

# Gates Creek Juvenile and Adult Salmonid Assessment – 2015 (16.SON.01)

D'arcy, British Columbia



FWCP Project No. 16.SON.01  
Prepared for:  
The Fish and Wildlife Compensation Program  
Lillooet Tribal Council  
Fisheries and Oceans Canada



Prepared by:  
**InStream Fisheries Research Inc.**  
1121A Enterprise Way  
Squamish, B.C. V8B 0E8Canada  
T: +1 (604) 892-4615

**IN**STREAM

File no. GATESCHAN.0009

*Report prepared with financial support of the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, First Nation and Public Stake Holders and Fisheries and Oceans Canada.*

March 2016

### **Note on this Report:**

This report consists of three chapters. The first chapter details the results of 2015 juvenile salmonid outmigration component of the study. The second chapter details the results of the 2015 adult Sockeye returns to Gates Creek. The third chapter summarized the 2015 Level 1 Fish Habitat Survey of Gates Creek.

### **Acknowledgements**

This project was conducted with financial support from St'át'imc Government Services, the Pacific Salmon Foundation and the Fish and Wildlife Compensation Program, on behalf of its program partners BC Hydro, the Province of British Columbia, First Nations, public stake holders, and the Department of Fisheries and Oceans Canada.

We would like to thank the following people for their cooperation and assistance on this project:

Harry O'Donaghey, N'Quatqua Fisheries  
Lance O'Donaghey, N'Quatqua Fisheries  
Chris Fletcher, N'Quatqua Fisheries  
Harry O'Donaghey, Jr., N'Quatqua Fisheries  
Spencer Thevarge, N'Quatqua Fisheries  
LJ Wilson - InStream Fisheries Research, Inc.  
Peter Campbell - Department of Fisheries and Oceans Canada  
Doug Lofthouse - Department of Fisheries and Oceans Canada  
Dave Willis - Department of Fisheries and Oceans Canada  
Matthew Foy - Department of Fisheries and Oceans Canada  
Andrew Grant - Department of Fisheries and Oceans Canada  
Brian Leaf - Department of Fisheries and Oceans Canada  
Paul Welch - Department of Fisheries and Oceans Canada

**Stephanie Lingard, R.P.Bio – Project Lead**  
**Project Biologist, InStream**

**Nich Burnett, MSc**  
**Project Biologist, InStream**

**Caroline Melville**  
**Managing Director, InStream**

**Suggested Citation:**

**Lingard, S.L., N.J. Burnett, C.C Melville. 2015.** Gates Creek Juvenile and Adult Salmonid Assessment - 2015. Report prepared for the Fish and Wildlife Compensation Program, The Lillooet Tribal Council and Fisheries and Oceans Canada. 102 p.

## Contents

<b>Section 1: Gates Creek Juvenile Salmonid Outmigration Assessment - Spring 2015 .....</b>	<b>6</b>
INTRODUCTION .....	2
0.0 Study Objectives .....	3
0.1 Study Area and Trapping Locations .....	3
METHODS .....	4
1.0 Fish Trap Operations .....	4
1.0.0 Gates Creek Traps - Inclined Plane and Rotary Screw Traps .....	4
1.0.1 Channel Trap .....	4
1.1 Sockeye Fry Marking and Recapture .....	5
1.2 Coho Juvenile Marking and Recapturing .....	6
1.3 Length and Weight .....	6
1.3.0 Sockeye Fry .....	6
1.3.1 Coho Smolt Data Collection .....	7
1.4 Environmental Monitoring .....	7
1.4.0 Temperature Monitoring .....	7
1.4.1 Water Level Data .....	7
1.5 Population Estimate Methods .....	8
1.5.0 Total Sockeye Fry Abundance .....	8
1.5.1 Gates Creek Spawning Channel Sockeye Fry Abundance .....	9
1.5.2 Gates Creek Sockeye Fry Abundance .....	9
1.5.3 Egg-to-fry Survival and Fry per Effective Female .....	9
RESULTS .....	10
2.0 Fish Trap Operations .....	10
2.0.0 IPT / RST .....	10
2.0.1 Channel Trap .....	10
2.1 Length and Weight Sampling .....	10
2.1.0 Sockeye Fry Length and Weight .....	10
2.1.1 Coho Smolt Length and Weight .....	11
2.2 Environmental Monitoring .....	11
2.2.0 Temperature .....	11
2.2.1 Water Level .....	12

2.3	Sockeye Population Estimates .....	12
2.3.0	Total Abundance of Sockeye Fry .....	12
2.3.1	Gates Creek Spawning Channel Sockeye Fry Abundance .....	13
2.3.2	Gates Creek Sockeye Fry Abundance .....	13
2.3.3	Egg-to-fry Survival and Fry per Effective Female .....	13
2.3.4	Coho Catch Data .....	14
DISCUSSION .....		14
3.0	Trap Operations .....	14
3.0.0	IPT and RST .....	14
3.0.1	Channel Trap .....	14
3.1	Fry Length and Weight Sampling .....	16
3.2	Water Temperature and ATU's .....	16
3.3	Sockeye Fry Migration .....	17
3.3.0	Sockeye Fry Abundance .....	17
3.3.1	Egg-to-Fry Survival and Fry per Effective Female .....	17
3.3.2	Sockeye Fry Run-Timing .....	18
3.4	Juvenile Coho Capture .....	19
SUMMARY and RECOMMENDATIONS .....		19
TABLES .....		22
FIGURES .....		32
REFERENCES .....		46
<b>Section 2.0- Adult Sockeye Assessment</b> .....		50
INTRODUCTION .....		56
1.0	METHODS .....	58
1.1	Loading Strategy .....	58
1.2	Temperature Monitoring .....	58
1.3	Generation of Abundance Estimates .....	59
1.3.1	Visual Survey Validation of Counter(s) .....	59
1.3.2	Video Validation of Counters .....	60
1.4	Classification of Female Percent Spawn .....	60
1.5	Fecundity Sampling .....	61
1.6	Percent Spawn and Total Egg Deposition .....	61
RESULTS .....		63
2.1	Temperature Monitoring .....	63
2.2	Video Validation .....	63

2.3	Abundance Estimates .....	63
2.3.1	Spawning Channel.....	63
2.3.2	Gates Creek .....	64
2.3.3	Spruce and Haylmore Creek .....	64
2.4	Fecundity and Female Size .....	64
2.5	Percent Spawn and Egg Deposition .....	65
2.5.1	Spawning Channel.....	65
2.5.2	Gates Creek .....	65
DISCUSSION.....		66
3.1	Temperature Monitoring .....	66
3.2	Counter Operations and Visual Survey/ Video Validation .....	66
3.3	Migration Timing and Sockeye Abundance .....	67
3.3.1	Migration Timing.....	67
3.3.2	Sockeye Abundance .....	67
3.4	Fecundity and Egg Deposition .....	68
3.5	Percent Spawn.....	68
Summary and Recommendations .....		69
TABLES.....		72
FIGURES .....		82
REFERENCES.....		91
<b>SECTION 3: Gates Creek Level 1 Fish Habitat Assessment .....</b>		<b>93</b>
Acknowledgements .....		97
INTRODUCTION.....		98
METHODS.....		100
2.1	Level 1 Fish Habitat Survey Procedures .....	100
2.2	Water Level Monitoring .....	101
2.3	GIS Mapping .....	102
RESULTS .....		103
3.1	Reach 1.....	103
3.2	Reach 2.....	104
3.3	Reach 3.....	104
3.4	Off Channel Habitat .....	105
DISCUSSION.....		107
4.1	Habitat Survey .....	107
4.2	Potential Restoration Opportunities .....	108

RECOMMENDATIONS ..... 110  
Note on Birken Landslide September 2015 ..... 110  
TABLES..... 111  
FIGURES ..... 116  
REFERENCES..... 125

**Section 1: Gates Creek Juvenile Salmonid Outmigration  
Assessment - Spring 2015**

## Executive Summary

This report presents the results of the juvenile salmonid outmigration study on Gates Creek in spring 2015. This was the fourth year of a proposed four year study of juvenile Sockeye salmon (*Oncorhynchus nerka*) abundance from Gates Creek and the Gates Creek spawning channel. The enumeration of Coho (*Oncorhynchus kisutch*) smolts (1+) is a secondary objective of this study, however due to high river levels during the migration of coho, it was not possible to meet this objective over the four study years.

Juvenile Sockeye fry were caught during their outmigration using two types of traps, a partial river inclined plane trap (IPT) on Gates Creek from March 27<sup>th</sup> until May 4<sup>th</sup>, and a full channel weir on the spawning channel from March 17<sup>th</sup> to May 21<sup>st</sup>, 2015. Sockeye fry abundance and migration timing were estimated from mark-recapture data collected during trap operations using Bayesian P-Spline models.

An estimated 9 432 039 (standard deviation [SD] 620 920) Sockeye fry migrated out of Gates Creek and the spawning channel in the spring of 2015. Of this total, 75% (7 004 343) out-migrated from Gates Creek and 25% (2 398 150) out-migrated from the spawning channel. An additional 94 997 fry were estimated to have left the spawning channel outside of the mark-recapture program. With these additional fry from the channel, a total estimated 9 527 035 fry migrated out of the system from March 17<sup>th</sup> to May 21<sup>st</sup>. This estimate may be an underestimate of the true Sockeye abundance, as it appeared that the run had already started when trapping began on March 27<sup>th</sup>. Egg-to-fry survival for the spawning channel was 23%, with an estimated 806 fry produced per effective female in 2015. Estimated egg-to-fry survival for Gates Creek was 40%, with an estimated 1,335 fry produced per effective female.

Abundance of Sockeye fry was 39% lower in 2015 than in 2014, a decrease that was driven mainly by a reduction in the number of females that effectively spawned in the 2014 brood year. Despite lower overall abundance of fry, egg-to-fry survival was the highest in 2015 out of the four study years.

# Table of Contents

Section 1: Gates Creek Juvenile Salmonid Outmigration Assessment - Spring 2015.....	6
INTRODUCTION.....	2
0.0 Study Objectives .....	3
0.1 Study Area and Trapping Locations .....	3
METHODS.....	4
1.0 Fish Trap Operations .....	4
1.0.0 Gates Creek Traps - Inclined Plane and Rotary Screw Traps .....	4
1.0.1 Channel Trap.....	4
1.1 Sockeye Fry Marking and Recapture .....	5
1.2 Coho Juvenile Marking and Recapturing .....	6
1.3 Length and Weight.....	6
1.3.0 Sockeye Fry.....	6
1.3.1 Coho Smolt Data Collection .....	7
1.4 Environmental Monitoring .....	7
1.4.0 Temperature Monitoring .....	7
1.4.1 Water Level Data.....	7
1.5 Population Estimate Methods.....	8
1.5.0 Total Sockeye Fry Abundance .....	8
1.5.1 Gates Creek Spawning Channel Sockeye Fry Abundance .....	9
1.5.2 Gates Creek Sockeye Fry Abundance .....	9
1.5.3 Egg-to-fry Survival and Fry per Effective Female .....	9
RESULTS .....	10
2.0 Fish Trap Operations .....	10
2.0.0 IPT / RST .....	10
2.0.1 Channel Trap.....	10
2.1 Length and Weight Sampling .....	10
2.1.0 Sockeye Fry Length and Weight .....	10
2.1.1 Coho Smolt Length and Weight.....	11
2.2 Environmental Monitoring .....	11

2.2.0	Temperature .....	11
2.2.1	Water Level.....	12
2.3	Sockeye Population Estimates .....	12
2.3.0	Total Abundance of Sockeye Fry .....	12
2.3.1	Gates Creek Spawning Channel Sockeye Fry Abundance .....	13
2.3.2	Gates Creek Sockeye Fry Abundance .....	13
2.3.3	Egg-to-fry Survival and Fry per Effective Female .....	13
2.3.4	Coho Catch Data.....	14
DISCUSSION.....		14
3.0	Trap Operations .....	14
3.0.0	IPT and RST .....	14
3.0.1	Channel Trap.....	14
3.1	Fry Length and Weight Sampling .....	16
3.2	Water Temperature and ATU's .....	16
3.3	Sockeye Fry Migration.....	17
3.3.0	Sockeye Fry Abundance .....	17
3.3.1	Egg-to-Fry Survival and Fry per Effective Female.....	17
3.3.2	Sockeye Fry Run-Timing.....	18
3.4	Juvenile Coho Capture.....	19
SUMMARY and RECOMMENDATIONS.....		19
TABLES .....		22
FIGURES .....		32
REFERENCES .....		46

**LIST OF TABLES**

Table 1. Start and end dates for all traps operated on Gates Creek, in spring 2015. .... 23

Table 2. Summary of Gates Creek Sockeye fry fork lengths measured at both the spawning channel and IPT sites in, 2011-2015. .... 24

Table 3. Summary of Gates Creek Sockeye fry weights (g) measured at both the spawning channel and IPT sites in, 2011-2015. .... 25

Table 4. Summary of daily water temperatures °C (mean, standard deviation (SD) and range) in both Gates Creek and the spawning channel August 20<sup>th</sup>, 2014 to May 20<sup>th</sup>, 2015..... 26

Table 5. Weekly totals of Sockeye fry marked at the spawning channel, recaptured and unmarked fish enumerated at the IPT in spring 2015. Trap efficiency is the proportion of marked fish that were recaptured. .... 27

Table 6. Modeled weekly estimates of total unmarked Sockeye fry passing the Gates Creek IPT site. Also displayed are the 2.5 and 97.5% credibility intervals, average weekly temperature (°C) and water level (m), standard deviation (SD), and relative standard deviation. Note: mean abundance does not match totals for system in table 7 as these strata totals do not include marks. .... 28

Table 7. Weekly abundance of Sockeye fry leaving Gates Creek and spawning channel and total abundance of fry past the IPT site on Gates Creek in spring 2015. .... 28

Table 8. Female Sockeye escapement, fecundity, survival figures for Gates Creek system for the 2011- 2014 broods (channel total of fry produced includes fry from before and after mark-recapture program). .... 29

## LIST OF FIGURES

Figure 1. Overview of the study area including the Gates Creek spawning channel and trap site. Sites of spawning channel (10 U 536706 5599716) and IPT/RST (10 U 537151 5599978) are indicated. ....	33
Figure 2. Overview of the Seton-Anderson watershed in Southwestern British Columbia. Map also shows Gates Creek flowing from Gates Lake in Birken to Anderson Lake in D'Arcy. ....	34
Figure 3. Weir at the Gates Creek spawning channel. Fish are funnelled through the black sampler structure in the middle of the trough to the wood box visible on the left. ....	35
Figure 4. Inclined plane trap (left) and rotary screw trap (right) in Gates Creek. ....	36
Figure 5. Frequency distribution of juvenile Sockeye fork lengths (mm) leaving Gates Creek spawning channel (top panel) and Gates Creek (bottom panel) in spring 2015. Red dotted line indicates sample mean. ....	37
Figure 6. Frequency distribution of juvenile Sockeye weight (g) leaving Gates Creek spawning channel (top panel) and Gates Creek (bottom panel) in spring 2015. Red dotted line indicates sample mean. ....	38
Figure 7. Frequency distribution of Coho smolt (1+) fork lengths (mm) leaving Gates Creek in spring 2015. Red dotted line indicates sample mean. ....	39
Figure 8. Frequency distribution of Coho smolt (1+) weights (g) leaving Gates Creek in spring 2015. Red dotted line indicates sample mean. ....	40
Figure 9. Average daily temperatures from fall 2014 to spring 2015 in the Gates Creek spawning channel (red) and in Gates Creek (black). ....	41
Figure 10. Accumulated thermal units (ATU) from peak of spawn (week starting September 11 <sup>th</sup> 2014) to peak of migration (week starting April 13 <sup>th</sup> 2015) for Sockeye incubating and rearing in Gates Creek. ATU's are estimated from surface water temperatures collected by TidbiT v2 water temperature data loggers. ....	42
Figure 11. Average weekly water level (m) in Gates Creek (IPT site) in spring 2015. ....	43
Figure 12. Run timing of Sockeye fry leaving the Gates Creek watershed in spring 2015. Total abundance estimates include fry from both Gates Creek and the Gates Creek spawning channel. ....	44
Figure 13. Run timing of Sockeye fry leaving Gates Creek (top) and Gates Creek spawning channel (bottom) 2015 in spring 2015. ....	45

## INTRODUCTION

Gates Creek is a major salmon-bearing tributary of the Seton-Anderson watershed, and runs 17 km from Gates Lake to Anderson Lake draining approximately 34 300 hectares (Komori 1997) (Figure 1 & 2). The Seton-Anderson watershed is located approximately 200 km north of Vancouver in the rain shadow of the southern Coast Mountains (Anon. 2000). No glaciers are present in the watershed, however Gates and Anderson Lakes provide storage within the Seton-Anderson watershed. Anderson Lake is connected to Seton Lake via Portage Creek, and Seton Lake drains into the Fraser River via Seton River (Figure 2). Gates Creek supports a population of Fraser River Sockeye salmon (*Onchorynchus nerka*) that is important for First Nation, commercial and recreational fisheries, as well as smaller populations of Coho (*O. kisutch*) and Pink salmon (*O. gorbuscha*).

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

In 1968, a spawning channel was constructed by the International Pacific Salmon Fisheries Commission (IPSFC) on Gates Creek 800 m upstream of Anderson Lake to enhance Sockeye escapement in the Seton-Anderson watershed. The IPSFC and the Department of Fisheries and Oceans Canada (DFO) originally oversaw this spawning channel. In 1987, responsibility for channel maintenance and monitoring was turned over to the N'Quatqua First Nation, with technical oversight from DFO. A gravel replacement project was undertaken in 2008 and 2009 by DFO and the BC Hydro Fish and Wildlife Compensation Program (FWCP), with the goal of increasing egg-to-fry survival in the Gates Creek spawning channel (Anon. 2009). In addition to gravel replacement, changes were made to channel structure and gradient during this project (Anon. 2009). While a long-standing time series of juvenile and adult abundances are available for the spawning channel, detailed assessment of the gravel replacement activities had yet to be undertaken. Previous to this study, data regarding Sockeye egg-to-fry survival and abundance from Gates Creek had not been collected. Enumeration of Coho juvenile

abundance in Gates Creek had also never been undertaken, although there has been a recent evaluation of habitat use by rearing juvenile Coho (Hillaby 2012).

In 2011, the DFO scientific advisors for the Gates Creek spawning channel requested that InStream Fisheries Research Inc. (IFR) submit a study design to enumerate out-migrant Sockeye fry and Coho juveniles in Gates Creek to compliment ongoing work on the spawning channel. A proposal, including the juvenile enumeration study and complimentary Sockeye adult monitoring (counts and fecundity assessments), was submitted by the Lillooet Tribal Council (LTC) and DFO to the BC Hydro FWCP. The following report summarizes the findings of the 2015 juvenile component of the fourth study year.

## **0.0 Study Objectives**

The main objectives of this study were to assess the following biological parameters for Sockeye and Coho salmon in Gates Creek.

1. Estimate the abundance, timing and biological characteristics of out-migrant Sockeye fry for both Gates Creek and the Gates Creek spawning channel.
2. Estimate egg-to-fry survival of Sockeye fry in both Gates Creek and the Gates Creek spawning channel.
3. Estimate Sockeye fry production per effective female spawner.
4. Estimate the abundance and timing of out-migrant Coho juveniles (1+) from Gates Creek.

## **0.1 Study Area and Trapping Locations**

The study area consists of two sites, a full weir on the spawning channel (Figure 1 & 3), and an inclined plane trap (IPT) or rotary screw trap (RST) downstream of the channel outlet on Gates Creek (Figures 1 & 4).

## METHODS

Two methods were used to enumerate out-migrant juvenile Sockeye in 2015, which were similar to previous years (Lingard et al. 2013). Partial traps (e.g., RSTs or IPTs), which sample a proportion of the out-migrant Sockeye fry and Coho smolts, require mark-recapture sampling methods and analyses to estimate juvenile outmigration. A complete channel trap was used to capture all out-migrating Sockeye fry from the spawning channel. The study design was developed to ensure sampling methods minimized fish mortality and stress.

### 1.0 *Fish Trap Operations*

#### 1.0.0 Gates Creek Traps - Inclined Plane and Rotary Screw Traps

Two downstream recapture traps were used in this study. An IPT was run from March 27<sup>th</sup> to May 4<sup>th</sup>. On May 5<sup>th</sup>, the IPT was replaced with a RST to facilitate the juvenile Coho component of the project. The RST was in operation for one week until May 11<sup>th</sup>, when high flows ended the program.

Both traps were oriented on a cableway pulley system, allowing the lateral position in the river to be adjusted to optimize the sampling location in the main flow. In addition the trap could be brought to shore on either side of the creek for cleaning and sampling (Figure 4). Traps were set to fish each day at dusk (between 6 pm and 8 pm), and were checked at 8 am the following day to manually count captured fish. Restriction of trap operations to night hours was deemed adequate because it is known from channel trap operations that relatively low numbers of fry migrate during daylight hours. During times of high water, the trap was brought to shore and operations were suspended to ensure the safety of crew and equipment.

#### 1.0.1 Channel Trap

The full channel trap at the downstream end of the spawning channel guides all out-migrating Sockeye fry to a single trough. A proportional sampler (Red Fish Services; Figure 3) divided out-migrants into two separate capture boxes, “sample” and “full channel”. The sample box is smaller than the full channel box, and is designed to capture approximately 5% of the nightly

fry outmigration. The full channel box was in place 1-2 times per week to capture the remaining 95% of the nightly migration and allow calibration of the sampler. The sampler structure is a rectangular box with a screened wall dividing it length wise in half. Fish were sampled by a small two-inch funnel that moved across an opening on the channel weir. Fish captured by the funnel are diverted into one chamber of the structure which is connected to the “sample” box. Fish not captured by the funnel enter the other chamber and are routed into the “full-channel” box, or are released into the river to continue their migration down river.

To test the variability in proportion of total catch captured by the sampler, all Sockeye leaving the spawning channel were counted or estimated by volume sampling (when there were < 3000 fry migrating per night, see Section 2.6.2) on marking nights. Only the sample box was run from Thursday to Saturday.

### **1.1 Sockeye Fry Marking and Recapture**

Mark-recapture methods were used to assess the capture efficiency of mainstem juvenile traps. A known number (approximately 2,500) of channel fish were marked and released from the channel (upstream of the IPT) four days a week (Monday to Thursday) at dusk. A proportion of the marked fish were subsequently caught in the downstream IPT, which provides an estimate of capture efficiency. No fish were marked during the remaining three days (Friday to Sunday), allowing for all marked fish from the previous marking period to pass by the IPT. This assumption was validated by the lack of recaptures of marked Sockeye fry on Monday mornings during our study period. This temporally stratified method was developed on the Cheakamus River and is documented in Melville and McCubbing (2012).

On marking days, Sockeye fry collected at the channel trap were not sampled but were held in the trap boxes until late afternoon. A maximum of 2,500 fry were marked each day by immersion in Bismark Brown Y dye (Sigma-Aldrich, St. Louis, USA) diluted to a ratio of 1:100 000 with river water. Fish were immersed for 45 minutes in 50 litres of dye solution aerated with electric air pumps. After marking, fish were immediately released into Gates Creek downstream of the channel trap. This marking technique was developed to minimize stress-related mortality of fry due to the marking and holding process (Melville and McCubbing 2002b). Daily fry catch data represented a 24-hour sampling period beginning at 8 am each morning.

## **1.2 Coho Juvenile Marking and Recapturing**

Coho juveniles have varied freshwater life histories prior to migration to saltwater. For the purpose of field marking and enumeration of fish, it is necessary to use discrete length intervals to identify the life stage of captured Coho juveniles. In the absence of Gates Creek specific length-frequency and ageing data, data from Melville and McCubbing (2005) were used to identify length cut-offs for the various life stages: smolts (1+ migrating): >70 mm, parr (1+ non-migrating): 60-70mm, fry (0+ non-migrating) < 60mm.

The RST functioned as both a mark and a recapture trap for Coho smolts. Starting on May 5<sup>th</sup>, unmarked Coho smolts captured in the RST were marked daily with a caudal fin clip. To allow for temporal stratification of capture efficiency, mark patterns were changed on Wednesday of each week. Thus, mark groups for Coho ran from Monday through Tuesday from May 6<sup>th</sup> to May 11<sup>th</sup>. Fish were marked in the morning after the RST catch had been enumerated. Marked Coho were then placed in a holding box in the channel flow downstream of the channel trap and released at dusk. Daily Coho catch was defined as the 24-hour period beginning at 8 am.

Fish were anaesthetized using a water bath with clove oil diluted in ethanol to reduce handling stress and ensure successful marking. Caudal fin clips consisted of a dorso-ventral cut approximately  $\frac{1}{4}$  the distance from the caudal peduncle to the tip of either the upper or lower caudal lobe. Temperature stress was minimized by frequent changes of anaesthetic baths, and by marking early in the morning in shade.

## **1.3 Length and Weight**

### **1.3.0 Sockeye Fry**

Samples of Sockeye fry (N=25) were taken from all trap sites twice a week. Fork length was measured for each fish to the nearest millimetre, and the weight of five fry was measured to the nearest hundredth of a gram. Fish were anaesthetized in water baths with clove oil diluted in ethanol to ensure accuracy of measurements and reduce handling stress.

### 1.3.1 Coho Smolt Data Collection

Coho juveniles were only sampled at the trap site, as few were captured in the channel trap. Fish were anaesthetized in water baths with clove oil diluted in ethanol to ensure accuracy of measurements and reduce handling stress. Fork length was measured to the nearest millimetre. Coho were weighed individually to the nearest tenth of a gram.

## 1.4 *Environmental Monitoring*

### 1.4.0 Temperature Monitoring

Temperature data were collected for both the spawning channel and Gates Creek over the period of spawning and egg incubation from August 10<sup>th</sup>, 2013 to May 20<sup>th</sup>, 2015. Three sites in Gates Creek and one site in the spawning channel were monitored with pairs of TidbiT v2 water temperature data loggers (accuracy of  $\pm 0.2^{\circ}\text{C}$ ; Onset HOBO data loggers, Bourne, USA). Temperature was logged every 15 minutes. Data were compiled to average daily temperature for analyses.

A pair of temperature loggers were placed in the spawning channel at the bottom leg. In Gates Creek, three pairs of temperature loggers were installed: (1) Davidson's horse farm (UTM 10535385E, 5596420N), (2) at a heavily used spawning area (UTM 10536331E, 5598092N), and (3) across from the spawning channel intake (UTM 10563462E, 5599630N).

Mean daily water temperature was used as an estimate of the daily thermal units. Accumulated thermal units (ATU) over the egg incubation period were calculated as the sum of the daily thermal units between the peak of spawn and peak of fry outmigration (September 11<sup>th</sup>, 2014 and April 20<sup>th</sup>, 2015).

### 1.4.1 Water Level Data

Water level was monitored using a staff gauge at the IPT site. Water level readings were recorded three times per day. Mean weekly water level over the survey period was calculated from the mean of daily staff gauge readings.

## 1.5 *Population Estimate Methods*

### 1.5.0 Total Sockeye Fry Abundance

The Bayesian P-SPLINE model developed by Bonner and Schwarz (2011) was used for mark-recapture data analysis. Analyses were carried out using the statistical software R (R Development Core Team, 2012), with the R2OpenBUGS (Sturtz et al. 2005) package for interfacing with Open Bugs (Lunn et al. 2009), BTSPAS (Bonner and Schwarz 2012), CODA (Plummer et al. 2006), Actuar (Dutang et al. 2008), and Lattice (Deepayan 2008) packages.

Historically, the Pooled Peterson estimate or temporally-stratified Peterson methods (e.g., Ricker 1975, Arnason et al. 1996) have been the preferred analysis method for mark-recapture data. These two methods make a number of assumptions as outlined by Seber (2002):

- 1) The population is closed such that there is no immigration or emigration
- 2) In a sample period, all untagged fish have the same probability of capture
- 3) Marking, clipping, and releasing fish upstream does not affect their subsequent catchability in the downstream trap
- 4) The sample caught in the downstream trap is a random sample, and all combinations of untagged and tagged fish have equal probabilities of occurrence
- 5) No marks are lost between release and recapture sites
- 6) All marks are reported on recovery in the downstream sample
- 7) Marked and unmarked fish have similar movement patterns from the release site to the downstream trap
- 8) Fish can pass the downstream trap once all marked fish pass the traps by the end of the study period, i.e., none of the fish remain above the downstream trap
- 9) There is no mortality and all fish pass the trap

Bonner and Schwarz (2011) developed an alternate method that uses Bayesian spline models for estimating population size. This modeling approach has many advantages over existing methods. Key features of this method are the use of splines to model the general shape of the run. Estimates of abundance are provided for each recapture stratum, making it possible to estimate quantities such as the time at which 50% of the run has passed, or the time needed to reach a pre-specified target number of fish. The model can also deal with the common problem of not being able to sample in all strata; the spline curve for the run is used to “interpolate” for the missing data. These last two features are difficult to obtain from the previous methods. The spline model, however, is not a panacea to solve all potential

problems encountered in capture-mark-recapture studies. There are a number of caveats that apply to this and other stratified models, which are further described in Bonner and Schwarz (2012).

### 1.5.1 Gates Creek Spawning Channel Sockeye Fry Abundance

Volume sampling was completed between 8 am and 12 pm daily, which consisted of weighing a subsample of 500 fry each day and then weighing the total catch of fry in batches. During the peak of the migration, the full channel box was sampled between 11 pm and 12 am to prevent mortality caused by overcrowding in the trap box. To convert the weights of fry to number of fry, a subsample of 500 fish was weighed each day. The number of fry per gram was then calculated and multiplied by the total weight of fry.

For Friday to Sunday when only the sample box was run, the mean sample rate of the sampler was divided into the nightly total for the sample box to yield the total nightly migration out of the spawning channel.

### 1.5.2 Gates Creek Sockeye Fry Abundance

Gates Creek fry abundance was calculated as the difference between the total fry abundance estimated from the IPT mark-recapture site and the Gates Creek spawning channel estimate.

### 1.5.3 Egg-to-fry Survival and Fry per Effective Female

Egg-to-fry survival was calculated by dividing fry abundance by the number of eggs successfully deposited in the previous year. Egg deposition for the Gates Creek channel was estimated using fecundity data for the 2014 brood year (Lingard et al. 2013a). Fry *per* effective female<sup>1</sup> was calculated by dividing the number of fry by the number of effective females for 2014. Lingard et al. (2013a) provides further information regarding the calculation of the number of effective females.

---

<sup>1</sup> Effective female refers to a female that successfully spawned

## RESULTS

### 2.0 Fish Trap Operations

#### 2.0.0 IPT / RST

The mark-recapture program in 2015 was 7 days shorter than the 2014 program. Recapture rates for the IPT ranged from 4.8% to 10.2% (mean  $\pm$  standard deviation [SD]: 7.6%  $\pm$  1.9%). Catches of Sockeye fry in the IPT ranged from 1,890 to 59,992, with a mean daily catch of 20,477 (SD 15,707).

Recapture rate of Coho smolts in the RST was 23%. Catches of Coho smolts ranged from 1 to 70 individuals in the 6 days of operation.

#### 2.0.1 Channel Trap

The channel trap was operated 100% of the study period (66 of 66 days). The proportional sampler worked 100% of days with a mean sample rate of 4.5% (SD 1.4%).

### 2.1 Length and Weight Sampling

#### 2.1.0 Sockeye Fry Length and Weight

Fry caught at the channel trap were larger on average than fry caught in the IPT; however no significant difference was found in mean fry length (Welch's t-test,  $P=0.11$ ). The mean length of Sockeye fry caught at the IPT was 30 mm ( $N=274$ ,  $SD=3$ ), and fry caught at the spawning channel were 31 mm on average ( $N=300$ ,  $SD=1.2$ ) (Table 2, Figure 5). Variance in fork length was significantly different (F-test,  $F_{(299,274)}=0.20$ ,  $P=2.22 \times 10^{-16}$ ) between the two sites (Table 2). Fry caught at the channel had a slightly contracted range (25 to 39 mm) from that of fry caught at the IPT (19 to 55 mm). Standard deviation of length data was 2.3-fold higher for IPT-caught fry compared to channel fry.

Fry weight was similar between the two capture sites. Mean fry weight was 0.24 g for the spawning channel ( $N=300$ ,  $SD=0.06$ ) and 0.23 g for the IPT ( $N=275$ ,  $SD=0.07$ ) (Table 3, Figure

6). Mean weight of fry caught at the channel was not significantly different than the mean weight of fry caught at the IPT (Welch's t-test:  $P=0.06$ ); however the variance in the range of fry weights between the two sites did differ (F-test:  $F_{(299,274)}=0.599$ ,  $P=1.54 \times 10^{-5}$ ). Distribution of fry weights for both the IPT and channel were unimodal and skewed towards smaller values (Figure 6). Fry caught in the IPT ranged from 0.14 to 0.58 g, while fry weighed at the channel ranged from 0.15 to 0.41 g.

### 2.1.1 Coho Smolt Length and Weight

A broad range of sizes were observed in the Coho juveniles captured in the RST. Coho Smolts sampled in 2015 ranged from 72 mm to 154 mm, with a mean fork length of 105 mm ( $N=220$ ,  $SD=13.4$ ) (Figure 7). Wet weight of Coho smolts sampled in 2015 ranged from 3.8 g to 35.8 g, with a mean of 12.9 g ( $N=220$ ,  $SD=5$ ) (Figure 8).

## 2.2 Environmental Monitoring

### 2.2.0 Temperature

Mean daily water temperature over the incubation period was similar between Gates Creek and the spawning channel. Mean daily temperature in Gates Creek ranged from 0.0°C to 14.4°C for the period of spawning, egg incubation and fry migration (August 20<sup>th</sup>, 2014 to May 26<sup>th</sup>, 2015) (Table 4, Figure 9). Mean daily water temperature in the spawning channel ranged from 0.1°C – 14.8°C over the same period (Table 4, Figure 9). Overall, mean water temperature from the beginning of the spawning period to end of the juvenile migration (i.e., August 20<sup>th</sup>, 2014 to May 26<sup>th</sup>, 2015) in both the spawning channel and Gates Creek were 5.9°C ( $SD=3.4$ ) and 6.0°C ( $SD=3.6$ ), respectively.

ATU's over the incubation period were similar between Gates Creek and the spawning channel. Total ATU's for the spawning channel were 1,044 from the peak of spawn to the peak of migration (i.e., September 11<sup>th</sup>, 2014 to April 20<sup>th</sup>, 2015). Gates Creek accumulated a total of 1,032 thermal units over the same period (Figure 10).

Over the period of the mark-recapture program, mean weekly water temperature ranged from 5.5°C to 7.5°C in Gates Creek and 5.2°C to 9.3°C for the spawning channel. During the peak week of migration (week of April 20<sup>th</sup>), the mean weekly water temperatures were 6.3°C and 6.5°C in Gates Creek and the spawning channel, respectively. Water temperatures gradually

increased over the mark-recapture program, and peaked in the last week of the study (Figure 9).

### 2.2.1 Water Level

Daily river water level measured at the IPT site ranged from 0.58 m to 0.63 m over the length of the sockeye mark-recapture program (March 27<sup>th</sup> to May 4<sup>th</sup>, 2015) (Figure 11). Over the week of RST operations (May 5<sup>th</sup> to May 11<sup>th</sup>), water levels reached 0.72 m and further increased to a maximum of 1.4 m on May 23<sup>rd</sup>. High water throughout May restricted future opportunities to fish for Coho juveniles.

## 2.3 Sockeye Population Estimates

### 2.3.0 Total Abundance of Sockeye Fry

A total of 51 933 marked Sockeye fry were released at the channel weir across five marking groups, of which 3,914 were recaptured. 700 129 Sockeye fry were captured at the IPT site from March 27<sup>th</sup> to May 12<sup>th</sup> (Table 5). From the IPT catch an estimated 9 432 038 (SD 620 920) Sockeye fry passed the IPT site between March 27<sup>st</sup> and May 4<sup>th</sup>, 2015 (Table 6). An additional 94 997 fry left the spawning channel outside of the mark-recapture program. Taken together, there was a total of 9 527 035 Sockeye fry produced from the Gates Creek system in 2015 (Table 6).

Based on estimated weekly abundance, it appeared that migration of Sockeye fry started prior to trapping (commencing on March 27<sup>th</sup>). An estimated 1 339 698 fry (SD 605 608), or 14% of the total migration, passed the trap in the first weekly strata (March 23<sup>rd</sup> to March 30<sup>st</sup>) (Table 6). Over the mark-recapture period, the run-timing of Sockeye fry past the IPT site was unimodal, peaking in the week of April 20<sup>th</sup> to April 27<sup>th</sup>, 2015 at 3 061 004 fry (Figure 12, Table 6). The run reached 50% and 90% of its total in the weeks of April 20<sup>th</sup> to 27<sup>th</sup> and April 27<sup>th</sup> to May 4<sup>th</sup>, respectively. Only 4% of the total abundance estimate was estimated to pass the trap in the week of April 28<sup>th</sup> to May 4<sup>th</sup>, 2015.

A total of 16 138 mortalities, representing 2.0% of the total catch or 0.2% of the total abundance estimate, were incurred at the IPT. Mortalities were included in abundance estimates.

### 2.3.1 Gates Creek Spawning Channel Sockeye Fry Abundance

An estimated 2 470 759 Sockeye fry migrated out of the Gates Creek spawning channel between March 17<sup>th</sup> and May 26<sup>th</sup>. During the operation of the IPT (March 27<sup>th</sup> to May 4<sup>th</sup>), the channel abundance of Sockeye fry (2 375 762) represented 25% of the total Sockeye estimated from the downstream IPT (Table 7, Figure 13).

Fry migration from the channel appeared to have started when trapping commenced, as only 2% of the total run was captured in the first week of sampling. Channel fry abundance reached 10%, 50% and 90% of the total migration during the weeks ending April 13<sup>th</sup>, April 20<sup>th</sup> and April 27<sup>th</sup>, respectively. Migration of fry out of the channel was unimodal, with a peak estimated weekly emigration of 1 314 933 fry (55% of total channel migration) occurring in the week ending April 20<sup>th</sup> (Table 7, Figure 13). More specifically, the channel peaked on April 15<sup>th</sup> with a total nightly migration of 472 092 fry. In the three-week period following the removal of the Gates Creek IPT, less than 3% (72 609) of total channel abundance migrated.

### 2.3.2 Gates Creek Sockeye Fry Abundance

An estimated 7 004 343 Sockeye fry migrated out of Gates Creek from March 27<sup>th</sup> to May 4<sup>th</sup>, 2015 (Table 7, Figure 13). Fry abundance from Gates Creek represented 75% of the estimated total Sockeye fry abundance in 2015. Similar to the spawning channel and total fry abundance from the system, Gates Creek fry abundance run timing was unimodal (Figure 13). The peak occurred in the week of April 13<sup>th</sup> to April 19<sup>th</sup> with a total of 1 786 601 fry (26% of the total creek abundance).

Based on the weekly abundance estimates, it appears the beginning and end of the Sockeye fry migration may have been missed by the mark-recapture program. In the first week of trapping, 1 292 512 fry migrated out of Gates Creek (18% of creek total). The migration reached 50% and 90% of the total abundance in the week ending April 13<sup>th</sup> and April 27<sup>th</sup>, respectively. In the final week of trapping (week of May 4<sup>th</sup>), 221 533 fry (3% of the total abundance) emigrated out of Gates Creek (Table 7, Figure 13).

### 2.3.3 Egg-to-fry Survival and Fry per Effective Female

Egg-to-fry survival and fry per effective female were both higher in Gates Creek than in the spawning channel. Egg-to-fry survival in Gates Creek was 1.7 times greater than in the spawning channel. Gates Creek also produced 2.7 times more fry per effective female as the spawning channel. Egg-to-fry survival for the spawning channel and Gates Creek for the 2014 brood year were estimated to be 23% and 40%, respectively. Fry per effective females was estimated to be 769 and 1 335 for the spawning channel and Gates Creek, respectively (Table 8).

#### 2.3.4 Coho Catch Data

A total of 314 Coho smolts were captured using the RST between May 5<sup>th</sup> and May 11<sup>th</sup>, 2015. Daily catches ranged from 1 to 70 individuals. 71 of the 313 marked Coho smolts were recaptured, yielding a recapture rate of 22% for the RST in the spring of 2015.

## DISCUSSION

### 3.1 *Trap Operations*

#### 3.1.1 IPT and RST

Stable low flow conditions in 2015 allowed for the IPT to be fished through the peak of the fry migration. In 2015 the IPT was fished 85% of the mark-recapture study period, an increase from 61% in 2014. However, the mark-recapture program was 7 days shorter in 2015 than in 2014. A decrease in Sockeye catches during the week of May 4<sup>th</sup>, as well as a forecasted increase in water levels, initiated a decision to switch to the Coho component of the study. The Coho component lasted 6 days until May 11<sup>th</sup> when trapping was suspended due to extended high water conditions.

High water conditions during the spring freshet over the past four study years suggest that trapping during the spring migration is not the best method for monitoring Coho populations. Other methods (e.g., summer stock assessment of juveniles using electro fishing, electronic counter technology to enumerate returning adult abundances in the fall) may prove to be better options for assessing this species.

#### 3.1.2 Channel Trap

Repairs made to the sampler in the 2014 off-season have sustained two seasons of wear, and allowed the proportional sampler to function 100% of the 2015 field season. Due to the consistency of this sampler, it was possible to let fish pass through the weir without being handled in 2015.

DRAFT

### **3.2 Fry Length and Weight Sampling**

Survival is positively correlated with juvenile size in salmonids and other species of teleost fish (West and Larkin 1987; Henerson and Cass 1991; Sogard 1997; Eimum and Fleming 2000). In this study, fry length and weight were similar between the IPT and channel samples. Mean fry lengths were found to be the similar (30 mm [IPT] and 31 mm [channel]) at both sites.

We found a significant difference in the variance of fry weight between sites in 2015. Error associated with using wet weights of live fry, however, leads to imprecise measures of weight and the associated error is likely larger than the difference between sites. It should also be noted that fry measured at the IPT are not an independent sample of Gates Creek Sockeye fry; they are a mixture of fry from the spawning channel and Gates Creek.

### **3.3 Water Temperature and ATU's**

Water temperature at the beginning of the mark-recapture program was highest in 2015 out of the three years of available data. Water temperatures in the first strata (last week of March) have varied from 3°C in 2013 (Lingard et al. 2013), to 1°C in 2014 (Lingard et al. 2014b), and 5°C in 2015.

Embryo development, survival, hatching, fry emergence date and migration timing in salmonids are known to be influenced by stream water temperature (Murray and McPhail 1987; Zydlewski et al. 2005). ATU's for the spawning channel and Gates Creek followed similar temperature profiles over the incubation period as estimated by surface water temperatures. Overall, water temperatures in the spawning channel did not differ in the accumulation of thermal units or mean water temperature between the two habitats. Nor does it appear that either habitat collected thermal units significantly faster than the other. Despite the similar temperature profiles at the two sites, surface water temperature in the spawning channel and Gates Creek are likely not an accurate indicator of the intra-gravel (redd) water temperatures experienced by the embryos. Intra-gravel water temperatures have been found to vary by 6°C in the summer and 1°C in the winter from surface water temperatures in similar Pacific Northwest streams, typically as a result of ground water influence (Shepherd et al. 1986).

### **3.4 Sockeye Fry Migration**

#### **3.4.0 Sockeye Fry Abundance**

The 2015 estimate of 9.4 million fry is the second lowest estimate in the four study years, and is 39% lower than the estimate in 2014. Notably, this is likely an underestimate as the program may not have captured the beginning of the run. Nearly 1.3 million fry were estimated to have passed the trap in the first strata which is 13 times the 100 000 fry estimated for the same strata in 2014. The tail end of the migration does appear to have been captured by the program, as only 4% of the total migration was captured in the week ending May 4<sup>th</sup>. The 419 000 fry estimated to have migrated past the IPT in the last strata of 2015 was 95% lower than the same strata in 2014 (8 583 464) (see Lingard et al. 2014a).

The 39% decrease in the abundance of Sockeye fry from 2014 to 2015 can be attributed to a decrease in the number of effective females in the 2014 brood. Overall, female escapement for the watershed decreased by 66% and the number of successful female spawners decreased by 63% (Lingard et al. 2014b). The decrease in fry abundance from 2014 to 2015 was less than the decrease in the number of females due to an increase in egg-to-fry survival in both the spawning channel and Gates Creek.

The relative contributions of Sockeye fry from Gates Creek and the spawning channel changed by ~7% from 2014 to 2015. In 2015, Gates Creek contributed 75% of total Sockeye fry abundance – a decrease from 82% in 2014. Conversely, the contribution of fry from the spawning channel increased from 16% in 2014 to 25% in 2015 (Lingard et al. 2014b). The change in the relative contribution of fry abundance from the two sites may be related to a similar change in the proportion of females spawning in each site in the fall of 2014 compared to 2013. From 2013 to 2014, the proportion of females spawning in Gates Creek decreased by 14%, but increased by 25% in the spawning channel (Lingard et al. 2014a).

#### **3.4.1 Egg-to-Fry Survival and Fry per Effective Female**

Over the four years of this study, egg-to-fry survival has varied both in the spawning channel and Gates Creek. Egg-to-fry survival in Gates Creek has increased every year from 16% in 2012 to 40% in 2015. Egg-to-fry survival in the spawning channel has fluctuated from a high of 33% in 2013 to a low of 16% in 2014.

Egg-to-fry survival in the spawning channel increased by 7% from 2013 to 2014, but survival in both of these years was lower than for the 2011 and 2012 broods (33%). The survival rates for the Gates Creek spawning channel across all four study years are low compared to other DFO-operated spawning channels. For example, egg-to-fry survival for the Nadina spawning channel ranged from 30% to 80% from 1994 to 2011. Similarly, egg-to-fry survival rates at Weaver Creek spawning channel ranged from 48% to 86% from 1988 to 2008 (DFO, unpublished data).

Six years have passed since the gravel replacement in the spawning channel. The low survival rates for the 2013 and 2014 broods indicate regular maintenance and expanded monitoring of water quality and sediment impaction are required. Experimental cleaning of the gravel (via an excavator) was undertaken in July and August 2015 by the N'Quatqua Fisheries manager (Harry O'Donaghey, pers. comm.). Results from the channel outmigration in the spring of 2016 will allow evaluation of the effectiveness of these activities.

Gates Creek has seen a steady increase in egg-to-fry survival since this study commenced in 2012. Egg-to-fry survival for the 2014 brood was 1.9 times the survival rate for the 2013 brood, and nearly 2.5 times the survival rates for 2011 and 2012 broods. Survival of the 2014 Gates Creek brood was comparable to spawning channels elsewhere (e.g., Nadina and Weaver), and was higher than any value observed in the Gates Creek spawning channel over the course of this study. While there has been considerable variation in egg-to-fry survival in Gates Creek over the course of this study, the range of values observed are comparable to ranges observed in other Fraser River stocks. In FoFar and Kynock Creeks, egg-to-fry survival has been found to vary from 10% to more than 60% (Patterson et al. 2008).

Few studies to date have estimated egg-to-fry survival in wild Sockeye salmon. Bradford (1995) and Quinn (2005), however, found that average egg-to-fry survival rates vary from 7% to 12%. Compared to the values reported in Bradford (1995) and Quinn (2005), and the values observed in FoFor and Kynock Creeks (Patterson et al. 2008), Gates Creek has performed at or above average survival rates for unenhanced Sockeye streams over the period of 2012-2015.

### 3.4.2 Sockeye Fry Run-Timing

Run timing was similar between Gates Creek and the spawning channel in 2015, however the start and peak of migration occurred earlier for both habitats in 2015 compared to previous years. Gates Creek peaked a week earlier (week ending April 13<sup>th</sup>) than the spawning channel

(week ending April 20<sup>th</sup>). Peak of migration in 2015 occurred two weeks earlier in the spawning channel and three weeks earlier in Gates Creek than in 2014.

Water temperature may be a contributing factor to the earlier start and peak of migration in 2015. Surface water temperatures were similar in both habitats over the migration period, but minimum water temperatures observed over the length of the mark-recapture program were higher than in previous years. While surface water temperatures are not necessarily indicative of temperatures experienced by fry rearing in gravel (Shepherd et al. 1986), earlier increases in water temperatures may have triggered fry to migrate earlier than in previous years. Differences in temperature regimes have been shown to influence the migration timing and duration of Atlantic salmon smolts (Zydlewski et al. 2005). Should this study be continued, the mark-recapture period may need to be broadened or shifted in response to varying temperature and flow regimes in Gates Creek.

### **3.5 Juvenile Coho Capture**

A partial estimate for Coho juveniles was derived in 2012, but since then three attempts to capture Coho juveniles through their migration window have failed due to high flows. While stable flows exist in April, May appears to be a turbulent month. May also happens to be the peak of juvenile Coho migrations in other Southern British Columbia watersheds (Cheakamus and Seymour Rivers; Lingard and Melville 2014, and Ramos-Espinoza and McCubbing 2012, respectively). Several other options exist for monitoring Coho populations: summer stock assessment of juveniles, or the use of passive electronic counter technology (e.g., resistivity counters) to enumerate of adults.

## **SUMMARY and RECOMMENDATIONS**

The primary objectives of obtaining data on the status of the Sockeye population in Gates Creek and spawning channel were largely met:

1. Total abundance of out-migrating Sockeye fry was estimated: 7 004 343 emigrating Sockeye fry from Gates Creek, and 2 470 759 from the Gates Creek spawning channel.
2. Egg-to-fry survival was estimated: 40% for Gates Creek, and 23% for the Gates Creek spawning channel.
3. Fry per effective female was estimated: 1 335 for Gates Creek, and 769 for the Gates Creek spawning channel.
4. Biological information on Sockeye fry was taken. Lengths and weights were measured for fry emigrating from Gates Creek and the spawning channel.

A final attempt at spring trapping of migrating 1+ Coho juveniles was attempted, but was unsuccessful due to high flows. Employment of alternative methods for monitoring Coho populations monitoring are recommended.

There are several important reasons for continuation of this study, but with some modification to the scope and focus. Since the construction of the spawning channel, it has generally been thought that Gates Creek has limited suitable habitat for salmon spawning. Further, the best operating regime for safe guarding the valuable Gates Creek Sockeye population against low productivity and stochastic environmental events has been to load the spawning channel to maximum capacity (Doug Lofthouse, pers. comm.). This study has indicated the opposite may be true for this population. Over the four years of this study, Gates Creek has produced a significant proportion of the total fry abundance leaving the watershed, and best practice would be to ensure the use of creek spawning habitat even in years of low escapement. However, a cautionary approach would be to use the spawning channel as well, as there appears to be substantial variation in the productivity of Gates Creek among years. Continued monitoring of Gates Creek should be undertaken to ensure survival for this habitat is not being over or under estimated from year to year.

Collection of juvenile abundance and survival data are crucial to the evaluation of the spawning channel management and developing best practices that will maximize fry abundance. Results from the four juvenile outmigration studies have aided the DFO scientific advisory staff in making informed channel loading decisions. Furthermore, this study compliments ongoing adult stock assessment activities by DFO.

Long-term data pertaining to juvenile abundances leaving the watershed each spring could be used in forecasting models by DFO to improve the accuracy of fisheries planning and further illuminate the complex dynamics of Fraser River Sockeye populations. Existing infrastructure and skilled N'Quatqua Fisheries staff make Gates Creek and its associated spawning channel a cost-effective method for generating high quality estimates of juvenile sockeye abundance and survival.

A Level 1 Habitat Assessment was conducted on Gates Creek in the spring of 2015 as a part of this study (Lingard et al. 2015c). Several opportunities exist for restoration projects focusing on Bull trout and Coho habitat on Gates Creek. Monitoring of Sockeye, Coho, and Bull trout should be undertaken before and after any restoration projects are completed. Monitoring will allow funders to quantify the benefits of restoration projects for each species.

Finally, this study is closely linked to a number of ongoing monitoring projects throughout the Seton-Anderson watershed, and provides a valuable employment and capacity building opportunity for the N'Quatqua First Nation. Ongoing projects, for example, include an assessment of adult Sockeye and Coho salmon passage through the Seton Dam fishway and their spawning success on spawning grounds (BC Hydro WLR requirement, 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), enumeration of smolts as they migrate out of the Seton-Anderson watershed, and the productivity of both Seton and Anderson Lakes (BRGMON-6, Seton Lake Aquatic Productivity Monitoring).

DRAFT

DRAFT

**TABLES**

**Table 1. Start and end dates for all traps operated on Gates Creek in spring 2015.**

Trap/Counter Name	Start Date	End Date	Comments
Channel Weir	March 17	May 26	Fished 7 days per week
IPT	March 27	May 4	Fished 7 days per week
RST	May 4	May 11	Installed when sockeye numbers dropped

DRAFT

**Table 2. Summary of Gates Creek Sockeye fry fork lengths (mm) measured at both the spawning channel and IPT sites from 2011 to 2015.**

	2012		2013		2014		2015	
	Channel	IPT	Channel	IPT	Channel	IPT	Channel	IPT
<b>N</b>	340	326	375	300	420	274	375	275
<b>Range (mm)</b>	25-54	26-40	23-44	22-39	23-47	27-36	25-39	19-55
<b>Mean (mm)</b>	30	29	29	29	29	29	31	30
<b>SD (mm)</b>	3	1	3	1	2	1	1	3

**Table 3. Summary of Gates Creek Sockeye fry weights (g) measured at both the spawning channel and IPT sites from 2011 to 2015.**

	2012		2013		2014		2015	
	Channel	IPT	Channel	IPT	Channel	IPT	Channel	IPT
<b>N</b>	340	326	375	275	420	274	375	275
<b>Range (g)</b>	0.12-0.80	0.14-0.58	0.12-0.62	0.15-0.40	0.10-0.52	0.13-0.33	0.15-0.41	0.14-0.58
<b>Mean (g)</b>	0.31	0.30	0.25	0.23	0.21	0.21	0.24	0.23
<b>SD (g)</b>	0.13	0.08	0.09	0.04	0.07	0.04	0.06	0.08

**Table 4. Summary of daily water temperatures (°C) in both Gates Creek and the spawning channel from August 20<sup>th</sup>, 2014 to May 20<sup>th</sup>, 2015.**

	Channel	Creek
<b>Average of average daily temp</b>	5.8	5.6
<b>SD of average daily temp</b>	3.4	3.2
<b>Min of average daily temp</b>	0.1	0.0
<b>Max of average daily temp</b>	14.1	13.7

**Table 5. Weekly totals of Sockeye fry marked at the spawning channel, recaptured and unmarked fish enumerated at the IPT in spring 2015. Trap efficiency is the proportion of marked fish that were recaptured.**

Week Ending	Marks	Recaptures	Unmarked	Mortalities	Trap Efficiency (%)
March-30	0	0	46 800	7 337	NA
April-6	11 439	726	80 859	239	6.3
April-13	10 000	1 024	204 879	595	10.2
April-20	10 550	913	264 242	550	8.7
April-27	9 944	768	84 929	4 816	7.7
May 4	10 000	483	14 506	2 601	4.8
<b>Total</b>	<b>51 933</b>	<b>3,914</b>	<b>696 215</b>	<b>16 138</b>	-

**Table 6. Modeled weekly estimates of total unmarked Sockeye fry passing the Gates Creek IPT site. Credible intervals (2.5% and 97.5%), average weekly temperature (°C) and water level (m), standard deviation (SD), and relative standard deviation are also displayed. Note: mean abundance does not match totals for system in Table 7, as these strata totals do not include marks.**

Week Ending	Mean	SD	Relative SD <sup>1</sup>	2.5%	97.5%	Temp (°C)	Water Level (m)
<b>30-Mar-14</b>	1 339 698	605 609	0.45	619 472	2 793 301	6.2	0.62
<b>06-Apr-14</b>	1 276 100	46 164	0.04	1 188 782	1 367 674	5.1	0.61
<b>13-Apr-15</b>	2 008 764	59 375	0.03	1 892 923	2 127 555	5.2	0.58
<b>20-Apr-15</b>	3 050 454	97 836	0.03	2 866 094	3 252 029	6.3	0.58
<b>27-Apr-15</b>	1 285 808	44 205	0.03	1 202 965	1 376 272	6.0	0.61
<b>04-May-15</b>	419 281	19 103	0.03	383 468	458 014	6.5	0.63
<b>Total Abundance</b>	<b>9 380 105</b>	<b>620 920</b>	<b>0.07</b>	<b>8 596 806</b>	<b>10 870 354</b>	-	-

<sup>1</sup> Relative SD is a measure of precision. Values > than 0.30 indicate low precision.

**Table 7. Weekly abundance of Sockeye fry leaving Gates Creek and the spawning channel. Total abundance of fry past the IPT site on Gates Creek in spring 2015.**

Week Ending	Channel	Creek	Total fry passing IPT (includes marks)
Mar-23	22 388	-	-
<b>Start of Mark - Recapture</b>			
Mar-30	47 186	1 292 512	1 339 698
Apr-06	71 592	1 204 509	1 287 539
Apr-13	222 163	1 786 601	2 018 764
Apr-20	1 314 933	1 735 521	3 061 004
Apr-27	512 141	773 667	1 295 752
May-04	207 748	211 533	429 281
<b>Sub Total</b>	<b>2 375 762</b>	<b>7 004 343</b>	<b>9 432 038</b>
May-11	45 755	-	-
May-18	24 819	-	-
May-25	2,035		
<b>Total</b>	<b>2 470 759</b>	<b>7 004 343</b>	<b>9 527 035</b>

**Table 8. Female Sockeye escapement, fecundity, and survival in the Gates Creek system for the 2011 to 2014 broods (channel total of fry produced includes fry from before and after mark-recapture program). Note numbers of effective female spawners have been changes from previous reports to match finalized DFO numbers.**

	2011			2012			2013		
	Creek	Channel	Whole System	Creek	Channel	Whole System	Creek	Channel	Whole System
<b>Total female escapement</b>	25907	9779	35686	8336	9791	18127	22376	6510	28886
<b>Effective females</b>	21297	5163	26460	4311	2588	6899	17702	5302	23004
<b>Mean Fecundity</b>	3260	3260	3260	3119	3119	3119	3378	3378	3378
<b>Egg deposition</b>	69428220	16831380	86259600	13446009	8071972	21517981	59797356	17910156	77707512
<b>Fry produced</b>	10214909	5515083	15792991	2154746	2637647	4792393	12738610	2845029	15583639
<b>Egg-to-fry survival</b>	15%	33%	18%	16%	33%	22%	21%	16%	20%
<b>Fry per effective female</b>	480	1068	597	500	1019	695	720	537	677

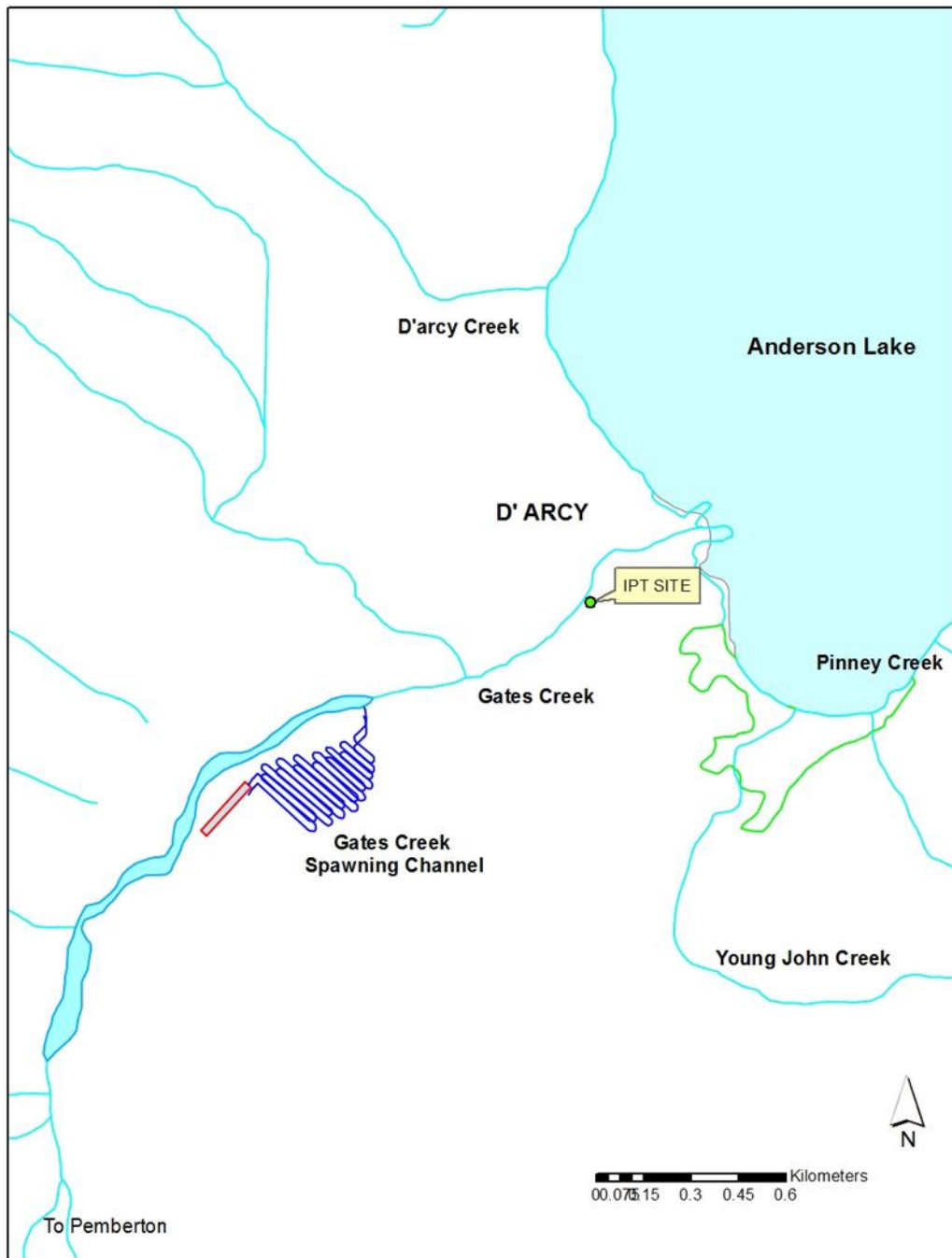
	2011			2012			2013		
	Creek	Channel	Whole System	Creek	Channel	Whole System	Creek	Channel	Whole System

<b>Total female escapement</b>	25 907	9 779	35 686	8 336	9 791	18 127	22 376	6 510	28 886
<b>Effective females</b>	21 297	5 163	26 460	4 311	2 588	6 899	17 702	5 302	23 004
<b>Mean Fecundity</b>	3 260	3 260	3 260	3 119	3 119	3 119	3 378	3 378	3 378
<b>Egg deposition</b>	69 428 220	16 831 380	86 259 600	13 446 009	8 071 972	21 517 981	59 797 356	17 910 156	77 707 512
<b>Fry produced</b>	10 214 909	5 515 083	15 792 991	2 154 746	2 637 647	4 792 393	12 738 610	2 845 029	15 583 639
<b>Egg-to-fry survival</b>	15%	33%	18%	16%	33%	22%	21%	16%	20%
<b>Fry per effective female</b>	480	1 068	597	500	1 019	695	720	537	677

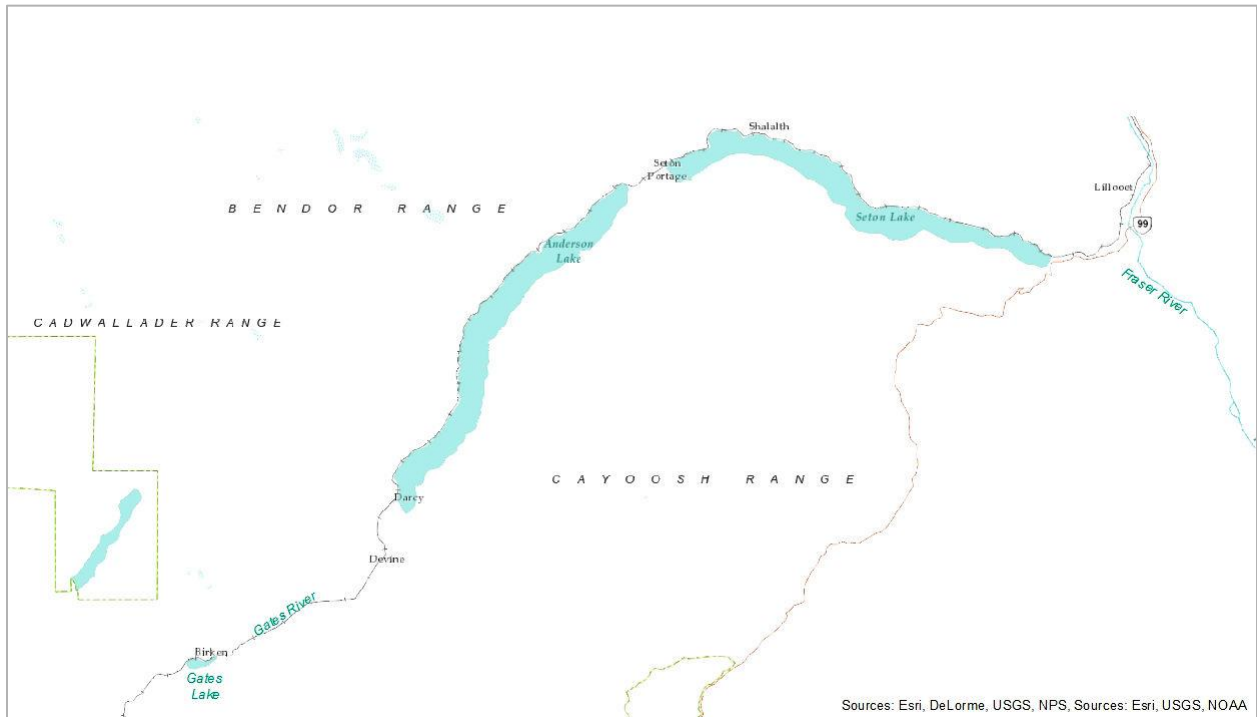
Table 8 Cont'd

	<b>2014</b>		
	Creek	Channel	Whole System
<b>Total female escapement</b>	6 160	3 739	9 899
<b>Effective females</b>	5 245	3 211	8 456
<b>Mean Fecundity</b>	3 358	3 358	3 358
<b>Egg deposition</b>	17 612 710	10 782 538	28 395 248
<b>Fry produced</b>	7 004 343	2 470 759	9 527 035
<b>Egg-to-fry survival</b>	40%	23%	33%
<b>Fry per effective female</b>	1 335	769	1 121

## FIGURES



**Figure 1. Overview of the study area including the Gates Creek spawning channel and trap site. Sites of spawning channel (10 U 536706 5599716) and IPT/RST (10 U 537151 5599978) are indicated.**



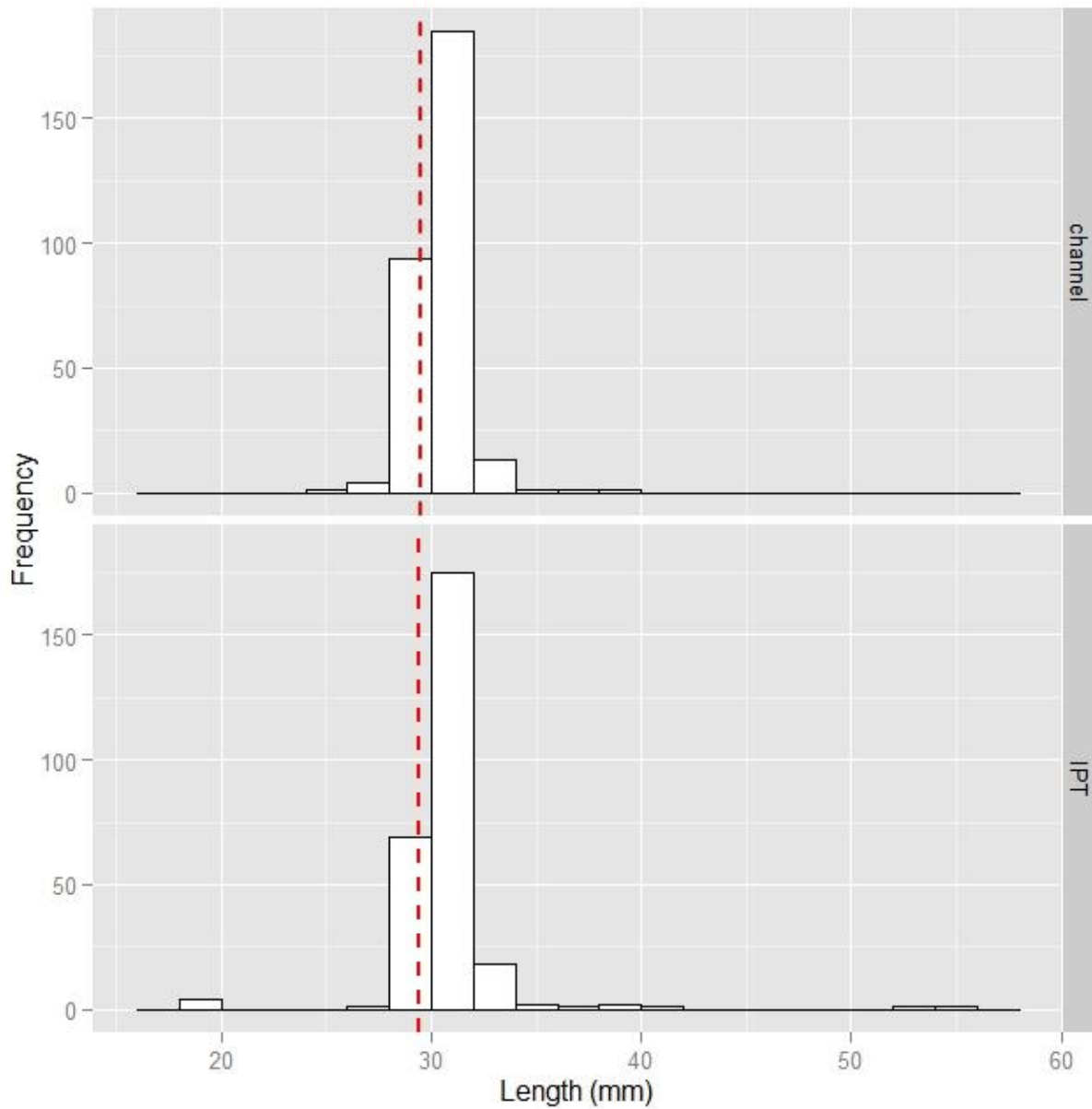
**Figure 2. Overview of the Seton-Anderson watershed in Southwestern British Columbia. Map also shows Gates Creek flowing from Gates Lake in Birken to Anderson Lake in D'Arcy.**



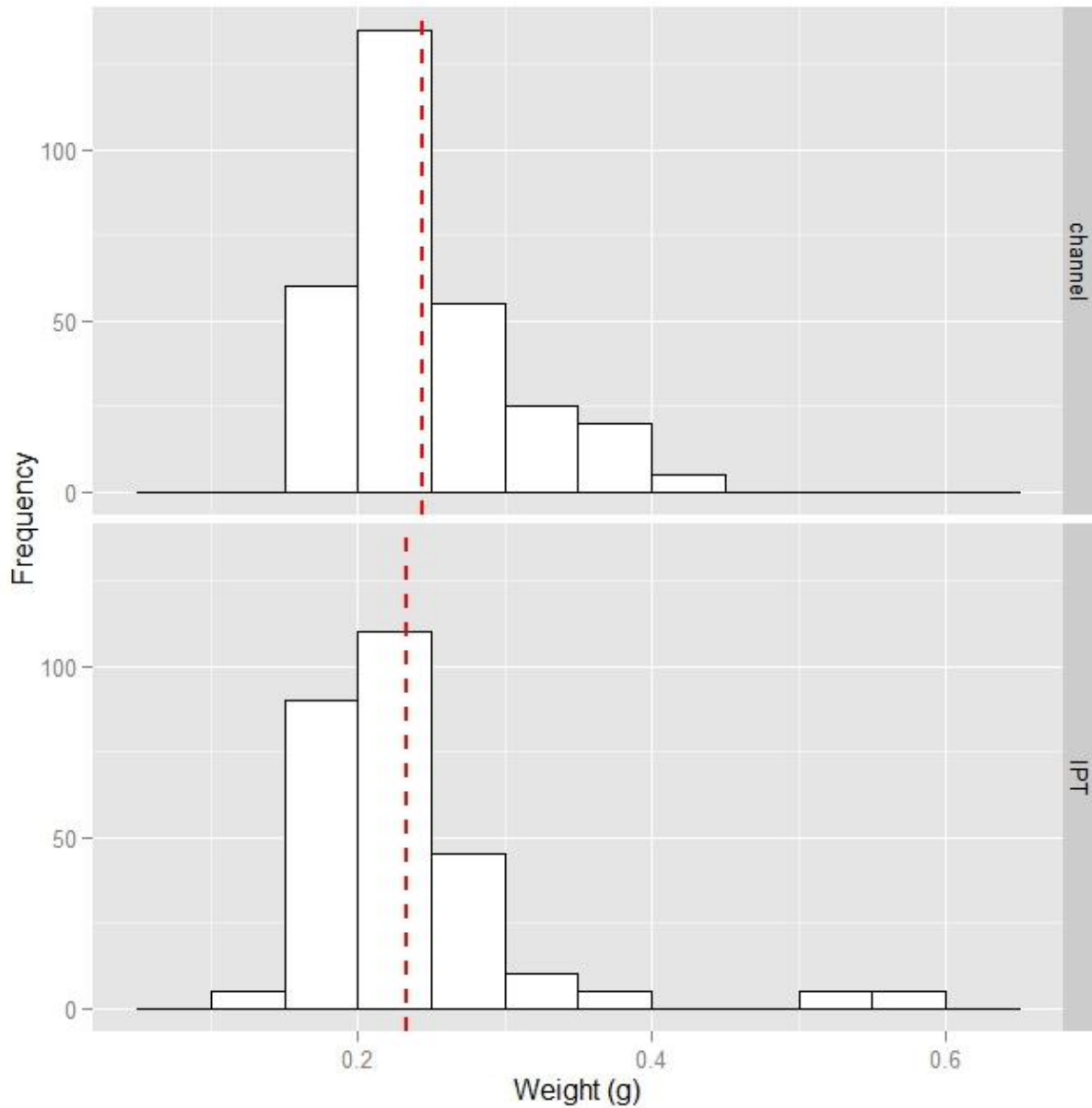
**Figure 3. Weir at the Gates Creek spawning channel. Fish are funnelled through the black sampler structure in the middle of the trough to the wood box visible on the left.**



**Figure 4. Inclined plane trap (left) and rotary screw trap (right) in Gates Creek.**



**Figure 5. Frequency distribution of juvenile Sockeye fork lengths (mm) leaving Gates Creek spawning channel (top panel) and Gates Creek (bottom panel) in spring 2015. Red dotted line indicates sample mean.**



**Figure 6. Frequency distribution of juvenile Sockeye weight (g) leaving Gates Creek spawning channel (top panel) and Gates Creek (bottom panel) in spring 2015. Red dotted line indicates sample mean.**

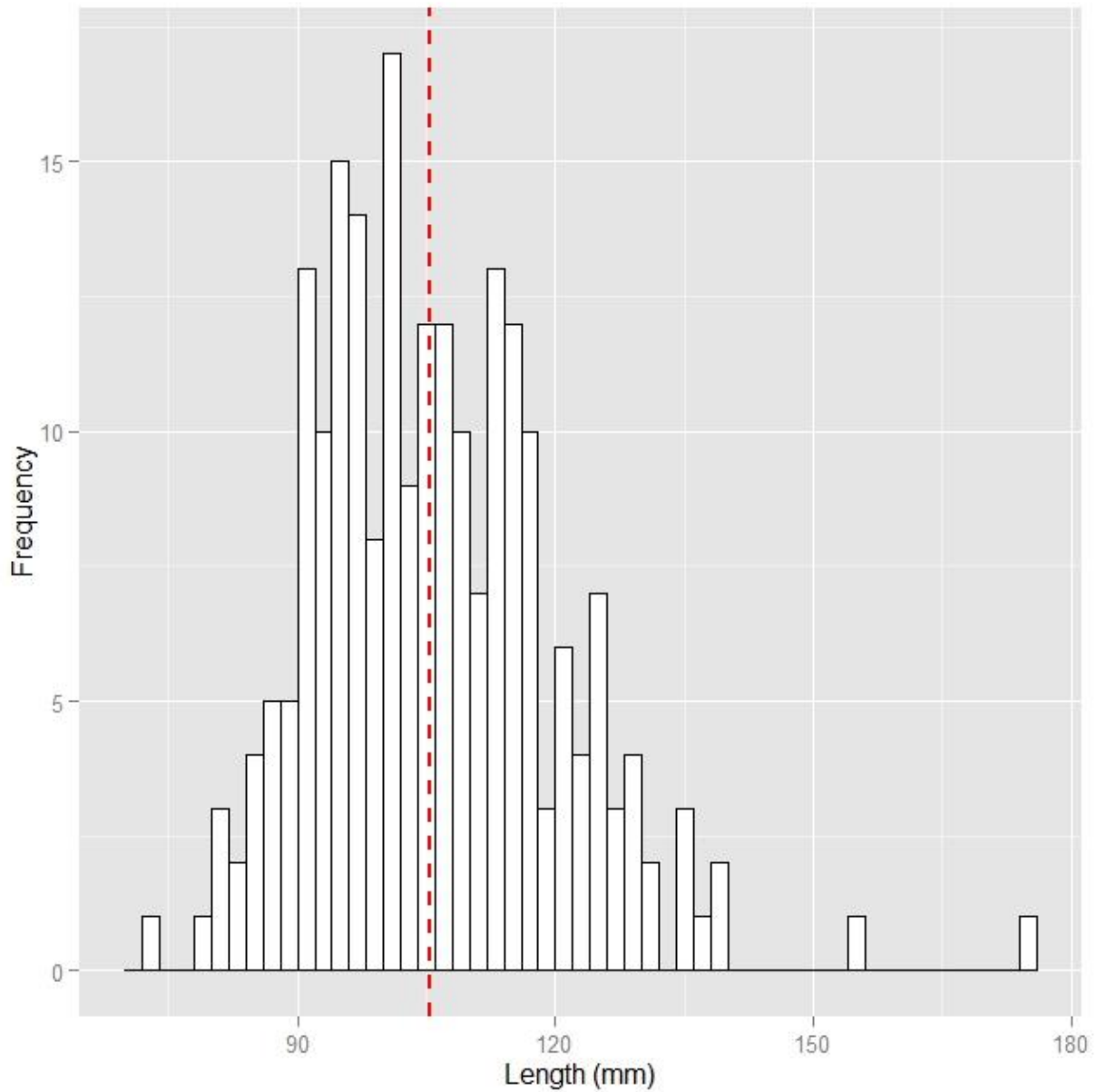
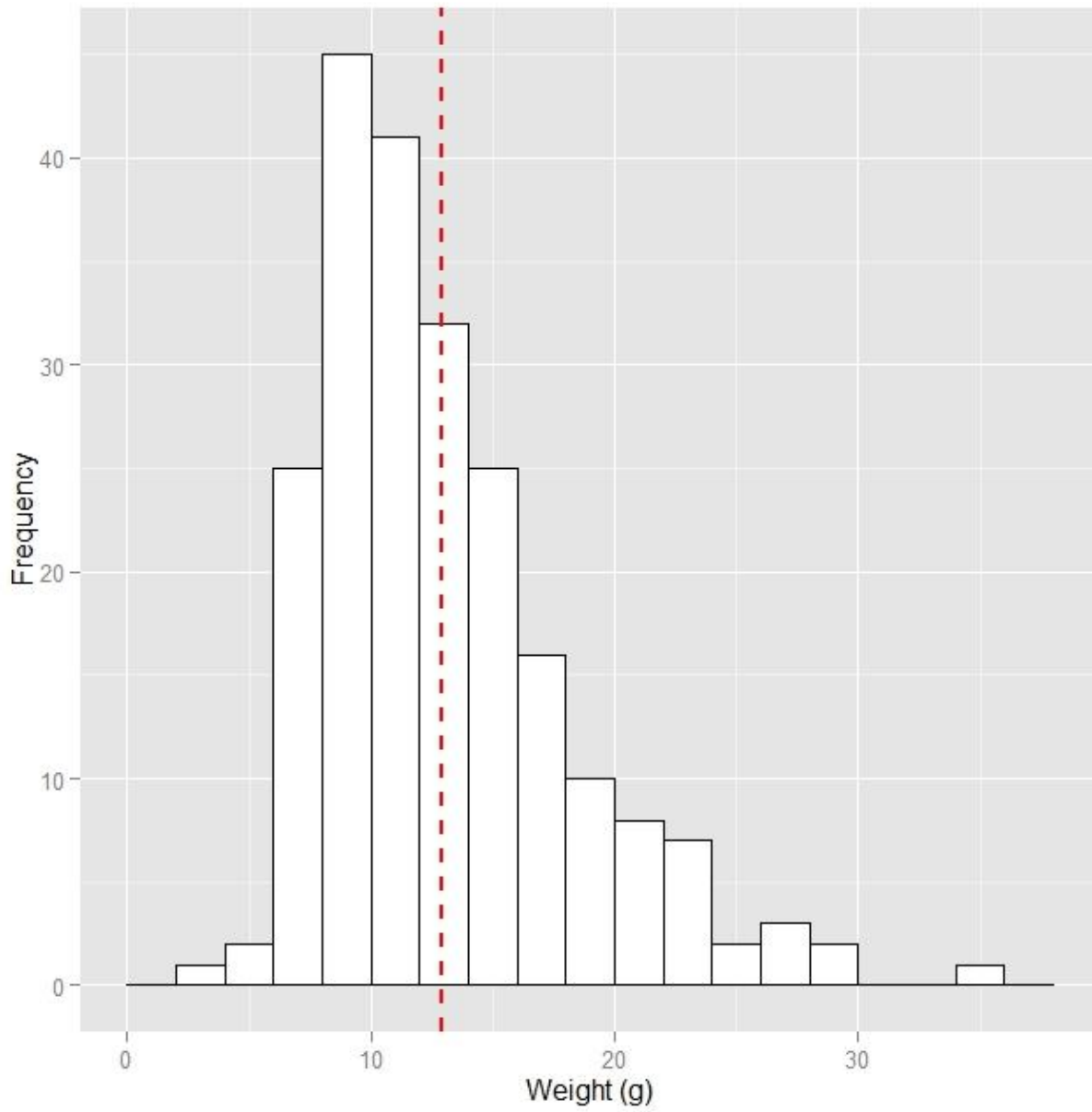
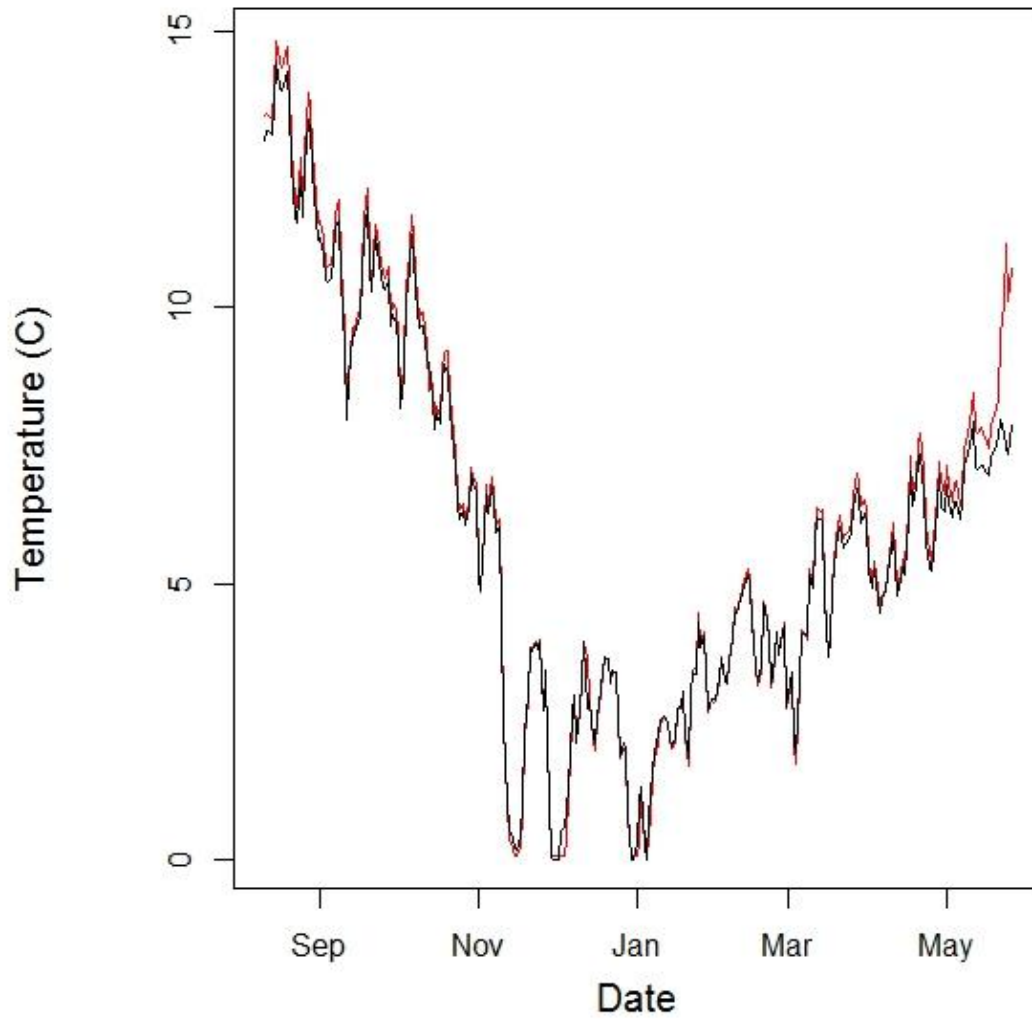


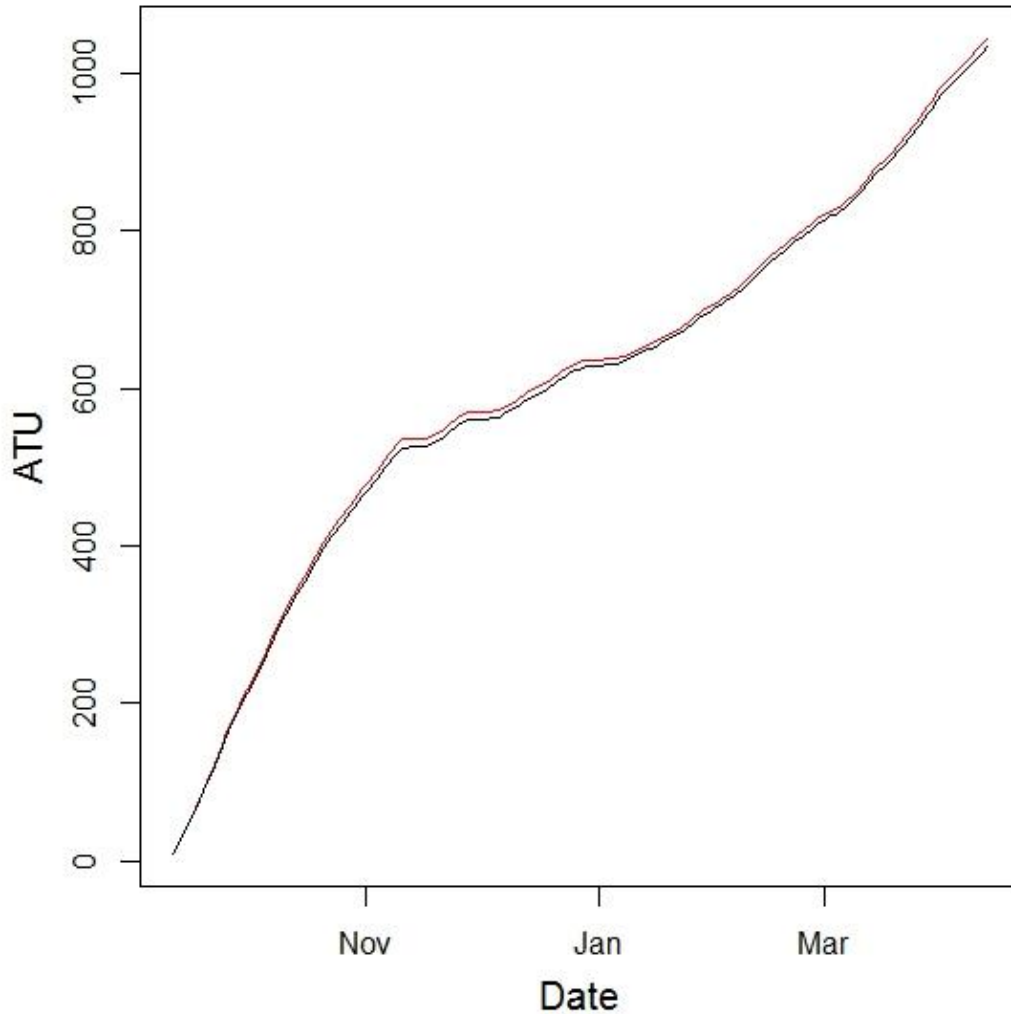
Figure 7. Frequency distribution of Coho smolt (1+) fork lengths (mm) leaving Gates Creek in spring 2015. Red dotted line indicates sample mean.



**Figure 8. Frequency distribution of Coho smolt (1+) weights (g) leaving Gates Creek in spring 2015. Red dotted line indicates sample mean.**



**Figure 9. Average daily temperatures from fall 2014 to spring 2015 in the Gates Creek spawning channel (red) and in Gates Creek (black).**



**Figure 10. Accumulated thermal units (ATU) from peak of spawn (week starting September 11<sup>th</sup> 2014) to peak of migration (week starting April 13<sup>th</sup> 2015) for Sockeye incubating and rearing in Gates Creek. ATU's are estimated from surface water temperatures collected by Tidbit v2 water temperature data loggers.**

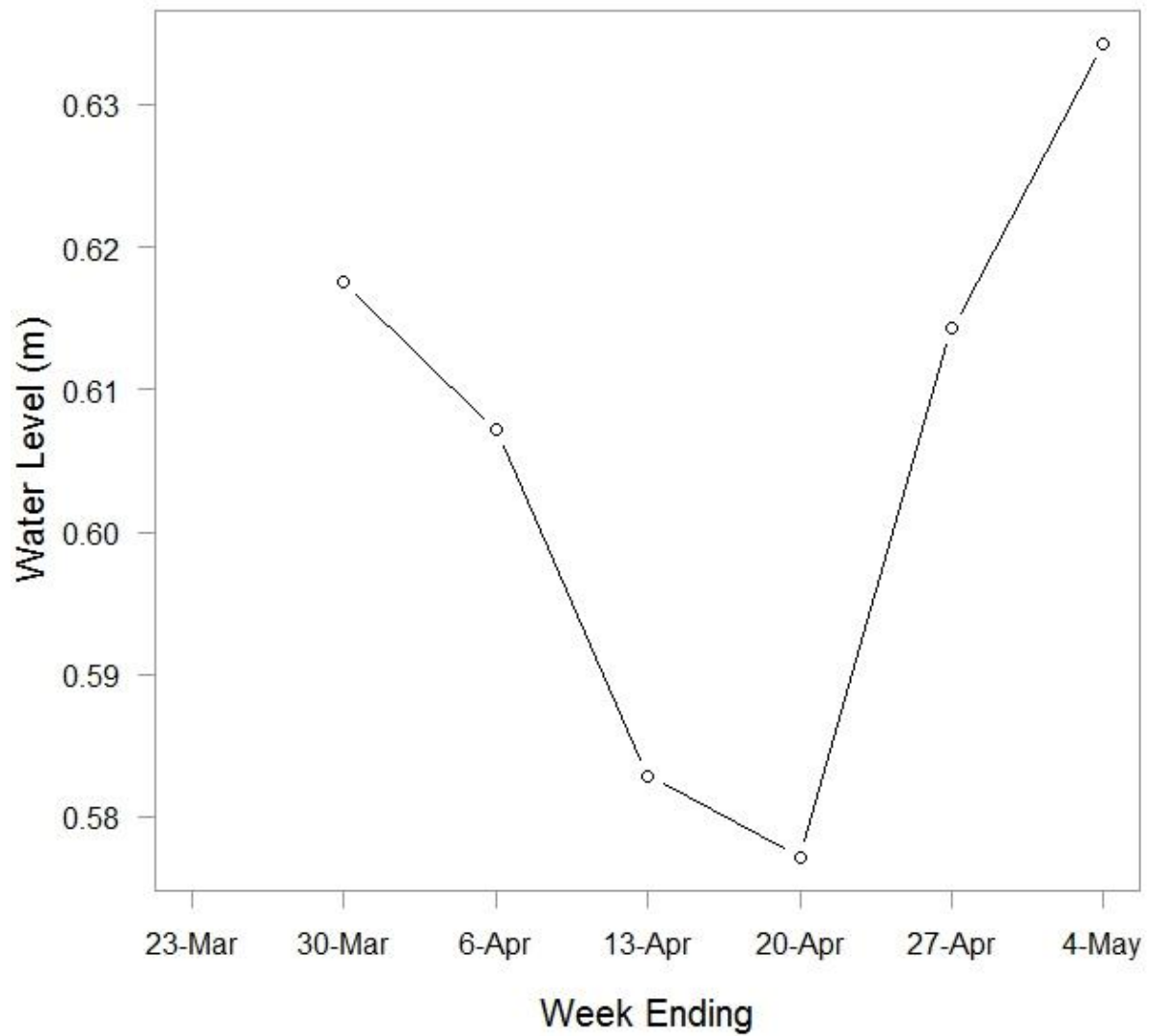
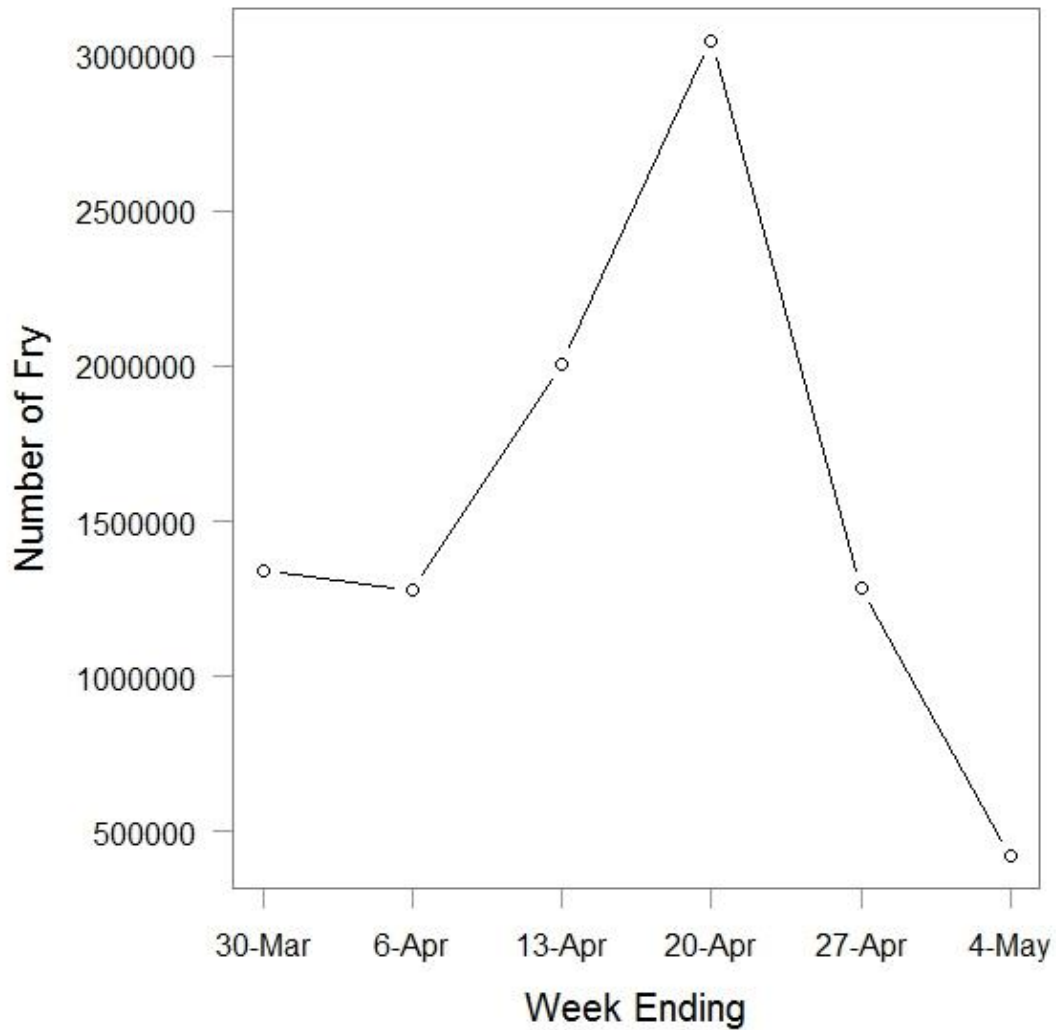


Figure 11. Average weekly water level (m) in Gates Creek (IPT site) in spring 2015.



**Figure 12. Run timing of Sockeye fry leaving the Gates Creek watershed in spring 2015. Total abundance estimates include fry from both Gates Creek and the Gates Creek spawning channel.**

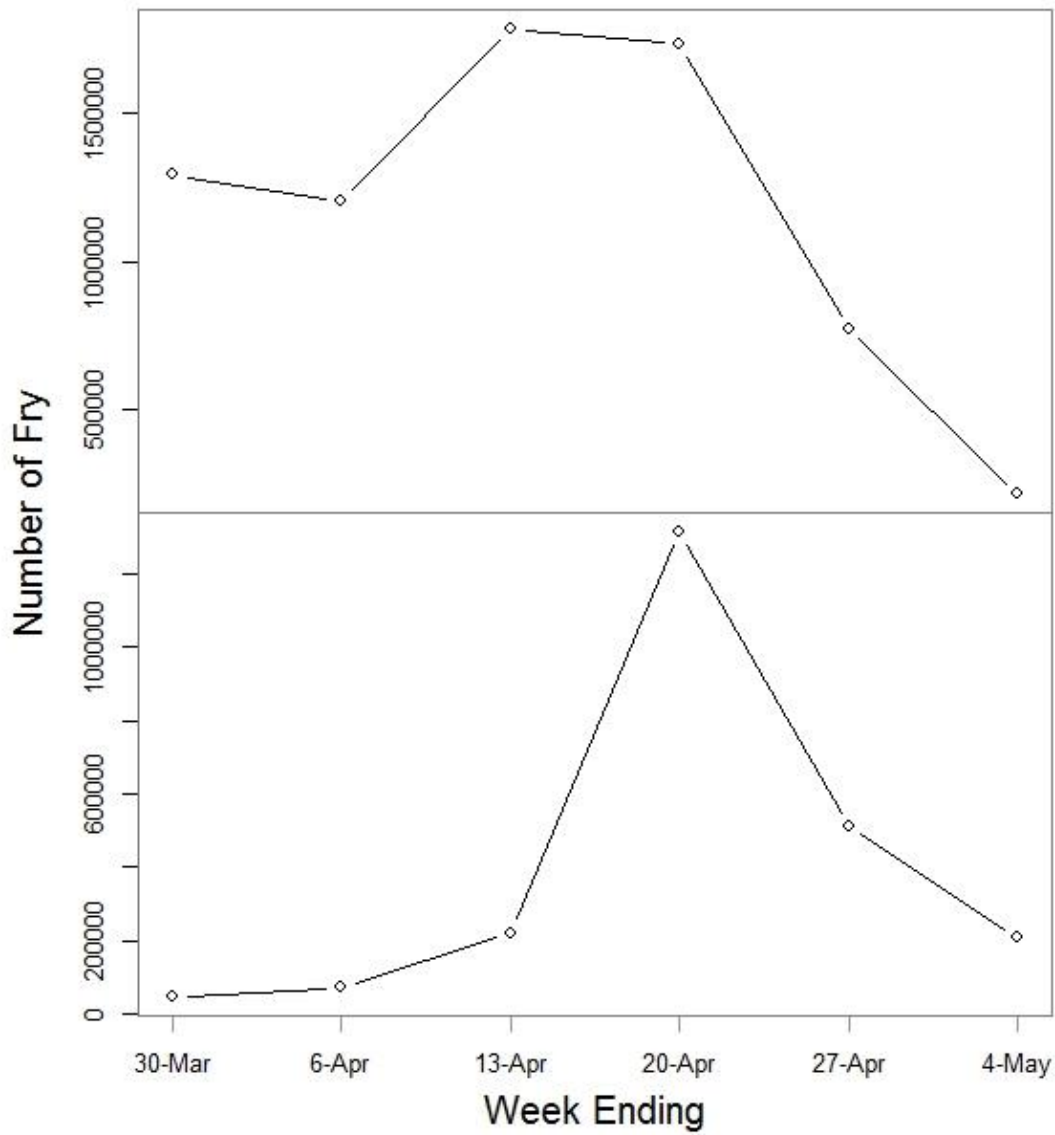


Figure 13. Run timing of Sockeye fry leaving Gates Creek (top) and the Gates Creek spawning channel (bottom) 2015 in spring 2015.

## REFERENCES

- Andrew FJ, and Green GH (1958) Sockeye and pink salmon investigations at the Seton Creek hydroelectric installation. Progress Report, International Pacific Salmon Commission, New Westminster, Canada. 78 p.
- Anon. (2001) Gates Creek assessment project. Creekside Resource Inc., Mount Currie, Canada. 35 p.
- Anon. (2009) Rehabilitation of Sockeye spawning gravel in the Gates Creek spawning channel-year 2. Northern St'at'imc Fisheries, Lillooet, Canada. 56 p.
- Anon. (2012) St'at'imc Draft Fisheries Implementation Plan. St'at'imc Government Service, Lillooet, Canada. 25 p.
- Arnason AN, Kirby CW, Schwarz C, J., and Irvine JR (1996) Computer analysis of data from stratified mark-recovery experiments for the estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106: 37 p.
- Bonner SJ and Schwarz C, J. (2011) Smoothed estimates for time stratified mark-recapture experiments using Bayesian p-splines. *Biometrics* 67: 1498-1507.
- Bonner SJ and Schwarz C, J. (2012) An application of a bayesian stratified-petersen model to estimate the number of outgoing fish on the Cheakamus River, British Columbia. BC Hydro. 119 p. Available at: <http://people.stat.sfu.ca/~cschwarz/Consulting/BCHydro-2012-04-04/Report-2012-04-04.pdf> .
- Bradford MJ (1995) Comparative review of Pacific salmon survival rates. *Canadian Journal of Fisheries and Aquatic Sciences* 52: 1327-1338.
- Crossin GT, Hinch SG, Cooke SJ, Welch DW, Patterson DA, Jones SRM, Lotto AG, Leggatt RA, Mathes MT, Shrimpton JM, Van Der Kraak G and Farrel AP (2008) Exposure to high temperature influences the behaviour, physiology, and survival of sockeye salmon during spawning migration. *Canadian Journal of Zoology*. 86(2): 127-140.
- Dutang C, Goulet V and Pigeon M (2008) Actuar: an R package for actuarial science. *Journal of Statistical Software* 25(7): 1-37.
- Einum S and Flemming IA (2000) Selection against late emergence and small offspring in Atlantic Salmon (*Salmo salar*). *Evolution*. 54(2): 628-639.
- Fretwell MR (1989) Homing behaviour of adult Sockeye salmon in response to a hydroelectric diversion of homewater at Seton Creek. *International Pacific Salmon Commission Bulletin* 25: 38 p.

- Grey D (2013) Fine sediment removal from streams; environmental effects, protocols and a proposed rule. Environment Canterbury Regional Council. 73 p.
- Henderson MA and Cass AJ (1991) Effect of smolt size on smolt-to-adult survival for chilko lake Sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fish and Aquatic Science. 48: 988-994.
- Hillaby J (2012) Late summer distribution of juvenile Coho salmon in the Gates Creek watershed. BC Hydro. 63 p.
- Komori V (1997) Strategic fisheries overview for the Bridge/ Seton habitat management area. Fraser River Action Plan, Department of Fisheries and Oceans, Vancouver, Canada. 83 p.
- Lingard S, Ladell J and McCubbing D (2013) Gates Creek Juvenile Salmonid Outmigration Assessment, Spring 2013. Prepared for the Lillooet Tribal Council and Department of Fisheries and Ocean, Canada, Instream Fisheries Research, Inc., North Vancouver, Canada. 33 p.
- Lingard S, Ladell J and McCubbing D (2014a) Gates Creek adult Sockeye abundance fall 2014. Prepared for the Lillooet Tribal Council and Department of Fisheries and Oceans, Canada, Instream Fisheries Research, Inc., North Vancouver, Canada. 20 p.
- Lingard S, Ladelle J and McCubbing D (2014b) Gates Creek Juvenile Salmonid Outmigration Assessment, Spring 2014. Prepared for the Lillooet Tribal Council and Department of Fisheries and Ocean, Canada, Instream Fisheries Research, Inc., North Vancouver, Canada. 33 p.
- Lunn D, Spiegelhalter D, Thomas A and Best N (2009) The BUGS project: Evolution, critique and future directions (with discussion). Statistics in Medicine. 28: 3049-3082
- Martins EG, Hinch SG, Patterson DA, Hague MJ, Cooke SJ, Miller KM, Robichaud D, English KK and Farrel AP (2012) High river temperature reduces survival of sockeye salmon (*Oncorhynchus nerka*) approaching spawning grounds and exacerbates female mortality. Canadian Journal of Fisheries and Aquatic Sciences. 69(2): 330-342.
- Melville CC and McCubbing DJF (2001) Assessment of the 2000 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 42 p.
- Melville CC and McCubbing DJF (2002a) Assessment of the 2001 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 53 p.
- Melville CC and DJF McCubbing. 2002b. Assessment of the 2002 Juvenile Salmon Migration from the Cheakamus River, using Rotary Traps. BC Hydro WUP Report. 36p.
- Melville CC and McCubbing DJF (2003) Assessment of the 2003 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report.

- Melville CC and McCubbing DJF (2004) Assessment of the 2004 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 80 p.
- Melville CC and McCubbing DJF (2006) Assessment of the 2005 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 76 p.
- Melville CC and McCubbing DJF (2007) Assessment of the 2006 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 71 p.
- Melville CC and McCubbing DJF (2008) Assessment of the 2007 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 104 p.
- Melville CC and McCubbing DJF (2009) Assessment of the 2008 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 103 p.
- Melville CC and McCubbing DJF (2010) Assessment of the 2009 juvenile salmon migration from the Cheakamus River, using rotary traps. BC Hydro WUP Report. 114 p.
- Melville CC and McCubbing DJF (2011) Cheakamus River juvenile salmonid outmigration enumeration assessment, spring 2010. Cheakamus River Water Use Plan Report. 118 p.
- Melville CC and McCubbing DJF (2012) Cheakamus River juvenile salmonid outmigration enumeration assessment summary report 2001-2012. Cheakamus River Water Use Plan Report, North Vancouver, Canada. 92 p.
- Melville CC and McCubbing DJF (2002b) Assessment of the 2002 juvenile salmon migration in the Cheakamus River, using rotary traps., Instream Fisheries Research, Inc. 36 p.
- Murray CB and McPhail JD (1987) Effect of incubation temperature on the development of five species of Pacific salmon (*Oncorhynchus*) embryos and alevins. Canadian Journal of Zoology. 66: 266-273.
- Patterson DA, Hague MJ (2008) Evaluations of the potential freshwater factors linked to the decline of early and late Stuart Sockeye Salmon: SEF Final Report. Fisheries and Oceans Canada. 260 p.
- Plummer M, Best N, Cowles K and Vines K (2006) CODA: convergence diagnosis and output analysis for MCMC. R News 6: 7-11.
- Quinn TP (2005) The Behaviour and Ecology of Pacific Salmon and Trout. University of Washington Press, Seattle, U.S.A. 378 p.
- Ramos- Espinoza D and McCubbing DJF (2012) Seymore River juvenile salmonid outmigration monitoring, Spring 2012. Prepared for Metro- Vancouver Policy and Planning Department- Utility Analysis & Environmental Management Division, Instream Fisheries Research, Inc., North Vancouver, Canada. 54 p.
- Ricker WE (1975) Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191: 382.

- Seber GAF (2002) The estimation of annual animal abundance and related parameters. Blackburn Press, New Jersey, USA. 676 p.
- Shepherd BG, Hartman GF and Wilson WJ (1986) Relationships between stream and intragravel temperatures in coastal drainages, and some implication for fisheries workers. Canadian Journal of Fish and Aquatic Science. 45: 1818-1822
- Sogard SM (1997) Size-selective mortality in the juvenile stage of teleost fishes: a review. Bulletin of Marine Science. 60(3): 1129-1157.
- Sturtz S, Ligges U and Gelman A (2005) R2WinBUGS: a package for running WinBUGS from R. Journal of Statistical Software. 12(3): 1-16.
- Talbot GB (1950) A biological study of the effectiveness of the Hell's Gate fishways. Bulletin 3, International Pacific Salmon Commission, New Westminster, Canada. 80 p.
- West CJ, and Larkin PA (1987) Evidence of size- selective mortality of juvenile Sockeye salmon (*Oncorhynchus nerka*) in Babine Lake, British Columbia. Canadian Journal of Fish and Aquatic Science. 44: 712-721.
- Zydlewski GB, Haro A, and McCormik SD (2005) Evidence for cumulative temperature as an initiating and terminating factor in downstream migrator behavior of Atlantic salmon (*Salmo salar*) smolts. Canadian Journal of Fisheries and Aquatic Sciences. 62(1): 68-78.

## Section 2.0- Adult Sockeye Assessment Fall 2015

## Executive Summary

This report presents the results of the 2015 adult component of the Gates Creek salmonid assessment project. The fall of 2015 marks the final year of a four year study monitoring egg to fry survival and salmonid abundance in both Gates Creek and the Gates Creek spawning channel.

The data from the adult components of this report are collected to compliment juvenile Sockeye Salmon abundance data to be collected for the Gates Creek spawning channel in the spring of 2016. The abundance, fecundity and percent spawn data from this report will be used to generate estimates of egg to fry survival for both Gates Creek spawning channel in the spring of 2016.

The first Sockeye arrived at Gates Creek on August 18<sup>th</sup> in 2015. The total estimated abundance of Sockeye returning to the Gates Creek watershed was 20,755 for the fall of 2015. Of the total abundance, a total of 12,755 fish were estimated to have spawned in Gates Creek, 93 were estimated to spawn in Spruce and Haylmore Creek and 7,479 were estimated to have ascended the spawning channel.

Mean fecundity for females sampled from the spawning channel was 3,216 (SD 644). Overall percent spawn for the watershed was estimated to be 92.6%. A total of 3,484 and 6,159 females successfully completed spawning in the spawning channel and Gates Creek, respectively. Egg deposition for Gates Creek was estimated to be 11,204,544 for the spawning channel and 19,807,344 for Gates Creek in the fall of 2015.

## Table of Contents

Section 2.0- Adult Sockeye Assessment .....	50
1.0 INTRODUCTION .....	56
2.0 METHODS .....	58
2.1 Loading Strategy .....	58
2.2 Temperature Monitoring .....	58
2.3 Generation of Abundance Estimates .....	59
2.3.1 Visual Survey Validation of Counter(s) .....	59
2.3.2 Video Validation of Counters .....	60
2.4 Classification of Female Percent Spawn .....	60
2.5 Fecundity Sampling .....	61
2.6 Percent Spawn and Total Egg Deposition .....	61
3.0 RESULTS .....	63
3.1 Temperature Monitoring .....	63
3.2 Video Validation .....	63
3.3 Abundance Estimates .....	63
3.3.1 Spawning Channel .....	63
3.3.2 Gates Creek.....	64
3.3.3 Spruce and Haylmore Creek.....	64
3.4 Fecundity and Female Size .....	64
3.5 Percent Spawn and Egg Deposition .....	65
3.5.1 Spawning Channel .....	65
3.5.2 Gates Creek.....	65
4.0 DISCUSSION.....	66
4.1 Temperature Monitoring .....	66
4.2 Counter Operations and Visual Survey/ Video Validation .....	66
4.3 Migration Timing and Sockeye Abundance .....	67
4.3.1 Migration Timing.....	67
4.3.2 Sockeye Abundance.....	67
4.4 Fecundity and Egg Deposition.....	68

4.5 Percent Spawn ..... 68  
Summary and Recommendations ..... 69  
TABLES ..... 72  
FIGURES ..... 82  
REFERENCES ..... 91

**LIST OF TABLES**

Table 9. Temperature data from TidbiT v2 Water Temperature Data Loggers in Gates Creek and Gates Creek spawning channel. Temperatures were logged every 15 minutes but are summarized as mean average daily temperature, Fall 2014 ..... 73

Table 10. Video validation data for mechanical counter in Gates Creek, Fall 2014 ..... 74

Table 11. Summary of Sockeye abundance estimates for Gates Creek spawning channel collected via visual surveys 2011-2014 ..... 75

Table 12. Summary of adult Sockeye abundance estimates for Gates Creek 2011- 2014. Abundance estimates for Gates Creek are developed using a combination of data from visual surveys and the mechanical counter ..... 76

Table 13 Summary of adult Sockeye abundance for Anderson Lake shore 2011-2014. Abundance estimates developed from visual survey data collected by DFO stock assessment 77

Table 14 Summary of adult Sockeye abundance for the Gates Creek Watershed from 2011-2014..... 78

Table 15. Mean fecundity and post-orbital hypural (POH) length (cm) in Gates Creek spawning channel females Sockeye for 2011 - 2014 ..... 79

Table 16. Break down of female percent spawn in Gates Creek spawning channel from visual survey data 2011 - 2014..... 80

Table 17. Estimated number of effective females, mean fecundity and egg deposition for the 2011-2014 brood years for Sockeye spawning in Gates Creek and Gates Creek spawning channel (estimates of effective females for Gates Creek were provided by DFO unpublished data) ..... 81

**LIST OF FIGURES**

Figure 15. Overview of Seton-Anderson watershed in South Western British Columbia ..... 83

Figure 16. Map of study area including Gates Creek and spawning channel near confluence with Anderson Lake. Also shown is the trap site for the juvenile monitoring component of the study..... 84

Figure 17. Schematic diagram of enumeration equipment at confluence of Gates Creek and Gates Creek spawning channel spawning channel..... 85

Figure 18. Average daily temperature in Gates Creek (dotted black line) and Gates Creek spawning channel (grey line) over the Sockeye spawning period from August 10<sup>th</sup> to October 6<sup>st</sup>, 2014 ..... 86

Figure 19. Scatter plot with fitted regression line ( $y= 159.3x+ -4459.7$ ,  $R^2 0.6127$ ) of post-orbital hypural (POH) length (cm) and female fecundity (number of eggs) in Gates Creek Sockeye, Fall 2014 ..... 87

Figure 20. Distribution of female percent spawn over the fall 2014 Sockeye spawning period at Gates Creek spawning channel. Red, blue and black lines represent 0, 50 and 100% spawned females respectively ..... 88

Figure 21 Temperature data for Fraser River at Mission for summer 2014 Sockeye migration window (<http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/reports-rapports/2014/2014-08-28/2014-08-28-eng.html>)..... 89

Figure 22 Total annual adult Sockeye (\*10<sup>2</sup>) loaded into Gates Creek Spawning channel (black solid line) plotted with annual percent spawn (dotted grey line) 1996-2014 (DFO unpublished data) ..... 90

## INTRODUCTION

Gates Creek is a major salmon bearing tributary of the Seton-Anderson Watershed and runs 12 kilometres from Gates Lake to Anderson Lake draining approximately 34,300 hectares (Komori 1997) (Figure 14). The Seton-Anderson watershed is located approximately 200 km north of Vancouver in the rain shadow of the southern Coast Mountains (Anon. 2000) and contains no glaciers. Anderson Lake is connected to Seton Lake via the Portage Creek, and Seton Lake drains into the Fraser River via Seton River (Figure 14). Gates Creek supports a population of Fraser River Sockeye Salmon (*Onchorynchus nerka*) that is important for First Nation, commercial and recreation fisheries, as well as smaller populations of Coho Salmon (*O. kisutch*), and Pink Salmon (*O. gorbuscha*).

The over 100 populations of Fraser River Sockeye are assigned into four distinct run timing groups based on the time period they enter freshwater to begin their upstream migration: Early Stuart, Early Summer, Summer and Late Summer. Gates Creek Sockeye fall into the early summer run-timing group entering the Fraser River from mid-July through to mid-August. Gates Creek Sockeye along with the Portage River population form the Anderson-Seton-ES conservation unit (Anon 2012). Fraser River Sockeye face numerous challenges during their upriver migration including recreational and commercial fisheries in the lower portion of the Fraser River and turbulent flows in the Fraser Canyon. Mean summer water temperature in the Fraser River has warmed ~2.0°C since the 1950's (Patterson et al. 2007) and is forecasted to continue to increase with climate change (Morrison et al. 2002, Ferrari et al. 2007). High temperatures have been associated with increased energetic demands, susceptibility to infection, and reduced spawning success in Pacific salmon (Lee et al. 2003, Crossin et al. 2008).

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

In 1968, a Sockeye specific spawning channel was constructed by the International Pacific Salmon Fisheries Commission (IPSFC) in Gates Creek 800 m upstream of Anderson Lake to enhance Sockeye escapement in the Seton-Anderson watershed (**Figure 15**). The spawning channel was originally overseen by the IPSFC and Fisheries and Oceans Canada (DFO). In 1987, responsibility for channel maintenance and monitoring was turned over to the N'Quatqua First Nation with technical oversight from DFO. A gravel replacement project was undertaken in 2008 and 2009 by DFO and the Fish and Wildlife Compensation Program (FWCP) with the goal of increasing egg-to-fry survival in Gates Creek spawning channel (Anon. 2009). In addition to gravel replacement, changes were made to channel structure and gradient during this project (Anon. 2009). While a long standing time series of juvenile and adult abundances are available for Gates Creek spawning channel, detailed assessment of the gravel replacement activities had yet to be undertaken. Previous to this study, data regarding Sockeye egg-to-fry survival and abundance from Gates Creek had never been collected.

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

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

This report summarizes the findings of the 2015 adult component of the study.

## **METHODS**

### ***1.1 Loading Strategy***

The Gates Creek spawning channel and Gates Creek are loaded with a known number of adults using a full channel weir and mechanical counters. Fish are excluded from Gates Creek by a full span diversion fence installed on the creek adjacent to the spawning channel out-flow (Figure 16). A second exclusion fence which houses the mechanical counters is installed in the spawning channel (Figure 16). The mechanical counters are similar to those used on subway entry gates which count a single up count as the gate is pushed past a trigger point. There are three counters on the exclusion fence with openings large enough for a single Sockeye salmon to enter at a time. Two of the gateways direct fish into the spawning channel. The third gate is attached to a culvert which returns fish approximately 100 m underground into Gates Creek above the diversion fence. Counter gates are lockable allowing fish to be directed into either the spawning channel or the creek based on a management strategy directed by DFO advisory staff. Ideally, the channel and creek are loaded so fish from each portion of the run are present in equal proportions in each environment.

The first Sockeye arrived at Gates Creek on August 18<sup>th</sup>, 2015. Sockeye were loaded into Gates Creek and the Spawning Channel concurrently through out the fall of 2015. The last Sockeye were counted into the on September 14<sup>th</sup>, 2015.

### ***1.2 Temperature Monitoring***

Pairs of Onset TidbiT v2 Water Temperature Data Loggers (accuracy range of 0.2°C) were placed in the spawning channel and Gates Creek in the summer of 2015. The loggers in the spawning channel were placed at the bottom leg. In Gates Creek the loggers were placed at the upper limit of the habitat used by Sockeye, near the Davidson horse farm (UTM 10535385E, 5596420N). Temperature was logged every 15 minutes. For analysis data was condensed to average daily temperature (°C).

### **1.3 Generation of Abundance Estimates**

Abundance estimates for Gates Creek and the spawning channel were generated using a combination of counter totals, visual survey data and video validation in the fall of 2015. In the spawning channel a visual survey was used to generate the total escapement for the entire channel. Visual foot surveys in Gates Creek are used to determine percent spawn and sex ratios, but do not validate the counter totals. To evaluate counter efficiency a secondary count is necessary for providing estimates of counter efficiency. In Gates Creek a combination of counter totals and video data were used to generate total abundance estimates.

#### **1.3.1 Visual Survey Validation of Counter(s)**

##### *Spawning Channel*

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

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

##### *Gates Creek*

Weekly visual surveys in Gates Creek are conducted by N'Quatqua technicians in conjunction with DFO stock assessment personnel. N'Quatqua technicians accompany DFO personnel on weekly visual surveys. Visual surveys in Gates Creek follow the same protocols for classification of percent spawn as outlined above for the spawning channel. However, in

Gates Creek only a sample of individuals are enumerated from the population as it would be unfeasible to recover all carcasses in an unmanaged environment. The primary objective of visual surveys in Gates Creek above the counting fence (exclusion fence) is to obtain sex ratio and percent spawn estimates, which are later applied to the total escapement estimates obtained by the mechanical counter. Downstream of the fence, weekly visual surveys include a live count as well as carcass recovery. Peak live count plus the cumulative carcass recovery to that date are used to generate an estimate of the number of spawners in the portion of Gates Creek below the fence. The visual survey data are collected by DFO stock assessment and are reported back as final estimates.

### 1.3.2 Video Validation of Counters

In 2015 video footage of fish passing through the mechanical counters was recorded. The counter totals were recorded at the start and end of each video clip. To achieve an estimate of counter efficiency, the total number of fish counted by the counter for all video segments was compared to the total number seen in all video segments combined.

Video was only recorded for the counter into Gates Creek as the spawning channel counters are validated via visual surveys.

## **1.4 Classification of Female Percent Spawn**

In 2011 inconsistencies were identified in survey methods employed by N'Quatqua technicians on the channel and the criteria used to estimate percent spawn of female carcasses on the creek by DFO stock assessment personnel. In an effort to eliminate these inconsistencies the N'Quatqua technicians accompanied DFO stock assessment staff during weekly Gates Creek enumeration activities in both the fall of 2012-2015. In general, the method of estimating female percent spawn is highly subjective and requires technicians to classify female mortalities as 0%, 50%, or 100% spawned. By DFO stock assessment definition a female Sockeye is categorized as:

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

To allow continuity of data collection between DFO and N'Quatqua Fisheries technicians, the above listed criteria were used for assessment of percent spawn in Sockeye females in Gates Creek and spawning channel in 2015.

### **1.5 Fecundity Sampling**

Mean fecundity of female Sockeye was estimated using intact egg skeins from 60 un-spawned (0%) females taken from the spawning channel. All sampled individuals were natural pre-spawn mortalities. Samples were distributed over the duration of the spawning period lasting from August 24<sup>th</sup> to September 10<sup>th</sup>. Post-orbital hypural (POH) lengths (cm) were taken for each fish. Total gonad weight (raw and water hardened) (g) was recorded for each female. A sub sample of 100 water hardened eggs was weighed from each fish. The sub sample weight was divided into the total gonad weight (water hardened) to arrive at the total number of eggs for each female. Full count of all eggs was carried out for 15% of the fish for verification of volume sampling technique.

### **1.6 Percent Spawn and Total Egg Deposition**

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

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

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

Where:

PS= Percent spawn

PSM= Pre-spawn mortality

S= Spawned females (100%)

U= Un-spawned females (0%)

P= Partial spawned females

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

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

$$ED = EF * MF$$

Where:

ED= Estimated egg deposition

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

MF= Mean fecundity

## RESULTS

### ***2.1 Temperature Monitoring***

The water level in the spawning channel was decreased part way through the spawning period in response to an up stream landslide. The decreased water levels resulted in the temperature loggers being above water for the majority of the spawning period. As such, no temperature data was available for the spawning channel in the fall of 2015.

Average daily water temperature in Gates Creek between August 1<sup>st</sup> and November 1<sup>st</sup>, 2015 ranged from 5.4°C to 13.8°C (Table 9, Figure 17).

### ***2.2 Video Validation***

Video validation indicates the creek counter inflated the count of the number of fish passing into Gates Creek by 27% in 2015. Total counts by the Gates Creek counter over the 42.5 hours of video was 1701 and the total number of fish observed in all video segments was 1242 (Table 10).

### ***2.3 Abundance Estimates***

The first Sockeye arrived at the exclusion fence on August 18<sup>th</sup>, 2015. From August 18<sup>th</sup> to September 14<sup>th</sup> a total of 12,755 (17,364 before adjustment) fish were counted into Gates Creek. Of the total fish counted into Gates Creek, 93 spawners were observed in Spruce and Haylmore Creeks in the fall of 2015. From August 18<sup>th</sup> to September 14<sup>th</sup> a total a total of 8,892 fish were counted into the channel by the counters.

#### **2.3.1 Spawning Channel**

The total estimated abundance of the 2015 brood for Gates Creek Sockeye from visual surveys was 7,479. Of the total abundance females represented 53% (3,941), and males (including 810 jacks) represented 47% (3,538) (Table 11).

### 2.3.2 Gates Creek

Visual survey data is collected and processed by DFO stock assessment staff for Gates Creek. DFO estimated (adjusted for counter efficiency for above the fence) a total of 12,755 Sockeye returned to spawn in Gates Creek in the fall of 2015. Of the total abundance, males represented 49% (6,282 including 1,224 jacks) and females represented 51% (6,473). The ratio of males (including jacks) to females was 1:1.03 in fall 2015 (Table 12).

### 2.3.3 Spruce and Haylmore Creek

In addition to spawning in Gates Creek and the spawning channel adult Sockeye were observed spawning on in Spruce and Haylmore Creeks, tributaries of Gates Creek. Of the four years surveyed for this study, 2015 is the only year spawner counts have been collected for these two creeks. In Spruce Creek, a total of 22 spawners were observed (9 males, 11 females and 2 jack males). In Haylmore Creek, a total of 71 spawners were observed (28 males, 36 females and 7 jack males) (Table 13, Table 15).

## 2.4 Fecundity and Female Size

Mean POH length and fecundity for the females sampled for fecundity from spawning channel in 2014 were estimated to be 48.9 cm (SD 2.0) and 3,216 (SD 644), respectively (Table 16). The linear relationship between POH length and fecundity for Sockeye sampled from Gates Creek spawning channel in 2015 can be expressed by the equation:

$$y = 175.9x + -5401.4 (R^2 = 0.276)$$

where

y= the number of eggs, and

w= POH length in cm

This regression analysis (**Figure 18**) shows a positive relationship between egg number and POH ( $R^2 = 0.276$ ) with approximately 28% of variability in egg number being explained by POH in 2015.

In 2015, mean female fecundity ranged from a minimum of 2,165 to a maximum of 4,231 (Table 16). Female Sockeye measured at Gates Creek spawning channel for fecundity sampling ranged in POH length from 44.7 cm to 53.4 cm with a mean of 48.9 cm (SD 2.0) (Table 16).

## **2.5 Percent Spawn and Egg Deposition**

### **2.5.1 Spawning Channel**

A total of 3,941 females were evaluated for percent spawn in the spawning channel in the fall of 2015. Female Sockeye spawning success in the channel was assessed as 421 un-spawned (0%), 73 partial spawners (50%), and 3,447 complete spawned (100%) (Table 17). With conversion of partial spawners to their effective female equivalents for all females loaded into the channel, percent spawn is estimated to be 88.4% or 3,484 females in total for the spawning channel in the fall of 2015. Estimated egg deposition for the fall of 2015 was 11,204,544 which is 4% higher than 2014 (Table 18).

The distribution of 0% and 100% spawned females changed over the spawning period. Early in the run, prior to September 10<sup>th</sup>, there was a greater proportion of 0% spawned female carcasses as compared to 100% carcasses. After September 10<sup>th</sup>, the number of 0% spawners approached zero (Figure 19).

### **2.5.2 Gates Creek**

The percent spawn estimate for Gates Creek was slightly (6%) higher than the estimate for the spawning channel. Of the 6,473 females estimated to have entered Gates Creek 95% or 6,159 are estimated to have been effective spawners. Estimated egg deposition in Gates Creek was 19,807,344 for the fall of 2015 which is a 12% increase from 2014 (Table 18).

## **DISCUSSION**

### ***3.1 Temperature Monitoring***

Temperature comparison between the spawning channel and Gates Creek were not possible in 2015 due to the lack of temperature data from the spawning channel. However, the spawning channel and Gates Creek have been found to be within 1 degree of each other in past years (Lingard and Ladell 2014). Mean daily temperatures Gates Creek remained below the threshold for thermal stress (Servizi and Jensen 1977, Eliason et al. 2011) over the spawning period.

### ***3.2 Counter Operations and Visual Survey/ Video Validation***

The mechanical counters for the spawning channel worked without issue in the fall of 2015. However, improvements could be made in the design of the counter on Gates Creek to decrease potential stress on fish as well as increase efficiency of the counter.

Video validation from 2013 to 2015 indicates the Gates Creek mechanical counter tends to overestimate the number of fish passing through the bypass into the creek. Video footage of the creek counter in 2015 indicated the mechanical counter inflated the count of fish into the creek by 27%. This estimate of counter efficiency does not take into account fish that were recycled through the counter when a high water event on September 2<sup>nd</sup>, 2015 overwhelmed the diversion fence on Gates Creek. Fish were seen being washed over the fence during this high water event. It was also noted fish were seen jumping over the fence during this same event. The video validation also does not take into account Pink salmon migrating concurrently with Sockeye into the creek.

The inflation of the count by the creek counter may result from fish moving the counter gate multiple times as they pass through the gate. The audio associated with the video segments suggests fish are moving with vigor as they pass through the counter and are likely triggering multiple up counts as they pass the counter.

The design of the counter also results in fish being partially out of the water for the period they are passing over the counter gates. Air temperatures reach as high as 30°C in August and September at the study site. Air exposure has been shown to cause stress and reduce

migration success in Sockeye (Nguyen et al. 2013). Alone, the Gates Creek counter is unlikely to impact the spawning success of salmon; however, Sockeye returning to Gates Creek experience a number of stressors including a hydro-electric dam, escape from fishing gear entanglement, and navigating through Hell's Gate. While the effects of cumulative and co-occurring stressors are still not fully understood, recent research suggests acute stressors such as fisheries capture or migration obstacles can have exacerbated effects on survival and spawning success when combined with thermal stress or disease in salmonids (Barton et al. 1986, Dietrich et al. 2014).

### **3.3 Migration Timing and Sockeye Abundance**

#### **3.3.1 Migration Timing**

The migration time between the Seton Dam counter and the Gates Creek counters in 2014 and 2015 was 25-50% longer than the expected migration time. The migration time for sockeye from the Seton Dam to Gates Creek is known to take approximately 10 to 14 days. The first fish arrived at Seton Dam on July 29<sup>th</sup> in 2015 (D. Braun, pers. comm.), but didn't arrive at Gates Creek until August 18<sup>th</sup>, 20 days later. In 2014 it took 25 day for the first fish to reach Gates Creek from Seton Dam (Lingard and Ladell, 2014). Arrival dates of Sockeye to Gates Creek in 2014 and 2015 were also approximately 7 to 10 days later than in 2012 and 2013. In 2011-2013 arrival date of Sockeye to Gates Creek ranged from August 10<sup>th</sup> to August 11<sup>th</sup> but in 2014 and 2015 fish arrived on August 20<sup>th</sup> and 18<sup>th</sup>, respectively. Potential changes in migration timing may be a response to warmer migration conditions in the Fraser River. From 2013 to 2015, water temperatures in the Fraser reached or exceeded 18°C (<http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/index-eng.html>), the known threshold for physiological stress and delayed migration in salmonids (Lee et al. 2003). As a result of extreme water temperatures, Sockeye may be spending extended periods of time in Seton and Anderson Lakes to recover from thermal stress.

#### **3.3.2 Sockeye Abundance**

Returns of adult Sockeye to the Gates Creek watershed in 2015 fell in the mid-range of observed values for this populations. For the period of time that DFO has kept records on Gates Creek Sockeye (1938-2015), returns of adult Sockeye have ranged from 400 to 69,000 (DFO unpublished data), annually. The 2015 return of 20,327, is the second highest return on record for this cycle, but was only 36% of the 2011 brood (57,433) (DFO unpublished data). Despite returns being less than half the 2011 brood (which was a record return for this

particular cycle), 2015 was the third consecutive year Sockeye returns to Gates Creek have exceeded cycle averages.

### **3.4 Fecundity and Egg Deposition**

Increased female abundance and percent spawn in 2015 resulted in an increase in egg deposition from 2014 for both Gates Creek and the spawning channel. Mean fecundity was reduced by 4% in 2015 over 2014. The estimates of egg deposition for Gates Creek (19,807,344) and the spawning channel (11,204,544) for the 2015 brood were 12% and 4% higher than 2014, respectively.

### **3.5 Percent Spawn**

Despite warm water temperatures ( $>18^{\circ}\text{C}$ ) in the Fraser and Seton Rivers during the migration window (**Figure 20**) (<http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/reports-rapports/2014/2014-08-28/2014-08-28-eng.html>), percent spawn was above the historical average for this cycle year of Gates Creek sockeye in 2015. Percent spawn in 2015 (92.6% overall) exceeded the long term average (73.8%) by 18.8%.

The relative abundance of 0% spawned fish to 100% spawned fish decreased as the spawning period progressed. The data for the 2012- 2015 visual surveys in the spawning channel indicates that the proportion of 0% fish decreases as the run progresses. A similar trend was seen in 2012 -2014 when on average 70% pre-spawn mortalities were observed in the first 10 days of the run. There does appear to be a trend for a higher proportion of early run females to be to be unsuccessful spawners which suggests best practice, as achieved in 2015, would be to devise a loading plan which ensures females from all parts of the run are loaded into each spawning habitat. Loading females from each portion of the run into each habitat would ensure that spawning occurs in both habitats which would help to provide insurance against stochastic events such as flooding or freezing during the fry incubation period.

Differences in percent spawn between Gates Creek and the spawning channel have varied among the years of this study. In both 2011 and 2012 there was ~30% difference between values of percent spawn for Gates Creek and the spawning channel; however in 2013 and 2014 the difference in the values decreased to ~2% and 1% respectively. Percent spawn in the spawning channel is a direct count of all female carcasses in the channel and in Gates Creek percent spawn is an estimate generated from weekly sub-samples of available carcasses. Because of the different methods used to generate percent spawn values for each habitat,

direct comparison of percent spawn between Gates Creek and the spawning channel is not advisable. The decrease in the difference between percent spawn values in from 2011-2012 and 2013-2015; however, suggests a change in some factor influencing spawning success. Some possible factors which may have influenced a reduction in the difference of percent spawn figures are: 1) a change in DFO staff conducting visual surveys in 2013 from 2012 and 2011 or 2) the lower density of females or Sockeye in general loaded into the spawning channel in 2013 -2015 or 3) the above mentioned lower discharge in 2013, 2014, and 2015 over 2011 and 2012 4) a change in an unmeasured environmental parameter such as water quality or available spawning substrate in either Gates Creek or the spawning channel.

Fish density may, in fact, partially drive percent spawn in the constrained environment of the spawning channel. Over the period of this study 2012 to 2015, percent spawn in the spawning channel has ranged from 52% (2012, highest density of fish) to 88% (2015, second lowest density of fish). Over an 18 year period (1996 - 2014) in all but in all by 4 years (1996, 2000, 2008 and 2012) peak in fish abundance in the channel coincided with low percent spawn values when compared to years with few fish loaded into the channel. In general over the last 18 years, the years with the lowest percent spawn have occurred in years where more than 15,000 fish have been loaded into the channel (**Figure 21**) (DFO unpublished data). Experimentation with fewer fish in the channel in future years may help to maintain high values of percent spawn for this habitat.

## Summary and Recommendations

The objectives were largely met in the fall of 2015 for the adult component of this study:

- 1) A total abundance estimate (adjusted for counter efficiency) of 20,327 Sockeye for the Gates Creek watershed (12,755 Gates Creek, 93 for Spruce and Haylmore Creeks, and 7,479 into the spawning channel) was obtained.
- 2) Total female abundance was estimated to be 3,941 for the spawning channel and 6,473 for Gates Creek.
- 3) Percent spawn was estimated to be 92.6% for the watershed overall (88.4% for the spawning channel and 95.1% for Gates Creek).
- 4) Mean female fecundity was estimated to be 3,216 in the fall of 2015
- 5) Egg deposition for Gates Creek and the spawning channel were estimated to be 19,807,344 and 11,204,544, respectively.

In addition to the main objectives of the study, several important gains were made on the project in the fall of 2015. Measurements of counter efficiency were obtained and the N'Quatqua technicians were trained to do video validation. Furthermore, communication with DFO stock assessment personnel and the N'Quatqua technicians also continued to

improve in the fall of 2015. Additionally, the N'Quatqua technicians have taken on more data collection as well as some data entry.

All three mechanical counters worked well for the entire 2015 spawning season. Although the mechanical counter on Gates Creek has been found to overestimate the number of fish entering Gates Creek, video validation is a useful tool for measuring and monitoring this tendency. One recommendation from 2015, again suggested for 2016, is that the design of the Gates Creek counter be modified to allow fish to swim through the counter. Currently the counter is designed such that the struggle of fish over the counter gates is audible. The erratic movement of fish though the counter gate is likely the source of inaccuracy in the counter.

Although this is the final year of this study we have a few recommendations for work in the future:

- Continue temperature monitoring in both habitats.
- Continued video validation of counter abundance estimates in Gates Creek.
- Development of pre-season equipment inspection and in-season maintenance schedule for counters to reduce risk of malfunction.
- Capacity building with local N'Quatqua technicians to ensure daily maintenance of counters is completed and trouble-shooting abilities are developed.
- Consider modifications to diversion fence in Gates Creek to minimize stranding of fish behind carcasses.
- Re-evaluation of optimum spawner density in spawning channel to improve percent spawn values.

Improve inter-organizational communication to prevent miscommunication on management strategies.

## TABLES

**Table 9.** Temperature data from TidbiT v2 Water Temperature Data Loggers in Gates Creek and Gates Creek spawning channel. Temperatures were logged every 15 minutes but are summarized as mean average daily temperature, fall 2015

Spawning Area	Site Name	Mean average daily temperature (°C)	SD	Min	Max
Gates Creek	Davidson Horse Farm	9.6	2.3	5.4	13.8

**Table 10.** Video validation data for mechanical counter in Gates Creek, Fall 2015

Date	Time Start	Time End	Time validated	Counter Start	Counter End	# fish on counter	# fish on Video
24-Aug-15	11:15:00	13:51:00	2:36:00	3453	3480	27	19
30-Aug-15	10:29:25	12:40:00	2:10:35	9000	9164	164	117
30-Aug-15	12:40:25	14:42:00	2:01:35	9164	9295	131	98
30-Aug-15	16:52:00	19:12:00	2:20:00	9472	9634	162	120
03-Sep-15	18:34:00	20:18:00	1:44:00	10439	10494	55	41
04-Sep-15	8:41:00	10:30:00	1:49:00	10841	10935	94	61
04-Sep-15	18:41:00	20:31:00	1:50:00	11279	11379	100	83
05-Sep-15	8:40:00	11:21:00	2:41:00	11860	11995	135	103
05-Sep-15	18:01:00	20:13:00	2:12:00	12347	12461	114	96
06-Sep-15	8:26:00	10:37:00	2:11:00	12951	13117	166	126
07-Sep-15	18:43:00	20:32:00	1:49:00	14314	14409	95	87
08-Sep-15	8:46:00	10:57:00	2:11:00	14687	14788	101	82
09-Sep-15	8:36:00	10:56:00	2:20:00	15413	15519	106	76
10-Sep-15	18:38:00	20:07:00	1:29:00	16353	16487	134	23
12-Sep-15	18:53:00	20:53:00	2:00:00	16941	16965	24	22
13-Sep-15	18:33:00	20:37:00	2:04:00	17237	17264	27	20
14-Sep-15	18:37:00	20:58:00	2:21:00	17364	17375	11	11
15-Sep-15	18:28:00	20:37:00	2:09:00	17478	17500	22	23
16-Sep-15	17:44:00	19:46:00	2:02:00	17557	17571	14	12
17-Sep-15	19:09:00	21:39:00	2:30:00	17643	17662	19	22
<b>Total</b>			<b>42.5 hours</b>			<b>1701</b>	<b>1242</b>

**Table 11.** Summary of Sockeye abundance estimates for Gates Creek spawning channel collected via visual surveys 2011-2015

	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>
<b>Males</b>	7,928	6,093	6,072	2,332	2,728
<b>Jacks</b>	623	1,719	700	481	810
<b>Females</b>	9,779	9,791	6,510	3,739	3,941
<b>Total</b>	<b>18,330</b>	<b>17,603</b>	<b>13,282</b>	<b>6,553</b>	<b>7,479</b>

**Table 12.** Summary of adult Sockeye abundance estimates for Gates Creek 2011- 2015. Abundance estimates for Gates Creek are developed using a combination of data from visual surveys and the mechanical counter

	<b>2011</b>	<b>2012</b>	<b>2013 (after adjustment)</b>	<b>2014 (after adjustment)</b>	<b>2015 (after adjustment)</b>
<b>Males</b>	12,224	4,264	19,864	3,448	5,058
<b>Jacks</b>	950	976	1,687	692	1,224
<b>Females</b>	25,907	8,336	22,376	6,160	6,473
<b>Total</b>	<b>39,081</b>	<b>13,576</b>	<b>43,927</b>	<b>10,299</b>	<b>12,755</b>

**Table 13** Summary of adult Sockeye abundance for Haylmore Creek 2011-2015. Abundance estimates developed from visual survey data collected by DFO stock assessment

	2011	2012	2013	2014	2015
<b>Males</b>	7	-	-	-	
<b>Jacks</b>	-	-	-	-	
<b>Females</b>	15	-	-	-	
<b>Total</b>	<b>22</b>	-	-	-	<b>71</b>

**Table 14** Summary of adult Sockeye abundance for Spruce Creek 2011-2015. Abundance estimates developed from visual survey data collected by DFO stock assessment

	2011	2012	2013	2014	2015
<b>Males</b>	-	-	-	-	9
<b>Jacks</b>	-	-	-	-	7
<b>Females</b>	-	-	-	-	11
<b>Total</b>	-	-	-	-	<b>22</b>

**Table 15** Summary of adult Sockeye abundance for the Gates Creek Watershed from 2011-2015

	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>
<b>Haylmore Creek</b>	22	-	-	-	71
<b>Spruce Creek</b>	-	-	-	-	22
<b>Anderson Lake Shore</b>	-	-	117	76	-
<b>Gates Creek</b>	39,081	13,576	43,927	10,299	12,755
<b>Spawning Channel</b>	18,330	17,603	13,282	6,553	7,479
<b>Total</b>	<b>57,433</b>	<b>31,179</b>	<b>57,326</b>	<b>16,928</b>	<b>20,327</b>

**Table 16.** Mean fecundity and post-orbital hypural (POH) length (cm) in Gates Creek spawning channel females Sockeye for 2011 - 2015

	<b>Sample size</b>	<b>Mean POH in cm (SD)</b>	<b>Mean Fecundity (SD)</b>	<b>Range of fecundity values</b>
<b>2011</b>	48	48.0 (2.2)	3,260 (571)	1,725-4,287
<b>2012</b>	40	46.5 (2.4)	3,119 (516)	1,469- 4,035
<b>2013</b>	46	49.0 (3.5)	3,378 (519)	2,351- 4,767
<b>2014</b>	60	49.1 (3.8)	3,358 (777)	685- 5,365
<b>2015</b>	60	48.9 (2.0)	3,216 (644)	2,165- 4,231

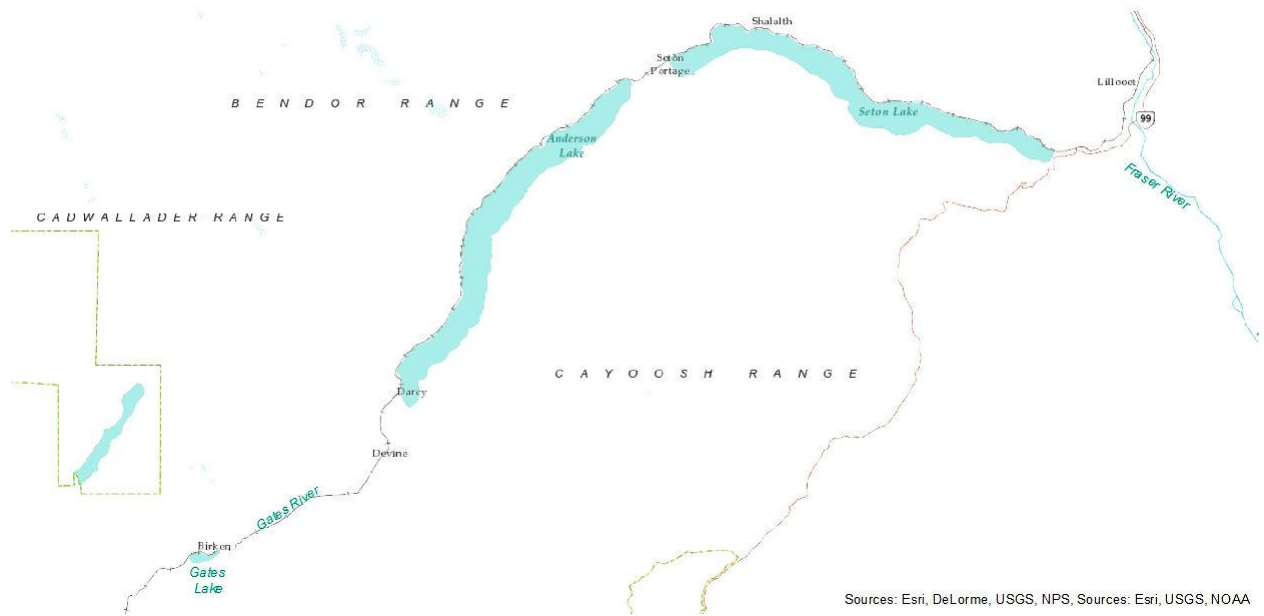
**Table 17.** Break down of female percent spawn in Gates Creek spawning channel from visual survey data 2011 - 2015

Percent spawn	<u>2011</u>	<u>2012</u>	<u>2013</u>	<u>2014</u>	<u>2015</u>
	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)
<b>0%</b>	3,647 (43.9%)	6,915 (72.6%)	1,131 (17.3%)	506 (14.0%)	421 (10.7%)
<b>50%</b>	588 (7.1%)	163 (1.7%)	154 (2.4%)	66 (1.8%)	73 (1.9%)
<b>100%</b>	4,067 (49.0%)	2,436 (25.6%)	5,225 (81.4%)	3,033 (84.1%)	3,447 (87.5%)
<b>Total</b>	<b>8,302</b>	<b>9,514</b>	<b>6,510</b>	<b>3,605</b>	<b>3,941</b>

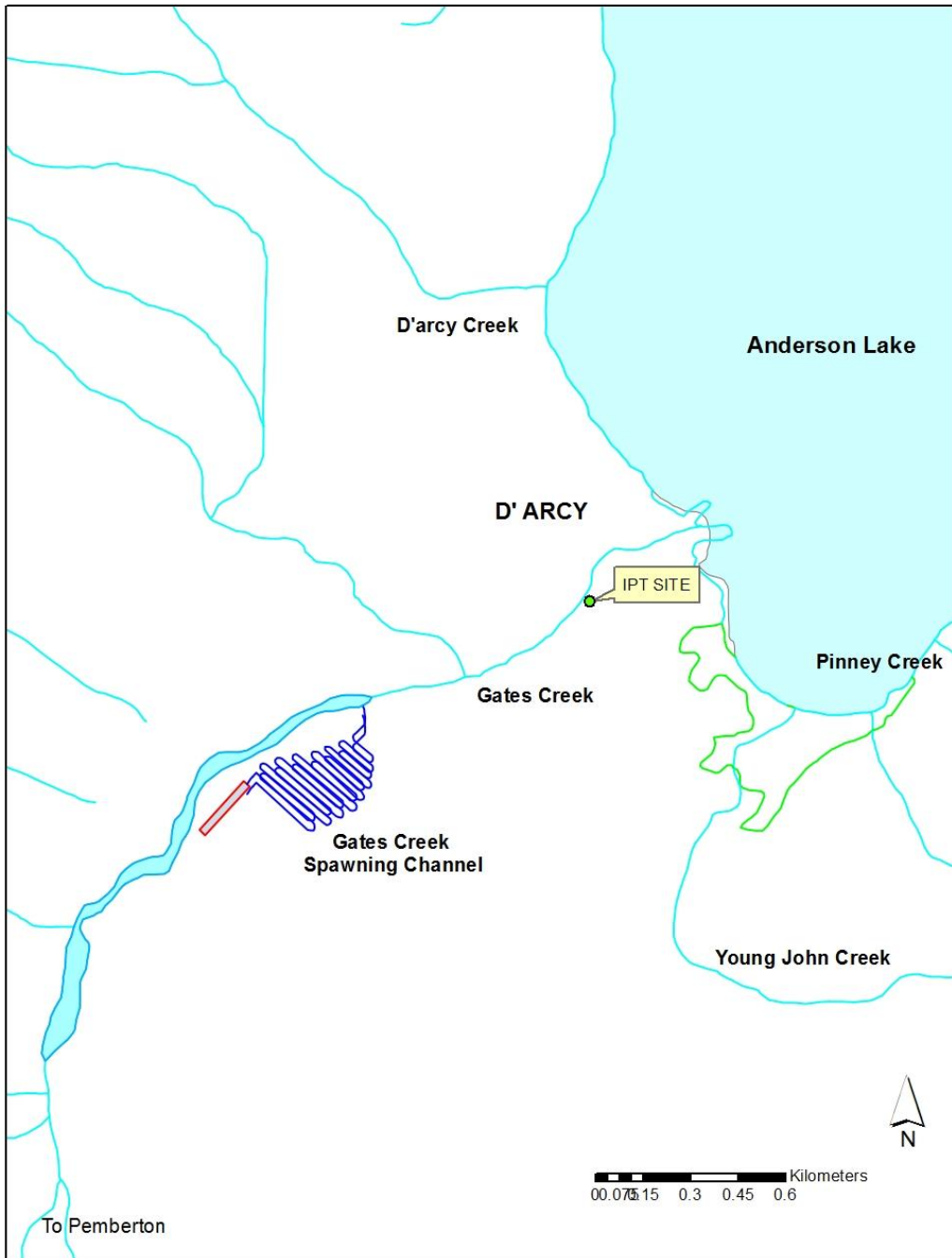
**Table 18.** Estimated number of effective females, mean fecundity and egg deposition for the 2011-2015 brood years for Sockeye spawning in Gates Creek and Gates Creek spawning channel (estimates of effective females for Gates Creek were provided by DFO unpublished data)

Spawning Area	Year	Effective Females	Mean Fecundity	Egg Deposition
<b>Spawning Channel</b>	2011	5,136	3,260	16,743,360
	2012	2,588	3,119	8,071,972
	2013	5,302	3,378	17,910,156
	2014	3,211	3,358	10,782,538
	2015	3,484	3,216	11,204,544
<b>Gates Creek</b>	2011	21,297	3,260	69,428,220
	2012	4,311	3,119	13,446,009
	2013	17,702	3,378	59,797,356
	2014	5,245	3,358	17,612,710
	2015	6,159	3,216	19,807,344

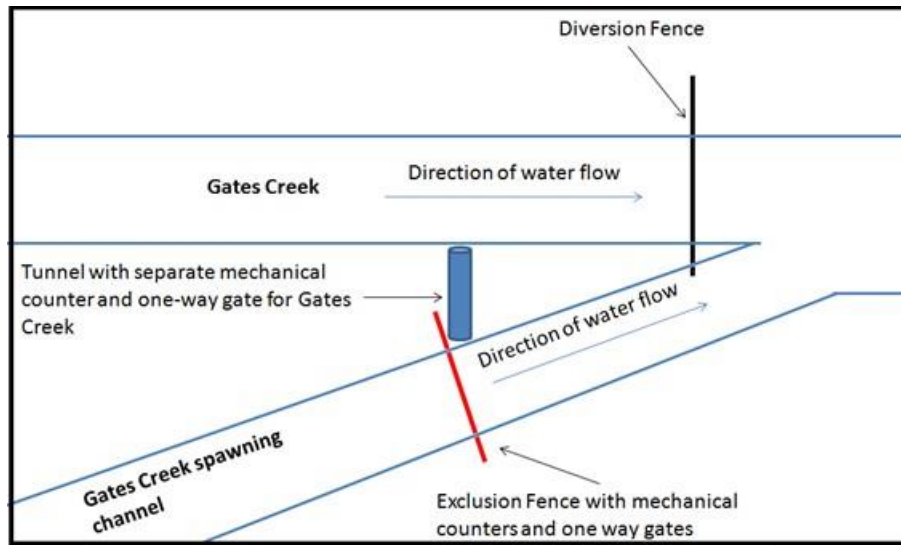
**FIGURES**



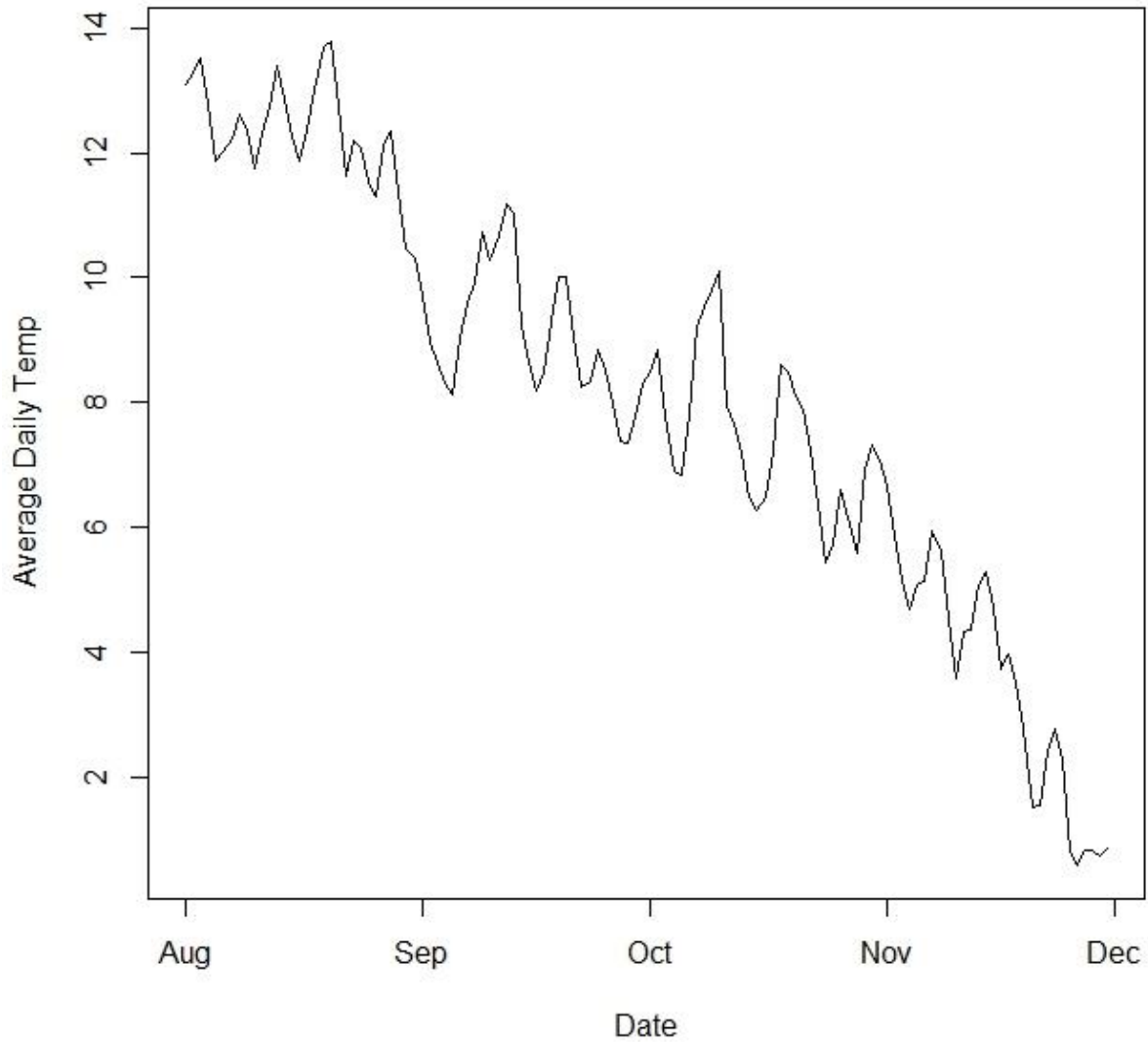
**Figure 14.** Overview of Seton-Anderson watershed in South Western British Columbia



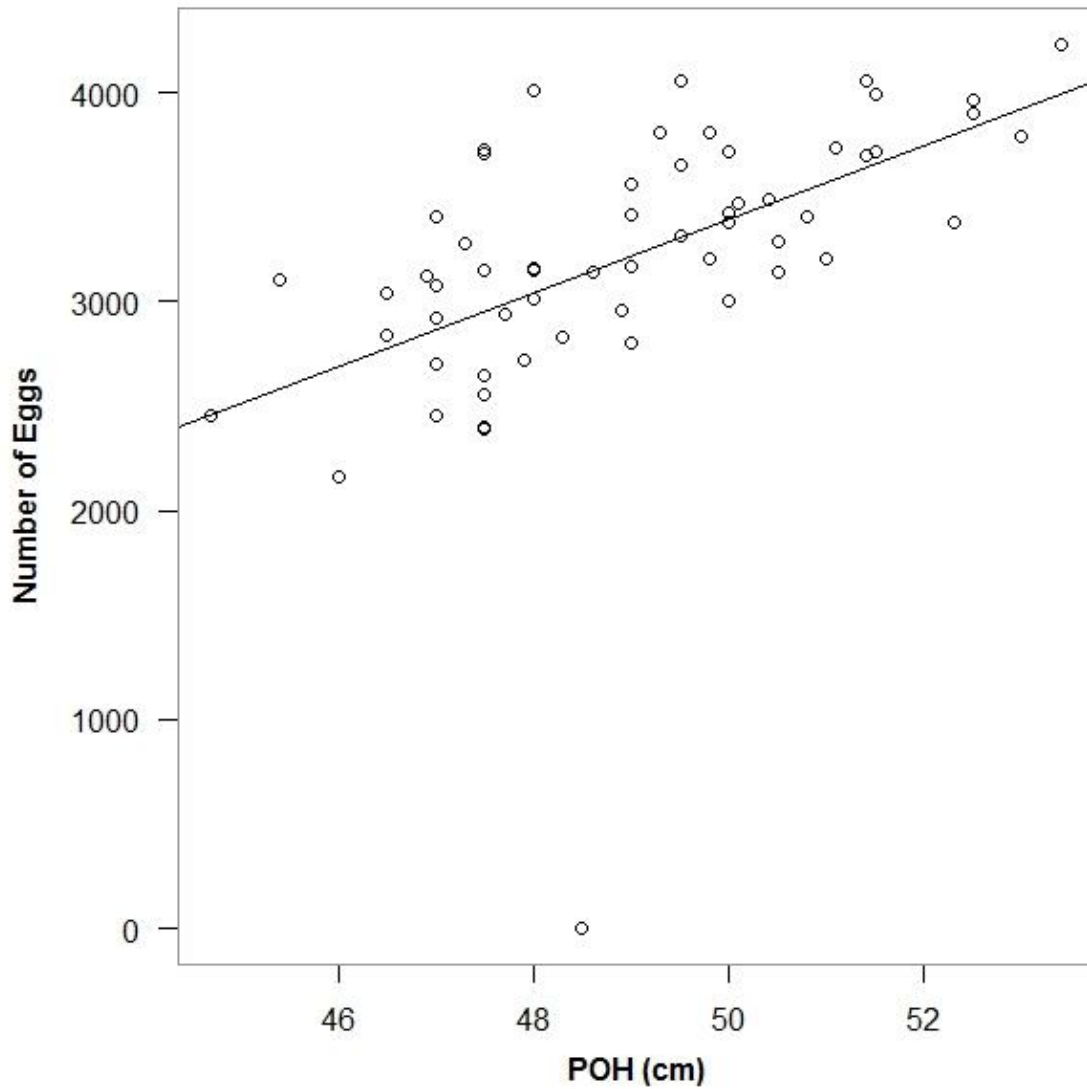
**Figure 15.** Map of study area including Gates Creek and spawning channel near confluence with Anderson Lake. Also shown is the trap site for the juvenile monitoring component of the study.



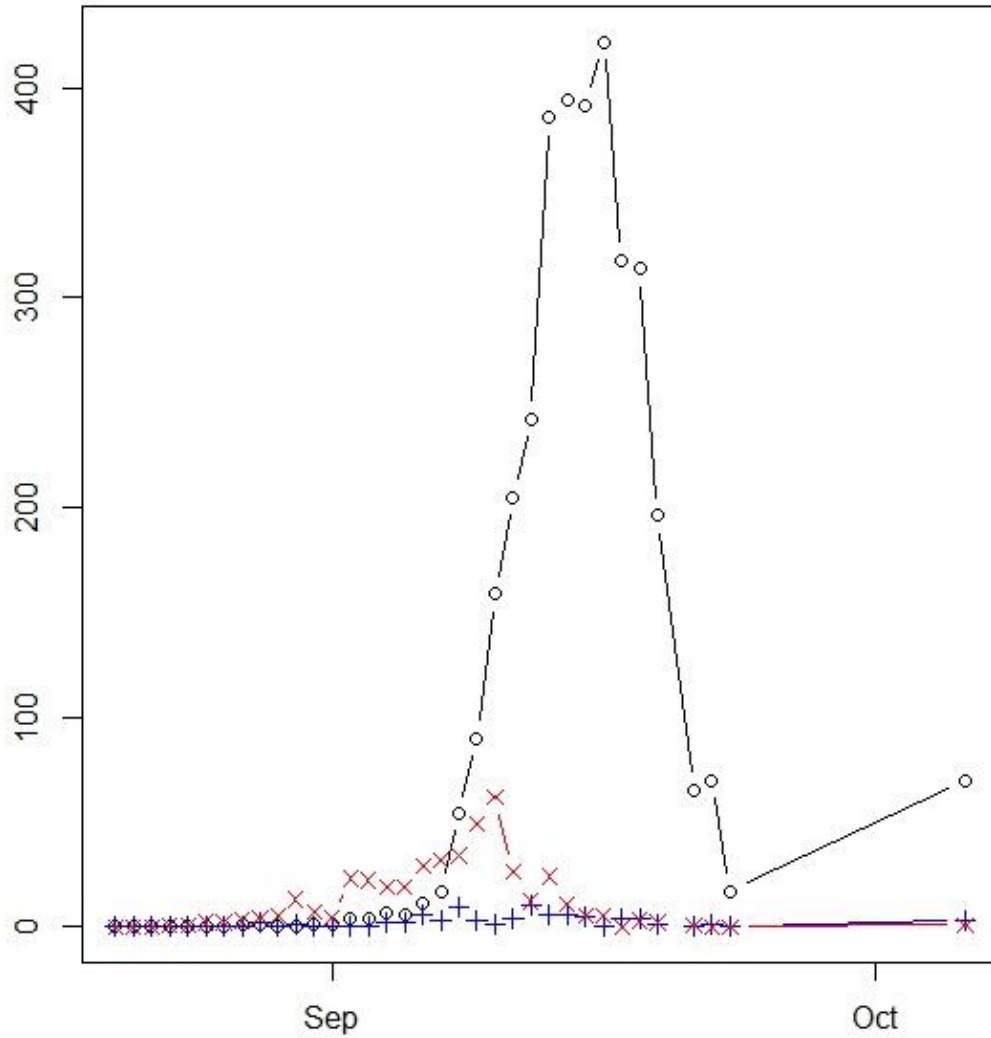
**Figure 16.** Schematic diagram of enumeration equipment at confluence of Gates Creek and Gates Creek spawning channel spawning channel



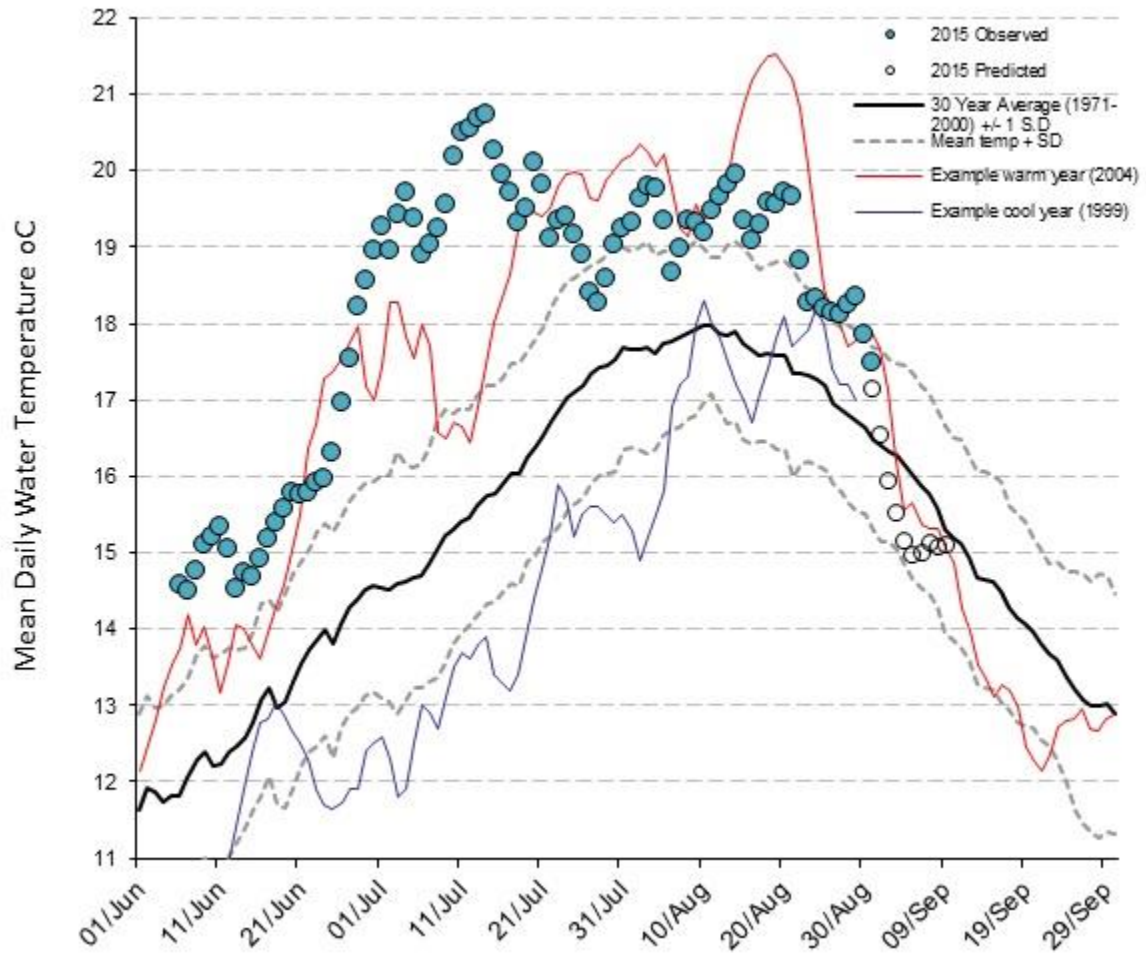
**Figure 17.** Average daily temperature in Gates Creek (dotted black line) and Gates Creek spawning channel (grey line) over the Sockeye spawning period from August 1<sup>st</sup> to December 1<sup>st</sup>, 2015



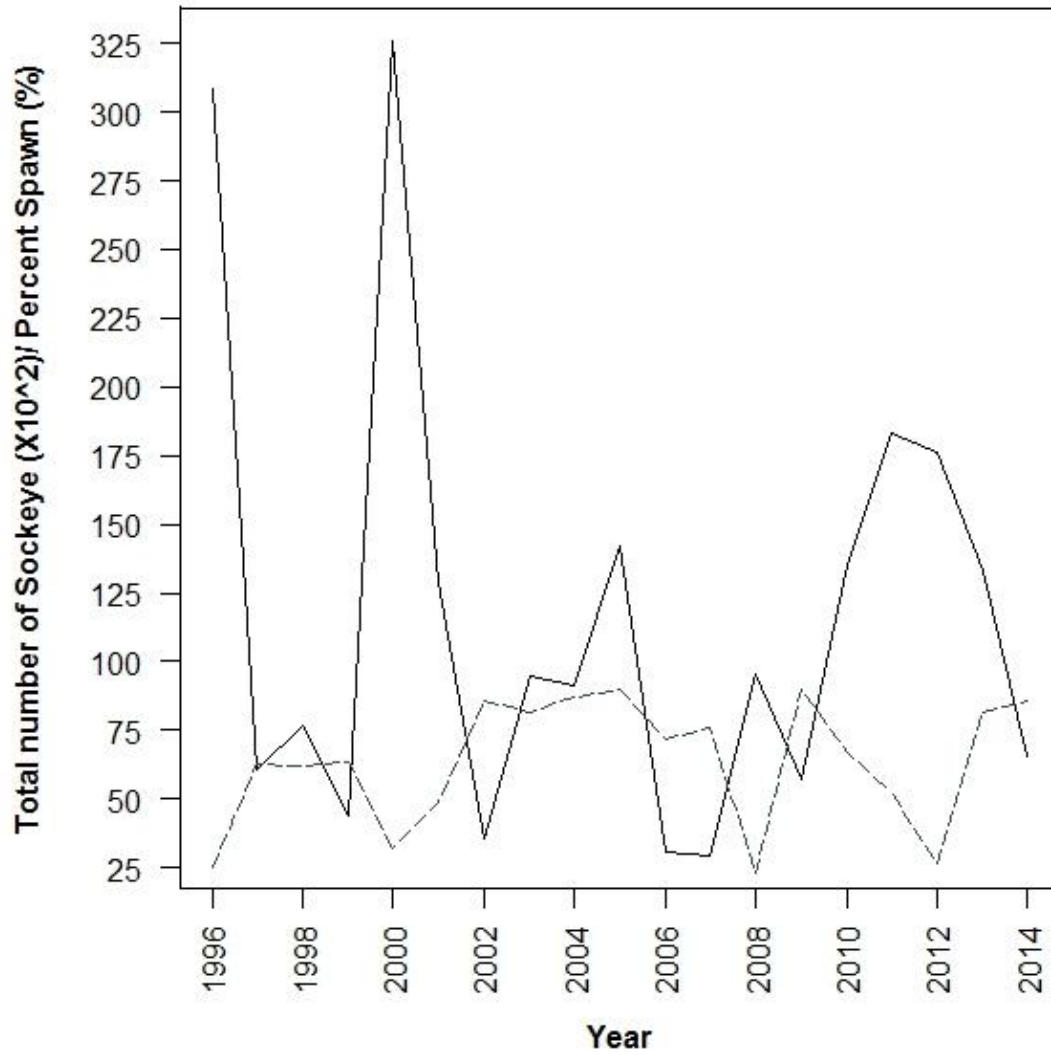
**Figure 18.** Scatter plot with fitted regression line ( $y = 175.9x + -5401.4$ ,  $R^2 0.276$ ) of post-orbital hypural (POH) length (cm) and female fecundity (number of eggs) in Gates Creek Sockeye, Fall 2015.



**Figure 19.** Distribution of female percent spawned over the fall 2015 Sockeye spawning period at Gates Creek spawning channel. Red, blue and black lines represent 0, 50 and 100% spawned females respectively.



**Figure 20** Temperature data for Fraser River at Mission for summer 2015 Sockeye migration window (<http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/reports-rapports/2014/2014-08-28/2014-08-28-eng.html>)



**Figure 21** Total annual adult Sockeye ( $\times 10^2$ ) loaded into Gates Creek Spawning channel (black solid line) plotted with annual percent spawn (dotted grey line) 1996-2014 (DFO unpublished data)

## REFERENCES

- Andrew F.J. and Green G.H. 1958. Sockeye and Pink salmon investigations at the Seton Creek hydroelectric installation. Progress Report, International Pacific Salmon Commission, New Westminster, Canada. 78 p.
- Anonymous. 2000. Bridge-Coastal fish and wildlife restoration program strategic plan. 1, Bridge Coastal Restoration Program. 56 p.
- Anonymous. 2001. Gates Creek assessment project. Creekside Resource Inc., Mount Currie, Canada. 35 p.
- Anonymous. 2009. Rehabilitation of Sockeye spawning gravel in the Gates Creek spawning channel- year 2. Northern St'at'imc Fisheries, Lillooet, Canada. 56 p.
- Anonymous. 2012. Integrated biological status of Fraser River Sockeye Salmon (*Oncorhynchus nerka*) under the Wild Salmon Policy. Fisheries and Oceans Canada- Pacific Region. Science Advisory Report 2012/056. 13p.
- Barton, B.A., Schreck, C.B., and Sigismondi, L.A. 1986. Multiple acute disturbances evoke cumulative physiological stress responses in juvenile Chinook salmon. *Transactions of the American Fisheries Society* 115(2):245-251
- Crossin, G.T., Hinch S.G., Cooke S.J., Welch D.W., Patterson D.A., Jones S.R.M., Lotto A.G., Leggatt R.A., Mathes M.T., Shrimpton J.M., Van Der Kraak G.V., and Farrell A.P. 2008. Exposure to high temperature influences the behavior, physiology and survival of Sockeye salmon during spawning migrations. *Canadian Journal of Zoology* 86(2): 127-140.
- Dietrich, J.P., Van Gaest, A.L., Strickland, S.A., and Arkoosh, M.R. 2014. The impact of temperatures stress and pesticide exposure on mortality and disease susceptibility of endangered Pacific salmon. *Chemosphere* 108: 353-359.
- Elaison, E.J., Clark T.D., Hague M.J., Hanson L.M., Gallagher Z.S., Jefferies K.M., Gale M.K., Patterson D.A., Hinch S.G., and Farrell A.P. 2011. Differences in thermal tolerance among Sockeye salmon populations. *Science* 332: 209-112.
- Ferrari, M.R., Miller J.R., and Russell G.L. 2007. Modeling changes in summer temperature of the Fraser River during the next Century. *Journal of Hydrology* 342(3-4): 336-346.
- Fretwell, M.R. 1989. Homing behaviour of adult Sockeye salmon in response to a hydroelectric diversion of home water at Seton Creek. *International Pacific Salmon Commission Bulletin* 25: 38 p.

- Komori, V. 1997. Strategic fisheries overview for the Bridge/ Seton habitat management area. Fraser River Action Plan, Department of Fisheries and Oceans, Vancouver, Canada. 83 p.
- Lee, C.G., Farrell A.P., Lotto A., MacNutt M.J., Hinch S.G., and Healey M.C. 2003. Effect of temperature on swimming performance and oxygen consumption in adult Sockeye (*Oncorhynchus nerka*) and coho (*O. kisutch*) salmon stocks. *Journal of Experimental Biology* 206: 3239-3251.
- Lingard, S., and Ladell J. 2014. Gates Creek juvenile and adult salmonid assessment 2014 (14.SON.01) Prepared for the Fish and Wildlife Compensation Program, Lillooet Tribal Council and Department of Fisheries and Oceans, Canada. Instream Fisheries Research, Inc., North Vancouver, Canada. 106 p.
- Morrison, J, Quick M.C., and Foreman M.G.G. 2002. Climate change in the Fraser River watershed: flow and temperature projections. *Journal of Hydrology* 263(1-4): 230-244.
- Nguyen, V.M., Martins E.G., Robichaud D., Raby G.D., Donaldson M.R., Lotto A.G., Willmore G.D., Patterson D.A., Farrell A.P., Hinch S.G., and Cooke S.J. 2014. Disentangling the roles of air exposure, gill net injury, and facilitated recovery on the post capture and release mortality and behavior of adult migratory Sockeye salmon (*Oncorhynchus nerka*). *Freshwater. Physiological and Biochemical Zoology* 87(1): 125-135.
- Patterson, D.A., Macdonald J.S, Skibo K.M, Barnes K.M., Guthrie I., and Hills J. 2007. Reconstructing the summer thermal history for the lower Fraser River, 1941 to 2006, and implications for adult sockeye salmon (*Oncorhynchus nerka*) spawning migration.
- Servizi, J.A. and Jensen J.O.T. 1977. Resistance of adult Sockeye salmon to acute thermal shock. International Pacific Salmon Fisheries Commission. Progress Report 34: 1-51.
- Talbot, G.B. 1950. A biological study of the effectiveness of the Hell's Gate fishways. Bulletin 3, International Pacific Salmon Commission, New Westminster, Canada. 80 p.

## SECTION 3: Gates Creek Level 1 Fish Habitat Assessment



## Executive summary

Evaluations were conducted on Gates Creek in the Seton-Anderson watershed of South Western British Columbia during the winter of 2015 to establish baseline data on the habitat quantity and quality as it pertains to potential fish production. The entire length of Gates Creek was surveyed using a modified Level 1 Fish Habitat Assessment procedure.

Gates Creek runs 17 km from Gates Lake to Anderson Lake. For the purpose of this survey Gates Creek was broken into three reaches. Reach 1 extended from the confluence with Anderson Lake to the beginning of agricultural lands. Reach 2 contained the section of river running through agricultural lands, and Reach 3 extended from the upstream end of Reach 2 through heavily wooded areas to Gates Lake.

Reach 1 was the longest and widest section of river. Reach 1 was 7,092 m long with a mean bankfull width of 13.7 m and a mean gradient of 1.2%. Reach 1 contained a mixture of glides, cascades and riffles. Pools were limited in number as was functional woody debris. Reach 1 had spawning substrate suitable for either anadromous or resident salmonids in 71% of units

Reach 2 was characterized as a deep, sandy, glide constrained by diking for agricultural land use. Reach 2 was 4,303 m long with a mean width of 10.1 m and a mean gradient of 0.3%. Ninety eight percent of Reach 2 was classified as glide with fine sediment. Riparian vegetation in Reach 2 provided little stream shading as the majority of the riparian area has been converted to grasses for pasturing livestock.

Reach 3 was the narrowest section of the river with a slightly steeper mean gradient than Reach 1. Reach 3 was 5,921 m in length with a mean bankfull width of 8.8 m and a mean gradient of 1.4%. Reach 3 contained a mixture of glides, cascades and riffles; however, similar to Reach 1 pools and woody debris were lacking. Reach 3 had spawning substrate suitable for either anadromous or resident salmonids in 78% of units.

Overall the survey revealed a need for increased stream complexity and building of pools in all reaches. Restoration of riparian vegetation and incorporation of larger substrate to Reach 2 are high priorities for future restoration works.

## Table of Contents

SECTION 3: Gates Creek Level 1 Fish Habitat Assessment.....	93
Acknowledgements.....	97
INTRODUCTION.....	98
METHODS.....	100
2.1 Level 1 Fish Habitat Survey Procedures.....	100
2.2 Water Level Monitoring.....	101
2.3 GIS Mapping.....	102
RESULTS.....	103
3.1 Reach 1.....	103
3.2 Reach 2.....	104
3.3 Reach 3.....	104
3.4 Off Channel Habitat.....	105
DISCUSSION.....	107
4.1 Habitat Survey.....	107
4.2 Potential Restoration Opportunities.....	108
RECOMMENDATIONS.....	110
Note on Birken Landslide September 2015.....	110
TABLES.....	111
FIGURES.....	116
REFERENCES.....	125

## List of Tables

Table 1. Habitat characteristic of Gates Creek broken into 3 reaches. ....	112
Table 2. Habitat type by reach parameters for the mainstem Gates Creek collected during spring 2015 .....	113
Table 3. Disturbance indicators by reach for Gates Creek collected during spring 2015. ....	114
Table 4. Off channel habitat by reach for Gates Creek collected in spring 2015. ....	115

## List of Figures

Figure 1. Map of Seton- Anderson Watershed including Gates Creek running from Gates Lake to Anderson Lake in the town of D’Arcy .....	117
Figure 2. Map of Gates Creek with reach breaks indicated .....	118
Figure 3 Map of Reach 1 of Gates Creek habitat survey extending south from Anderson Lake. Individual habitat units are shown by colour. ....	119
Figure 4. Proportion each cover type represents of total available cover in each reach. ....	120
Figure 5. Proportion of units with in a reach where each substrate type was dominant.....	121
Figure 6. Proportion of available spawning substrate with in a reach appropriate for resident or anadromous spawners. ....	122
Figure 7. Map of Reach 2 of Gates Creek habitat survey. Individual habitat units are shown by colour.....	123
Figure 8. Map of Reach 3 of Gates Creek habitat extending south-west from end of Reach 2 to Gates Lake. Individual habitat units are shown by colour.....	124

## Acknowledgements

This project was conducted with financial support of St'at'imc Government Services, the Pacific Salmon Foundation and the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of British Columbia, First Nations, public stakeholders, and Fisheries and Oceans Canada.

We would like thank the following people for their cooperation and assistance on this project:

Harry- O'Donaghey, N'Quatqua Fisheries

Lance O'Donaghey, N'Quatqua Fisheries

Chris Fletcher, N'Quatqua Fisheries

Harry O'Donaghey, Jr., N'Quatqua Fisheries

Spencer Thevarge, N'Quatqua Fisheries

LJ Wilson- Instream Fisheries Research Inc.

Judy Hillaby- Fisheries and Oceans Canada

**Stephanie Lingard, R.P.Bio.– Project Lead  
Junior Biologist, Instream Fisheries  
Research Inc.**

**Jason Ladell, R.P.Bio.-  
Fisheries Biologist**

**Caroline Melville  
Managing Director, Instream Fisheries  
Research Inc.**

### Suggested Citation

Lingard, S.L., Ladell J.J., and Melville C.C.. 2015. Gates Creek Level 1 Fish Habitat Survey- Spring 2015. Report prepared for Lillooet Tribal Council and Fisheries and Oceans Canada. 25p.

## INTRODUCTION

Gates Creek is a major salmon bearing tributary of the Seton-Anderson Watershed and runs 17 kilometres from Gates Lake to Anderson Lake draining approximately 34,300 hectares (Komori 1997) (Figure 22). The Seton-Anderson watershed is located approximately 200 km north of Vancouver in the rain shadow of the southern Coast Mountains. There are no glaciers in the watershed; however water storage is provided by Gates Lake above Gates Creek and Seton and Anderson Lakes downstream of Gates Creek. Anderson Lake is connected to Seton Lake via the Portage River, and Seton Lake drains into the Fraser River via the Seton River (Figure 23). Gates Creek supports a population of Fraser River Sockeye Salmon (*Onchorynchus nerka*) that is important for First Nation, commercial and recreation fisheries, as well as smaller populations of Coho Salmon (*O. kisutch*), and Pink Salmon (*O. gorbuscha*).

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

In 1968, a Sockeye Salmon specific spawning channel was constructed by the International Pacific Salmon Fisheries Commission (IPSF) on Gates Creek 800 m upstream of Anderson Lake to enhance Sockeye escapement in the Seton-Anderson watershed. Enumeration of Sockeye Salmon returning to Gates Creek Watershed and juveniles migrating out of the spawning channel has been collected since the 1960's. From 2012 through 2015 the abundance of Sockeye Salmon fry leaving Gates Creek was evaluated (Lingard et al. 2015).

Coho Salmon and Bull Trout are also known to spawn in Gates Creek (Hillaby 2012). In 2012 a survey of habitat use by juvenile Coho Salmon was undertaken with funding from the Fish and Wildlife Compensation Program (FWCP). Fisheries and Oceans Canada (DFO) also do stream walks enumerating adult Coho Salmon in Gates Creek. To date no data has been collected addressing the population status of Bull Trout in Gates Creek. Estimates of population size and habitat usage are unknown for either Coho Salmon or Bull Trout in the Gates Creek watershed at present.

Enhancement of critical Bull Trout and Coho Salmon habitat in the Gates Creek watershed has been identified as high priority for by the Ministry of Environment (MOE) and BC Hydro (Fish and Wildlife Compensation Program 2011). In the spring of 2015, a Level 1 Habitat

Assessment was completed on Gates Creek. The goal of this study was to provide a baseline assessment of the current state of salmonid habitat in Gates Creek and identify restoration opportunities within the watershed.

## METHODS

### *2.1 Level 1 Fish Habitat Survey Procedures*

The habitat assessment was carried out according to the guidelines described in the Fish Habitat Assessment Procedures Manual (FHAP), Watershed Restoration Technical Circular 8 (Johnston and Slaney 1996). The fish habitat assessment procedure is a multi-step stream evaluation that quantitatively assesses forested, salmonid bearing streams. The procedure identifies fish species at risk, generates a quantitative description of fish habitat conditions, evaluates fish habitat conditions and identifies opportunities for effective fish habitat rehabilitation within the watershed (Johnston and Slaney 1996). The first step in the FHAP is to generate an overview summary of the existing fish species information in the watershed. Abundances of spawning Sockeye in Gates Creek and the spawning channel have been collected for the Pacific Salmon Commission and DFO from 1938 to the present. Abundances of Sockeye juveniles leaving the spawning channel have been collected since 1964, also by DFO. From 2012-2015 a juvenile Sockeye enumeration project was undertaken on Gates Creek. In addition to the Sockeye study, a survey of habitat utilization by juvenile Coho was carried out in the watershed over the summer and fall of 2011 (Hillaby 2012). During the juvenile Coho survey a smaller number of Bull Trout were also captured. Hillaby (2012) also surveyed habitat characteristics of the tributaries of Gates Creek, but did not complete a formal habitat survey on Gates Creek itself.

The entire mainstem of Gates Creek was assessed for this project. Major tributaries (Haylmore, Black Water and Spruce Creeks) were not surveyed during this work as they were previously assessed by Hillaby (2012). Gates Creek was sampled over the entire course of the river from its northern end near at Anderson Lake to the headwaters of Gates Lake. The total length of the river (17,310 m) was divided into 3 reaches that ranged from 4,303 m to 7,092 m (Figure 23). Survey teams consisted of a minimum of three experienced fisheries technicians. All staff participated in training sessions led by a qualified watershed restoration specialist trained in habitat assessment methods.

Within each reach, hydraulic units were separated into riffles, pools, cascades, glides and log jams. There were several large log jams on the river that consisted of complex habitat for multiple meters and spanned the entire width of the channel. Because the log jams spanned the entire channel it was decided to create a separate unit for them as they represented a unique type of habitat.

Other physical habitat measurements were made with meter sticks and laser range finders (accurate to  $\pm 1$  m). Measurements included the lengths of hydraulic units, bankfull width, wetted width, bankfull depth, mean wetted depth, maximum pool depth, and residual pool depth. Gradient measurements were taken with laser range finders. Velocity measurements were not taken during this survey.

The total amount of large woody debris (LWD) was counted within the bankfull width. To be counted, a piece of wood needed to exceed 2 m in length and 10 cm in diameter. Functional wood (within wetted width), defined as that which influences channel geomorphology, was also counted. The functional LWD was further categorized into size classes of 10-20 cm diameter, 20-50 cm diameter and >50 cm diameter. Within-reach large wood numbers were then compared to diagnostics table (Table 5, Johnston and Slaney 1996) values and rated accordingly. In order for the reach to gain a rating of "good" salmonid habitat a threshold of two pieces of LWD per bankfull width must have been reached.

Another diagnostic value calculated from measurements collected in each reach was pool frequency or mean pool spacing per bankfull width. This was calculated by dividing total reach length by the number of pools within a reach multiplied by mean bankfull width. In the diagnostics table found in Johnston and Slaney (1996) a value of less than two is considered to be good salmonid habitat, but similar to LWD this value is expected for streams of bankfull widths less than 15 m. In larger streams/rivers a value between 5-7 bankfull widths between pools was seen as being closer to natural salmonid habitat (Montgomery et al. 1995; Myers and Swanson 1997). Diagnostic values were used based on the bankfull width of the stream in question. Additional parameters estimated in the surveys included available cover, off channel habitat, disturbance indicators, riparian vegetation and substrate type and size.

Off channel habitat is important as it may serve as refuge or rearing areas for fish during times of high flows (Johnston and Slaney 1996) or over-wintering habitat. It is important to note the accessibility of these channels to fish as isolated channels could be reconnected as a restoration project.

GPS records of reach breaks and digital photographs were taken as a record of locations and a visual aid to record the site. Data has been collated into a master database (Appendix 1) attached to this summary report.

## ***2.2 Water Level Monitoring***

Discharge is not monitored on Gates Creek. Water level measured by a staff gauge at the spawning channel intake is recorded daily. This survey was conducted when water levels fell

between 0.6 and 0.65 m, which are near the minimum water levels observed during winter months (Lingard et al. 2015).

### ***2.3 GIS Mapping***

Polygons of habitat units were drawn from data collected during the survey onto the Freshwater Fisheries Atlas Stream Network Layer (available from DataBC). Units were matched to reach break co-ordinates taken with GPS. Only primary units were mapped as data was not collected with enough data to accurately map mid channel bars and secondary channels.

---

## RESULTS

Reaches in Gates Creek were numbered in ascending order upstream from Anderson Lake, with Reach 1 being directly above Anderson Lake. A total of 3 reaches were designated in the river (Figure 23). Reach length ranged from 4,303 m in Reach 2 to 7,092 m in Reach 1 (Table 19). The total wetted area sampled was 168,202 m<sup>2</sup>, with Reach 2 being the smallest (39,276 m<sup>2</sup>) and Reach 1 being the largest at 84,725 m<sup>2</sup>.

### **3.1 Reach 1**

Reach 1 began at the mouth of Gates Creek directly upstream of Anderson Lake and was 7,092 m long with a mean gradient of 1.2 %. Mean bankfull and wetted widths were 13.7 m and 10.7 m respectively. Of the total 84,725 m<sup>2</sup> of wetted area in Reach 1, 25,432 m<sup>2</sup> (30.0%) were composed of glide, 51,600 m<sup>2</sup> (60.9%) of riffle, 1,326 m<sup>2</sup> (1.6%) of pool, 3,614 m<sup>2</sup> (4.3%) of cascade, and 2,752 m<sup>2</sup> (3.2%) of log jams (Figure 25, Table 20).

Pool frequency was rated as poor according to the diagnostics table at a value of 103.8 bankfull widths per pool (Table 19). LWD was also rated as poor with 0.86 total pieces of LWD per bankfull width. In total, 912 pieces of LWD were observed in Reach 1 (Table 19). When large log jams were excluded total LWD is reduced 726 pieces. Of the total LWD found in Reach 1 (inclusive of log jams) 313 pieces were functional. Cover within the reach was provided primarily by overhanging vegetation, with 33% of total available cover provided by this category (Figure 25). Other important cover types in this reach included large woody debris (23%) and cut banks (20%) (Table 19).

Riparian vegetation along the reach was composed of mainly mixed forest in 73% of units. Conifer forests represented a further 8% of riparian vegetation in the reach. Closure of the riparian vegetation over the stream was minimal with 66% percent of units having 0-20% closure and 28% of units having 20-40% cover. Reach 1 appears to be somewhat unstable with 35% of units showing signs of disturbances in the form of eroding banks, log jams and extensive areas of (un-vegetated) bar (Table 19).

Dominant substrate within the reach was shared between cobble (45% of units) and boulders (20% of units) (Figure 26, Table 19). Gravel was the dominant substrate in 19% of units in Reach 1. Spawning gravel suitable to both resident and anadromous species was present in 71% of the habitat units. Extensive areas of spawning gravel for both resident and anadromous species were present in 23% of units, and 18% of units contained isolated

pockets. Within Reach 1, 2% of units contained extensive areas of gravel for anadromous species, while 14% of units contained isolated pockets. Extensive areas of spawning substrate for resident species was found in 5% of units, with an addition 9% of units containing isolated pockets (Figure 27).

### **3.2 Reach 2**

Reach 2 covered the portion of the creek that runs through agricultural lands (Figure 23 & Figure 28). Reach 2 was a total of 4,303 m long with a total wetted area of 39,276 m<sup>2</sup>. Mean bankfull and wetted widths were 10.1 m and 8.8 m, respectively. Of the 107 units in this reach, there were 106 glides. Glides composed 39,084 m<sup>2</sup> (99.5% of total area) and riffle composed 192 m<sup>2</sup> (0.5%) (Figure 28, Table 20). Mean water depth for this reach was 75.3 cm.

Pool frequency was rated as poor with zero pools contained in the reach (Table 19). LWD was also rated as poor with 0.78 total pieces of LWD per bankfull width. In total 1020 pieces of LWD were observed in Reach 2 (Table 19). Of the total LWD found in Reach 2, 338 pieces were functional. Overhanging vegetation provided 74% of the cover encountered in Reach 2 (Figure 25). Cut banks contributed another 17% to total cover.

Riparian vegetation along the reach was composed of mainly deciduous trees (43% of units) and shrubs (37% of units). Closure of riparian vegetation over the stream was limited in Reach 2. The majority (72% of units) had 0-20% closure. Reach 2 appears to be unstable with 36% of units showing signs of disturbances in the form of eroding banks and extensive areas of un-vegetated bar (Table 21).

Substrate in Reach 2 was dominated by fine sediments (98% of units) and gravel (2% of units) (Figure 26) Spawning gravel suitable for both resident and anadromous fish was present in isolated pockets in 7.5% of units. Extensive of substrate suitable for resident spawning were found in 25.2% of units and isolated pockets were present in 51.4% of units (Figure 27).

### **3.3 Reach 3**

Reach 3 covered the portion of the creek that runs from the southern edge of the agricultural lands to Gates Lake in Birken (Figure 23 & Figure 29). Reach 3 was 5,921 m long with a total wetted area of 44,201 m<sup>2</sup> and a mean gradient of 1.4%. Mean bankfull and wetted widths were 8.8 m and 7.2 m, respectively. Glides composed 33,710 m<sup>2</sup> (76% of total area), riffles composed 7,128 m<sup>2</sup> (16%), cascades composed 2,027 m<sup>2</sup> (5%), pools composed 632 m<sup>2</sup> (1.4%),

and log jams composed 704 m<sup>2</sup> (1.5%) (Table 20, Figure 29). Mean water depth for this reach was 37.9 cm.

Pool frequency was rated as poor with 335.3 bankfull widths per pool (Table 19). LWD was also rated as poor with 0.75 total pieces of LWD per bankfull width. In total 1,286 pieces of LWD were observed in Reach 3 (Table 19). Of the total LWD found in Reach 3, 567 pieces were functional (excluding log jams). Similar to Reach 1 there were several large log jams that were separated into distinct units. Overhanging vegetation provided 37% of the total cover encountered in Reach 3, cut banks contributed another 28% (Figure 25).

Riparian vegetation along the reach was varied. Over the length of the reach mixed forests composed the vegetation in 26% of the units, shrubs were present in 25% of units, conifer forests were present in 24% of units, and deciduous forests were present in 23% of units. Closure of riparian vegetation over the stream was greater in Reach 3 than in other reaches. Overall, 58% of the units had 0-20% closure, 24% had 20-40%, 15% had 40-70% and 3% had greater than 90% closure. Reach 3 appears to be relatively unstable with 34% of units containing signs of disturbances in the form extensive areas of (un-vegetated) bar, braiding (multiple channels) and log jams (Table 21).

Substrate in Reach 3 was dominated by gravel (32% of units) and fine sediment (34% of units) (Table 19, Figure 26). Spawning gravel suitable for both resident and anadromous fish was present in extensive areas in 34% of units and in isolated pockets in 19% of units. Extensive areas of substrate suitable for anadromous spawning were present in 8% of units, and in isolated pockets in 6% of units. Extensive areas for resident spawning were found in 9% of units (Figure 27).

### ***3.4 Off Channel Habitat***

A total of 2,626 m of off-channel habitat were measured along the extent of Gates Creek. Off-channel habitats took the form of ponds, wetlands, sloughs and side channels. Across all reaches side channels were the most abundant off channel habitat.

Reach 1 had an array of off-channel habitats measuring 1,515 m in length that may serve as over wintering and refuge areas. Within Reach 1 there was a total of 23 side channels of which 12 had good access at all flows, 11 had poor access, and 1 had no access. In addition to side channels, Reach 1 also had a ground water fed wetland with poor access located approximately 250 m upstream of Anderson Lake. There were also 2 inaccessible ponds within the reach.

Reach 2 had a total 276 m meters of over wintering habitat composed of 10 side channels, and 1 wetland. The wetland as well as 9 if the side channels had good access at most flows. The remaining side channel was inaccessible at all flows.

Reach 3 had a total of 23 side channels, 5 sloughs and 10 wetlands totally 835 m in length. Less than half the side channels had good access (10) while 12 had poor access and 1 had no access. Of the sloughs in Reach 3: 2 had good access, 2 had poor access and 1 had no access. Access to wetlands in Reach 3 could be improved: 2 out of 10 had good access, 1 out of 10 had poor access, and 7 out of 10 had no access (Table 22).

## DISCUSSION

### ***4.1 Habitat Survey***

The goal of this study was to provide baseline estimates of spawning and rearing habitat in Gates Creek as well as identify restoration potential. Overall, this study identified a need for increased complexity in the stream. Both functional woody debris and pools were found to be sparse along the length of Gates Creek. Both reaches 1 and 3 had a variety of habitat types and contained good quality spawning substrate. Reach 2 has been the most impacted by land use practices.

Reach 1 had a wider bankfull channel width and (13.7 m) than reaches 2 and 3 (10.1 and 8.8 m, respectively). Several large, steep tributaries (Haymore, Black Water and Spruce Creeks) enter Gates Creek in Reach 1. Reach 1 contained an abundance of spawning gravel for either anadromous or resident salmonids (71% of units) as well as side channels for refuge during high water events. While mature forest existed along Reach 1, in areas where it ran between Portage Road and the rail line the canopy tended to be thinner and more open. Disturbances, such as gravel bars and eroding banks, in Reach 1 give the impression habitat in this reach is dynamic, changing with sediment transport during high water events. Bank stabilization should be evaluated further, in a Level 2 Habitat Survey, to ensure spawning habitat isn't at risk of being compromised.

Reach 2 can be described as a deep, sandy, glide with invasive grasses covering the banks of the constrained channel. Diking has forced the creek into a narrow deep channel with little overhead cover except from that provided by occasional pockets of shrubs. Instream cover and spawning substrate were both lacking along the length of the reach. Conversion of the riparian vegetation to pastures of invasive grasses has reduced the amount of stream cover. The majority (98%) of Reach 2 was glides greater than 1 m deep, with fine sediment. Further evaluation of Reach 2 in a Level 2 Habitat Survey is needed to develop options for remediating the impacts of agricultural land use.

Reach 3 was the narrowest section of Gates Creek with tight canopy cover in areas, and a slightly steeper mean gradient (1.4%) than Reach 1. Reach 3 had an abundance of quality spawning habitat for both anadromous and resident salmonids (78% of units), but was lacking in pools and functional woody debris. While Sockeye Salmon are not typically seen spawning above Reach 1 (DFO unpublished data), juvenile Coho were found rearing in several sites in Reach 3 when surveyed by Hillaby (2012) which suggests Coho spawn in Reach 3.

Multiple types of off-channel habitat occur along Gates Creek. Reaches 1 and 3. Both reaches had multiple side channels with good access, shade, cover and substrate for providing over-wintering habitat and refuge from high water events. A lesser amount of off-channel habitat

also exists in Reach 2 which also had good access. Increasing access to off-channel habitat in Reach 3 and building off-channel habitat in Reach 2 may be options for future restoration work.

#### ***4.2 Potential Restoration Opportunities***

Habitat suitability indexes (HSI) can be useful in determining potential factors limiting a species in a stream. Juvenile Bull Trout density (both young of the year and 1+) has been positively associated with overhead cover (large woody debris, cobble, boulder, and cut banks) and slow moving water (McPhail and Baxter 1996). Shallow margins with gravel or cobble are preferred by young of the year while deeper water (up to 1 m) are preferred by 1+ and older fish (McPhail and Baxter 1996). Pools are important habitat for rearing juveniles once they move out of stream margins. Bull Trout are also cold water specialists, and prefer habitats with temperatures below 14-16°C (Dunham et al. 2003).

Coho Salmon young of the year and yearlings typically prefer smaller streams (< 5 m) and low gradients (Rosenfeld et al. 2000). Coho have been shown to be associate with slow moving waters, off channel ponds, deep pools and large woody debris (Swales et al. 1986). Habitat preferences of Coho shift throughout the year. Juvenile Coho Salmon have been found to move from pools in the summer to beaver ponds, wetlands and sloughs for overwintering (Nickelson et al. 2011).

Hillaby (2012) observed Coho Salmon in all three reaches surveyed in this study; however, Coho biomass decreased from downstream to upstream trap sites. Biomass of rearing Coho juveniles was highest in Reach 1 (the area extending upstream from Anderson Lake to the start of the agricultural lands) and lowest near Gates Lake. Reach 1 is also where the majority of spawning Sockeye are found. The available data regarding fish habitat usage in Gates Creek suggest future restoration works should focus on reaches 2 and 3.

Using the above mentioned habitat preferences from McPhail and Baxter (1996), Rosenfeld et al. (2000) and Swales et al. (1986), additions of functional woody debris, gravel, and boulders to Reach 2 should be a focus of future restoration projects. In addition to increasing instream cover and spawning substrate in Reach 2, restoration of riparian vegetation will be needed to increase stream shading. Forest canopy is important for insulating streams from solar radiation (Hotlby 1988). Currently, summer water temperatures in Gates Creek can reach up to 15°C (Lingard et al. 2015) and may exceed levels favored by Bull Trout in coming years with climate change (Mantua et al. 2010).

Gaining support of private land owners for restoration works in Reach 2 is a potential challenge to restoring fish habitat in this particular reach. With the exception of two properties purchased by BC Hydro (9523 and 9484 Portage Road), the majority of this reach

runs through private lands currently used for agricultural purposes. However, the properties owned by BC Hydro provide a valuable opportunity for restoration. Complexing, addition of larger substrate, building of side channels and restoration of the riparian vegetation adjacent to the stream could begin on these two properties as model projects to encourage surrounding land owners.

Access to off channel wetlands in Reach 3 was limited. As previously mentioned, rearing Coho Salmon prefer slow moving water like ponds, sloughs, and wetlands for overwintering (Nickelson et al. 2011). Therefore, improving access to these wetlands has potential to increase rearing habitat for Coho in Reach 3. Building of pools and additions of large woody debris complexes along the length of the reach may also increase rearing habitat and instream cover for both Bull Trout and Coho Salmon.

Despite an abundance of suitable spawning habitat in Reach 3, fewer Coho Salmon juveniles were found in Reach 3 than in reaches 1 and 2 by Hillaby (2012) suggesting fewer fish are spawning in Reach 3. Compared to adult Sockeye Salmon returns in Gates Creek, which number upwards of 50,000 fish in years of favorable returns (DFO unpublished data), returns of Coho are small. Between 2001 and 2010, total returns of adult Coho Salmon to Gates Creek ranged between 54 and 1,700 fish (DFO unpublished data) indicating low densities of Coho Salmon spawners compared to the volume of available spawning habitat in Gates Creek.

Spawning site selection in Coho Salmon has been positively related to the presence of other salmon redds (Mull and Wilzbach 2007). Therefore, the lower number of fish using Reach 3 compared to Reach 1 may, itself, contribute to the underutilization of spawning habitat in this reach. More in-depth surveys of both Bull Trout and Coho Salmon habitat utilization and population dynamics in Gates Creek would aid in informing the limiting factors for each species and assist prioritization of restoration initiatives.

This Level 1 Habitat Survey provided a snap shot of the available spawning and rearing habitat for Bull Trout and Coho Salmon in Gates Creek. While key areas for restoration were identified, further evaluation of the stream in a Level 2 Habitat Survey are needed to develop specific habitat prescriptions along the length of the stream. Because little information exists on the status of Coho Salmon and Bull Trout populations in this creek, population monitoring of both species should be initiated prior to restoration works to establish bench marks against which effects of projects can be evaluated.

## RECOMMENDATIONS

From the data collected during this Level 1 habitat survey the following next steps are recommended to guide restoration works on Gates Creek:

- Completion of a Level 2 Habitat Survey focusing on those areas identified in this report as having the potential for improving fish habitat.
- Completion of vegetation surveys in riparian areas of Reach 2 to guide development of restoration prescriptions of riparian buffer for this section of stream.
- Generation of a restoration plan for the entire Gates Creek watershed (including tributaries) with input from land owners and surrounding communities.
- Initiation of abundance and distribution surveys of Bull Trout and Coho Salmon populations in Gates Creek to establish benchmarks against which future works can be evaluated.

### Note on Birken Landslide September 2015

Unfortunately, after this study was completed in March 2015, a landslide occurred at 9282 Portage Road on September 20<sup>th</sup>, 2015. The slide containing fine sediment, rock and woody debris went into Gates Creek where this property abuts the channel. Therefore, some of the results presented in this report may no longer be a true representation of this available spawning habitat in Gates Creek as significant amounts of mud were reported (Harry O'Donaghey pers. comm.) in the water column of Gates Creek in the days following the slide. In addition to the sediment load immediate following the slide, repeated events of high turbidity have been reported during rain events in the weeks following the slide (Chris Fletcher pers. comm.). The area where the slide entered the creek should be included in future Level 2 Habitat Surveys and restoration plans.

## **TABLES**

**Table 19. Habitat characteristic of Gates Creek broken into 3 reaches.**

	Reach		
	1	2	3
<b>Reach length(m)</b>	7,092	4,303	5,921
<b>Total wetted area (m<sup>2</sup>)</b>	84,724	39,276	44,201
<b>Mean gradient (%)</b>	1.2	0.3	1.4
<b>Mean bankfull width (m)</b>	13.5	10	8.8
<b>Mean wetted width (m)</b>	10.7	8.8	7.2
<b>Mean water depth (m)</b>	48.1	75.3	37.9
<b>Mean bankfull depth (m)</b>	48.3	50.2	39.3
<b>Mean pool spacing per channel width</b>	104.8	-	323.5
<b>Number of functional LWD pieces per channel width</b>	0.84	0.77	0.75
<b>Dominant substrate</b>	C/B	S	G
<b>Dominant cover</b>	OV/LWD	OV/CB	OV/CB

**Table 20. Habitat type by reach parameters for the mainstem Gates Creek collected during spring 2015**

		Reach		
		1	2	3
<b>Riffle</b>	<b>Length in reach(m)</b>	4416.8	24.0	1126.0
↓	<b>Total wetted area (m<sup>2</sup>)</b>	51,601	192	7,128
	<b>Reach amount (%) of total area</b>	60.9	0.5	16.1
<b>Pool</b>	<b>Length in reach (m)</b>	112.3	0.0	50.0
↓	<b>Total wetted Area (m<sup>2</sup>)</b>	1,326.0	0.0	632.0
	<b>Reach amount (%) of total area</b>	1.6	0.0	1.4
<b>Cascade</b>	<b>Length in reach(m)</b>	376.8	0.0	442.0
↓	<b>Total wetted Area (m<sup>2</sup>)</b>	3,514.0	0.0	2,027.0
	<b>Reach amount (%) of total area</b>	4.3	0.0	4.6
<b>Glide</b>	<b>Length in reach (m)</b>	2460.9	4328	4555
↓	<b>Total wetted Area (m<sup>2</sup>)</b>	25,432	39,084	33,710
	<b>Reach amount (%) of total area</b>	30.0	99.5	76.3
<b>Log Jam</b>	<b>Length in reach (m)</b>	231.4	0.0	86.0
↓	<b>Total wetted Area (m<sup>2</sup>)</b>	2,752.0	0.0	704.0
	<b>Reach amount (%) of total area</b>	3.2	0.0	1.6

**Table 21. Disturbance indicators by reach for Gates Creek collected during spring 2015.**

(EB=Eroding Banks, PD=Most LWD parallel to banks, MC=Multiple channels (braiding), MB=Elevated mid-channel bars, DW=Extensive areas of (un-vegetated) bar, WG=Large, extensive sediment wedges, and LJ/JM= Recently formed log jams)

Reach	Number of Units with Disturbances	Percent of units with Disturbance	Disturbance Type
1	72	35	DW, EB, JM, PD
2	38	36	DW, EB
3	69	34	DW, MB, JM

Table 22. Off channel habitat by reach for Gates Creek collected in spring 2015.

SC= Side channel, SL= Slough, WL= Wetland, and PD= Pond (Good= Accessible at most flows, Poor= Accessible only at high flows, None= isolated from main channel)

Reach	Number of off channel Habitat	Length (m)	Type	Current Fish Access
1	26	1515	26 SC, 1 WL, 2 PD	13 x Good, 13 Poor, 3 x None
2	10	276	10 SC, 1 WL	10 x Good, 1 x Poor
3	38	835	23 SC, 5 SL, 10 WL	14 x Good, 13 x Poor, 13 x None

## FIGURES

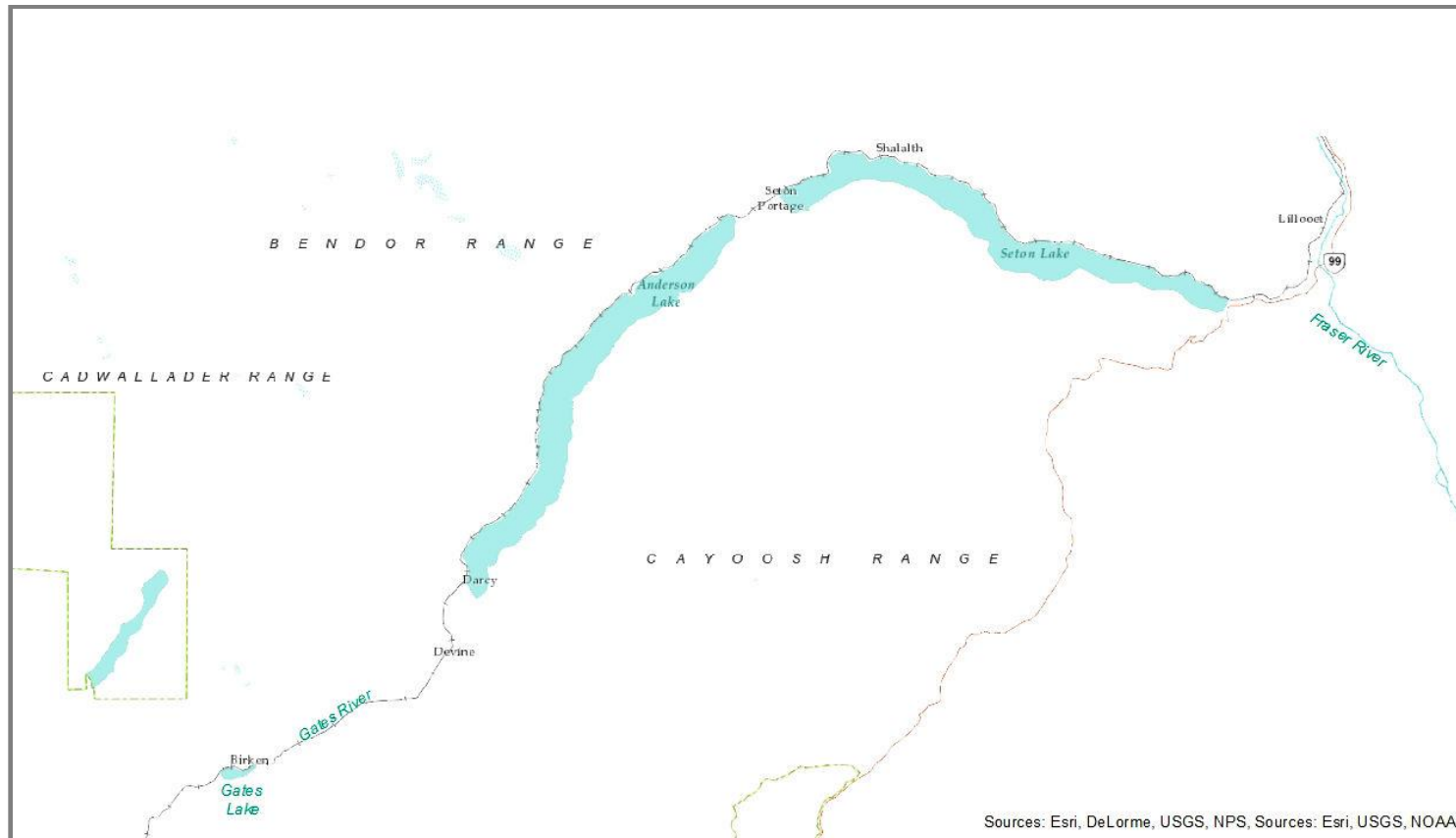


Figure 22. Map of Seton- Anderson Watershed including Gates Creek running from Gates Lake to Anderson Lake in the town of D'Arcy

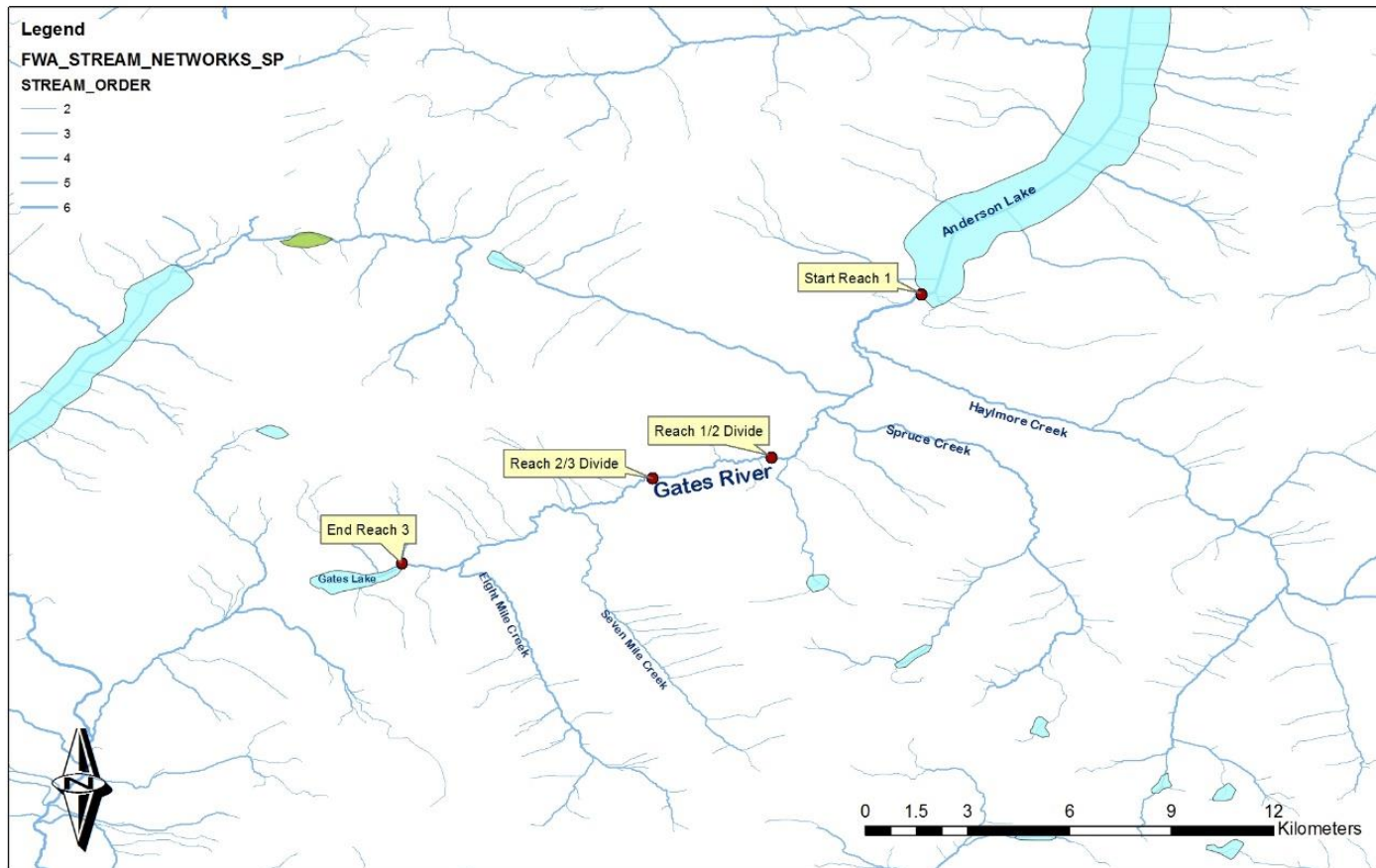


Figure 23. Map of Gates Creek with reach breaks indicated

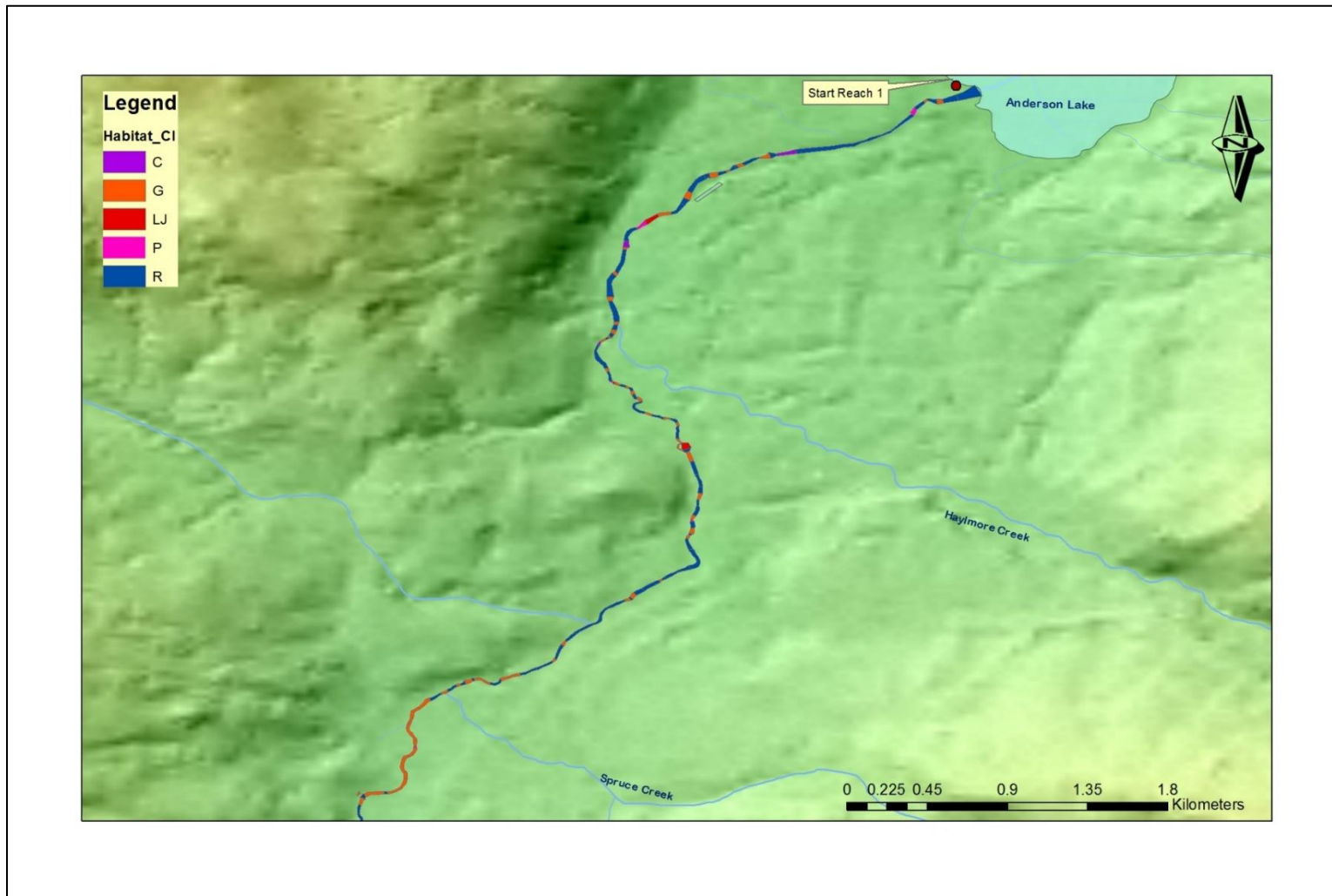
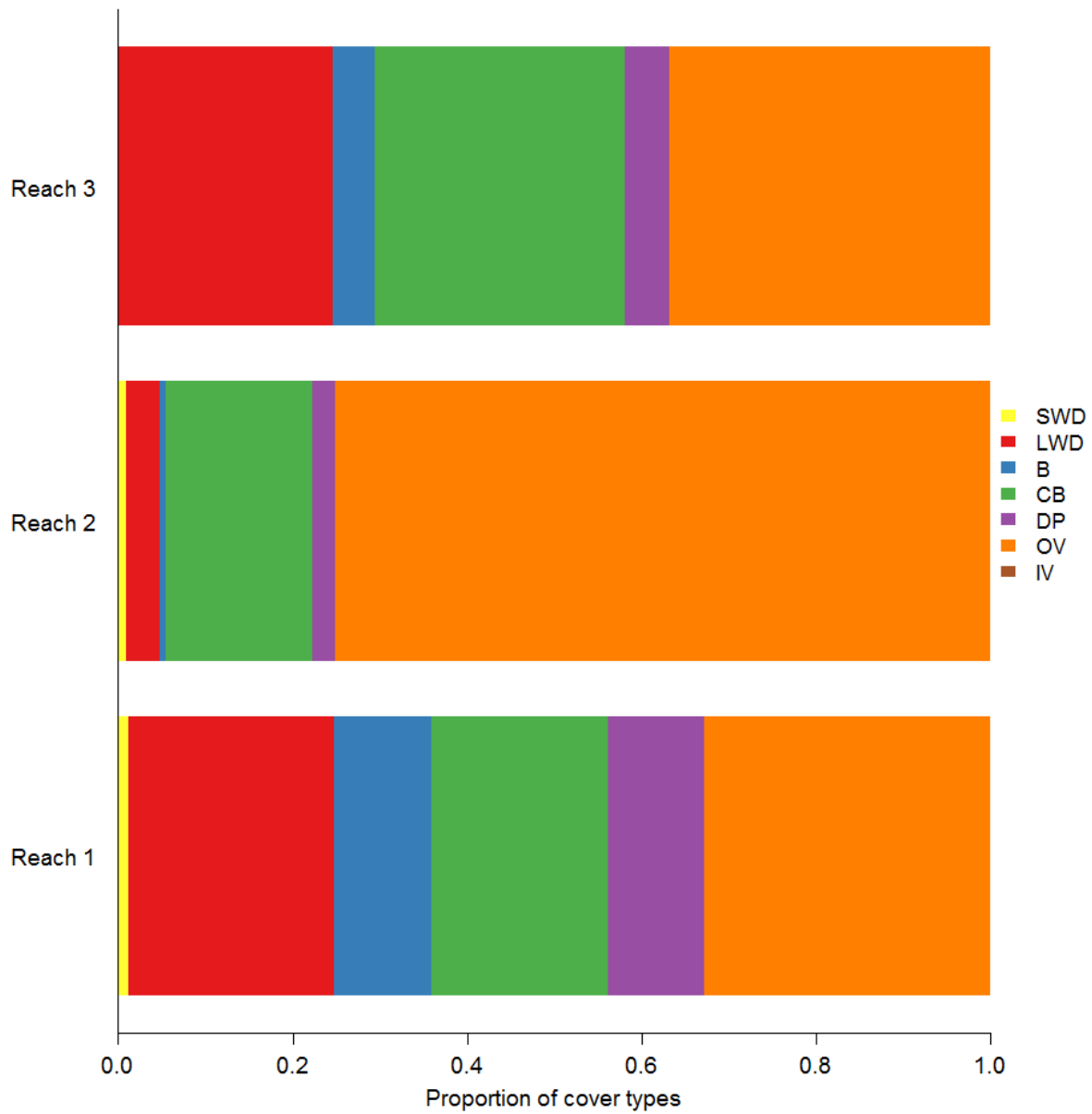
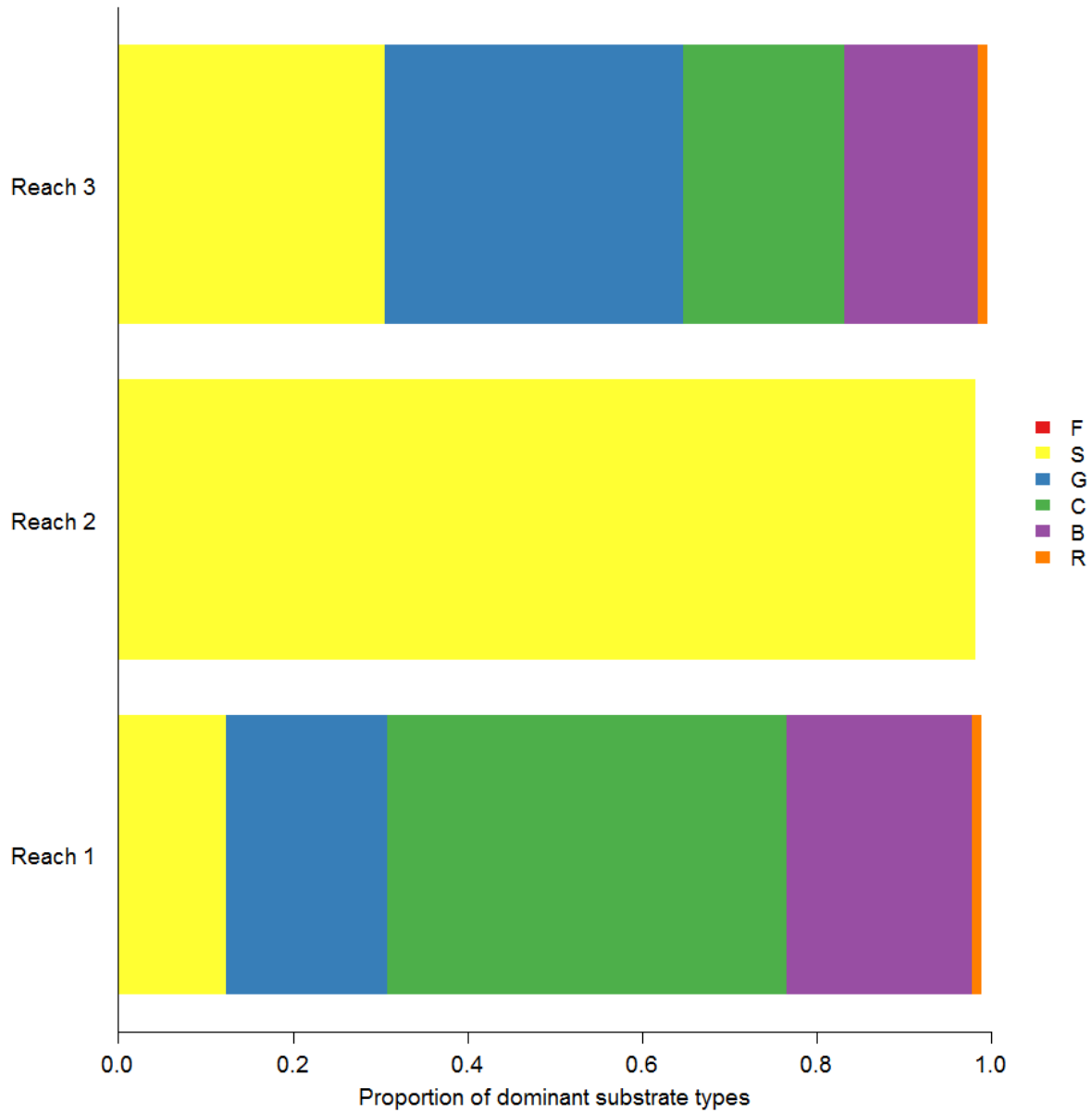


Figure 24 Map of Reach 1 of Gates Creek habitat survey extending south from Anderson Lake. Individual habitat units are shown by colour.

(C= Cascade, G= Glide, LJ= Log Jam, P=Pool, R=Riffle)



**Figure 25. Proportion each cover type represents of total available cover in each reach. (SWD= small woody debris, LWD= large woody debris, B= boulder, CB= cut bank, DP= deep pool, OV= over hanging vegetation, IV= instream vegetation)**



**Figure 26. Proportion of units with in a reach where each substrate type was dominant. (F=finest, S=sand, G=gravel, C= cobble, B=boulder, R= bedrock)**

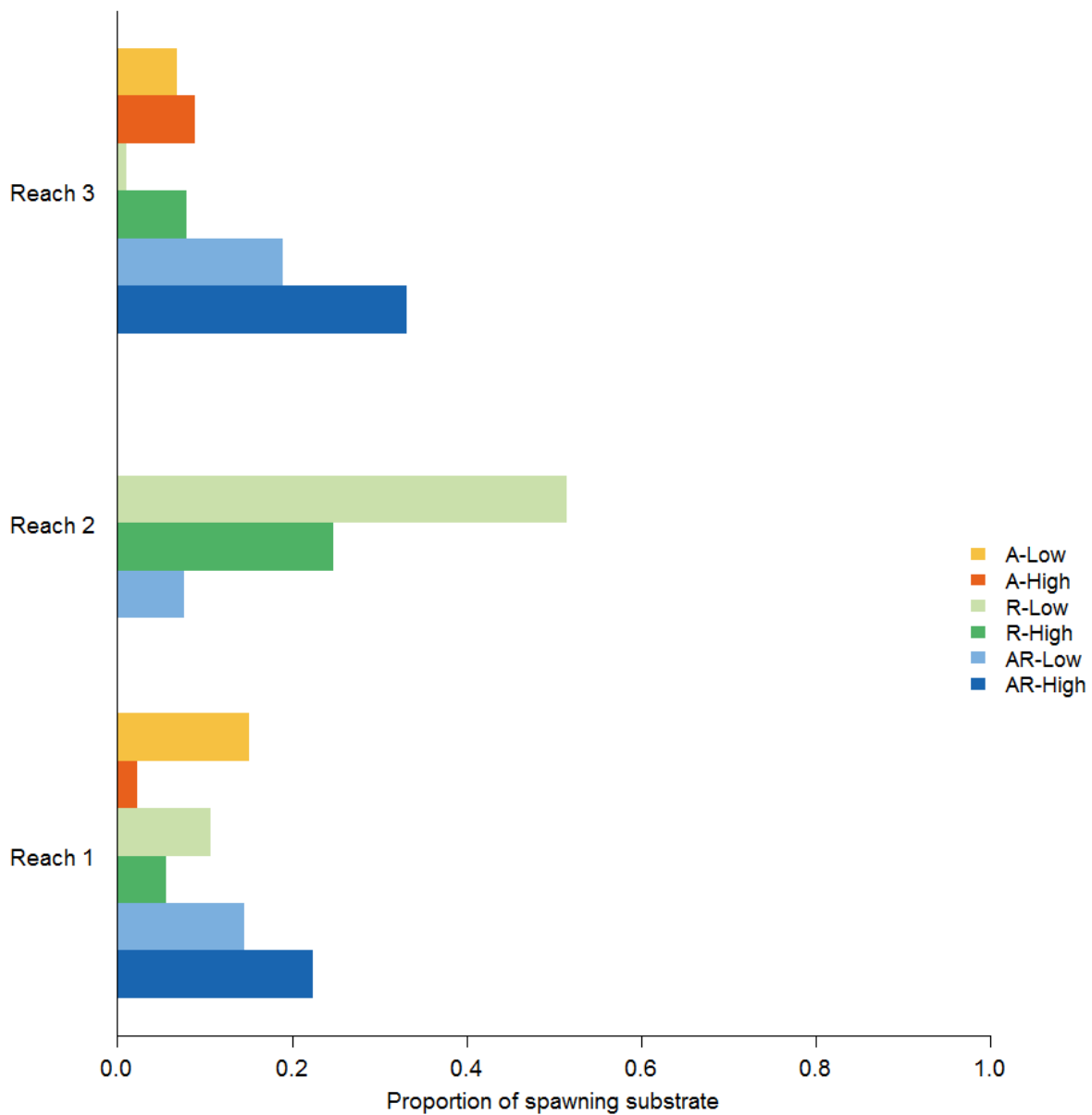
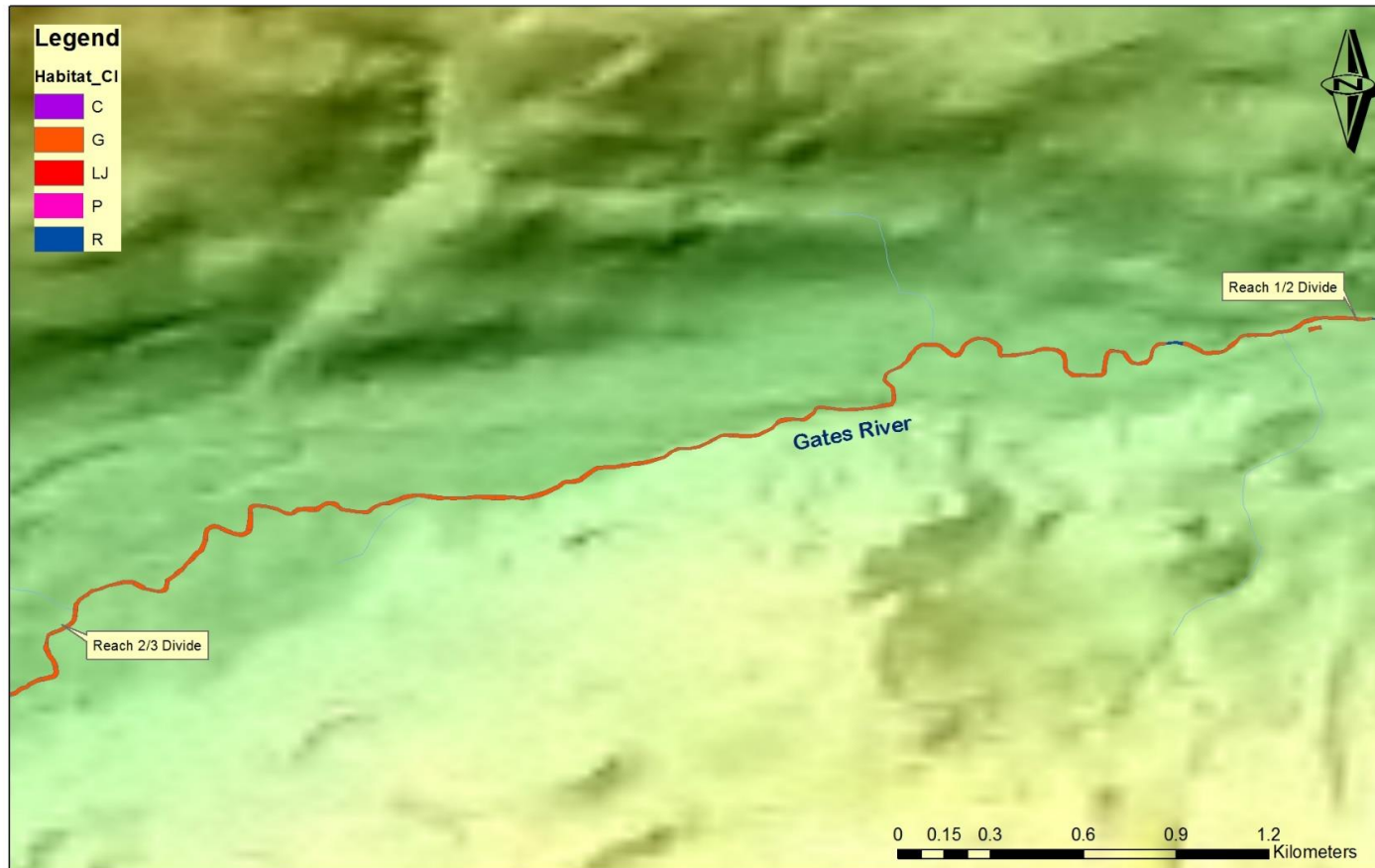
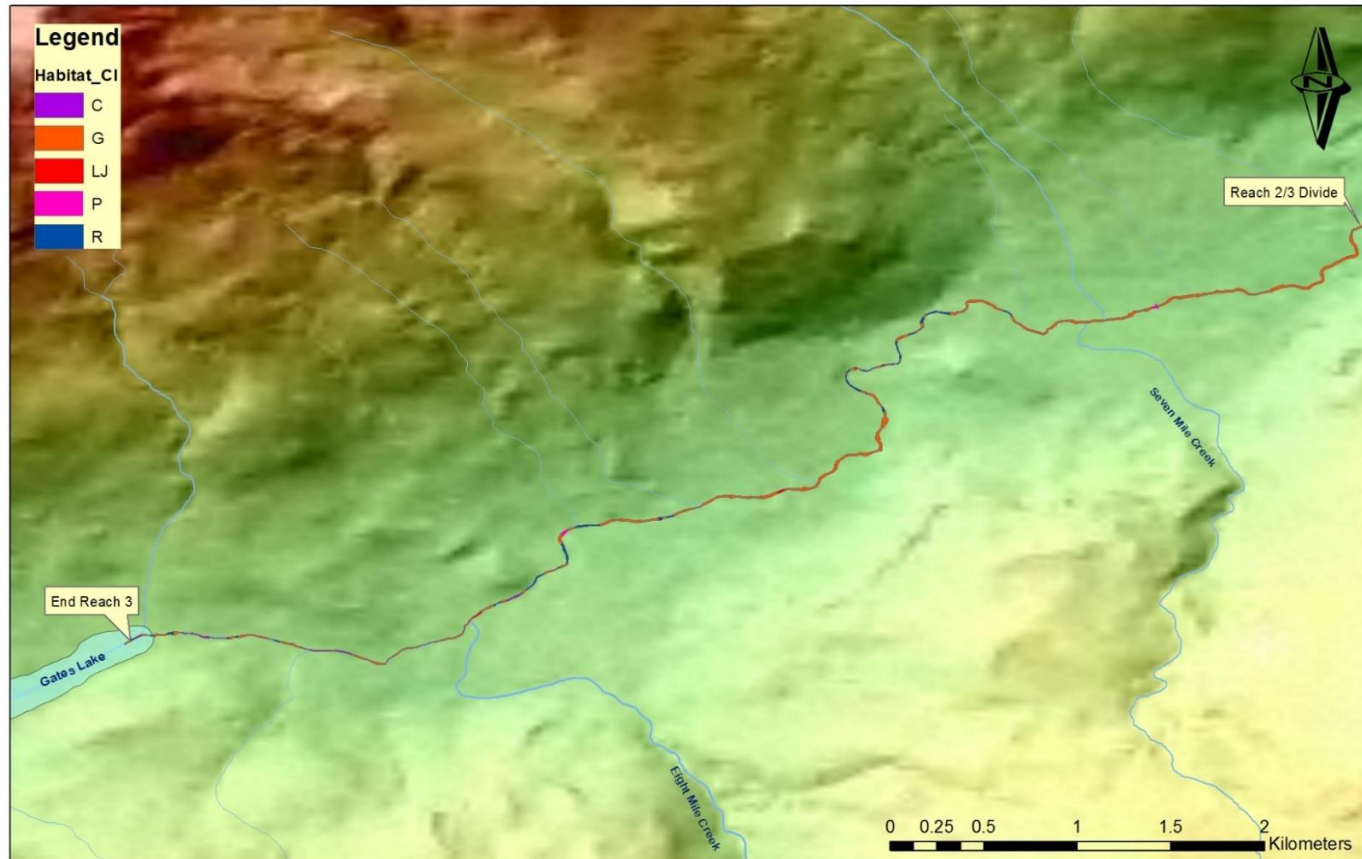


Figure 27. Proportion of available spawning substrate with in a reach appropriate for resident or anadromous spawners.

(A= Anadromous, R= Resident, L= isolated patches, H= extensive areas)



**Figure 28. Map of Reach 2 of Gates Creek habitat survey. Individual habitat units are shown by colour.**  
(C= Cascade, G= Glide, LJ= Log Jam, P=Pool, R=Riffle)



**Figure 29. Map of Reach 3 of Gates Creek habitat extending south-west from end of Reach 2 to Gates Lake. Individual habitat units are shown by colour.**

**(C= Cascade, G= Glide, LJ= Log Jam, P=Pool, R=Riffle)**

## REFERENCES

- Andrew FJ and Green GH. 1958. Sockeye and pink salmon investigations at the Seton Creek hydroelectric installation. Progress Report, International Pacific Salmon Commission, New Westminster, Canada. 78 p.
- Fish and Wildlife Compensation Program. 2011. Bridge/Seton River watershed salmonid action plan final draft. Fish and Wildlife Compensation Program. 24 p.
- Fretwell MR. 1989. Homing behavior of adult Sockeye salmon in response to a hydroelectric diversion of home water at Seton Creek. International Pacific Salmon Commission Bulletin 25: 38 p.
- Holtby B.L. 1988. Effects of logging on stream temperatures in Carnation Creek British Columbia, and associated impacts on Coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 45(3):502-515.
- Hillaby J. 2012. Late summer distribution of juvenile Coho Salmon in the Gates Creek Watershed. Report Prepared for Lillooet Tribal Council with funding from Fish and Wildlife Compensation Program. 62p. Project No. 11.SON.01.
- Johnston N.T., and Slaney P.A. 1996. Fish Habitat assessment procedures. Province of BC Watershed Restoration Technical Circular No. 8: 97p.
- Komori V. 1997. Strategic fisheries overview for the Bridge/ Seton habitat management area. Fraser River Action Plan, Department of Fisheries and Oceans, Vancouver, Canada. 83 p.
- Lingard S.L., Burnett N., Melville C.C. 2015. Gates Creek juvenile salmonid outmigration assessment, spring 2015. Report prepared for Lillooet Tribal Council and Fisheries and Oceans Canada with funding from the Fish and Wildlife Compensation Program. 55 p. Project No. 16.SON.01.
- Mantua N., Tohver I., Hamlet A. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change. 102:187:223.
- Myers T., and S. Swanson 1997. Variability of pool characteristics with pool type and formative feature on small Great Basin rangeland streams. Journal of Hydrology 201:62-81.
- Nickelson T.E., Rodgers S.L, Johnson M.F. 1992. Seasonal changes in habitat use by juvenile Coho Salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences. 49(4):783-789.

- Rosenfeld J., Porter M., Parkinson E. 2000. Habitat factors affecting the abundance and distribution of juvenile Cutthroat Trout (*Oncorhynchus clarki*) and Coho Salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Science*. 57: 766-774.
- Slaney P.A. and Andusak H. 2003. Fish habitat assessment of the Lardeau River (2002) integrated with habitat assessments of the Duncan River. Contract report for the Ministry of Water, Land and Air Protection. 37p
- Swales S., Lauzier R.B., Levings C.D. 1986. Winer habitat preferences of juvenile salmonids in two interior rivers in British Columbia. *Canadian Journal of Zoology*. 64(7):1506-1514.
- Talbot G.B. 1950. A biological study of the effectiveness of the Hell's Gate fishways. Bulletin 3, International Pacific Salmon Commission, New Westminster, Canada. 80 p.

This page has been left intentionally blank.