tailrace activity recorded by acoustic telemetry

Fish ID	Time in Tailrace	Detections	% of Activity Recorded
01	1.3 h	10	2.1%
02	1.9 h	73	10.9%
07	80.4 h	319	1.1%
08	2.1 h	46	6.0%
13	1.4 h	6	1.2%
15	37.1 h	161	1.2%
21	1.8 h	65	10.2%
22	21.9 h	1,586	20.1%
24	8.9 h	546	17.3%
25	0.8 h	103	34.0%
26	30.7 h	561	5.1%
31	5.9 h	82	3.8%
32	7.8 h	395	14.1%
33	51.6 h	5,429	29.2%
40	0.5 h	13	7.2%
41	116.8 h	491	1.2%

Note: A single detection represents a 10 s activity period.

Analysis of fish detection patterns within the tailrace indicated that fish delaying below Seton Dam primarily held in the radial gate spillway with limited time in the fishway entrance area. Nearly all acoustic detections within the tailrace occurred in the radial gate spillway with less than 1% of tailrace detections occurring in the fishway entrance area (Table 3-11). However, high levels of turbulence in the fishway entrance would have reduced the detection efficiency of the VR2 receivers, likely resulting in an under-estimate of fish presence in this area. Currently, it is not possible to quantify the proportion of time fish spent in the fishway entrance area. Installing additional receivers in this area in future years could improve detection efficiency.

Table 3-11: The total number of acoustic detections for Gates Creek sockeye in two areas of the Seton Dam tailrace

Tailrace Area	Receivers	Fish Detected	Detections	Proportion of Detections
Radial Gate Spillway	VR2-4894 VR2-5110 VR2-4898	15 of 16	9,798	99.1%
Fishway Entrance	VR2-4893 VR2-4897 VR2-5005	10 of 16	88	0.9%

Movement patterns of fish in the tailrace (Appendix IX) were used to quantify the number of attempts fish made to enter the fishway (Table 3-12). Fish that were known to enter the fishway but not detected at the entrance were excluded. At high discharge, only one fish was detected in the entrance area but entered the fishway on the first attempt. Fish were less successful at entering the fishway at low discharge with four fish entering the fishway on the first attempt, but four fish making two attempts and one fish making three attempts. During the radial gate opening, fish were not detected in the fishway entrance area and likely made no attempts to enter the fishway. It is unlikely that turbulence limited fish detections during the radial gate opening because the radial gate is on the opposite bank to the entrance area. Although future study years should attempt to improve detection capacity within the fishway entrance area, initial results suggest radial gate openings can impact the ability of fish to locate the fishway entrance.

Table 3-12: The number of fishway entrance attempts made by Gates Creek sockeye during each discharge condition

Variable	High Discharge ($48\ m^3 \cdot s^{-1}$)	Radial Gate Opening (Variable Discharge)	Low Discharge ($35\ m^3 \cdot s^{-1}$)
Fish Detected	1 of 3	0 of 2	9 of 11
Successful Fish	1	-	9
Identified Attempts	1	-	17
Attempts per Fish	1.0	-	1.7

The swimming speed of fish differed with discharge conditions (Table 3-13). During high discharge, the mean swimming speed of fish within the radial gate spillway was significantly higher than during low discharge (t-test: $t=2.89$, $d.f.=11$, $p=0.015$). Minimum and maximum swim speeds of fish did not differ with discharge, although the low sample size limited statistical power. Regardless, minimum swim speeds in the radial gate spillway at low discharge were the lowest observed in this study. Comparison of fish activity during high and low discharge with fish activity during the radial gate opening were not made due to the low number of fish that were in the detected in the tailrace during the radial gate opening ($n=2$). However, based on the data obtained, swimming speeds during the radial gate opening were intermediate to those during high and low discharge.

Table 3-13: Swimming speeds of Gates Creek sockeye during each Seton Dam discharge level for each area of the tailrace

	High Discharge ($48\ m^3 \cdot s^{-1}$)	Radial Gate Opening (Variable Discharge)	Low Discharge ($35\ m^3 \cdot s^{-1}$)
A. Radial Gate Spillway			
Fish Detected	3 of 3	2 of 2	10 of 11
Mean (Range)	$1.48 \pm 0.20\ BL \cdot s^{-1a}$ (1.35 – 1.71)	$1.19\ BL \cdot s^{-1}$ (1.05 / 1.32)	$1.02 \pm 0.25\ BL \cdot s^{-1b}$ (0.73 – 1.61)
Maximum (Range)	$2.81 \pm 0.78\ BL \cdot s^{-1}$ (1.97 – 3.51)	$2.01\ BL \cdot s^{-1}$ (1.61 / 2.42)	$2.55 \pm 0.71\ BL \cdot s^{-1}$ (1.71 – 3.41)
Minimum (Range)	$0.98 \pm 0.11\ BL \cdot s^{-1}$ (0.87 – 1.10)	$0.94\ BL \cdot s^{-1}$ (0.72 / 1.15)	$0.68 \pm 0.19\ BL \cdot s^{-1}$ (0.51 – 1.15)
B. Fishway Entrance			
Fish Detected	1 of 3	0 of 2	9 of 11
Mean (Range)	$1.49\ BL \cdot s^{-1}$	-	$1.83 \pm 0.36\ BL \cdot s^{-1}$* (1.30 – 2.28)
Maximum (Range)	$1.50\ BL \cdot s^{-1}$	-	$2.50 \pm 0.92\ BL \cdot s^{-1}$ (1.32 – 3.58)
Minimum (Range)	$1.48\ BL \cdot s^{-1}$	-	$1.29 \pm 0.21\ BL \cdot s^{-1}$* (0.96 – 1.67)

Note: Values are presented as mean ± S.D. Significant differences across discharges are indicated by differing letters. Significant differences in activity between tailrace areas are indicated by a (*).

Comparison of fish activity in different tailrace areas was limited to the low discharge period because too few fish were detected in the fishway entrance during high discharge and the radial gate opening. During low discharge, both the mean and minimum swimming speed of fish was significantly greater in the fishway entrance area than in the radial gate spillway (minimum: RM ANOVA: $t=8.53$, d.f.=15, $p<0.001$; mean: RM ANOVA: $t=6.04$, d.f.=15, $p<0.001$) Increased swim speed in the fishway entrance was expected, given the high discharge from the fish water release gate and dam siphons designed to attract fish to the fishway entrance area. The difference in swimming speed between areas of the tailrace indicates that acoustic accelerometer transmitters were capable of capturing sufficient activity data to allow for clear differentiation of high and low levels of fish activity.

The swimming behaviour correlated to mean fish swimming speeds during high and low discharge revealed fish could swim in the radial gate spillway at speeds that could be maintained indefinitely. Mean swimming speed in the radial gate spillway at low and high discharge was below $1.66\ BL \cdot s^{-1}$ above which Gates Creek sockeye will engage in some burst swimming behaviour (Lee et al 2003). However, intermittent swimming speeds were detected in the radial gate spillway that exceeded $2.08\ BL \cdot s^{-1}$ where Gates Creek sockeye will engage in full-bursting swimming behaviour. Detection of burst swimming in the low-velocity radial gate spillway may have been a result of delayed detections from fish exiting the fishway entrance area. Due to the 10 s recording period for accelerometers and the brief processing delay, data could have been recorded while a fish was in the fishway entrance area but subsequently crossed the tailrace and was in the radial gate spillway at the time of data transmission. Future analysis will aim to further investigate the detection of burst swimming behaviour in the radial gate spillway and its relation to spatial data of fish movements.

Mean swimming speeds in the fishway entrance area at low discharge (1.83 $BL\cdot s^{-1}$) suggests Gates Creek sockeye must engage in some burst swimming to enter the fishway. Similar swimming speeds are likely required during the opening of the radial gate and during high discharge periods. At the observed swimming speeds, fish would be unable to hold in the fishway entrance area for extended periods since fish would have to resort to anaerobic swimming. Given the low swimming speeds observed in the radial gate spillway during the low discharge period, this area likely serves as a recovery area for fish attempting to enter the fishway. Loss of this recovery area during radial gate openings could contribute to the low attraction efficiency observed during that period.

3.4.4 Sex-specific Differences

In previous telemetry studies, female sockeye salmon have perished at higher rates than males during stressful migratory periods (Martins et al. 2012) including previous observations of passage through the Seton Dam fishway (Roscoe and Hinch 2008). In 2012, male and female comparisons were limited to passage through the Seton Dam and fishway and tailrace activity. Future BRGMON-14 study years will incorporate sex-specific data from 2005 and 2007 into analyses of Seton Dam fish passage and migration to spawning grounds.

In 2012, females were less successful than males at entering the fishway although discharge conditions may have contributed to the observed difference (Table 3-14). Statistical power was limited by the low number of males, but some trends were apparent. Incorporating all discharges, the attraction efficiency for females was 23% lower than males (Fisher exact test: p=0.375). However, 4 of 19 females were present in the tailrace during the radial gate opening whereas only 1 of 7 males were present. As previously discussed, no fish entered the fishway during the radial gate opening (Section 3.4.2). If females that were present in the tailrace during the radial gate opening are excluded, female attraction efficiency is 80%, a value comparable to males. Since only one male was present in the tailrace during the radial gate opening, it is not possible to determine if sex-specific differences exist for this operating condition. No differences in entrance delay or overall delay were observed between sexes (Mann-Whitney rank sum test; entrance: T=52, p=0.673; overall: T=40, p=0.821).

Table 3-14: Summary of fish passage success at Seton Dam for male and female Gates Creek sockeye

Variable	Male	Female
Discharge Experience	Radial Gate (*n*=1) Low (*n*=6)	High (*n*=4) Radial Gate (*n*=4) Low (*n*=11)
Attraction Efficiency	86% (6 of 7)	63% (12 of 19)
Mean Entrance Delay	9.0 ± 3.6 h	23.7 ± 7.8 h
Median Entrance Delay	5.4 ± 9.5 h	6.9 ± 34.1 h
Entrance Delay Range	1.9 – 21.9 h	0.5 – 114.7 h
Passage Efficiency	83% (5 of 6)	92% (11 of 12)
Overall Success	71% (5 of 7)	58% (11 of 19)
Mean Overall Delay	10.9 ± 4.2 h	16.4 ± 5.8 h
Median Overall Delay	9.2 ± 9.5 h	6.5 ± 19.1 h

Note: Mean entrance delay is mean ± S.E. Median entrance delay is median ± S.D.

No differences were found between male and female swimming speeds in the tailrace (Table 3-15). Comparison of male and female activity in the tailrace was limited to fish with acoustic accelerometer transmitters. Further, activity was only examined under low discharge conditions because no male sockeye were detected in the fishway entrance area during either the high discharge period or the radial gate opening. Additional activity data in future years will be important to determine if discharge or swimming speed are factors in the sex-specific differences in attraction efficiency.

Table 3-15: Sex-specific fish swimming speeds during the low Seton Dam discharge period for each area of the tailrace

Variable	Male	Female
A. Radial Gate Spillway		
Fish Detected	3 of 4	6 of 7
Mean (Range)	0.91 ± 0.18 BL·s^{-1a} (0.73 – 1.08)	1.09 ± 0.28 BL·s^{-1} (0.82 – 1.71)
Maximum (Range)	2.31 ± 0.62 BL·s^{-1} (1.94 – 3.23)	2.72 ± 0.77 BL·s^{-1} (1.61 – 3.51)
Minimum (Range)	0.60 ± 0.09 BL·s^{-1} (0.51 – 0.70)	0.73 ± 0.22 BL·s^{-1} (0.52 – 1.15)
B. Fishway Entrance		
Fish Detected	3 of 4	6 of 7
Mean (Range)	1.69 ± 0.47 BL·s^{-1} (1.30 – 2.21)	1.81 ± 0.33 BL·s^{-1} (1.40 – 2.28)
Maximum (Range)	2.25 ± 1.13 BL·s^{-1} (1.32 – 3.50)	2.47 ± 0.91 BL·s^{-1} (1.50 – 3.58)
Minimum (Range)	1.22 ± 0.05 BL·s^{-1} (1.16 – 1.26)	1.35 ± 0.24 BL·s^{-1} (0.96 – 1.67)

Note: All swimming speeds are mean ± S.D.

3.5 Salmon Olfactory Sensitivity

Blood plasma analysis and olfactory gene expression analysis was not completed for the Year 1 report due to limited laboratory processing capacity. Results will be presented in the Year 2 report.

Of the 113 sockeye salmon collected for olfactory sensitivity trials, a total of 70 (63%) were Gates Creek sockeye (Table 3-16). The high proportion of stray sockeye salmon reduced the number of Gates Creek sockeye in some experimental groups to less than half of the original sample size. However, sample sizes for Gates Creek sockeye are still sufficient for gene expression analysis and comparisons of olfactory sensitivity to Caysooh Creek dilution amongst the experimental groups.

Opportunistic collection of fish from Cayoosh Creek was a result of the unexpected arrival of migrating sockeye salmon in Cayoosh Creek during experimental trials. Cayoosh Creek was not previously identified as supporting sockeye salmon spawning and prior to holding trials, no sockeye salmon were observed in Cayoosh Creek. Sockeye salmon were placed into holding chambers in Cayoosh Creek on 20 August 2012 and 12 hours later on 21 August 2012 approximately 20 sockeye salmon were observed swimming adjacent to the holding chambers installed in Cayoosh Creek. Four of these fish were collected and stock ID results indicated that all four were stray sockeye from either the Stellako River or Tachie River. While it appears that this migratory event was linked to the presence of experimental fish in Cayoosh Creek, an exact explanation is not yet forth-coming and gene expression analysis may provide further insight. Management implications for this event will be presented as part of the Year 2 report.

Table 3-16: Summary of the stock ID and sampling results for the groups of sockeye salmon used for olfactory sensitivity trials

	Control	1A	1B	2A	2B	3A	3B	4A	4B	Cayoosh
Gates Creek (n)	17	5	7	7	5	8	10	6	6	-
Fork Length (cm)	56.9 ± 1.8	58.0 ± 3.3	57.5 ± 1.4	55.3 ± 1.7	56.7 ± 1.5	57.8 ± 1.9	58.2 ± 2.3	55.8 ± 2.3	57.9 ± 1.6	-
Mass (Kg)	1.94 ± 0.30	1.99 ± 0.43	2.01 ± 0.28	1.7 ± 0.3	1.76 ± 0.19	2.00 ± 0.26	2.04 ± 0.42	1.66 ± 0.23	1.99 ± 0.21	-
GSE (%)	6.8 ± 0.3	5.8 ± 1.7	7.1 ± 0.7	6.5 ± 0.6	6.9 ± 0.8	6.8 ± 0.6	6.9 ± 0.8	6.9 ± 0.4	6.6 ± 0.6	-
Stray Sockeye (n)	7	7	6	4	5	0	0	3	4	4
Fork Length (cm)	57.0 ± 1.8	55.7 ± 1.8	54.0 ± 1.9	54.4 ± 0.9	56.4 ± 3.3	-	-	54.3 ± 2.4	52.8 ± 2.5	55.7 ± 3.3
Mass (Kg)	1.82 ± 0.30	1.78 ± 0.29	1.87 ± 0.42	1.55 ± 0.08	1.94 ± 0.48	-	-	1.61 ± 0.2	1.54 ± 0.19	1.89 ± 0.43
GSE (%)	8.4 ± 0.3	8.0 ± 0.6	7.9 ± 0.6	7.4 ± 0.2	7.9 ± 1.1	-	-	7.9 ± 0.5	6.8 ± 1.4	8.6 ± 0.1

Note: All values are presented as mean ± S.D. Gross somatic energy (GSE) was estimated using Fatmeter readings.

4.0 DISCUSSION

Year 1 of the BRGMON-14 adult fish passage monitoring program focused on physical parameter monitoring and improving fish enumeration and fish passage monitoring at the Seton Dam and fishway. Studies of olfactory sensitivity for Gates Creek sockeye were completed but require further analysis and will be presented and discussed in the Year 2 report.

4.1 Physical Parameters

Seton Dam discharges in 2012 exceeded those in 2005 (Pon et al. 2006) but approximated the discharges that occurred in 2007 (Roscoe and Hinch 2008). Unique in 2012 was the monitoring of fish tagged with telemetry transmitters during a radial gate opening at Seton Dam. Opening of the radial gate occurred three times in 2012 on 30 July, 08 August, and 21 August with the last opening coinciding with telemetry studies. Although total Seton Dam discharge was not reported to increase with the opening of the radial gate, the opening was simultaneous with increased flow from the fish water release gate and decreased flow from the dam siphons. Combined, these operational changes altered the flow patterns in the Seton Dam tailrace and may have detrimentally affected fish holding patterns and passage success (see Section 4.6.2). Future study years will benefit from characterization of the tailrace flow patterns that occur during radial gate openings as well as during other discharges.

Temperatures of the Fraser River and the Seton River exceeded the optimal temperatures of Gates Creek sockeye salmon in 2012. Temperature in the Fraser River during the Gates Creek migration peaked at 19.6°C while temperature in the Seton River reached a maximum of 18.0°C. Gates Creek sockeye have an optimal temperature of 17.5°C (Lee et al. 2003) and display reduced performance above this temperature. However, the maximum temperature of the Seton River was just 0.5°C above optimal and was unlikely to have had a significant impact on Gates Creek sockeye passage at Seton Dam. On the other hand, temperatures in the Fraser River were up to 2°C above the optimal temperature for Gates Creek sockeye. Migration in the Seton River could be affected by Fraser River temperatures since the thermal history of sockeye is known to affect migration success (Crossin et al. 2008, Mathes et al. 2010). Although Fraser River temperatures were not incorporated into analyses in 2012, they will be an important future consideration when comparing sockeye migration in the Seton River across study years.

Elevated temperatures in the Fraser River or Seton River may cause fish to seek thermal refuge during their migration through the Seton-Anderson watershed. In 2012, the Seton Generating Station tailrace was 1-2°C cooler than the Fraser River throughout much of the study period. Temperatures differences of up to 4°C were also seen between the Seton River and cooler Cayoosh Creek. During periods of elevated temperature, migrating sockeye or other salmon species will seek cooler waters (Mathes et al. 2010) and fish could use the Seton Generating Station tailrace or Cayoosh Creek as temporary thermal refugia. Telemetry in 2012 showed that one fish released into the Seton River held in Cayoosh Creek for an extended period prior to attempting (but failing) passage at Seton Dam. Whether this holding was due to temperature is not clear, but delay in thermal refugia by salmon could be a factor affecting migration success and should be monitored during future telemetry studies.

Conductivity between the upper Seton River and Cayoosh Creek varied during salmon migration in the Seton River. The difference in conductivity between the waterways was 17.0 ± 14.7 µS/cm during the Gates Creek migration. However, an increase in the conductivity of Cayoosh Creek and a decrease in the conductivity of the upper Seton River resulted in a 78.0 ± 17.4 µS/cm difference during the Portage Creek migration. Although monitoring ended during the Portage Creek migration, the overall trend in 2012 suggested the conductivity of the two water sources would continue to diverge. Diverging conductivities of the watersheds are an important consideration when assessing the effectiveness of the fixed dilution ratios for Gates Creek and Portage Creek sockeye migration, since the dilution of Cayoosh Creek by the Seton River could be less effective with a greater difference in water chemistry. Further, deviations above the dilution ratio target may have varied effects on salmon olfaction depending on water chemistry differences. The results of olfactory sensitivity trials and the incorporation of differences in conductivity into fish passage models will help determine if the effectiveness of the dilution ratio targets vary with changes in water chemistry.

4.2 Fish Enumeration

Although video validation on counter efficiency was limited in Year 1, there are several indicators that the counter was operating with a high level of efficiency on channels 1 and 2. No false counts due to debris or counter malfunction were recorded. Further, for the 379 counts that were validated by video the fish counter was operating with a very high level of efficiency (99%). Counter efficiencies >90% have been observed for salmonid species in other British Columbia watersheds using similar equipment (Galesloot and McCubbing 2003, Andrusak 2010). Therefore, application of the 99% upstream and 99% downstream efficiency estimated for 2012 are appropriate. It should be noted that while some daily fluctuation in counter efficiency can occur (Nicholson et al. 1995, McCubbing et al. 1999) overall escapement estimates are likely within 5% of the total escapement.

A relationship between PSS and fish size has yet to be established at the Seton Dam fish counter. Sockeye salmon were observed to create the maximum PSS that could be recorded on the fish counter (PSS=127), a value that is more commonly associated with larger Chinook salmon. Further video validation data is required in future study years to improve the relationship between PSS and fish size and separate co-migrant Chinook salmon from sockeye salmon escapement estimates.

The total escapement of Gates Creek sockeye for 2012 was estimated as a maximum of 26,179 fish with a potential of up to approximately 1,200 of these being co-migrant Chinook salmon. In comparison, an estimated 30,644 sockeye were enumerated at the Gates Creek spawning grounds (DFO data on file). Escapement at Gates Creek was estimated by a complete spawning channel dead pitch (verified by mechanical counter, 3% variance) and a mechanical counter estimate for fish spawning in Gates Creek itself with limited visual verification of accuracy. Plans to validate both mechanical counters at the Gates Creek spawning area is proposed in 2013 as part of a project funded by BC Hydro under their Fish and Wildlife compensation program to assist in evaluating discrepancies in abundance estimates. Current data indicates that one or other method of enumeration at present contains a bias, although survivorship between the lower Seton River enumeration site and Gates Creek in 2012 appears to have been high, even if pre-spawn mortality on arrival was rated as very high (Lingard et al. 2013).

Between 01 September and 15 November 2012 a total of 2,005 upstream migrant fish were recorded at the Seton Dam fish counter. Video validation was not performed for this cohort of fish. However, all Chinook and coho salmon appeared on the Bridge River spawning grounds during this period (McCubbing et al. 2013). Therefore, it is likely that at least a portion of fish recorded between 01 September and 15 November were upstream migrant Chinook and coho salmon. Portage Creek sockeye are typically observed migrating into the Seton River at this time, although visual numbers were reported by DFO visual observers were extremely low in 2012 (Steven Hall, personal communication). Currently, it is not possible to evaluate number of each species recorded on the fish counter during this migration period. Video data collected in future years as well as proposed capture and tagging studies should allow for the separation of these data.

Overall, delays in counter set up due to contracting issues, safety protocols, site access requirements and availability of required wiring all resulted in less than ideal conditions for enumeration in 2012. Despite these constraints, an estimate of Gates Creek sockeye salmon escapement was generated along with a preliminary indication of Portage sockeye, Chinook and coho salmon escapement. Both escapements were completed with an overall enumeration precision of 5%.

4.3 Fish Sampling

Collection and tagging of fish began on 17 August 2012, five days after the peak migration of Gates Creek sockeye and during declining Seton River discharges. Delay in the start of fish collection was due to contracting issues. In future years, all fish collection should begin at the start of the Gates Creek sockeye run in late-July. Earlier start dates will be important for ensuring sufficient numbers of fish are collected for proposed future work. In addition, collecting fish at the start of migration will allow the entire Gates Creek migration to be monitored over a broader range of discharge conditions.

Stock identification of sockeye salmon collected in 2012 showed that 57 of 154 sockeye (37%) were strays from the Chilko River, Stellako River, or Tachie River stocks. Although straying is common in all species of Pacific salmon (Quinn 1993) the proportion of stray sockeye salmon in 2012 was unusual and considerably higher than observed in previous study years. In 2005, none of the 50 sockeye collected were strays (Pon et al. 2006) and in 2007, only one of the 87 collected sockeye was a stray (Roscoe and Hinch 2008). For 2012, stray sockeye salmon were excluded from telemetry analysis because of differences in migratory behavior. Consequently, this reduced the number of sockeye used for telemetry analysis from 41 to 26 fish. For olfactory sensitivity trials, 71 of the 109 sockeye included in the trials were Gates Creek sockeye.

Identifying Gates Creek and Portage Creek sockeye from stray sockeye prior to tagging or use in experimental trials will be important in future study years. For example, Gates Creek and Portage Creek sockeye salmon are required for water preference experiments in Year 2. Gross somatic energy differences between Gates Creek sockeye and stray sockeye may provide a method to identify and exclude stray sockeye salmon in future studies. The mean estimated GSE of stray sockeye from Chilko River (8.4 ± 0.9 MJ Kg^{-1}), Stellako River (8.3 ± 1.2 MJ Kg^{-1}), and Tachie River (7.9 ± 0.9 MJ Kg^{-1}) were significantly greater than Gates Creek sockeye (6.6 ± 0.8 MJ Kg^{-1}). GSE estimates from Fatmeter readings taken at the time of fish sampling showed minimal overlap in the GSE of Gates Creek sockeye and stray sockeye. In future years, Fatmeter readings in combination with a GSE threshold could be used to reduce the number of stray sockeye collected. However, due to possible annual variation in sockeye salmon GSE for both Seton-Anderson and stray sockeye (Crossin et al. 2004), a threshold could only be implemented after in-season verification. As an alternative, stock identification DNA analysis could be performed while collected sockeye were held on site, although this would require holding infrastructure and could not be applied to telemetry studies where holding fish would likely have consequences for migration. No Portage Creek sockeye were sampled in Year 1 so it is unknown if GSE estimates for this population will differ from stray sockeye stocks. However, the run timing and possible low incidence of strays during Portage Creek migration may not require screening protocols for this population.

The high incidence of strays collected in Year 1 also highlights a need to improve fish collection methods. Although past studies have collected fish from the Seton Dam fishway (Fretwell 1989, Pon et al. 2006, Roscoe and Hinch 2008) the efficiency of collection at this site was low in Year 1, although this was partly due to the late start of fish collection. Construction of a partial-spanning fish weir downstream of Cayoosh Creek will be critical since future study years will require greater numbers of fish and additional fish may have to be collected and screened to compensate for the presence of stray sockeye.

Injury monitoring on Gates Creek sockeye recorded an 8% prevalence of cranial injuries attributed to attempted migration at the Seton Generating Station. In 2012, dilution ratio targets were met on all days except one during the <20% target ratio period for Gates Creek sockeye from 20 July to 31 August. The overall incidence of cranial injuries in 2012 was judged to be low and probably reflects the continued effectiveness of target dilution ratios at limiting sockeye injury in the Seton Generating Station tailrace (Fretwell 1989). Continued injury monitoring in future years will be important if target dilution ratios are exceeded more frequently than in 2012. Injury monitoring should also be coupled with visual observation of the Seton Generating Station for attempted migration. Further, an injury monitoring protocol to record the extent and physical location of injuries as well as overall fish condition should be implemented. Such a protocol would aid in identifying fish that have attempted migration at the Seton Generating Station and provide a means of quantifying fish injuries so condition can be more accurately related to migration success.

4.4 Fish Passage Monitoring

Acoustic accelerometers were the most effective transmitters for monitoring fish movements and activity within the Seton Dam tailrace. The six receiver array at Seton Dam detected 100% of the acoustic-tagged Gates Creek sockeye that entered the tailrace (n=16) and recorded a total of 9,886 unique time-stamped location and acceleration detections. Previous studies that used acoustic telemetry at Seton Dam also reported high detection efficiencies but raised concerns of delayed detection of fish arrival at Seton Dam (Roscoe and Hinch 2008). In 2012, tagged fish with paired radio and acoustic transmitters were first detected by radio telemetry in the tailrace. However, the differences in first detection time between telemetry methods were minimal (0.3 ± 0.3 h) indicating the acoustic tailrace array could effectively detect fish arrival in the tailrace and provide accurate estimates of delay at Seton Dam.

Within the tailrace, radio telemetry was incapable of precisely tracking fish due to radio interference from Seton Dam discharge. Discharge interfered with radio transmitter reception and did not permit accurate identification of transmitter ID codes. The applicability of radio transmitters was further reduced by the need to pair radio transmitters with externally attached accelerometer loggers. Although external tagging did not impact fish swimming ability, none of the 10 accelerometer loggers that were applied to fish were recovered and therefore no activity data were available for these fish. In contrast, acoustic accelerometer detections were of sufficient resolution to generate detailed movement profiles for individual fish while characterizing fish swimming speeds at three different Seton Dam discharges in two different areas of the tailrace. Acoustic accelerometers did suffer from poor detection efficiency near the fishway entrance and this reduced the quantity of data collected in this area. Regardless, acoustic accelerometers demonstrated that fish required increased swimming speeds to enter the Seton Dam fishway, the latter consistent with visual observations in 2012. Therefore, acoustic accelerometer transmitters are most suitable for the detailed assessment of how operations at Seton Dam affect salmon passage.

4.5 Salmon Olfactory Sensitivity

Although the results of olfactory sensitivity trials will be reported in Year 2, there were several key findings from Year 1.

Fluctuations in the dilution ratio of the Seton River in 2012 demonstrated the direct applicability of olfactory sensitivity trials to sockeye migration. During the Gates Creek sockeye migration, increased Cayoosh Creek flow caused the Seton River mean daily dilution ratio to increase from approximately 12% on 06 August to 25% on 07 August followed by a decrease in the dilution ratio to target values. Five similar events occurred during the Portage Creek migration period. For Gates Creek sockeye, the temporary increase in the dilution ratio above the target ratio was approximately the same duration as the 24 h holding period of fish in Cayoosh Creek. Therefore, the results of the olfactory sensitivity trials can be related directly to conditions encountered by Gates Creek sockeye during their migration.

The arrival of migrating sockeye salmon in Cayoosh Creek during holding trials was an unexpected event with implications for Year 2 studies. No records could be located to indicate that sockeye salmon historically spawned in Cayoosh Creek and no sockeye salmon were observed in Cayoosh Creek prior to holding studies. However, approximately 20 sockeye appeared at the holding site in Cayoosh Creek less than 24 hours after holding studies commenced. This event suggests sockeye entered Cayoosh Creek after sensing chemical cues from the salmon being held there, challenging the widely-accepted olfactory imprinting hypothesis (Hasler and Wisby 1951) that salmon navigate to spawning grounds using olfactory cues in their natal stream water. This hypothesis was the basis for the original water preference experiments that determined the dilution ratio for Seton River (Fretwell 1989) and is the basis for water preference experiments in Year 2. Alternatively, the arrival of sockeye in Cayoosh Creek suggests that salmon may, at least in part, navigate using cues released by other members of their own population (Nordeng 1971). As a result, studies in Year 2 should account for this alternative hypothesis by performing behavioral water preference experiments with water containing cues from sockeye salmon as well as the previously planned experiments with natal Seton River water and Cayoosh Creek water.

4.6 Management Questions and Hypotheses

Data collected in Year 1 of the BRGMON-14 monitoring program can be used to address Management Questions 1.1, 1.2, 3.1 and 3.2:

1.1 Are the Cayoosh flow dilution requirements for Seton River derived from by the IPSFC effective for mitigating delays in migrations of Gates Creek and Portage Creek sockeye salmon populations?

1.2 How sensitive is Gates and Portage Creek sockeye migration to variations in the Cayoosh dilution rate?

3.1 Does the operation of Seton Dam and fishway affect salmon passage upstream of Seton Dam?

3.2. What changes to the fishway or operation may mitigate salmon migration issues at Seton Dam?

Management Questions 1.1 and 1.2 are addressed by the testing of four hypotheses:

H_{O1}: Gates Creek sockeye upstream migration is not significantly delayed when the Cayoosh Creek dilution rate exceeds 20%.

H_{O2}: Portage Creek sockeye upstream migration is not significantly delayed when the Cayoosh Creek dilution rate exceeds 10%.

H_{O3}: There is not a predictable relationship between flow dilution and the delay of upstream migrations of Gates Creek sockeye.

H_{O4}: There is not a predictable relationship between flow dilution and the delay of upstream migrations of Portage Creek sockeye.

Management Question 3.1 and 3.2 are addressed by testing of two hypotheses:

H_{O8}: Operation of Seton Dam and fishway does not affect attraction to the fishway.

H_{O9}: Operation of the Seton Dam and fishway does not affect passage efficiency at the fishway.

The Management Questions were addressed by testing the related hypotheses testing as described below.

4.6.1 Hypotheses H_{O1} to H_{O4}

Data to support hypotheses H_{O1} to H_{O4} were collected through fish enumeration and olfactory sensitivity trials in Year 1. While fluctuations above the dilution ratio could affect upstream migration rates, fish migration would also be affected by discharge, Seton Dam operating conditions, temperature, the sensitivity of fish to dilution, and numerous other factors. Proper analysis of this suite of variables will require further data collection and the development of a model to determine how Gates Creek and Portage Creek sockeye respond to different dilution targets. Additional data to support this analysis will be collected in Year 2 to Year 4.

4.6.2 Hypotheses H_{O8} and H_{O9}

Salmon passage at Seton Dam in 2012 was studied with radio and acoustic telemetry on Gates Creek sockeye (*n*=26). Attraction efficiency was 69% and was lower than the attraction efficiency in 2005 (77%: Pon et al. 2006) and in 2007 (86%: Roscoe and Hinch 2008). Passage efficiency in 2012 was 89% and was also lower than in 2005 (100%) and 2007 (93%), but was still considered high overall. Both Pon et al. (2006) and Roscoe and Hinch (2008) concluded that attraction to the fishway was the primary impediment to successful salmon passage at Seton Dam and the results in 2012 further support that conclusion.

Fish passage at Seton Dam was assessed under three operating conditions in 2012: high discharge (48 $m^3 \cdot s^{-1}$), during a radial gate opening where discharge was gradually decreased, and low discharge (35 $m^3 \cdot s^{-1}$). Attraction efficiency differed with discharge and was 75% at high discharge (n=4), 88% at low discharge (n=17), and 0% during the radial gate opening (n=5). Although the differences were not significant due to low sample sizes, the 0% attraction efficiency associated with the radial gate opening was notably lower than either high or low discharge. Poor attraction efficiency during the radial gate opening was the primary factor contributing to attraction efficiency being lower in 2012 than previous years.

Behavioral entrainment and lack of refuge in the tailrace may explain the low attraction efficiency during the radial gate opening. Studies in 2005 and 2007 did not investigate fish passage during a radial gate opening so recent comparison is not possible. Visual observations by Andrew and Geen (1958) reported that opening the radial gate entrained sockeye in high flows at the end of the radial gate spillway on the opposite bank to the fishway. As a result, fish did not attempt to cross through lower velocity waters towards the fishway entrance. In 2012, movement data for sockeye in the tailrace during the radial gate opening were limited (n=2). Regardless, no fish were detected at the fishway entrance during the radial gate opening and visual observations confirmed behavioral entrainment occurred in 2012. Further, opening of the radial gate likely forced fish to hold in high velocity turbulent water by eliminating the low-velocity refuge in the radial gate spillway that fish used during high and low discharges. This loss of refuge may have contributed to the low attraction efficiency during the radial gate opening.

Further investigation of fish activity during radial gate openings will be important to determining the reasons behind the low attraction efficiency. Complex flow patterns present in turbulent water are known to be energetically costly for salmon (Hinch and Rand 1998) and lead to increased stress and migration failure (Hinch and Bratty 2000). The use of an Acoustic Doppler Current Profiler in future years will yield data on tailrace flow patterns during radial gate openings while olfactory stress experiments may help explain why fish failed to enter the fishway even after the radial gate was closed. Study of the radial gate opening would also benefit from the installation of additional receivers in the radial gate spillway to improve detection capacity and activity estimates. Coordination with BC Hydro operations will be important to ensure telemetry studies take place during radial gate openings.

Specific recommendations regarding the operation of Seton Dam cannot be made at this time and additional evidence is needed before the null hypotheses H_{O8} and H_{O9} can be rejected. Future study years should aim to capture a broader range of discharge conditions and repeat the study of specific conditions encountered in 2012. However, 2012 studies were valuable in that they performed initial tests of these hypotheses and data from 2012 will be used in future analyses to determine if Seton Dam operations influence fishway attraction and passage.

4.7 Summary

In 2012, water quality monitoring sites were established throughout the Seton-Anderson watershed. Water chemistry data from the Seton River and Cayoosh Creek demonstrated differences in the chemical composition of these two water sources while temperature monitoring identified areas of potential thermal refuge that could affect upstream sockeye migration.

Modifications to the fish counter at Seton Dam greatly improved the detection efficiency that was verified with video recordings. Escapement was estimated for Gates Creek sockeye, Chinook salmon, and Portage Creek sockeye.

Despite stray sockeye migrating through the Seton-Anderson watershed, a sufficient number of Gates Creek sockeye were collected to assess telemetry technologies for their suitability in monitoring dam passage and to carry out olfactory sensitive trials. An initial assessment of fish passage at Seton Dam was also performed that identified operating conditions that should be studied in future years.

4.8 Monitoring Program Schedule

An annual schedule of activities outlining the tasks completed in Year 1 and the revised schedule of tasks to be completed in Year 2 to Year 5 is presented in Table 4-1. Due to the delayed start of Year 1 studies, adult salmon telemetry investigations of coho, pink, and Chinook as well as the water source preference tests proposed in the Terms of Reference were not completed. These investigations will begin in Year 2. All other tasks proposed for Year 1 were completed as scheduled.

Table 4-1: Tasks completed in Year 1 of the BRGMON-14 adult fish passage monitoring program and the tasks proposed for Year 2 to Year 5

Task	Year 1 (2012)	Year 2 (2013)	Year 3 (2014)	Year 4 (2015)	Year 5 (2016)
1) Project Coordination	X	X	X	X	X
2) Physical Parameter Monitoring					
i. Discharge and Dilution Ratio	X	X	X	X	-
ii. Water Temperature	X	X	X	X	-
iii. Water Chemistry	X	X	X	X	-
3) Adult Salmon Telemetry					
i. Radio Transmitters	-	X	X	X	-
ii. PIT Tags	-	X	X	X	-
4) Adult Sockeye Telemetry					
i. Radio Transmitters	X	X	X	X	-
ii. Accelerometer Loggers	X	-	-	-	-
iii. Accelerometer Transmitters	X	X	X	X	-
iv. PIT Tags	-	X	X	X	-
5) Salmon Dilution Sensitivity					
i. Olfactory Sensitivity Trials	X	-	-	-	-
ii. Water Source Preference Tests	-	X	X	-	-
6) Physiology and Injury Monitoring	X	X	X	X	-
7) Fishway Fish Counter	X	X	X	X	X
8) Final Reporting	-	-	-	-	X

5.0 RECOMMENDATIONS

Given the findings in 2012, the overall objectives of the BRGMON-14 monitoring program, and the tasks already scheduled for Year 2 to Year 4, the following recommendations are made for Year 2 of the monitoring program:

- Install all water temperature loggers in duplicate to ensure data security.
- Expand conductivity monitoring to include all of the Gates Creek and Portage Creek salmon migration periods
- Install additional wiring for a second Logie fish counter and resolve detection errors due to electrical shorting.
- Improve video validation of the fish counter by using additional infrared lighting and multiple cameras over an expanded monitoring period.
- Establish fish counter methods for enumerating the Chinook and pink salmon to be co-migrating with sockeye salmon in Year 2.
- Begin fish collection and tagging at the start of the Gates Creek sockeye migration period
- Install a fish collection weir in the Seton River downstream of Cayoosh Creek
- Use GSE estimates derived from Fatmeter measurements to quickly identify stray sockeye salmon
- Implement a formal injury monitoring protocol
- Use internal acoustic accelerometer transmitters for the study of fish passage at Seton Dam
- Install additional receivers in the Seton Dam tailrace to improve detection capacity in the radial gate spillway and fishway entrance area
- Coordinate with BC Hydro to ensure fish passage is monitored during radial gate openings
- Use water that contains chemical cues from salmon as part of water preference experiments

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APPENDICES

Appendix I

SOP for Fast Gene Expression Analysis
Using Evagreen

SOP for Fast Gene Expression Analysis

Using EvaGreen

Introduction

The use of DNA binding dyes for gene expression analysis is a lower cost alternative to the use of labeled probes. The method is sensitive and when coupled with melt curve analysis the specificity of the primers can be confirmed. For this protocol we are recommending the use of EvaGreen® dye, which has several advantages over SYBR® Green I (1, 2). This document provides a fast cycling protocol that can be used on either the BioMark™ HD with fast ramp rates (5.5ºC/s) or the BioMark with the normal ramp rate (2ºC/s). This protocol can be used with the 48.48 Dynamic Array™ integrated fluidic circuit (IFC) or the 96.96 Dynamic Array IFC. The use of the fast ramp rate on the BioMark HD System requires the use of a PCR master mix that has been optimized for fast cycling. The fast master mix recommended for use in this protocol includes both EvaGreen® and ROX in the master mix, which makes it convenient to use. This master mix also works well on the BioMark System with the normal ramp of 2ºC/s. The total cycling time on the BioMark System will be longer than the cycling time on the BioMark HD System, but still faster than standard protocols. (Our lab has BioMark System.) Primers need to be designed to reduce the potential for primer dimer formation and to be highly specific for the target of interest. We recommend the use of specific target amplification (STA) to increase the number of copies of target DNA. Prior to qPCR reactions the STA reaction is treated with Exonuclease I to eliminate the carryover of unincorporated primers.

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What You Need for Experiments

Stored at -20°C

- ExoSAP-IT (MJS Biolynx 78202- 4x 1ml, or PN# 78201 -1ml) for Exo I treatment,
- SsoFast™ EvaGreen® Supermix with Low ROX (Bio-Rad Laboratories, PN 172-5211)

Stored at 4°C

- 2X TaqMan® PreAmp Master Mix (Applied Biosystems, PN 4391128)
- 20X DNA Binding Dye Sample Loading Reagent (Fluidigm, PN 100-3738)
- 2X Assay Loading Reagent (Fluidigm, PN 85000736) Stored at 4°
- 50µM each Forward and Reverse Primer Stock Mixture for each assay of interest

Stored at Room Temperature

- TE Buffer (10 mM Tris, pH 8.0, 1.0 mM EDTA) (TEKnova, PN T0224)
- PCR Certified Water (TEKnova, PN W3330)

Sample Requirements

- **Making cDNA :** We use SuperScript VILO MasterMix (PN#11755500) from ABI

Making cDNA

Component	Volume per reaction
cDNA master mix (ssVILO PN11755500)	4 uL
1ug RNA + water	16 uL
Total volume	20 uL

Incubate: 25°C for 10 min, 42°C for 60min, then 85°C for 5min

- **DNA Quality :** cDNA should have an 260:280 Ratio between 1.5 and 1.8. Prior to use on a chip, monitor the integrity of your cDNA on a system such as the Agilent bioanalyzer.

- **cDNA Input:** The exact amount of cDNA to be used for each experiment depends on the relative abundance of the target gene. Unless you have concentrations in excess of 1,000 copies of your target template per µl of sample, we recommend that you increase the your target concentration by using target specific amplification as described in Chapter 4, “Multiplex Target Specific Amplification Protocol for Gene Expression Analysis,” in the *BioMark Real-Time Quantitative PCR Data Collection User Guide (PN 68000080)*.

- **cDNA Storage:** Avoid multiple freeze-thaw cycles by storing cDNA at 4ºC. For longer storage, aliquots may be stored at -80ºC.

Primers dilution

1. Resuspend or purchase primers at 100 uM in 1X DNA suspension buffer.

2. Dilute and mix primer pairs (F & R) to 50 uM each.

   Mix an equal amount of F & R primers (100uM), eg. 20uL F + 20uL R

I. Fluidigm® Gene Expression Specific Target Amplification (STA)

STA Primer Dilution

1.) Resuspend or purchase primers at 100 µM in 1X DNA Suspension Buffer.
2.) Create the Assay Mix Primer Pairs. Combine each forward and reverse primer pair to a final concentration of 20 uM each
3.) Make a 200 nM STA Primer Mix by combining equal volumes of each 100 µM primer pair and dilute using 1X DNA Suspension Buffer. Each primer is at a final concentration of 200 nM. This mix represents a 4X concentration of STA Primers.

Example preparation of 200nM pooled STA primer Mix

48 primer pairs (example)	Volume (uL)
2uL each primer pair (50uM each)	2 uL (x48 = 96 uL)
1X DNA Suspension Buffer	404
Total	500

STA Thermal Cycling

1.) Combine the following:

STA Reaction solution

Component	Volume for One Reaction (uL)	Volume for 60 Reactions
TaqMan PreAmp Master Mix (Applied Biosystems PN 4391128)	2.5	150
200 nM pooled STA primer Mix	1.25	75
cDNA	1.25	
Total	5	225

* Note: The final concentration of each primer pair in the STA reaction is 50 nM

2.) In a 96-well plate, combine 3.75 µL STA Pre-Mix with 1.25 µL each cDNA sample for a total 5 µL STA Reaction volume.

3.) Amplify for 14 cycles using the following thermal protocol as guide. (the same as TaqMan).

Condition	Activate	14 Cycles		Hold
Temperature	95°C	95°C	60°C	4°C
Time	10 min	15 sec	4 min	for ever

II. Exonuclease I (Exo I) Treatment Method

For best results, we recommend using a cleanup step to remove unincorporated primers. This can be

done with Exonuclease I (*E.coli*). Our lab uses ExoSAP-IT to do the step.

1.) Remove ExoSAP-IT from -20oC freezer and keep on ice throughout this procedure.

2.) Mix 5uL of post-PCR reaction product with 2ul of ExoSAP-IT for a combined 7ul reaction volume. Note: When treating PCR product volumes greater than 5ul, simply increase the amount of ExoSAP-IT proportionally.

Condition	Digest	Inactive	Hold
Temperature	37°C	80°C	4°C
Time	15 min	15 min	for ever

3.) Dilute the final products to an appropriate concentration for testing. The minimum amount of dilution that should be used is 5-fold but if the Ct values are consistently below 6 for some of the assays this may need to be increased to 10-fold or 20-fold. Use low EDTA TE or DNA Suspension Buffer (TEKnova, PN T0221) to dilute the products as shown:

	Volume to Add		
Volume of STA Reaction + Exonulease I	5-fold dilution	10-fold dilution	20-fold dilution
7 uL	18 uL	43 uL	93 uL

We used 5-fold dilution.

4.) Store diluted STA products at -20^{o}C or use immediately for on-chip PCR.

III. Preparing the Sample Pre-Mix and Samples

Component	Volume per inlet (uL)	Volume per inlet with Overage (uL)	Sample Pre-Mix for 48.48 (uL)	Sample Pre-Mix for 96.96 (uL)
2X SsoFast EvaGreen Supermix with Low ROX (Bio-Rad, PN 172-5211)	2.5	3	180	360
20X DNA Binding Dye Sample Loading Reagent (Fluidigm, PN 100-0388), green cap	0.25	0.3	18	36
STA and Exo I- treated sample	2.25	2.7		
Total Volume	5	6		

IMPOTANT: Use caution when pipetting the 20XDNA Binding Dye Sample Loading Reagent as bubbles can be introduced.

IV. Preparing the Assay Mix

Component	Volume per inlet (uL)	Volume per inlet with Overage (uL)	Volume for 50 uL Stock (uL)
2X Assay Loading Reagnet	2.5	3	25
1X DNA Suspension Buffer	2	2.4	20
50 uM each mixed Forward and Reverse Primers	0.5	0.6	5
Total Volume	5	6	50

CAUTION! Votex thoroughly and centrifuge all assay and samples solutions before pipetting into the chip inlets. Failure to do so may result in a decrease in data quality.

IMPORTANT! For unused sample inlets, use 3.3 uL of sample pre-mix and 2.7 ul of DNA-free water per inlet. For unused assay inlets, use 3.0 uL assay loading reagent and 3.0 uL of water. DO NOT leave any inlets empty.

IMPORTANT! Run NTC in sample inlet #22, which is in D4 position in 96 well plate.

CAUTION! Start the chip run on the Biomark instrument within 4 hours of loading the samples.

V. Priming the Chip and Loading Assay and Samples

CAUTION! Due to different accumulator volumes, use the appropriate control syringe for your chip type: **300 µL** (for the 48.48 Dynamic Array IFC) or **150 µL** (for the 96.96 Dynamic Array IFC).

1. Inject control line fluid into each accumulator on the chip (see Figure 1 for the 48.48 Dynamic Array IFC or Figure 2 for the 96.96 Dynamic Array IFC). Please see

   Fluidigm® 48.48 Real-Time PCR Workflow Quick Reference
2. Remove and discard the blue protective film from the bottom of the chip.
3. Place the chip into the IFC Controller MX (for the 48.48 Dynamic Array IFC) or the IFC Controller HX (for the 96.96 Dynamic Array IFC), then run the **Prime (113x)** script (for the 48.48 Dynamic Array IFC, it takes about 11min.) or the **Prime (136x)** script (for the 96.96 Dynamic Array IFC, it takes about 20min.).
4. When the **Prime** script has finished, press **Eject** to remove the primed chip from the IFC Controller.

CAUTION! While pipetting, do not go past the first stop on the pipette. Doing so may introduce air bubbles into the inlets.

5. Pipette 5 µL of each assay and 5 µL of each sample into their respective inlets on the chip.
6. Return the chip to the IFC Controller.
7. Using the IFC Controller software, run the **Load Mix (113x)** script (for the 48.48 Dynamic Array IFC, it takes about 1hr.) or **Load Mix (136x*)*** script *(*for the 96.96 Dynamic Array IFC, it takes about 1.5hrs) to load the samples and assays into the chip.

   * 20 minutes before the **Load Mix** script has finished, turn on the lamp.
8. When the **Load Mix** script has finished, remove the loaded chip from the IFC Controller.
9. Remove any dust particles or debris from the chip surface using scotch tape.

You are now ready for your chip run.

VI. Using the Data Collection Software

1. Double-click the Data Collection Software icon on the desktop to launch the software.

2. Click Start a New Run.

3. Check the status bar to verify that the lamp and the camera are ready. Make sure both are green before proceeding.

4. Place the chip into the reader.

5. Click Load.

6. Verify chip barcode and chip type.

   a. Choose project settings (if applicable).
   b. Click Next.

7. Chip Run file:

   a. Select New or Predefined.
   b. Browse to a file location for data storage.
   c. Click Next.

8. Application, Reference, Probes:

   a. Select Application Type--Gene Expression.
   b. Select Passive Reference: ROX.
   c. Select Probe--Single probe.
   d. Select probe type: EvaGreen
   e. Click Next.

9. Click Browse to find the thermal cycling protocol file.

   a. For the 48.48 chip: GE 48x48 PCR+Melt v2.pcl. (EvaGreen)
   b. For the 96.96 chip: GE 96x96 PCR+Melt v2.pcl. (EvaGreen)

10. Confirm Auto Exposure is selected.

11. Click Next.

12. Verify the chip run information.

13. Click **Start Run**.

Using the Real-Time PCR Analysis Parameters

1. Double-click the Real-Time PCR Analysis software icon on the desktop to launch the software.
2. Click **Open Chip Run**.
3. Double-click a ChipRun.bml file to open it in the software.
4. Enter detector and sample information.
5. Select **Analysis Views**. We recommend using the **AutoGlobal** method to set the threshold.
6. We recommend using **Linear Derivative** as the baseline correction method. For more information about baseline correction methods, contact Fluidigm Technical Support.
7. Always compare the Tm of the intended products to a positive control sample.
8. Click **Analyze**.

Appendix II

Gene Expression Analysis Primers

Appendix II: **GenBank accession numbers and sequences of primers used for quantitative PCR of olfactory genes in sockeye salmon**

Gene	*Species*	*Accession Number*	*Forward Primer*	*Reverse Primer*	*Source*
OlfC 2.1	*S. salar*	HM133629	TCC GGT TCT GCT CAG TCT ATT GTC G	TCA CCG AGG CAC GCG C	Johnstone et al. 2011
OlfC 2.2	*S. salar*	HM133630	ACT CTG GGA AGG AGC TGG CAA	TGT CAC ATG GTA CAC AGT C	Johnstone et al. 2011
OlfC 3.1	*S. salar*	HM133631	ACA AGA GGA CAG CAG TGC CTC TTT T	CAT GGG GCA GTG GGC TCG AT	Johnstone et al. 2011
OlfC 4.1	*S. salar*	HM133632	CAT CGC CAC GGC AAC CAT A	CAG AAG GCC GGC CAA TGA AG	Johnstone et al. 2011
OlfC 4.5	*S. salar*	HM133626	TCA GAG GCT TGA CAT CGA GAG T	TCT CAC TGC ACA CTG ACA CAG G	Johnstone et al. 2011
OlfC 4.9	*S. salar*	HM133620	ATA GCC ACT TAT GAG CTG GTC AAT	CCT CTC CAT GTC AAA CCT CTG G	Johnstone et al. 2011
OlfC 4.10	*S. salar*	HM133621	TAG AGT GTG ATG TGG GTT CAA	TGA AGT TAT CAG GCA GCT TCC G	Johnstone et al. 2011
OlfC 11.2	*S. salar*	HM133614	GGT CAT CCG CAA GTT ACC GTC TAG G	AGC AGG TTT TTT GGG GCG GC	Johnstone et al. 2011
OlfC 11.5	*S. salar*	HM133617	CAC TCA CAG CAG GTG CCT T	AAG CAG AGC TTG AGC GAC AGC AGT	Johnstone et al. 2011
OlfC 12.1	*S. salar*	HM133618	TTC CAG CCA GTA ATG TCA TG	ACT CTC ACG TGT CAT CAG TC	Johnstone et al. 2011
OlfC 13.1	*S. salar*	HM133609	TGT CTG CTG CTT CGA CTG C	TGG AAC ACA GTG GTC TCT G	Johnstone et al. 2011
OlfC 14.1	*S. salar*	HM133610	AGG AGA GGA TGC CTG GGT GC	GGC ACA GTC CGC AGG AAC GA	Johnstone et al. 2011
OlfC 15.1	*S. salar*	HM133612	TGA GGT GGT TTG GAC CCG GT	GTA AGG AAG GGG AGA GCT CAC GG	Johnstone et al. 2011
OlfC 15.2	*S. salar*	HM133611	CCT CGA CAG CAC GTG TGA TCC TAG T	CCC ACT ACG CCC CGA GAG ACA TTA A	Johnstone et al. 2011
OlfC 16.1	*S. salar*	HM133613	TCA GAA CCA TCC CCA GTG ACG C	GAC CGG GCA GCG TAA ACT CCA TA	Johnstone et al. 2011
OlfC 16.2	*S. salar*	HM133603	CGA CTG CAT CTC CTG TGC TG	AGT CCT CTG GAC ATC TCA AGC	Johnstone et al. 2011
OlfC 16.3	*S. salar*	HM133604	GCC TGA GCG ACC GGA GCA AG	ACA GCC CCC TGA CTC GGC TA	Johnstone et al. 2011
OlfC 17.1	*S. salar*	HM133605	CAG CTG TAT ATG CCA TTG CAC AT	TCA CCT CCT TCA GGT ACT GC	Johnstone et al. 2011
OlfC 17.2	*S. salar*	HM133606	AGA ATG ACA CAG ACA GCG GT	CCA GTT CAC TAG GTC GTA GC	Johnstone et al. 2011
OlfC 17.P1	*S. salar*	HM133607	GCT CAA CAC TGT CCT CCA TGC G	TGC CGT AGG CGT TGT CAC TTC TAA	Johnstone et al. 2011
OlfC 17.P3	*S. salar*	HM133608	GGC ATT TGA GCA GAC AGG TCC G	GGG CGC TGT GTC CCT CGA	Johnstone et al. 2011

Gene	*Species*	*Accession Number*	*Forward Primer*	*Reverse Primer*	*Source*
mGluR8	*S. salar*	Contig 38414 Cluster Id 3941877**	ATA CGG CGT ATC CTG GAC GCG GCC AAG CAC AAC AAC CAG A	CAG AAC TCA GCG AAC CAC AC	Johnstone et al. 2011
OR	*S. salar*	AY007188	CCA ACA GGG TAG ACC TCC AA	TCC CTC TGC GTT ACC TCA CT	Johnstone et al. 2011
ora1	*S. salar*	EU143808	CTT GAC CTT CTT ATT GGA GC	CAC GGG ACT TTG CCT TTG	Johnstone et al. 2011
SOIG	*S. salar*	Hino *et al.* 2007	AGC AAG TAA TGG TCG GTC TGT	TTC ATA GCC CTG TTT CTG TTG	Johnstone et al. 2011
OR	*S. salar*	TC131008*	GCA AGT CGC TAA ACA GCA AG	CGA TGA AGA AAG ACA ATG ACG A	Johnstone et al. 2011
OR	*S. salar*	TC145364*	GTC AAA AAC AAG GGG AGG AA	CAG GTC TAC AAC CCG AAA CA	Johnstone et al. 2011
OR	*S. salar*	TC136672*	CCG CAT ACT CTG TAA ACT GGA ACC ACT GAA TTT ATT GAG C	GGA GTC TAT GGT CCC TGA AAT G	Johnstone et al. 2011
OR	*S. salar*	TC116352*	TGT GTT GCT CTC CCT GAC TG	TGT AGT GAA TCC CAT TTT CTG G	Johnstone et al. 2011
OR	*S. salar*	TC128042*	GCC TGG TTC TGC TTC TAA TGT TGG CAT GAG AAT GAT AGG G	CTT TCC CCT CCC GTT CTC T	Johnstone et al. 2011
EF1Aa	*S. salar*	NM_001141909	CCC CTC CAG GAC GTT TAC AAA	CAC ACG GCC CAC AGG TAC A	Johnstone et al. 2011
EF1Aa	*S. salar*	NM_001141909	CCT GTG GAA GTT TGA GAC TGG	GAG TCT GCC CGT TCT TTG AG	Johnstone et al. 2011
CYP1A	*O. mykiss*	AF059711	AGTGCTGATGGCACAGAACTCAA	AGCTGACAGCGCTTGTGCTT	Matsuo et al. 2008
CYP2K1	*O. mykiss*	AF0455053	CTCACACCACCAGCCGAGAT	CTTGACAAATCCTCCCTGCTCAT	Matsuo et al. 2008
CYP2M1	*O. mykiss*	OMU16657	GCTGTATATCACACTCACCTGCTTTG	CCCCTAAGTGCTTTGCATGTATAGAT	Matsuo et al. 2008
CYP3A27	*O. kisutch*	U96077.1	TCTGCTGATGCCCAAACGA	CGTTGTTGGACTCTTCAGAGTGGTA	Matsuo et al. 2008
SOIG	*O. nerka*	-	ACACTCAAGTCCATTGTGGG	GGACGACCATTTTTGTCAGTC	Hino et al. 2007

* Gene Index Project Atlantic salmon TC Annotator (http://compbio.dcfi.harvard.edu/tgi/)

** GRASP Atlantic salmon EST database (http://web.uvic.ca/grasp)

References: 1) Johnstone, K.A., Lubieniecki, K.P., Koop, B.F., and Davidson, W.S. 2011. Expression of olfactory receptors in different life stages and life histories of wild Atlantic salmon (*Salmo salar*). Molecular Ecology. 20:4059-4069. 2) Matsuo A., Gallagher, E., Trute, M., Stapleton, P., Levado, R., Schlenk, D. 2008. Characterization of Phase I biotransformation enzymes in coho salmon (*Oncorhynchus kisutch*) Comparative Biochemistry and Physiology C Toxicology and Pharmacology.147:78-84 3) Hino, H., Iwai, T., Yamashita, M. and Ueda, H. 2007. Identification of an olfactory imprinting-related gene in the lacustrine sockeye salmon, *Oncorhynchus nerka*. Aquaculture. 273: 200–208.

Appendix III

Temperature Data

Appendix III: **Spot temperature readings (ºC) from water chemistry sites during BRGMON-14 Year 1**

Date	W01-LFR	W02-UFR	W03-LSR	W04-LCC	W05-USR	W06-SSC	W07-SFW	W08-SLK	W09-UCC	W10-LPC	W11-UPC	W12-GSC
02-Aug	15.8		15.5	14.3	15.7	15.5	-	16.8	-	-	-	-
03-Aug	14.7		14.2	13.7	14.8	14.7	-	17.4	-	18.5	18.6	-
04-Aug	15.3	17.7	14.8	13.0	14.5	14.9	-	15.6	-	-	-	-
05-Aug	16.2	18.3	16.0	14.0	15.4	15.5	-	16.7	-	-	-	-
06-Aug	16.2		15.7	14.3	15.5	16.0	-	16.8	-	-	-	-
07-Aug	17.4		16.8	14.8	17.6	17.2	-	18.0	-	-	-	-
08-Aug	18.4		17.7	14.1	18.0	17.6	-	17.4	-	-	-	-
15-Aug	14.1		13.6	13.8	13.5	-	-	14.1	-	-	-	-
16-Aug	16.1	18.1	15.7	14.0	15.9	-	-	16.8	-	-	-	-
18-Aug		18.5	16.0			-	-	-	-	-	-	-
25-Aug	15.3	18.4	14.8	12.3	14.7	-	-	-	-	-	-	-
26-Aug		18.1	15.5	13.2	15.9	-	-	-	-	-	-	-
27-Aug			17.1	14.1	17.8	-	-	-	-	-	-	-
28-Aug	17.3	16.9	16.3	11.8	17.4	-	-	-	-	-	-	-
04-Sep	15.5	17.1	15.4	11.9	15.9	-	-	-	-	-	-	-
07-Sep	14.7	17.8	14.9	11.2	15.0	-	-	-	-	-	-	-
10-Sep	15.1	16.5	15.1	10.9	15.2	-	-	-	-	-	-	-
14-Sep	14.6	15.1	14.8	11.7	15.0	-	-	-	-	-	-	-
18-Sep	14.2		14.1	9.7	14.0	-	-	-	-	-	-	-
20-Sep	14.7	16.7	14.0	10.3	15.0	-	-	-	-	-	-	-
25-Sep	14.5	14.6	14.7	11.8	17.2	-	-	-	-	-	-	-
29-Sep	15.0	13.9	13.6	10.4	15.6	-	-	-	-	-	-	-
03-Oct	13.7	12.2	13.1	9.1	14.1	-	-	-	-	-	-	-
07-Oct	12.9	15.4	10.8	7.3	13.8	-	-	-	-	-	-	-
10-Oct	13.3	11.2	12.3	8.9	14.0	-	-	-	-	-	-	-
12-Oct	13.1	11.6	13.1	9.9	13.8	-	-	-	-	-	-	-

Appendix IV

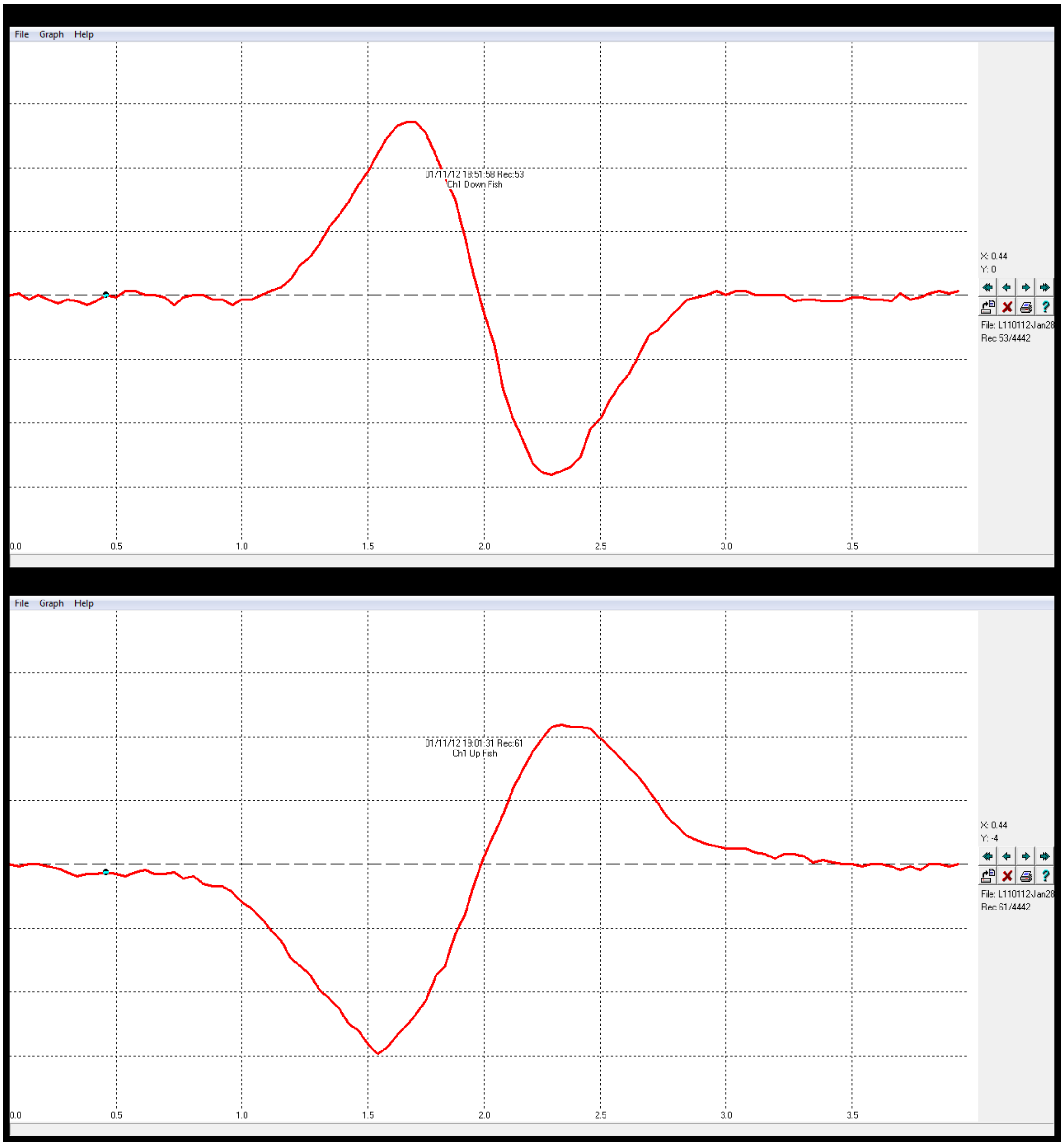
Specific Conductivity Readings

Appendix IV: **Specific conductivity (μS/cm) readings from water chemistry sites during BRGMON-14 Year 1**

Date	W01-LFR	W02-UFR	W03-LSR	W04-LCC	W05-USR	W06-SSC	W07-SFW	W08-SLK	W09-UCC	W10-LPC	W11-UPC	W12-GSC
02-Aug	94.1	-	97.2	94.7	93.9	98.6	-	97.9	-	-	-	-
03-Aug	95.7	-	96.7	109.3	94.1	90.2	-	97.0	-	110.4	111.2	-
04-Aug	95.3	121.4	93.3	102.3	95.2	94.8	-	95.2	-	-	-	-
05-Aug	95.8	122.6	95.9	102.3	95.3	95.4	-	94.7	-	-	-	-
06-Aug	96.1	-	96.6	99.6	95.3	93.9	-	96.0	-	-	-	-
07-Aug	97.1	-	95.8	90.5	97.1	97.0	-	96.4	-	-	-	-
08-Aug	93.2	-	92.7	101.7	93.6	93.3	-	94.7	-	-	-	-
15-Aug	85.6	-	91.6	113.7	86.4	-	-	87.5	-	-	-	-
16-Aug	90.2	125.4	92.5	113.8	89.9	-	-	91.5	-	-	-	-
18-Aug	-	140.8	92.7	-	-	-	-	-	-	-	-	-
25-Aug	86.4	138.8	95.0	120.7	86.2	-	-	-	-	-	-	-
26-Aug	-	121.4	96.0	116.9	87.9	-	-	-	-	-	-	-
27-Aug	-	-	98.2	119.5	90.6	-	-	-	-	-	-	-
28-Aug	88.9	127.7	98.9	127.5	86.5	-	-	-	-	-	-	-
04-Sep	88.7	177.1	94.1	137.9	74.6	-	-	-	-	-	-	-
07-Sep	86.7	190.1	93.9	143.8	85.7	-	-	-	-	-	-	-
10-Sep	86.9	325.4	88.5	141.1	86.4	-	-	-	-	-	-	-
14-Sep	86.6	196.8	94.1	143.0	82.5	-	-	-	-	-	-	-
18-Sep	82.0	-	93.0	149.3	79.4	-	-	-	-	-	-	-
20-Sep	78.0	137.3	95.2	151.5	82.9	-	-	-	-	-	-	-
25-Sep	85.3	186.0	97.7	149.0	67.8	-	-	-	-	-	-	-
29-Sep	84.0	167.1	105.9	147.4	84.2	-	-	-	-	-	-	-
03-Oct	83.2	157.1	96.9	151.7	79.3	-	-	-	-	-	-	-
07-Oct	82.3	74.8	110.4	155.5	86.3	-	-	-	-	-	-	-
10-Oct	80.1	243.6	105.1	152.8	75.2	-	-	-	-	-	-	-
12-Oct	80.6	240.6	105.0	158.8	51.2	-	-	-	-	-	-	-

Appendix V

Peak Signal Size (PSS) Trace Pattern



Appendix V: **Typical trace of up count (top figure) and down count (bottom figure) migrating sockeye salmon at Seton Dam fishway**

Appendix VI

Fish Counter Enumeration Data

Appendix VI: Estimated net daily up counts and cumulative escapement for fish passage at Seton Dam fishway in 2012.

	July		*August*		*September*		*October*		*November*	
Day	***Net Daily Up Counts***	***Cumulative Up Counts***	***Net Daily Up Counts***	***Cumulative Up Counts***	***Net Daily Up Counts***	***Cumulative Up Counts***	***Net Daily Up Counts***	***Cumulative Up Counts***	***Net Daily Up Counts***	***Cumulative Up Counts***
1			180	816	37	26216	53	27177	6	28108
2			58	875	56	26273	43	27220	8	28116
3			37	912	33	26305	52	27271	7	28123
4			112	1024	22	26327	51	27322	6	28129
5			193	1217	18	26345	37	27359	7	28136
6			768	1985	6	26351	37	27396	6	28143
7			1485	3470	18	26370	45	27441	6	28148
8			952	4422	21	26390	44	27486	8	28156
9			899	5321	29	26419	35	27521	6	28163
10			1193	6513	11	26429	43	27564	6	28168
11			2065	8578	16	26445	37	27601	3	28171
12			2793	11371	13	26458	57	27658	5	28176
13			2557	13928	11	26469	36	27695	4	28180
14			938	14866	15	26484	39	27734	4	28184
15			469	15335	16	26500	31	27765		
16			952	16287	8	26508	43	27808		
17			756	17043	11	26518	23	27831		
18			877	17920	3	26521	48	27878		
19			1411	19332	30	26552	24	27902		
20			1172	20503	39	26590	29	27930		
21			1052	21555	45	26635	20	27950		
22			531	22086	41	26676	19	27970		
23			773	22859	51	26727	20	27990		
24			1072	23931	49	26776	19	28008		
25	25	25	379	24311	57	26833	20	28028		
26	41	66	321	24632	59	26892	18	28047		
27	60	126	903	25535	48	26940	14	28060		
28	157	283	396	25931	78	27019	15	28075		
29	98	381	167	26098	50	27068	8	28083		
30	112	493	48	26146	56	27124	9	28092		
31	143	637	33	26179	-	-	11	28102		

Note: Net daily up counts and cumulative up counts up may not sum due to the 0.81 correction factor used to correct for errors on channel 3 and 4.

Appendix VII

Fish Collection Data

Appendix VII: **Collection and sampling data of adult Fraser River sockeye salmon collected for BRGMON-14 Year 1**

Fish ID	*Date Collected*	*Stock ID*	*Treatment*	*Sex*	*Fork Length* (cm)	*Mass* (Kg)	*GSE* (MJ Kg^{-1})	*Injury Notes*
1	17-Aug-12	Gates	Tagging Group B	F	57.5	-	7.3	missing dorsal spines, open wound next to anal fin
2	18-Aug-12	Gates	Tagging Group B	F	59.0	-	6.5	lesions, fungus
3	18-Aug-12	Chilko	Tagging Group A	F	56.0	-	8.4	missing adipose, red left eye
4	19-Aug-12	Stellako	Tagging Group B	F	56.7	-	10.1	healthy fish
5	19-Aug-12	Stellako	Tagging Group B	M	59.0	-	9.0	missing right eye, gill net marks, cloudy in left eye
6	19-Aug-12	Stellako	Tagging Group A	F	57.0	-	9.9	hook wound
7	20-Aug-12	Gates	Tagging Group B	M	58.0	-	7.2	sea lice, scar behind dorsal
8	20-Aug-12	Gates	Tagging Group B	F	56.0	-	6.7	
9	20-Aug-12	Gates	Tagging Group A	F	56.0	-	7.2	
10	21-Aug-12	Gates	Tagging Group A	F	53.5	-	6.3	
11	21-Aug-12	Gates	Tagging Group A	F	54.0	-	5.6	
12	21-Aug-12	Gates	Tagging Group A	M	62.0	-	6.2	fishing line out of mouth, hook wound, net marks
13	21-Aug-12	Gates	Tagging Group C	F	55.0	-	7.0	multiple lesions, old hook wound
14	21-Aug-12	Chilko	Tagging Group C	F	58.0	-	9.4	gill net marks
15	21-Aug-12	Gates	Tagging Group C	F	56.0	-	5.9	
16	22-Aug-12	Gates	Tagging Group A	F	55.0	-	5.9	
17	22-Aug-12	Gates	Tagging Group A	F	57.0	-	6.2	fungus on the fins
18	22-Aug-12	Gates	Tagging Group A	M	57.5	-	7.3	scaring on dorsal fin
19	22-Aug-12	Chilko	Tagging Group C	M	58.5	-	8.9	old hook scar
20	22-Aug-12	Chilko	Tagging Group C	F	57.0	-	11.2	small amount of fungus on dorsal
21	22-Aug-12	Gates	Tagging Group C	M	59.0	-	7.3	blind in left eye
22	23-Aug-12	Gates	Tagging Group B	M	59.0	-	5.1	
23	23-Aug-12	Stellako	Tagging Group B	F	56.0	-	9.2	old gill net marks
24	23-Aug-12	Gates	Tagging Group B	M	59.2	-	7.1	blind in one eye
25	23-Aug-12	Gates	Tagging Group C	F	54.5	-	7.5	leisons
26	23-Aug-12	Gates	Tagging Group C	F	59.0	-	5.9	
27	23-Aug-12	Chilko	Tagging Group C	F	56.0	-	8.6	blind in right eye
28	24-Aug-12	Chilko	Tagging Group A	F	56.0	-	8.1	missing right eye
29	24-Aug-12	Chilko	Tagging Group A	F	55.0	-	10.2	
30	24-Aug-12	Stellako	Tagging Group A	F	55.5	-	9.8	

Fish ID	*Date Collected*	*Stock ID*	*Treatment*	*Sex*	*Fork Length (cm)*	*Mass (Kg)*	*GSE (MJ Kg^{-1})*	*Injury Notes*
31	24-Aug-12	Gates	Tagging Group C	F	58.0	-	7.2	
32	24-Aug-12	Gates	Tagging Group C	F	56.0	-	6.5	
33	24-Aug-12	Gates	Tagging Group C	F	59.0	-	6.5	
34	25-Aug-12	Gates	Tagging Group A	F	55.0	-	3.9	sea lice scars
35	25-Aug-12	Gates	Tagging Group A	M	59.0	-	4.3	old seal wound, fungus, hook wound
36	25-Aug-12	Gates	Tagging Group A	F	55.0	-	5.3	gill net mark, hook mark
37	27-Aug-12	Stellako	Tagging Group A	M	53.0	-	9.6	scar on dorsal
38	27-Aug-12	Chilko	Tagging Group B	F	54.0	-	8.9	hook wound nose, wounded tail
39	27-Aug-12	Stellako	Tagging Group B	F	58.0	-	7.2	missing bottom half of caudal fin
40	27-Aug-12	Gates	Tagging Group B	F	54.0	-	6.4	net scarring and fungus, missing right eye
41	28-Aug-12	Gates	Tagging Group B	F	57.0	-	6.3	minor sea lice, healthy fish otherwise
6001	17-Aug-12	Gates	Olfaction Group 1A	F	54.8	1.56	7.0	
6002	17-Aug-12	Stellako	Olfaction Group 1B	M	53.0	1.46	7.3	fungus lesions on both sides of gills
6003	17-Aug-12	Gates	Olfaction Group 1B	F	57.4	1.85	7.2	
6004	17-Aug-12	Gates	Olfaction Group 1B	F	57.4	2.00	7.8	
6005	17-Aug-12	Chilko	Olfaction Group 1A	F	56.5	1.67	8.2	
6006	17-Aug-12	Chilko	Olfaction Group 1A	M	53.0	1.53	8.4	
6007	17-Aug-12	Stellako	Olfaction Group 1B	M	55.3	1.97	8.4	
6008	17-Aug-12	Stellako	Olfaction Group 1A	M	56.4	1.74	7.9	
6009	17-Aug-12	Gates	Olfaction Group 1B	F	57.5	1.98	7.4	
6010	17-Aug-12	Gates	Olfaction Group 1A	M	57.5	1.85	6.2	
6011	17-Aug-12	Tachie	Olfaction Group 1A	M	58.4	2.17	6.8	
6012	17-Aug-12	Stellako	Olfaction Group 1B	F	52.4	1.69	7.7	
6013	17-Aug-12	Chilko	Olfaction Group 1A	F	56.0	2.04	8.4	
6014	17-Aug-12	Gates	Olfaction Group 1A	M	60.8	2.16	2.9	
6015	18-Aug-12	Gates	Olfaction Group 1A	M	62.0	2.64	6.7	
6016	18-Aug-12	Chilko	Olfaction Group 1A	F	54.0	1.38	7.6	
6017	18-Aug-12	Gates	Olfaction Group 1B	F	55.3	1.75	7.1	
6018	18-Aug-12	Stellako	Olfaction Group 1A	F	55.9	1.94	8.4	
6019	20-Aug-12	Gates	Olfaction Group 3A	M	58.3	1.95	7.0	Gillnet marks, worms
6020	20-Aug-12	Gates	Olfaction Group 3B	M	59.2	1.89	6.1	
6021	18-Aug-12	Gates	Olfaction Group 1B	F	57.2	2.07	5.9	Internal parasites
6022	18-Aug-12	Tachie	Olfaction Group 1B	F	57.1	1.92	7.3	Fungus on fills (both sides), adipose missing

Fish ID	***Date Collected***	***Stock ID***	***Treatment***	***Sex***	***Fork Length* (cm)**	***Mass* (Kg)**	***GSE* (MJ Kg^{-1})**	***Injury Notes***
6023	18-Aug-12	Stellako	Olfaction Group 1B	F	54.2	2.63	8.4	Fungus on body
6024	18-Aug-12	Tachie	Olfaction Group 1B	F	52.0	1.56	8.5	blind in one eye
6025	18-Aug-12	Gates	Olfaction Group 1B	F	58.0	1.85	6.5	Internal Parasites
6026	18-Aug-12	Gates	Olfaction Group 1B	M	60.0	2.60	7.7	Fungus on gills, Internal Parasites
6027	18-Aug-12	Gates	Olfaction Group 1A	F	54.8	1.72	6.3	Internal Parasites
6028	20-Aug-12	Gates	Olfaction Group 2B	F	55.6	1.71	5.8	
6029	20-Aug-12	Tachie	Olfaction Group 2B	F	53.5	1.71	7.5	cloudy eye, fungus
6030	20-Aug-12	Stellako	Olfaction Group 2B	F	56.3	1.77	7.1	fungus on gills
6031	20-Aug-12	Gates	Olfaction Group 2B	F	58.5	1.93	8.0	Lots of fungus, had to take DNA clip from operculum
6032	20-Aug-12	Tachie	Olfaction Group 2B	F	55.0	1.91	9.7	fungus
6033	20-Aug-12	Gates	Olfaction Group 2B	F	56.5	1.45	6.3	
6034	20-Aug-12	Gates	Olfaction Group 2B	F	55.0	1.83	7.1	fungus in nares and on gills
6035	20-Aug-12	Gates	Olfaction Group 2A	F	55.0	1.74	5.9	
6036	20-Aug-12	Gates	Olfaction Group 2A	F	52.5	1.26	6.3	
6037	20-Aug-12	Chilko	Olfaction Group 2A	M	54.0	1.46	7.2	
6038	21-Aug-12	Chilko	Olfaction Group 2A	F	55.5	1.66	7.6	Fungus on body
6039	20-Aug-12	Gates	Olfaction Group 2A	F	58.0	1.96	5.7	
6040	27-Aug-12	Gates	Olfaction Group 4A	F	53.4	1.44	6.4	
6041	20-Aug-12	Gates	Olfaction Group 3B	M	59.5	1.96	6.1	Fungus
6042	20-Aug-12	Gates	Olfaction Group 3B	F	54.8	1.64	6.8	Seal lice, fungus
6043	20-Aug-12	Gates	Olfaction Group 3A	F	58.4	2.10	7.1	
6044	20-Aug-12	Gates	Olfaction Group 3A	F	57.5	2.07	7.5	Internal parasites
6045	20-Aug-12	Gates	Olfaction Group 3A	F	55.5	1.59	6.8	Fungus, internal parasites
6046	20-Aug-12	Gates	Olfaction Group 3A	M	59.5	2.31	7.0	Internal parasites
6047	20-Aug-12	Gates	Olfaction Group 3A	F	54.5	1.64	6.0	Internal parasites
6049	20-Aug-12	Gates	Olfaction Group 3B	F	57.5	1.71	7.5	Internal parasites, fungus on gills
6050	20-Aug-12	Gates	Olfaction Group 3B	F	61.5	2.53	8.4	cloudy left eye
6051	20-Aug-12	Gates	Olfaction Group 3B	M	58.7	2.62	6.8	
6052	20-Aug-12	Gates	Olfaction Group 3A	F	59.0	2.19	7.1	
6053	20-Aug-12	Gates	Olfaction Group 3A	M	59.9	2.12	5.7	Sea lice, internal parasites
6054	20-Aug-12	Gates	Olfaction Group 3B	F	55.5	1.63	7.0	hookwound in mouth
6055	20-Aug-12	Gates	Olfaction Group 3B	F	58.0	1.89	6.7	Cloudy eyes, fungus
6056	23-Aug-12	Stellako	Olfaction Cayoosh	F	55.0	1.76	8.7	

Fish ID	***Date Collected***	***Stock ID***	***Treatment***	***Sex***	***Fork Length (cm)***	***Mass (Kg)***	***GSE (MJ Kg^{-1})***	***Injury Notes***
6057	23-Aug-12	Stellako	Olfaction Cayoosh	F	55.8	1.91	8.5	
6058	23-Aug-12	Tachie	Olfaction Cayoosh	F	52.1	1.43	8.5	
6060	23-Aug-12	Tachie	Olfaction Cayoosh	M	60.0	2.45	8.7	Gillnet mark
6061	22-Aug-12	Chilko	Olfaction Group 2B	M	62.0	2.77	8.2	
6062	22-Aug-12	Chilko	Olfaction Group 2B	F	55.3	1.56	7.3	Gill net marks
6063	22-Aug-12	Tachie	Olfaction Group 2A	F	53.4	1.54	7.4	
6064	22-Aug-12	Gates	Olfaction Group 2A	F	56.7	1.92	7.0	Blind left eye
6065	22-Aug-12	Gates	Olfaction Group 2A	M	54.6	1.92	7.2	Gillnet mark
6066	22-Aug-12	Gates	Olfaction Group 2A	F	55.0	1.59	7.1	
6067	22-Aug-12	Chilko	Olfaction Group 2A	F	54.8	1.55	7.5	Hook wound, sea lice, fungus
6068	22-Aug-12	Gates	Olfaction Group 2B	F	57.9	1.90	7.2	Blind in left eye
6069	22-Aug-12	Gates	Olfaction Group 2A	F	55.5	1.62	6.4	
6070	24-Aug-12	Chilko	Olfaction Control	M	57.5	1.85	8.7	
6071	24-Aug-12	Gates	Olfaction Control	F	57.6	1.86	6.9	
6072	24-Aug-12	Chilko	Olfaction Control	F	59.8	2.31	9.2	
6073	24-Aug-12	Gates	Olfaction Control	F	57.5	1.97	7.1	
6074	24-Aug-12	Chilko	Olfaction Control	F	56.5	1.99	8.4	
6075	24-Aug-12	Gates	Olfaction Control	F	55.5	1.83	6.6	
6076	24-Aug-12	Chilko	Olfaction Control	F	56.0	1.75	7.1	
6077	24-Aug-12	Gates	Olfaction Control	F	56.5	1.91	6.8	
6078	24-Aug-12	Gates	Olfaction Control	F	56.5	1.73	7.1	
6079	24-Aug-12	Gates	Olfaction Control	F	58.0	2.07	7.1	
6080	24-Aug-12	Gates	Olfaction Control	F	52.5	1.42	7.0	
6081	24-Aug-12	Stellako	Olfaction Control	M	55.5	1.14	9.1	
6082	24-Aug-12	Gates	Olfaction Control	F	57.0	1.85	6.7	
6083	24-Aug-12	Chilko	Olfaction Control	M	58.0	1.94	8.9	
6084	24-Aug-12	Gates	Olfaction Control	F	55.5	1.67	6.8	
6085	24-Aug-12	Gates	Olfaction Control	F	56.5	1.79	6.6	
6086	24-Aug-12	Chilko	Olfaction Control	F	56.0	1.76	7.7	
6087	24-Aug-12	Gates	Olfaction Control	F	59.2	2.15	7.4	
6088	24-Aug-12	Gates	Olfaction Control	F	58.0	2.04	6.8	
6089	24-Aug-12	Gates	Olfaction Control	F	55.2	1.70	6.5	
6090	24-Aug-12	Gates	Olfaction Control	F	59.6	2.17	6.2	

Fish ID	*Date Collected*	*Stock ID*	*Treatment*	*Sex*	*Fork Length (cm)*	*Mass (Kg)*	*GSE (MJ Kg^{-1})*	*Injury Notes*
6091	24-Aug-12	Gates	Olfaction Control	F	55.0	1.84	6.8	
6092	24-Aug-12	Gates	Olfaction Control	F	57.0	2.84	6.4	
6093	24-Aug-12	Gates	Olfaction Control	F	59.6	2.08	7.0	
6094	22-Aug-12	Gates	Olfaction Group 3B	F	56.0	1.82	7.6	Fungus
6095	22-Aug-12	Gates	Olfaction Group 3B	M	61.5	2.71	6.3	
6096	23-Aug-12	Stellako	Olfaction Group 4A	F	54.7	1.64	8.4	
6097	23-Aug-12	Gates	Olfaction Group 4A	F	53.7	1.51	7.5	
6098	23-Aug-12	Gates	Olfaction Group 4A	F	57.0	1.91	7.3	Cloudy eyes, fungus
6099	23-Aug-12	Gates	Olfaction Group 4B	M	60.0	2.23	6.1	
6100	23-Aug-12	N/A	Olfaction Group 4B	M	57.7	2.27	9.0	Fungus around mouth
6101	23-Aug-12	Gates	Olfaction Group 4B	F	56.6	1.79	6.7	
6102	23-Aug-12	Stellako	Olfaction Group 4B	F	52.6	1.6	7.3	
6103	23-Aug-12	Gates	Olfaction Group 4B	F	57.3	1.83	6.0	Fungus
6104	23-Aug-12	Gates	Olfaction Group 4B	F	60.0	2.16	7.0	
6105	23-Aug-12	Tachie	Olfaction Group 4B	F	49.4	1.38	7.1	Fungus
6106	27-Aug-12	Chilko	Olfaction Group 4B	F	54.2	1.76	8.0	Missing one eye, fungus
6107	27-Aug-12	Chilko	Olfaction Group 4A	F	51.7	1.34	7.4	One rosette covered with fungus
6108	27-Aug-12	Chilko	Olfaction Group 4A	F	56.5	1.79	8.0	Fungus
6109	27-Aug-12	Gates	Olfaction Group 4A	F	54.5	1.50	6.5	
6110	27-Aug-12	Gates	Olfaction Group 4B	F	56.5	2.04	6.4	
6111	27-Aug-12	Stellako	Olfaction Group 4B	M	55.0	1.37	4.9	
6112	27-Aug-12	N/A	Olfaction Group 4B	F	55.0	1.73	7.7	Fungus on nose and rosettes
6113	28-Aug-12	Gates	Olfaction Group 4B	F	57.2	1.82	7.5	
6114	28-Aug-12	Gates	Olfaction Group 4A	M	56.9	1.65	6.9	
6115	28-Aug-12	Gates	Olfaction Group 4A	F	59.1	1.97	6.5	

Appendix VIII

Fish Tagging Data

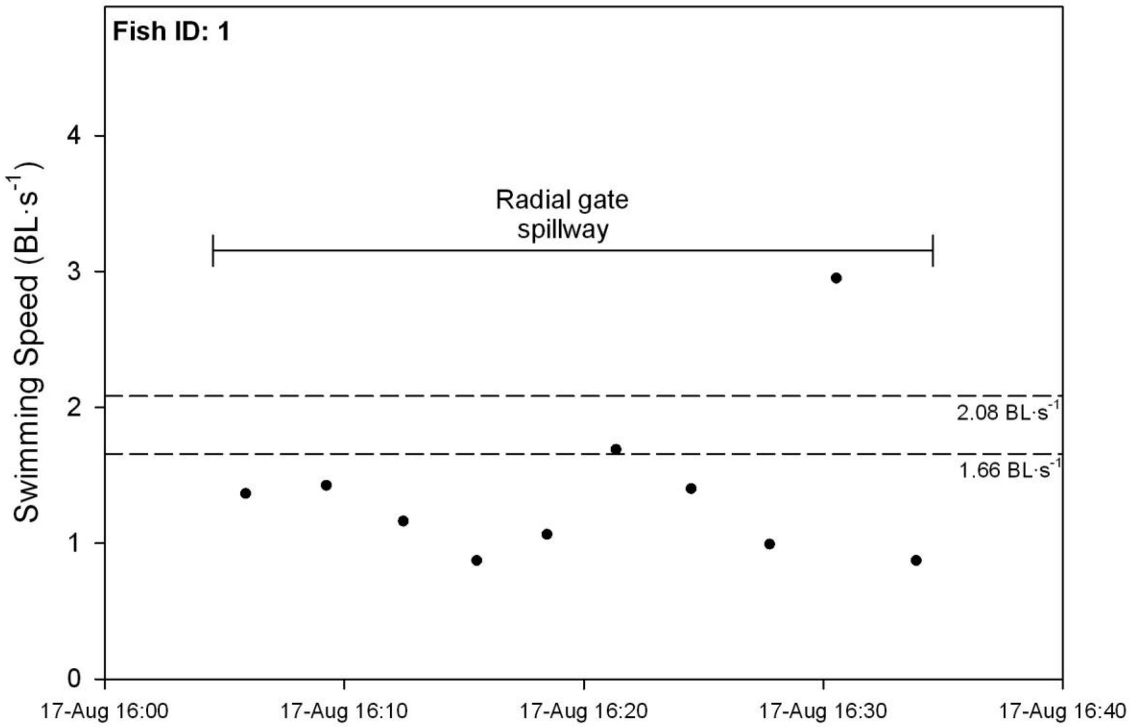
Appendix VIII: **Release date and conditions, stock ID, tag IDs, and fate for sockeye used for telemetry studies in BRGMON-14 Year 1**

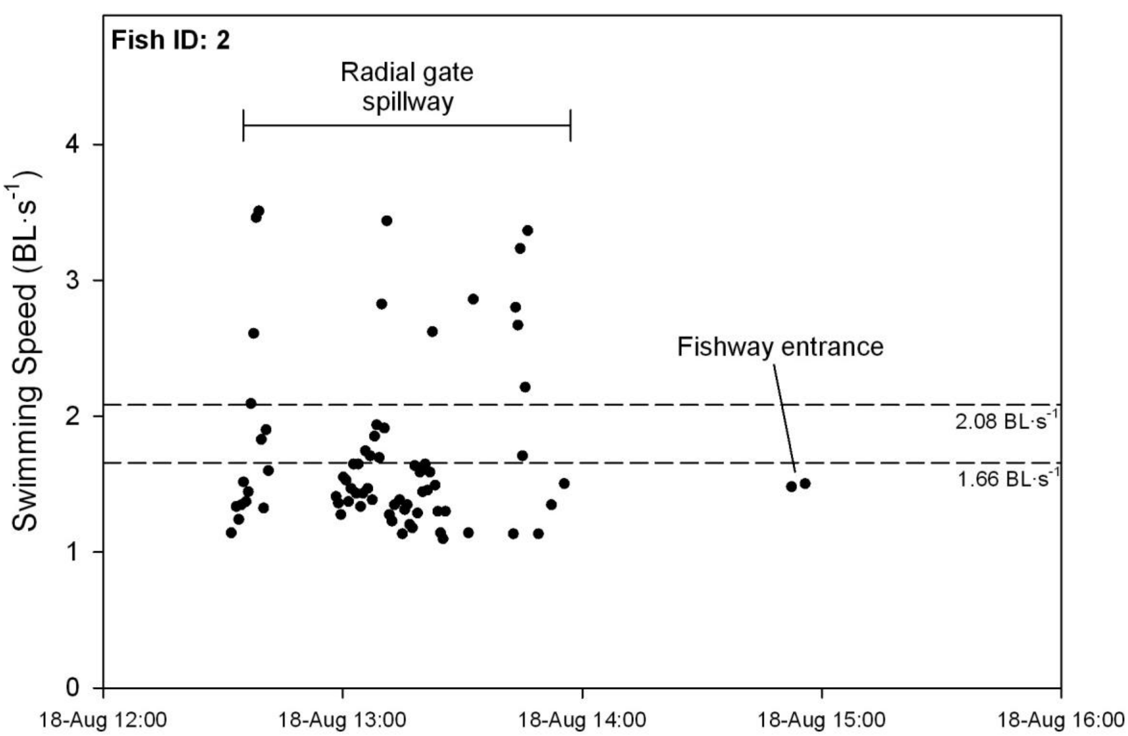
Fish ID	***Date and Time Released***	***Stock ID***	***Treatment***	***Radio ID***	***Acoustic ID***	***Tailrace Experience***	***Fate***
1	17-08-2012 12:04:00	Gates	Tagging Group B	121	9	High Discharge	Recapture in Fishway
2	18-08-2012 11:01:00	Gates	Tagging Group B	109	9	High Discharge	Entered Seton Lake
3	18-08-2012 11:01:00	Chilko	Tagging Group A	2	-	-	Fall-back
4	19-08-2012 09:00:00	Stellako	Tagging Group B	152	26	-	Fall-back
5	19-08-2012 09:00:00	Stellako	Tagging Group B	121	23	-	Exited System
6	19-08-2012 09:00:00	Stellako	Tagging Group A	18	-	-	Fall-back
7	20-08-2012 09:49:00	Gates	Tagging Group B	178	22	Low Discharge	Fall-back
8	20-08-2012 09:49:00	Gates	Tagging Group B	138	25	High Discharge	Recapture in Fishway
9	20-08-2012 09:50:00	Gates	Tagging Group A	62	-	High Discharge	Fall-back
10	21-08-2012 10:21:00	Gates	Tagging Group A	203	-	Radial Gate Opening	Fall-back
11	21-08-2012 10:21:00	Gates	Tagging Group A	193	-	Radial Gate Opening	Fall-back
12	21-08-2012 10:21:00	Gates	Tagging Group A	34	-	Radial Gate Opening	Fall-back
13	21-08-2012 10:19:21	Gates	Tagging Group C	-	21	Radial Gate Opening	Fall-back
14	21-08-2012 10:19:21	Chilko	Tagging Group C	-	24	-	Fall-back
15	21-08-2012 10:19:21	Gates	Tagging Group C	-	211	Radial Gate Opening	Fall-back
16	22-08-2012 11:06:45	Gates	Tagging Group A	92	-	Low Discharge	Fall-back
17	22-08-2012 11:06:45	Gates	Tagging Group A	80	-	Low Discharge	Entered Seton Lake
18	22-08-2012 11:06:45	Gates	Tagging Group A	46	-	Low Discharge	Recapture in Fishway
19	22-08-2012 11:10:00	Chilko	Tagging Group C	-	210	-	Exited System
20	22-08-2012 11:10:00	Chilko	Tagging Group C	-	212	-	Exited System
21	22-08-2012 11:10:00	Gates	Tagging Group C	-	213	Low Discharge	Entered Seton Lake
22	23-08-2012 09:12:00	Gates	Tagging Group B	159	218	Low Discharge	Entered Seton Lake
23	23-08-2012 09:12:00	Stellako	Tagging Group B	1	217	-	Exited System
24	23-08-2012 09:12:00	Gates	Tagging Group B	116	215	Low Discharge	Entered Seton Lake
25	23-08-2012 09:09:00	Gates	Tagging Group C	-	219	Low Discharge	Entered Seton Lake
26	23-08-2012 09:09:00	Gates	Tagging Group C	-	214	Low Discharge	Entered Seton Lake
27	23-08-2012 09:09:00	Chilko	Tagging Group C	-	216	-	Entered Seton Lake
28	24-08-2012 10:28:00	Chilko	Tagging Group A	89	-	-	Fall-back
29	24-08-2012 10:28:00	Chilko	Tagging Group A	177	-	-	Exited System
30	24-08-2012 10:28:00	Stellako	Tagging Group A	133	-	-	Exited System
31	24-08-2012 10:34:08	Gates	Tagging Group C	-	220	Low Discharge	Entered Seton Lake

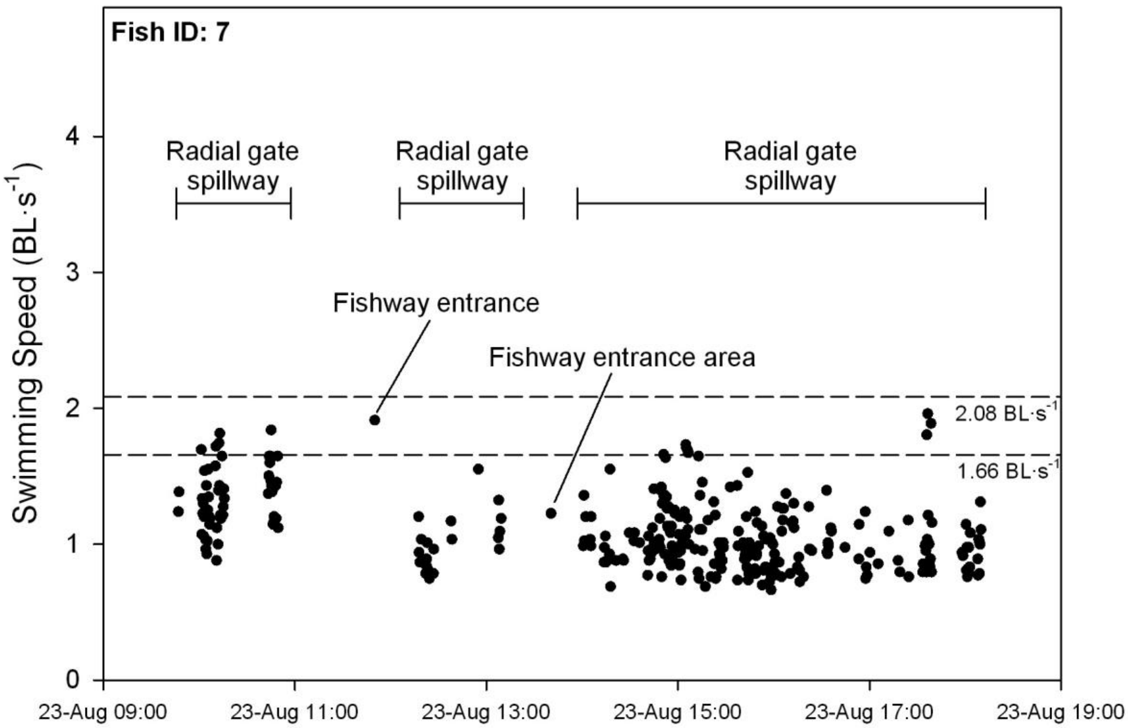
Fish ID	Date and Time Released	Stock ID	Treatment	Radio ID	Acoustic ID	Tailrace Experience	Fate
32	24-08-2012 10:34:08	Gates	Tagging Group C	-	221	Low Discharge	Entered Seton Lake
33	24-08-2012 10:34:08	Gates	Tagging Group C	-	224	Low Discharge	Entered Seton Lake
34	25-08-2012 11:12:10	Gates	Tagging Group A	52	-	Low Discharge	Entered Seton Lake
35	25-08-2012 11:12:10	Gates	Tagging Group A	22	-	Low Discharge	Entered Seton Lake
36	25-08-2012 11:12:10	Gates	Tagging Group A	64	-	Low Discharge	Fall-back
37	27-08-2012 12:32:55	Stellako	Tagging Group A	181	-	-	Fall-back
38	27-08-2012 12:32:55	Chilko	Tagging Group B	111	25	-	Fall-back
39	27-08-2012 12:32:55	Stellako	Tagging Group B	210	222	-	Fall-back
40	27-08-2012 12:32:55	Gates	Tagging Group B	6	223	Low Discharge	Recapture in Fishway
41	28-08-2012 10:17:00	Gates	Tagging Group B	6	223	Low Discharge	Fall-back

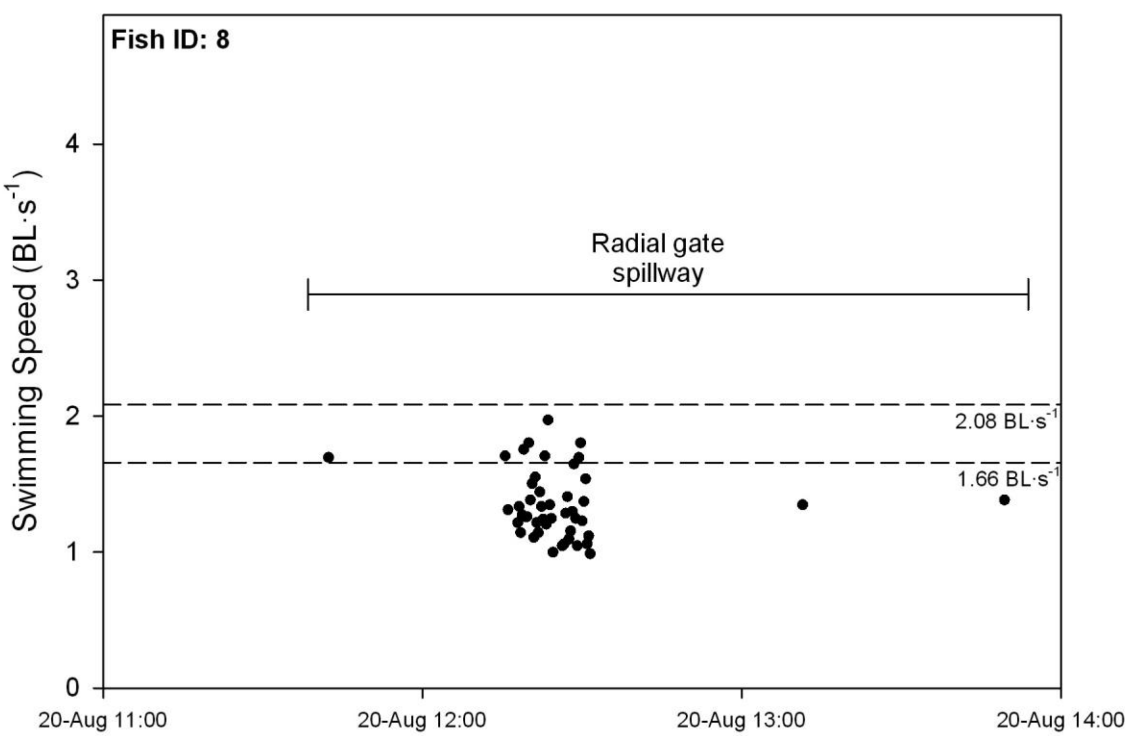
Appendix IX

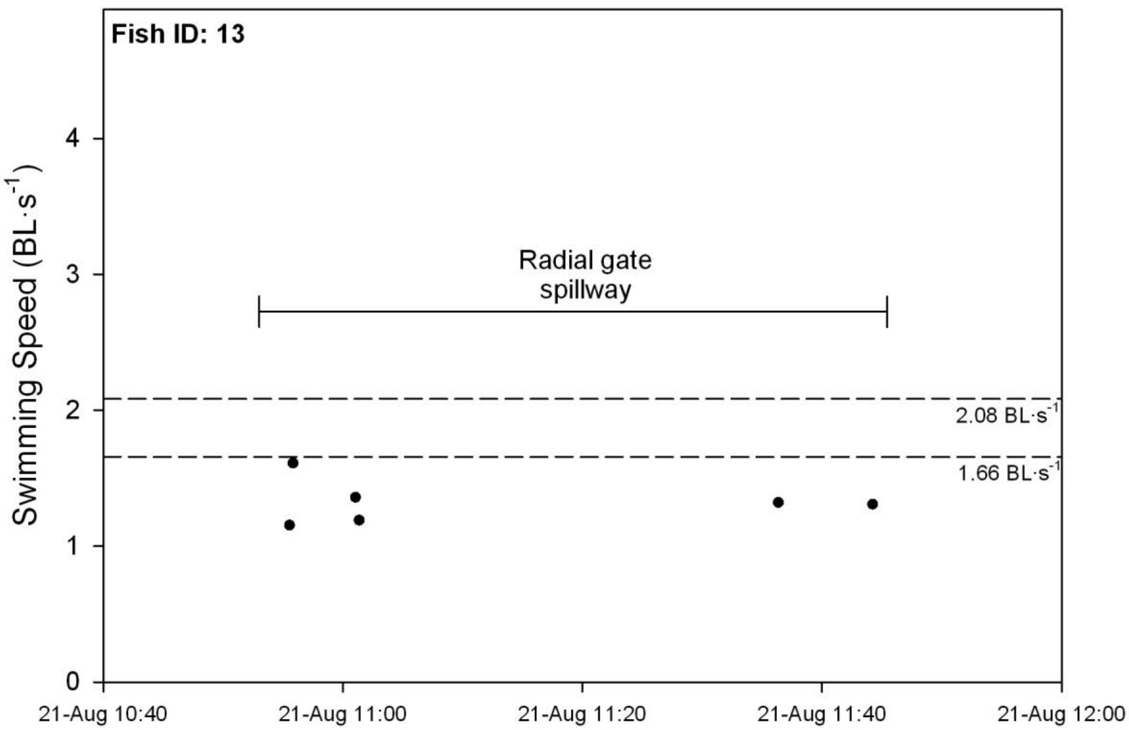
Tailrace movement and activity profiles

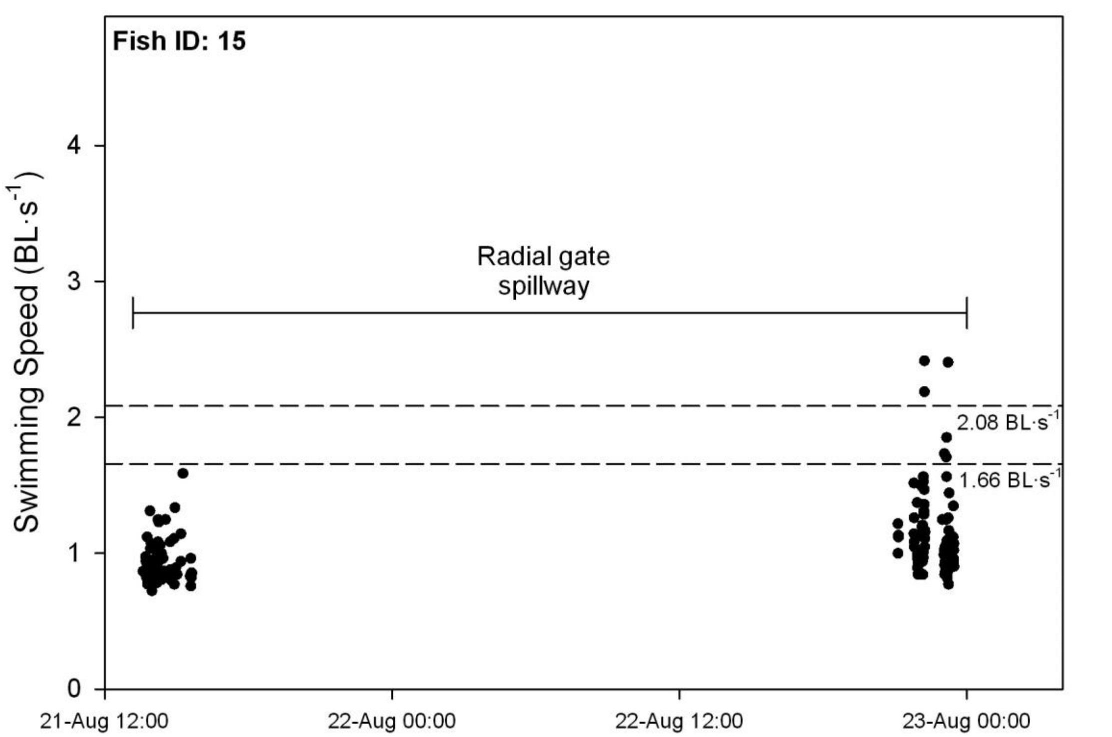

Fish ID: 1
Radial gate spillway
Swimming Speed (BL·s-1)
2.08 BL·s-1
1.66 BL·s-1
0
1
2
3
4
17-Aug 16:00
17-Aug 16:10
17-Aug 16:20
17-Aug 16:30
17-Aug 16:40

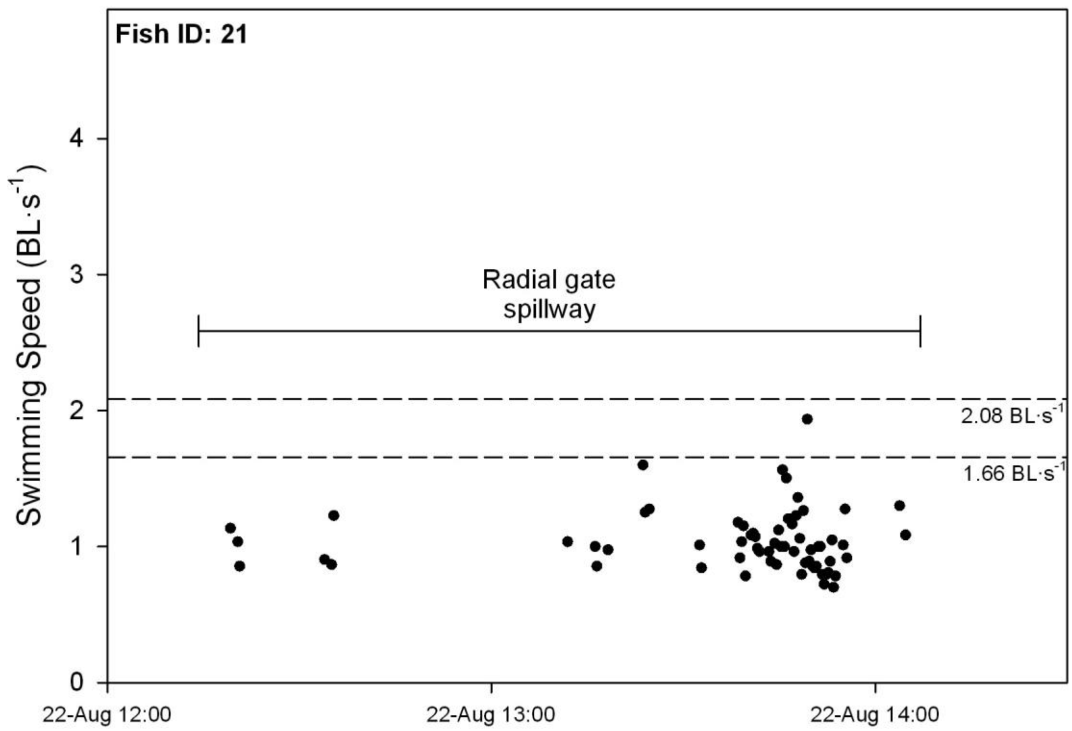

Fish ID: 2
Radial gate spillway
Fishway entrance
Swimming Speed (BL·s-1)
2.08 BL·s-1
1.66 BL·s-1
0
1
2
3
4
18-Aug 12:00
18-Aug 13:00
18-Aug 14:00
18-Aug 15:00
18-Aug 16:00

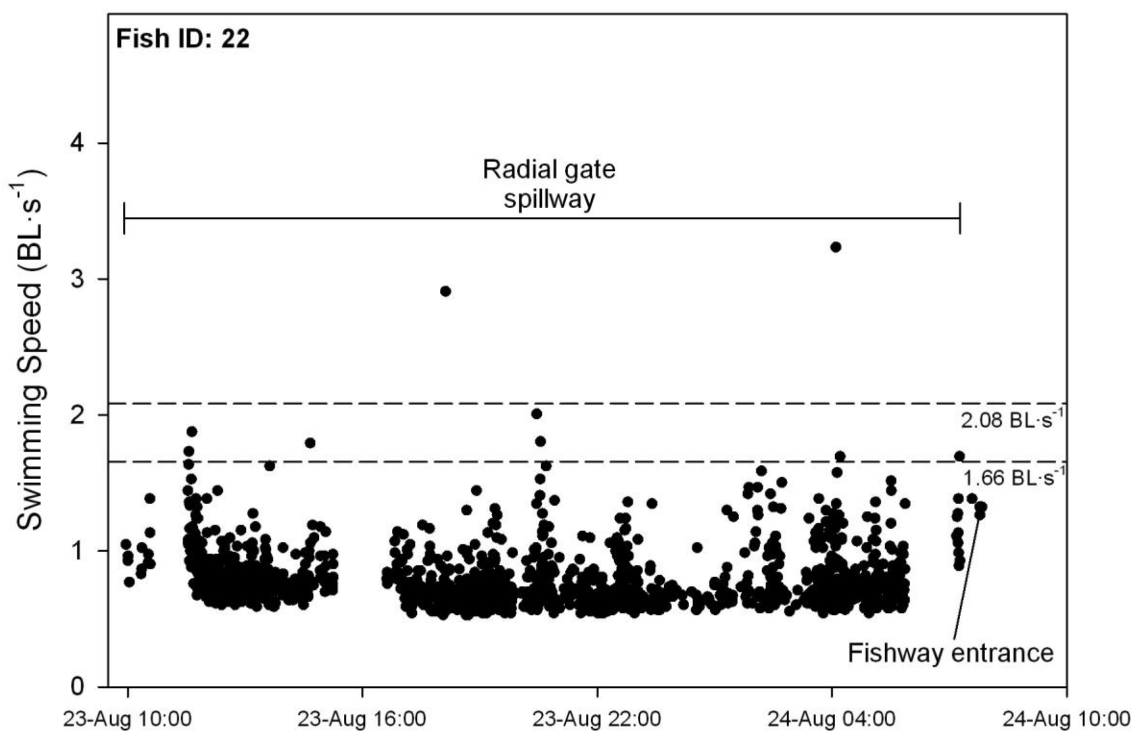

Fish ID: 7
Radial gate spillway
Radial gate spillway
Radial gate spillway
Fishway entrance
Fishway entrance area
2.08 BL·s-1
1.66 BL·s-1
Swimming Speed (BL·s-1)
0
1
2
3
4
23-Aug 09:00
23-Aug 11:00
23-Aug 13:00
23-Aug 15:00
23-Aug 17:00
23-Aug 19:00

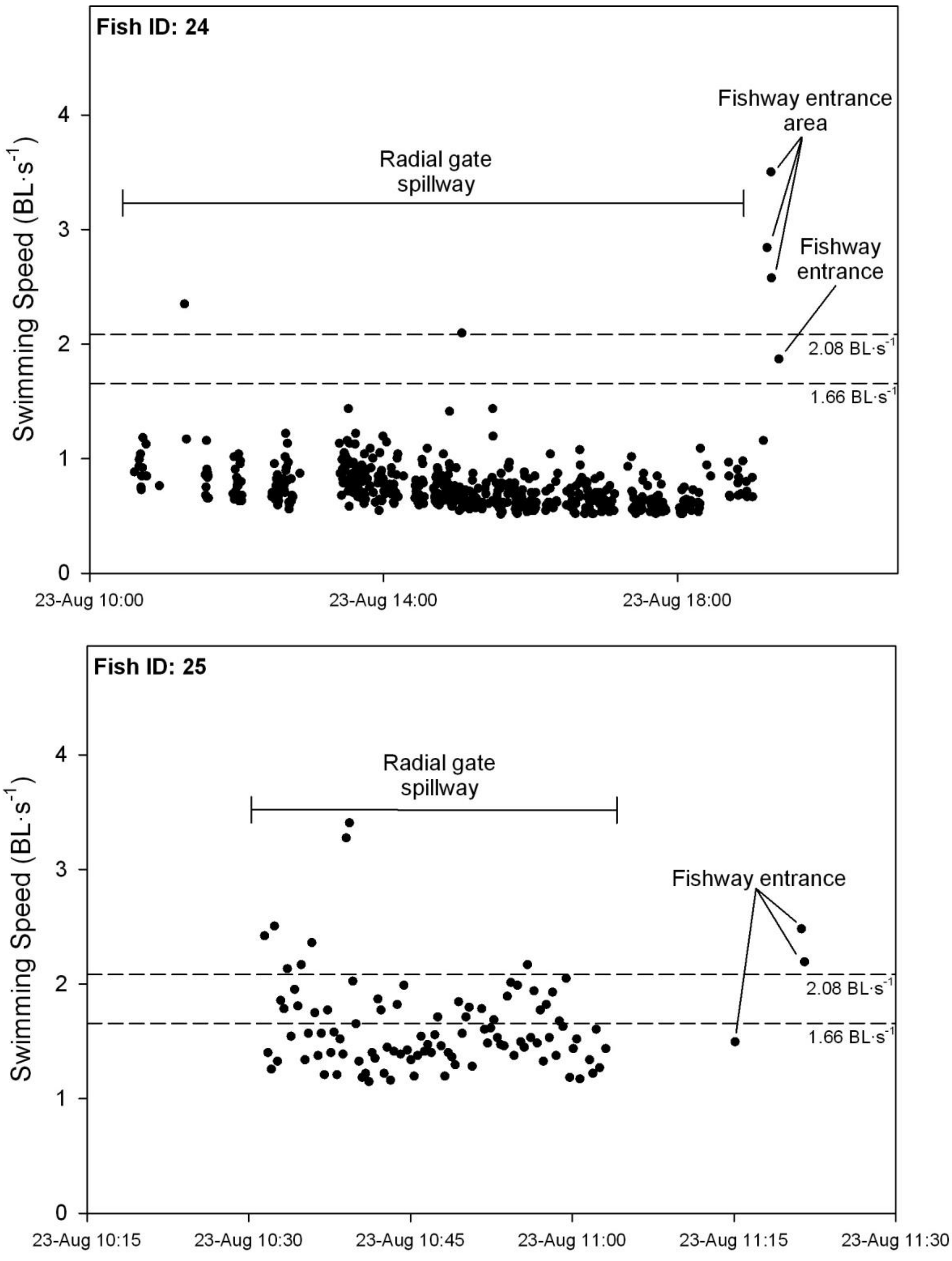

Fish ID: 8
Radial gate spillway
2.08 BL·s-1
1.66 BL·s-1
Swimming Speed (BL·s-1)
0
1
2
3
4
20-Aug 11:00
20-Aug 12:00
20-Aug 13:00
20-Aug 14:00


Fish ID: 13
Radial gate spillway
2.08 BL·s-1
1.66 BL·s-1
Swimming Speed (BL·s-1)
0
1
2
3
4
21-Aug 10:40
21-Aug 11:00
21-Aug 11:20
21-Aug 11:40
21-Aug 12:00

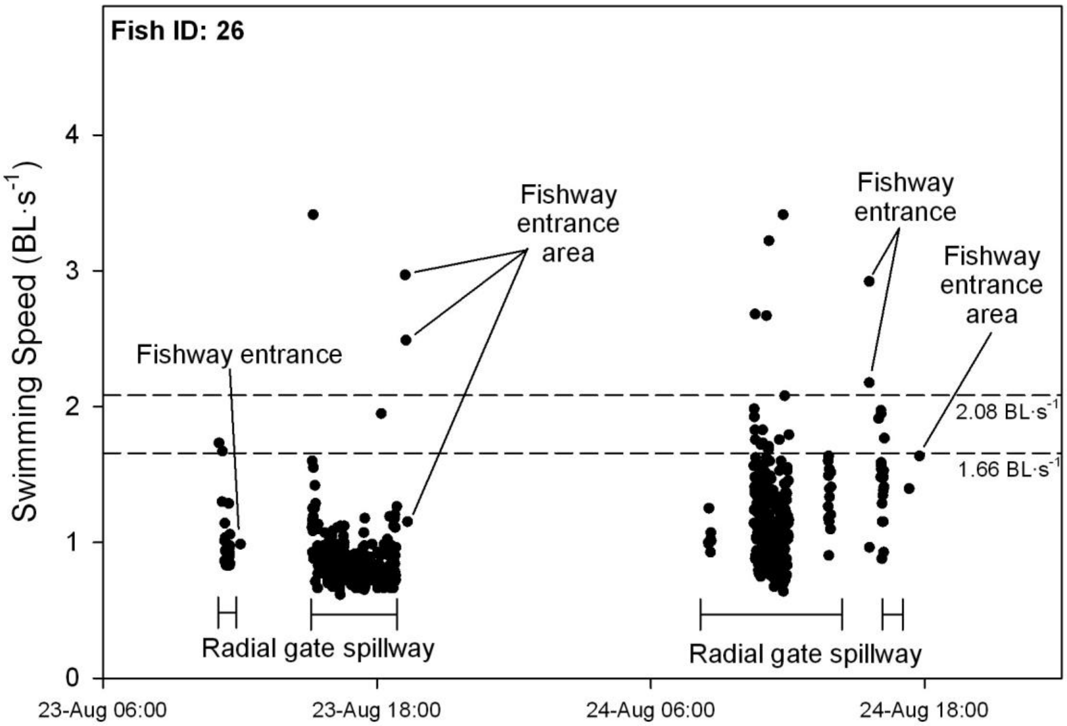

Fish ID: 15
Radial gate spillway
2.08 BL·s-1
1.66 BL·s-1
Swimming Speed (BL·s-1)
0
1
2
3
4
21-Aug 12:00
22-Aug 00:00
22-Aug 12:00
23-Aug 00:00


Fish ID: 21
Radial gate spillway
2.08 BL·s-1
1.66 BL·s-1
Swimming Speed (BL·s-1)
0
1
2
3
4
22-Aug 12:00
22-Aug 13:00
22-Aug 14:00

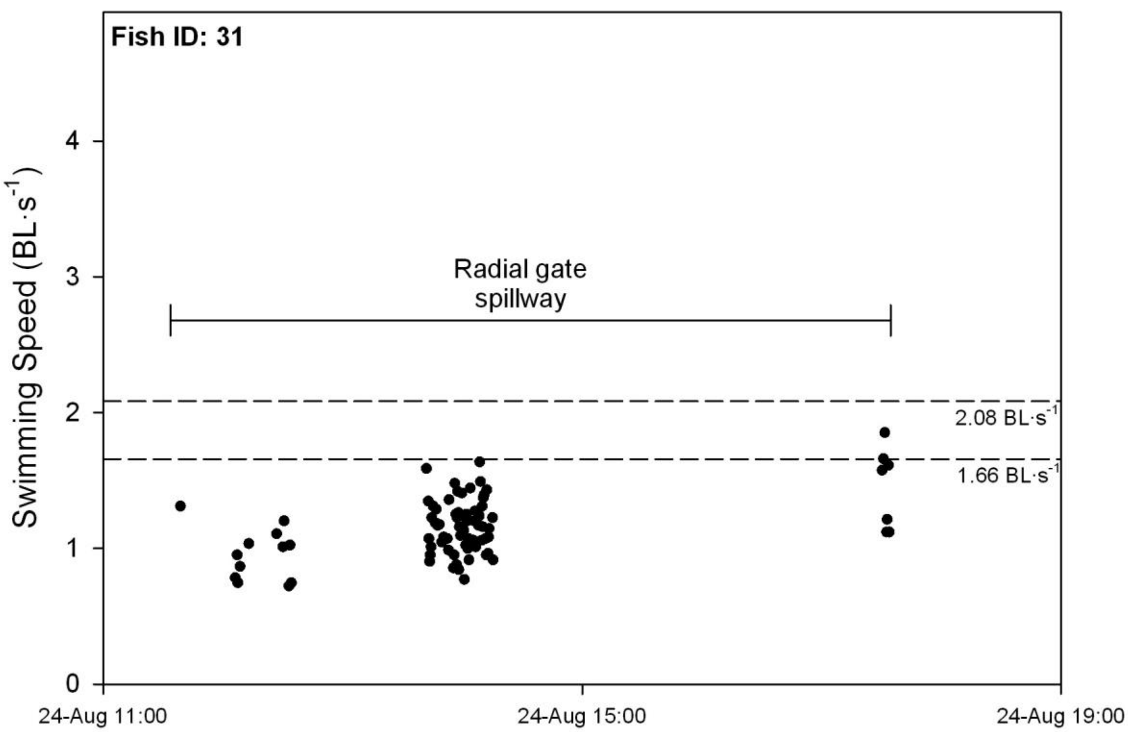

Fish ID: 22
Radial gate spillway
2.08 BL·s-1
1.66 BL·s-1
Fishway entrance
Swimming Speed (BL·s-1)
0
1
2
3
4
23-Aug 10:00
23-Aug 16:00
23-Aug 22:00
24-Aug 04:00
24-Aug 10:00



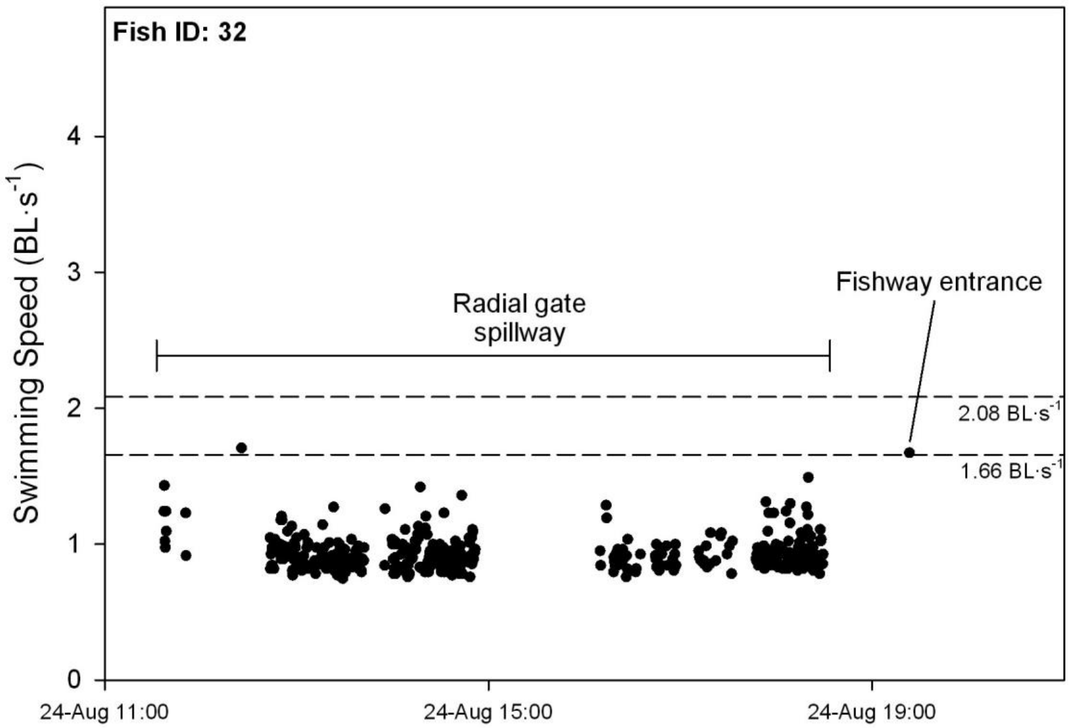
Fish ID: 24
Swimming Speed (BL·s-1)
Radial gate spillway
Fishway entrance area
Fishway entrance
2.08 BL·s-1
1.66 BL·s-1
23-Aug 10:00
23-Aug 14:00
23-Aug 18:00
Fish ID: 25
Swimming Speed (BL·s-1)
Radial gate spillway
Fishway entrance
2.08 BL·s-1
1.66 BL·s-1
23-Aug 10:15
23-Aug 10:30
23-Aug 10:45
23-Aug 11:00
23-Aug 11:15
23-Aug 11:30



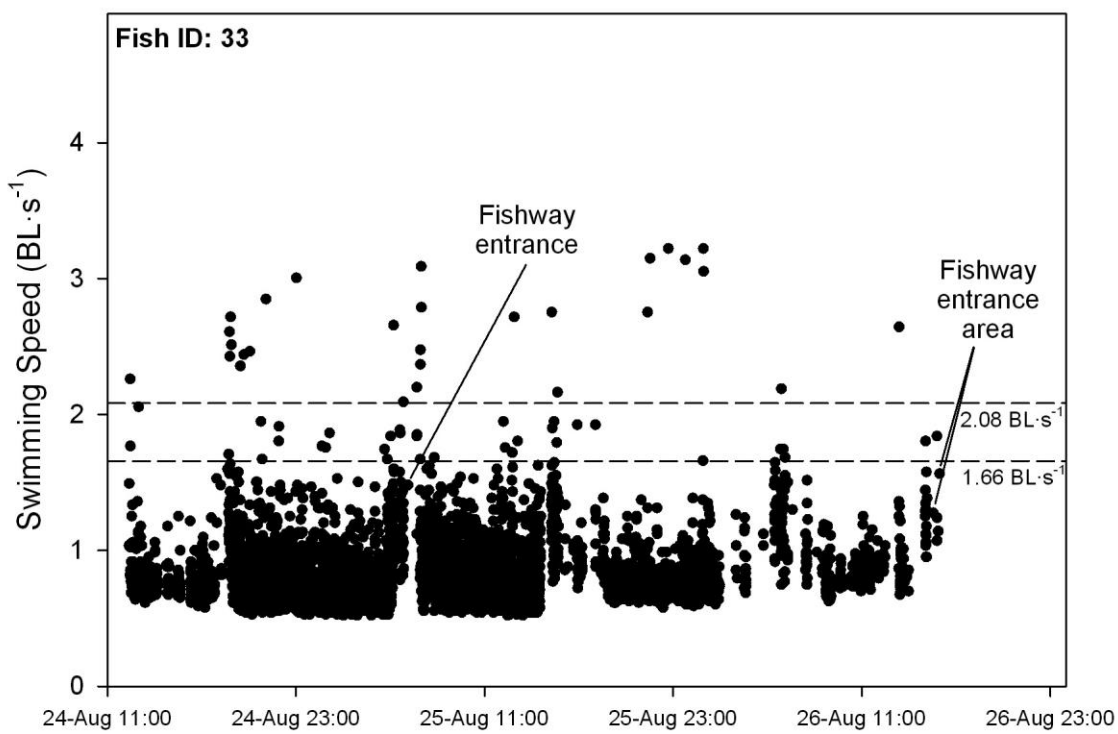
Fish ID: 26
Swimming Speed (BL·s⁻¹)
Fishway entrance
Fishway entrance area
Fishway entrance
Fishway entrance area
2.08 BL·s⁻¹
1.66 BL·s⁻¹
Radial gate spillway
Radial gate spillway
23-Aug 06:00
23-Aug 18:00
24-Aug 06:00
24-Aug 18:00



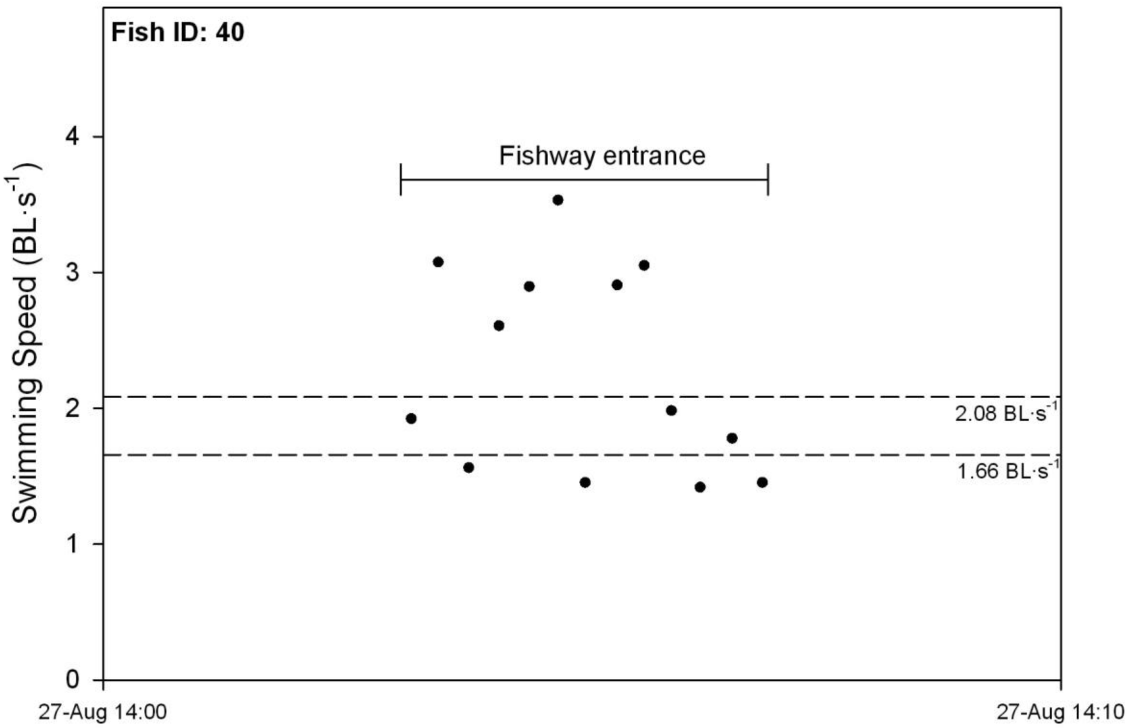
Fish ID: 31
Swimming Speed (BL·s⁻¹)
Radial gate spillway
2.08 BL·s⁻¹
1.66 BL·s⁻¹
24-Aug 11:00
24-Aug 15:00
24-Aug 19:00

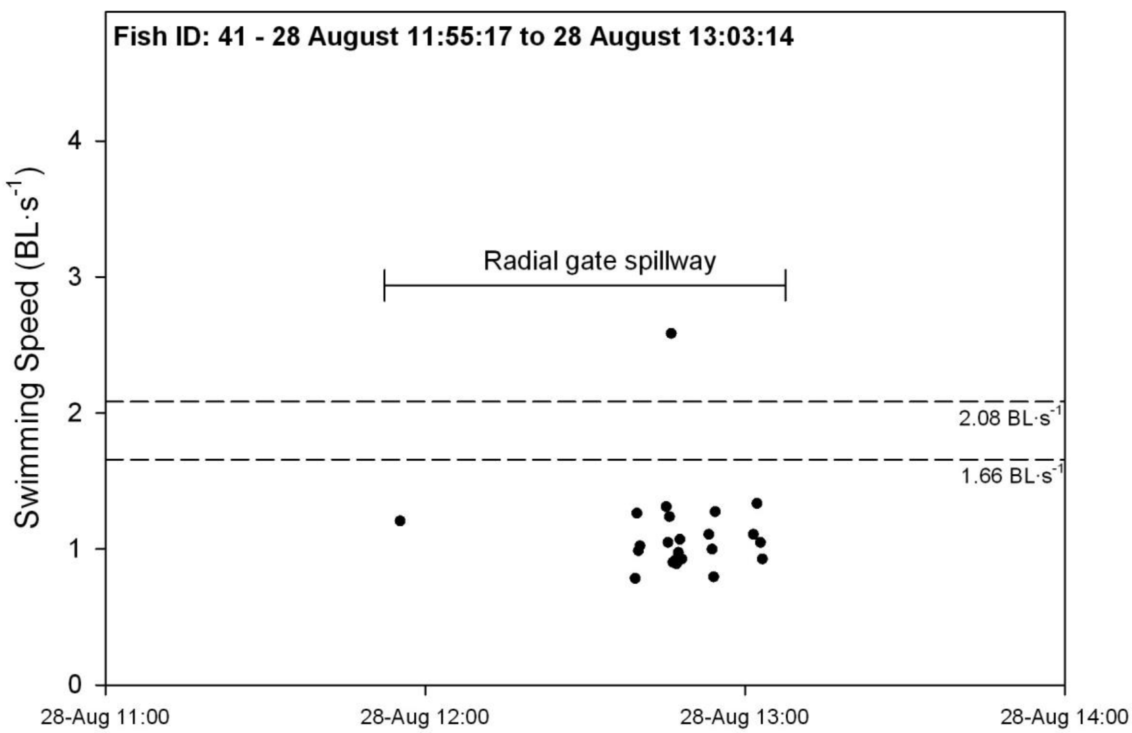


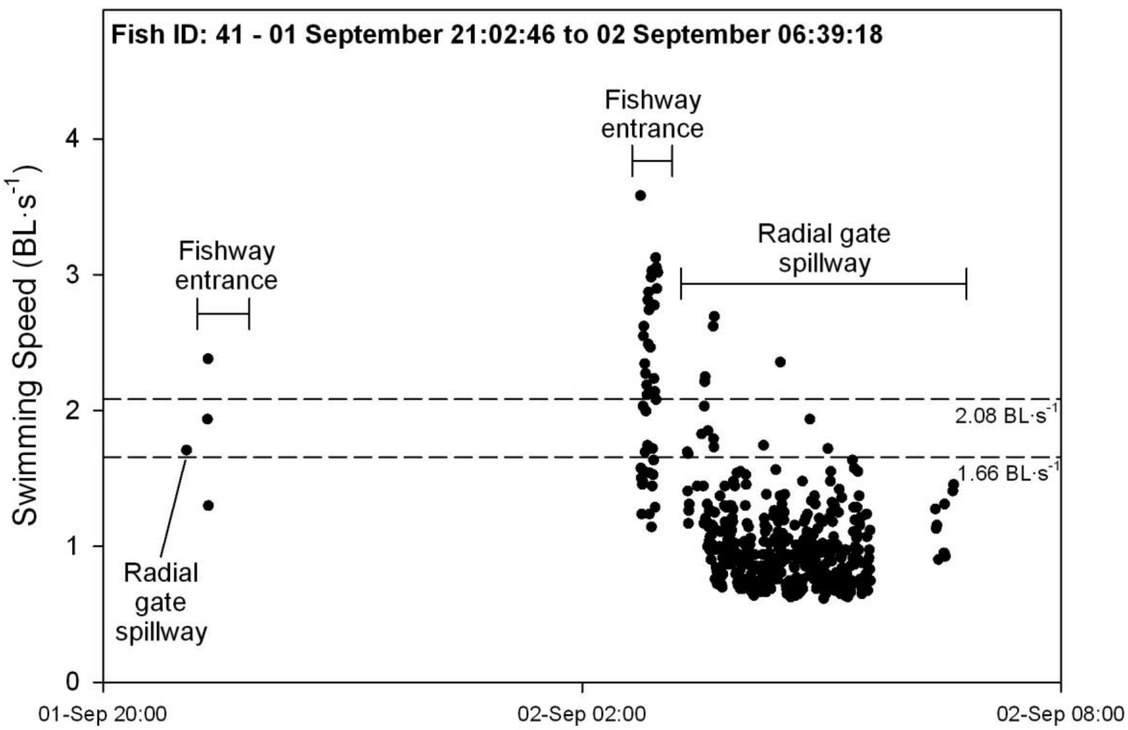
Fish ID: 32
Swimming Speed (BL·s-1)
Radial gate spillway
Fishway entrance
2.08 BL·s-1
1.66 BL·s-1
24-Aug 11:00
24-Aug 15:00
24-Aug 19:00



Fish ID: 33
Swimming Speed (BL·s-1)
Fishway entrance
Fishway entrance area
2.08 BL·s-1
1.66 BL·s-1
24-Aug 11:00
24-Aug 23:00
25-Aug 11:00
25-Aug 23:00
26-Aug 11:00
26-Aug 23:00


Fish ID: 40
Fishway entrance
Swimming Speed (BL·s-1)
2.08 BL·s-1
1.66 BL·s-1
4
3
2
1
0
27-Aug 14:00
27-Aug 14:10


Fish ID: 41 - 28 August 11:55:17 to 28 August 13:03:14
Radial gate spillway
Swimming Speed (BL·s-1)
2.08 BL·s-1
1.66 BL·s-1
4
3
2
1
0
28-Aug 11:00
28-Aug 12:00
28-Aug 13:00
28-Aug 14:00



Fish ID: 41 - 01 September 21:02:46 to 02 September 06:39:18
Swimming Speed (BL·s-1)
Fishway entrance
Fishway entrance
Radial gate spillway
Radial gate spillway
2.08 BL·s-1
1.66 BL·s-1
0
1
2
3
4
01-Sep 20:00
02-Sep 02:00
02-Sep 08:00