Gates Creek Salmonid Population Assessment, Spring and Summer 2016

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Executive Summary

This report summarizes the monitoring activities of the Gates Creek Salmonid Habitat and Population Assessment. The project was funded by the Fish and Wildlife Compensation Program. The Gates Creek Salmonid Habitat and Population Assessment primarily addresses the "research and information acquisition" action in the Bridge Seton Salmonid Action Plan by providing baseline population estimates for rearing salmonids in the Gates Creek watershed.

This report is broken into two chapters to accommodate the difference in methodologies used between the two field components of the project.

The “Gates Creek Juvenile Sockeye Salmon Migration and Survival” is the first chapter and discusses the final year of data collection for juvenile Sockeye Salmon that commenced in the spring of 2012. The chapter summarizes the abundance and survival estimates for Sockeye Salmon fry leaving Gates Creek and the Gates Creek spawning channel over the past five years with emphasis on the data collected in the spring of 2016.

The second chapter, the “Gates Creek Juvenile Salmonid Assessment” presents the results of the first year of a proposed four-year open site electrofishing mark-recapture survey for juvenile Coho Salmon, Bull Trout and Rainbow Trout. Fish density for age 0+ Rainbow Trout and catch statistics for Coho Salmon and Bull Trout juveniles are provided in this chapter.

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Project Background

Gates Creek is a major salmon-bearing tributary of the Seton-Anderson watershed that extends 17 km from Gates Lake to Anderson Lake and drains approximately 34 300 hectares (Komori 1997) (Figures 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. gorbushca*).

Salmonid populations in Gates Creek 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 populations through entrainment of juveniles and reduced adult escapement (Fretwell 1989; Komori 1997). In addition to these downstream impacts, salmonid 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 Salmon 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 not been conducted. Prior to this study, egg-to-fry survival and abundance data from Gates Creek had not been collected. Enumeration of juvenile Bull Trout, Rainbow Trout or Coho Salmon abundances in Gates Creek had also not been conducted, although there has been a recent evaluation of habitat use by rearing juvenile Coho Salmon (Hillaby 2012). This report addresses these knowledge gaps by providing baseline population estimates for rearing salmonids in the Gates Creek.

Chapter 1: Gates Creek Juvenile Sockeye Salmon Migration and Survival

Executive Summary

This chapter presents the results of the juvenile salmonid outmigration study on Gates Creek in spring 2016. This was the fifth-year monitoring juvenile Sockeye Salmon (*Oncorhynchus nerka*) abundance from Gates Creek and the Gates Creek spawning channel.

Juvenile fry were caught during their outmigration using two types of traps, a partial river inclined plane trap (IPT) on Gates Creek from March 29th to April 19th, and a full channel weir on the spawning channel from March 22nd to May 9th, 2016. Fry abundance and migration timing were estimated from mark-recapture data collected during trap operations using Bayesian P-Spline models.

An estimated 9 896 980 (standard deviation 546 917) fry migrated out of Gates Creek and the spawning channel combined in spring 2016. Of this total, 68% (6 682 451) out-migrated from Gates Creek and 32% (3 214 530) out-migrated from the spawning channel. An additional 150 347 fry were estimated to have left the spawning channel before and after outside of the mark-recapture program. With the additional fry from the channel, a total of 10 085 228 fry were estimated to have migrated out of the system between March 22nd to May 9th. Fry abundance in 2016 should be considered a minimum estimate of what left Gates Creek, as water levels prevented sampling in the final three weeks of the typical out-migration period. It is also likely that the program missed a portion of the fry early in their migration, as 332 438 fry were estimated in the first strata of 2016 indicating that the migration was underway when the assessment began. Egg-to-fry survival for the spawning channel was 30%, with an estimated 966 fry produced per effective female in 2016. Estimated egg-to-fry survival for Gates Creek was 34%, with an estimated 1 091 fry produced per effective female.

Despite a contracted study period in 2016, the abundance of fry leaving the Gates Creek watershed was the third highest estimate of the five years assessed, 6% higher than the abundance estimated in 2015.

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1.0 INTRODUCTION

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 adult monitoring (counts and fecundity assessments), was submitted by the Lillooet Tribal Council (LTC) and DFO to the BC Hydro FWCP. The original study proposal was for a four-year cycle; however, in September 2015 there was a debris torrent in the community of Birken that affected Gates Creek (Figure 2). A fifth year of Sockeye enumerate was proposed for 2016 to evaluate whether the debris flow negatively affected egg to fry survival of Sockeye Salmon in Gates Creek. The following report summarizes the findings of the 2016 juvenile component of the fifth study year.

1.1 Study Objectives

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

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

1.2 Study Area and Trapping Locations

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

2.0 METHODS

Two methods were used to enumerate out-migrant juvenile Sockeye Salmon in 2016, and were similar to previous study years (Lingard et al. 2013):

- An inclined plane trap (IPT), which samples a proportion of the out-migrant Sockeye Salmon fry, requiring mark-recapture sampling methods and analyses to estimate juvenile outmigration from Gates Creek.

- A complete channel trap used to capture all out-migrating fry from the spawning channel.

The study design was developed to ensure sampling methods minimized fish mortality and stress.

2.1 Fish Trap Operations

2.1.1 Gates Creek Traps - Inclined Plane Trap (IPT)

An Incline Plane Trap was used as the downstream recapture trap in this study. The IPT was operated from March 29th to April 19th. The IPT was 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). The trap was set to fish each day at dusk (between 6 pm and 8 pm), and was 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 and previous year's operation of the IPT 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.

2.1.2 Channel Trap

The full channel trap at the downstream end of the spawning channel guides all out-migrating 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 its length 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.

2.2 Sockeye Fry Marking and Recapture

Mark-recapture methods were used to assess the capture efficiency of the mainstem juvenile trap (IPT). A known number (up to 2500) 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 provided 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 temporally stratified method was developed for enumerating Pink and Chum Salmon in the Cheakamus River and is documented in Melville and McCubbing (2012).

On marking days, fry collected at the channel trap were not sampled but were held in the trap boxes until late afternoon. A maximum of 2500 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 L 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 2002). Daily fry catch data represented a 24-hour sampling period beginning at 8 am each morning.

2.3 Length and Weight Sampling of Sockeye Fry

Samples of Sockeye Salmon fry (N=25) were taken from both 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.

2.4 Environmental Monitoring

2.4.1 Water Level

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.

2.4.2 Water Temperature

Water temperature in Gates Creek was monitored over the incubation period (extending from peak of spawn to peak of juvenile migration). Temperature loggers in the spawning channel were vandalized part way through the incubation period.

2.5 Population Estimate Methods

2.5.1 Total Sockeye Salmon 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, 2015, 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 methods make several 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).

2.5.2 Gates Creek Spawning Channel Sockeye Salmon 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 the 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.

When only the sample box was run (Friday to Sunday), 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.

2.5.3 Gates Creek Sockeye Salmon 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.

2.5.4 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 2015 brood year (Lingard et al. 2015a). Fry *per* effective female[1] was calculated by dividing the number of fry by the number of effective females for 2015. Lingard et al. (2015a) provides further information regarding the calculation of the number of effective females.

3.0 RESULTS

3.1 Fish Trap Operations

3.1.1 IPT

The mark-recapture program in 2016 was 28 days long and the shortest of all five study years. From 2012-2015 the mean length of the mark-recapture program was 55 days (range: 45 to 65).

[1] Effective female refers to a female that successfully spawned

Recapture rates for the IPT ranged from 1.5% to 12.5% (mean ± standard deviation (SD): 6.5% ± 4.0%). Fry catches in the IPT ranged from 4305 to 26 186, with a mean daily catch of 10 885 (SD 5 596).

3.1.2 Channel Trap

The channel trap was operated 100% of the study period (49 of 49 days). The proportional sampler functioned 100% of the study period with a mean sample rate of 4.8% (SD 1.3%) and a range of 3% to 8%.

3.2 Bio-Sampling of Sockeye Salmon Fry

Fry caught in the channel trap were similar in size to fry caught in the IPT and no significant difference was found in mean fry length (Welch's t-test, P=0.47). The mean length of fry caught at the IPT (N=100, SD=1.4) and spawning channel (N=200, SD=0.8) was 28 mm (Table 2, Figure 5). Variance in fork length was significantly higher in Gates Creek than in the Spawning Channel that in Gates Creek (F-test, $F_{(99,199)}$ =0.50, P <0.001) (Table 2, Figure 5). Fry caught at the IPT and spawning channel had similar ranges (26 to 30 mm and 25 to 31 mm, respectively).

Mean fry length in the spawning channel and IPT fell with in similar ranges among study years. From 2012 to 2016 mean fry length in the spawning channel and IPT ranged from 28 to 31 mm and 28 to 30 mm, respectively. Estimates of mean fry length in both the spawning channel and IPT, in 2016, were the lowest obtained since 2012 (28 mm).

The mean and variance for fry weight was the same between the two capture sites (ipt: N=100, mean=0.17 g, SD=0.03; spawning channel: N=200, mean=0.17 g, SD=0.03) and were not significantly different (Welch's t-test: P=0.58; F-test: $F_{(99,199)}$ =0.81, P=0.27). 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 0.13 to 0.23 g, while fry weighed at the channel ranged from 0.12 to 0.26 g.

Mean fry weight has varied more than fry length among years. Between 2012 and 2016 mean fry length varied from 0.17 g to 0.31 g in the spawning channel and 0.17 g and 0.30 g in the IPT. Similar to mean fry length, mean fry weight in 2016 was the lowest observed since 2012 in both the spawning channel and IPT.

3.3 Environmental Monitoring

3.3.1 Water Level

Daily river water level measured at the IPT site ranged from 0.49 to 0.95 m over the length of the mark-recapture program (March 29th to April 19th, 2016) (Figure 7).

3.3.2 Water Temperature

Daily water temperatures in Gates Creek ranged from 0.02 to 11.9 ºC (Figure 8) over the incubation period (September 15th, 2015 to May 1st, 2016).

3.4 Sockeye Salmon Population Estimates

3.4.1 Total Abundance of Sockeye Salmon Fry

A total of 37 900 marked fry were released at the channel weir across five marking groups, of which 2350 were recaptured. A total of 185 037 fry were captured at the IPT site from March 29th to April 19th (Table 4). An estimated 9 896 981 (SD 546 917) fry passed the IPT site between March 29th to April 19th, 2016 (Table 5). An additional 150 347 fry left the spawning channel outside of the mark-recapture program. Taken together, an estimated 10 085 228 Sockeye Salmon fry migrated out of the Gates Creek system in 2016 (Table 5)**.**

Based on estimated weekly abundance, it appeared that the out-migration of fry started prior to trapping commencing on March 29th. An estimated 332 438 fry (SD 10 313), or 3.3% of the total migration, passed the trap in the first weekly strata (March 28th to April 4th) (Table 5). Over the mark-recapture period, the run-timing of fry past the IPT site was unimodal, peaking in the week of April 19th to April 25th, 2016 at 6 809 869 fry (Table 5 &Table 6; Figure 9). The run reached 50% and 90% of its total in the week of April 19th to 25th. In the last strata (April 19th to 25th), 68.5 % of the total abundance estimate was estimated to have passed the trap.

A total of 22 700 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 the total abundance estimates.

Fry abundance in Gates Creek in 2016 was near the average of the abundances estimated since 2012. Fry abundance in 2016 was 67 % greater than the lowest estimate in 2013, but 52 % less than the highest estimate in 2012 (Figure 10, Table 7).

3.4.2 Gates Creek Spawning Channel Sockeye Salmon Fry Abundance

An estimated 3 364 877 fry migrated out of the Gates Creek spawning channel between March 22nd and May 8th. During the operation of the IPT (March 29nd to April 19th), the channel abundance of fry (3 214 530) represented 32% of the total Sockeye Salmon estimated from the downstream IPT (Table 6, Figure 9).

Fry migration from the channel had just begun when trapping commenced, as less than 1% of the total run was captured in the first week of sampling. Channel fry abundance reached 50% and 90% of the total migration during the week ending April 25th. Migration of fry out of the channel was unimodal, with a peak estimated weekly emigration of 1 713 990 fry (51% of total channel migration) occurring in the week ending April 25th (Table 6, Figure 9). More specifically, the channel peaked on April 20th with a total nightly migration of 606 035 fry. In the three-week period following the removal of the Gates Creek IPT, 55% (1 842 336) of the spawning channel fry migrated.

3.4.3 Gates Creek Sockeye Salmon Fry Abundance

An estimated 6 682 451 fry migrated out of Gates Creek from March 29th to April 19th, 2016 (Table 6, Figure 9). Fry abundance from Gates Creek represented 68% of the estimated total fry abundance in 2016. Due to high water and a reduced sampling period, the migration timing of out-migrating fry could not be confirmed (Table 6, Figure 9). The peak likely occurred in the week of April 18th to April 25th, where a total of 5 095 879 fry (76% of the total creek abundance) were estimated to have out-migrated based on the migration timing of fry from the spawning channel.

Based on the weekly abundance estimates, it appears a portion of the fry out-migration was missed prior to the mark-recapture program commencing. In the first week of trapping, an estimated 223 162 fry migrated out of Gates Creek (3% of the Gates Creek total). In the week of April 19th to April 25th approximately 68% of the total migration occurred. Due to the high abundance of fry migrating in the final week of the mark-recapture program, the migration reached both 50% and 90% of the total abundance in the week ending April 25th (Table 6, Figure 9).

3.4.4 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. Despite missing three weeks of data collection, egg-to-fry survival in Gates Creek was 4% higher than in the spawning channel. Egg-to-fry survival for the spawning channel and Gates Creek for the 2015 brood year were estimated to be 30% and 34%, respectively. Fry per effective females was estimated to be 966 and 1 091 for the spawning channel and Gates Creek, respectively (Table 7).

4.0 DISCUSSION

4.1 Trap Operations

Incline Plane Trap

Unstable flow conditions in 2016 resulted in a reduced sampling period with the IPT. In 2016 the IPT sampling period was 13 days shorter than in 2015 and 27 days shorter than the average sampling period for all other years combined. The shorter sampling period resulted in a minimum estimate of Sockeye Salmon fry from Gates Creek.

Channel Trap

Repairs made to the proportional sampler in 2014 allowed the proportional sampler to function 100% of the 2016 field season. These repairs have also improved the sampling consistency of the sampler making it possible to allow majority of fish to pass through the weir without being handled in 2016. Prior to the repairs the proportion of fry captured by the sampler varied from 1% to 17%, and since the repairs functions between 3% and 8%.

4.2 Bio sampling-Sockeye Fry

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 same (28 mm) at both sites in 2016. Mean fry length in the spawning channel and IPT have had similar ranges over the five years of this study (28-31 and 28-30 mm, respectively). In 2016, mean fry weight for both the spawning channel and IPT samples were the smallest obtained since 2012 (28 mm). Fish captured in 2015 were the largest of all years in both the spawning channel and IPT (31 and 30 mm, respectively). Multiple factors may have contributed to the difference in mean fry length between 2015 and 2016 including: environmental conditions during spawner migrations, incubation temperature, and maternal phenotype (Braun et al. 2013).

Throughout the five years of study we have consistently found that variance in fry length in the spawning channel has been larger than fish captured by the IPT. It is possible that this difference in size is related to sampling bias at the channel, and difference type of traps used in each habitat.

Differences in fry weight between the spawning channel and IPT samples are likely not biologically significant. The associated error in wet weights of live fry is likely larger than the difference between the two sites. It should also be noted that fry measured at the IPT are not an independent sample of Gates Creek Sockeye Salmon fry; they are a mixture of fry from the spawning channel and Gates Creek.

4.3 Sockeye Salmon Fry Migration

4.3.1 Sockeye Salmon Fry Abundance

The 2016 estimate of 10.1 million fry should be interpreted as a minimum estimate of the number of fry that migrated out of Gates Creek. Due to the timing of the high water in 2016, the final three weeks of the run were missed, including the historic peak of migration. It is likely that the abundance of fry in Gates Creek was significantly higher than our estimate as the run appeared to be approaching the peak of migration when trapping stopped. In previous years, as much as 76% of the migration occured in the last week of April and the first week of May (Lingard et al. 2014).

In addition to the last three weeks of the fry out-migration being missed, it is likely that the beginning of the migration was also missed in 2016. Approximately 300 000 fry were estimated to have passed the IPT in the first week in 2016. While the number of fish in the first strata in 2016 was a 75% reduction from the 1.3 million estimated in the first strata of 2015, there was still a substantial number of fish migrating in the first week.

Gates Creek contributed 68% of the total fry abundance while the IPT was operating. The most likely reason for the higher contribution of fry from Gates Creek is the difference in the number of effective females spawning in the two habitats, given that egg-to-fry survival was similar between the two habitats. In 2015, 6159 effective females spawned in Gates Creek and 3484 in the spawning channel (Lingard et al. 2015).

Comments on the relative change in Sockeye fry abundance from the spawning channel and Gates Creek for fry produced by the 2014 and 2015 broods cannot be made as the migration was not complete from fry produced by the 2015 brood at the time trapping stopped.

4.3.2 Egg-to-Fry Survival and Fry per Effective Female

Egg-to-fry survival has varied in the spawning channel and Gates Creek over the five study years. Egg-to-fry survival in Gates Creek has generally increased year-to-year from 16% in 2012 to 40% in 2015. In 2016, egg to fry survival was at least 32%. The observed decline in survival in 2016 is likely a consequence of the protracted sampling period. The minimum estimate of egg-to-fry survival for Gates Creek in 2016 falls within the range of survival estimates found in the previous four years of this study; ranking second to 2015.This would indicate that the September 2015 debris torrent in Birken did not negatively affect Sockeye Salmon survival.

Egg-to-fry survival in the spawning channel has fluctuated over the course of the study 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 the 2014 brood (23%) to the 2015 brood (30%); however, survival in 2015 was slightly lower than survival for the 2011 and 2012 broods (33%). The survival rates for the Gates Creek spawning channel across all five 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).

The spawning channel gravel was last replaced in 2009. The low survival rates for the 2013 and 2014 broods indicate regular maintenance and expanded monitoring of water quality and sediment impaction are required to maintain higher egg-to-fry survivals. Cleaning of the channel gravel (via an excavator) was undertaken in July and August 2015 by the N'Quatqua Fisheries manager (Harry O'Donaghey, pers. comm.). Cleaning of sediment from the gravel likely contributed to the higher egg-to-fry survival in 2016.

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% in summaries of data from 12 populations of Sockeye Salmon. 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 exhibited at or above average survival rates for unenhanced Sockeye Salmon streams between 2012 and 2016.

Despite similar ranges in egg-to-fry survival between the two habitats, Gates Creek has consistently produced more fry than the spawning channel. Egg-to-fry survival for Gates Creek has ranged from 16% to 40% whereas survival has ranged from 16% to 33% in the spawning channel. Likewise fry per effective female has ranged from 480 to 1335 in Gates Creek and 537 to 1068 in the spawning channel. Considering the similarity in the ranges of egg-to-fry survival and fry per effective female between habitats, the higher fry abundance in Gates Creek over the five years of this study is likely a result of a greater habitat capacity in the creek.

4.3.3 Sockeye Fry Run-Timing

Comparison of migration timing for Gates Creek with other years and the channel is difficult to make for 2016 as the assessment was cut short prior to the peak of the run.

Peak of migration for the spawning channel in 2016 occurred during the week ending April 25th, a week later than the peak in 2015. The peak of migration in 2016 was the earliest observed in since 2012. Generally, the peak migration in the spawning channel has occurred between April 23rd and May 1st (Lingard et al. 2015).

5.0 SUMMARY and RECOMMENDATIONS

Our objectives of obtaining data on the abundance of the Sockeye Salmon population in Gates Creek and spawning channel were largely met:

1. Total abundance of out-migrating fry was estimated: 6 682 451 fry from Gates Creek, and 3 364 877 fry from the spawning channel.
2. Egg-to-fry survival was estimated: 34% for Gates Creek, and 30% for the spawning channel.
3. Fry per effective female was estimated: 1 091 for Gates Creek, and 966 for the Gates Creek spawning channel.
4. Biological information on fry was collected. Lengths and weights were measured for fry out-migrating from Gates Creek and the spawning channel.

There are several important reasons for the continuation of this study. 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. Data collected over the five study years 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 Salmon populations. Existing infrastructure and skilled N'Quatqua Fisheries staff make Gates Creek and its associated infrastructure a cost-effective method for generating high quality estimates of juvenile sockeye abundance and survival. Finally, this study provides a valuable employment and capacity building opportunity for the N'Quatqua First Nation.

6.0 TABLES

Table 1. Start and end dates for juvenile traps operated at Gates Creek in spring 2016.

Trap/Counter Name	Start Date	End Date	Comments
Channel Weir	March 22	May 9	Fished 7 days per week
IPT	March 29	April 19	Fished 7 days per week

Table 2. Summary of Gates Creek Sockeye Salmon fry fork lengths (mm) measured at the spawning channel and IPT sites from 2011 to 2016.

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

	2016	
	Channel	IPT
N	200	100
Range (mm)	25-31	26-30
Mean (mm)	28	28
SD (mm)	1	1

Table 3. Summary of Gates Creek Sockeye Salmon fry weights (g) measured at the spawning channel and IPT sites from 2011 to 2016.

	2012		2013		2014		2015	
	Channel	IPT	Channel	IPT	Channel	IPT	Channel	IPT
N	340	326	375	275	420	274	375	275
Range (g)	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
Mean (g)	0.31	0.30	0.25	0.23	0.21	0.21	0.24	0.23
SD (g)	0.13	0.08	0.09	0.04	0.07	0.04	0.06	0.08

	2016	
	Channel	IPT
N	200	100
Range (g)	0.12-0.26	0.13-0.23
Mean (g)	0.17	0.17
SD (g)	0.03	0.03

Table 4. Weekly totals of Sockeye Salmon fry marked at the spawning channel, recaptured and unmarked fish enumerated at the IPT in spring 2016. Trap efficiency is the proportion of marked fish that were recaptured.

Week Ending	Marks	Recaptures	Unmarked	Trap Efficiency (%)
April-4	7 500	941	29 718	12.5%
April-11	10 000	537	42 302	5.4%
April-18	10 300	718	95 638	7.0%
April-25	10 100	154	15 029	1.5%
Total	**37 900**	**2 350**	**182 687**	**6.2%**

Table 5. Modeled weekly estimates of total unmarked Sockeye Salmon 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 coefficient of variance 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	CV	2.5%	97.5%	Temp (°C)	Water Level (m)
04-Apr-16	332 438	10 314	0.03	312 751	352 885	7.2	0.53
11-Apr-16	1 374 217	57 771	0.04	1 264 712	1 490 367	7.2	0.64
18-Apr-16	1 380 457	50 014	0.04	1 286 572	1 481 071	7.5	0.63
25-Apr-16	6 809 869	539 428	0.08	5 832 331	7 956 364	7.9	0.84
Total abundance	**9 896 981**	**546 917**	**0.06**	**8 909 034**	**11 047 127**	-	-
[1] Relative SD is a measure of precision. Values > than 0.30 indicate low precision.							

Table 6. Weekly abundance of Sockeye Salmon fry leaving Gates Creek and the spawning channel. Total abundance of fry past the IPT site on Gates Creek in spring 2016.

Week Ending	Channel	Creek	Total fry passing IPT (includes marks)
Mar-28	22 001		
Start of Mark-Recapture			
Apr-04	109 275	223 162	332 438
Apr-11	479 659	894 558	1 374 217
Apr-18	911 606	468 851	1 380 457
Apr-25	1 713 990	5 095 879	6 809 869
Sub Total	**3 214 539**	**6 682 451**	**9 896 981**
May-02	81 272	-	-
May-09	47 074	-	-
Total	**3 364 877**	**6 682 451**	**9 896 981**

Table 7. Female Sockeye Salmon escapement, fecundity, and survival for the Gates Creek system for the 2011 to 2015 broods (fry produced in the channel includes fry from before and after mark-recapture program). Note numbers of effective female spawners have been changed from previous reports to match finalized DFO numbers.

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

Table 7 Cont'd

	2014			2015		
	Creek	Channel	Whole System	Creek	Channel	Whole System
Total female escapement	6 160	3739	9 899	6 473	3941	10 414
Effective females	5 245	3211	8 456	6 159	3484	9 643
Mean Fecundity	3358	3358	3358	3216	3216	3216
Egg deposition	17 612 710	10 782 538	28 395 248	19 807 344	11 204 544	31 011 888
Fry produced	7 004 343	2 470 759	9 527 035	6 682 451	3 364 877	10 085 228
Egg-to-fry survival	40%	23%	33%	34%	30%	32%
Fry per effective female	1335	769	1121	1091	966	1046

7.0 FIGURES

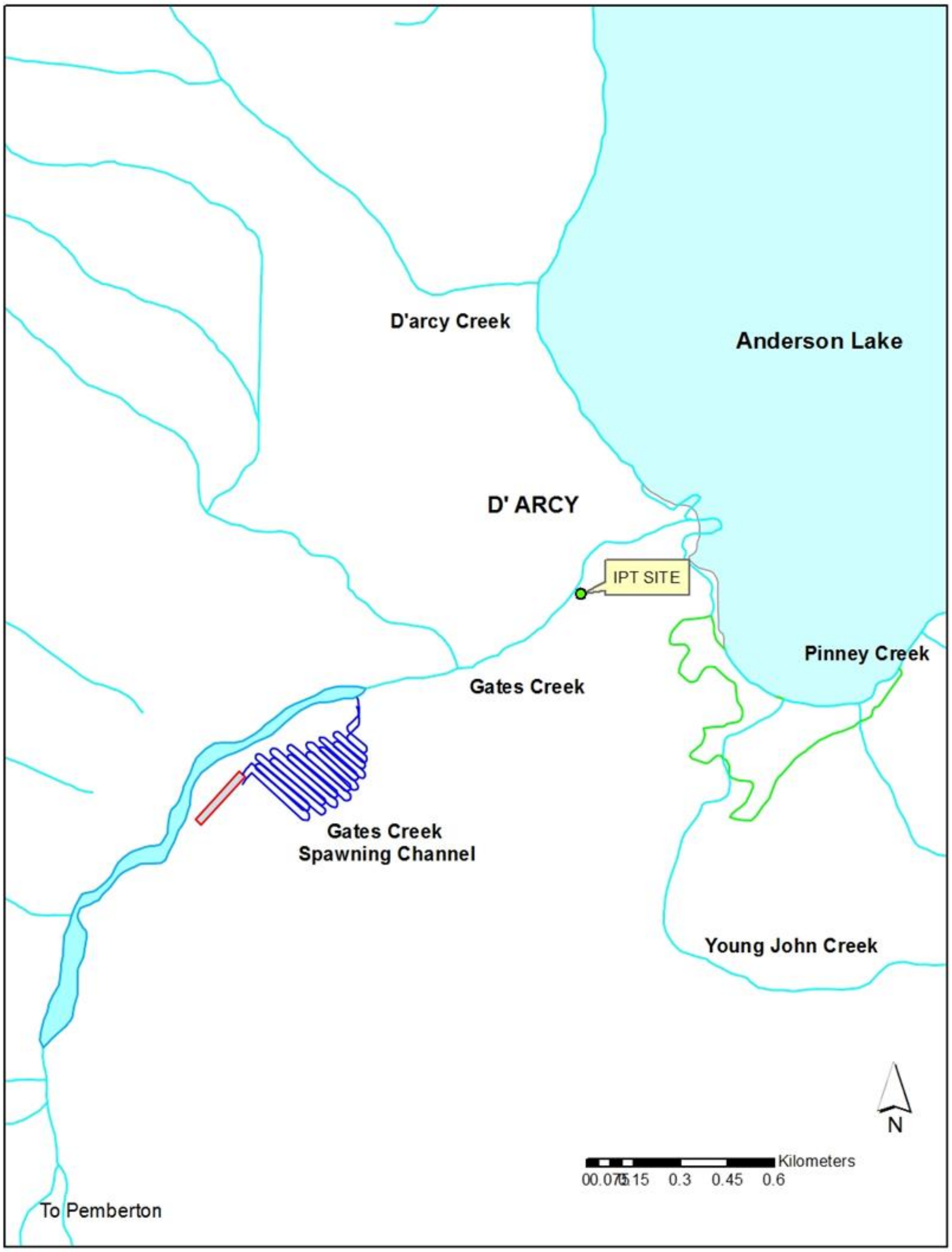

Figure 1. Map of the study area including the Gates Creek spawning channel and trap site. Spawning channel (10 U 536706 5599716) and IPT/RST (10 U 537151 5599978) sites are indicated.

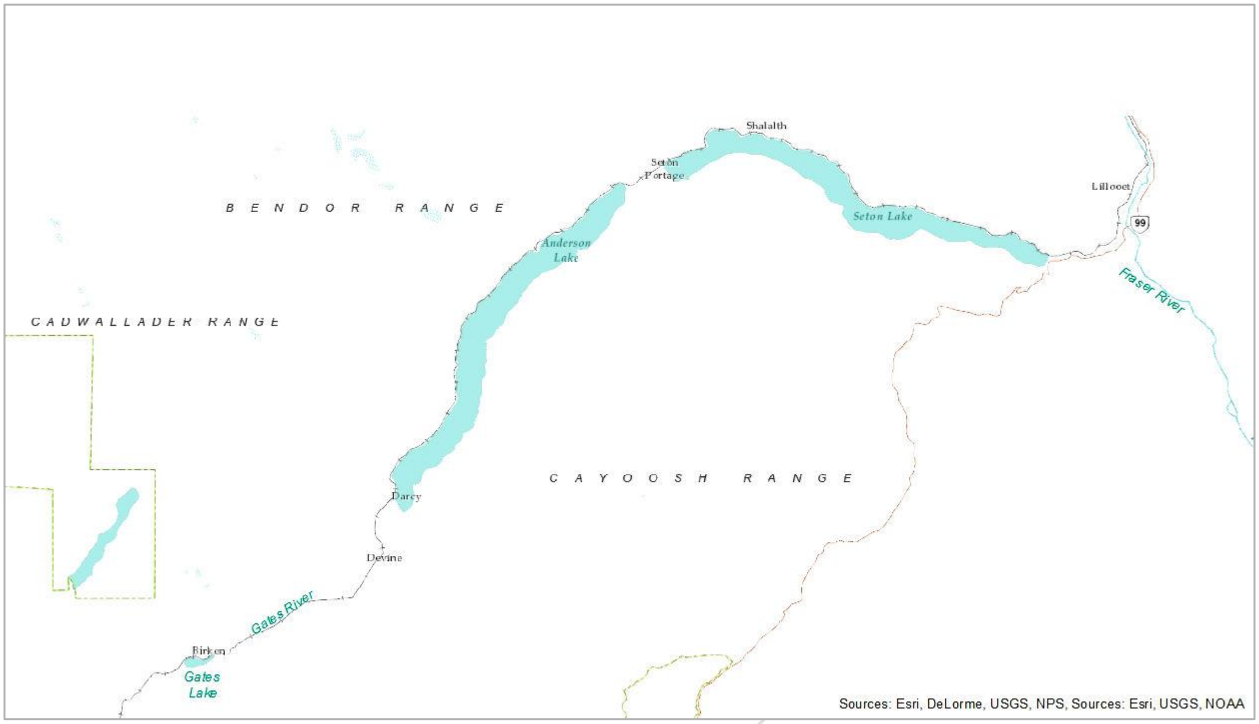

Figure 2. Map of the Seton-Anderson watershed in Southwestern British Columbia. Map also shows Gates Creek flowing from Gates Lake in Birken to Anderson Lake in D'Arcy.

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 (IPT) in Gates Creek.

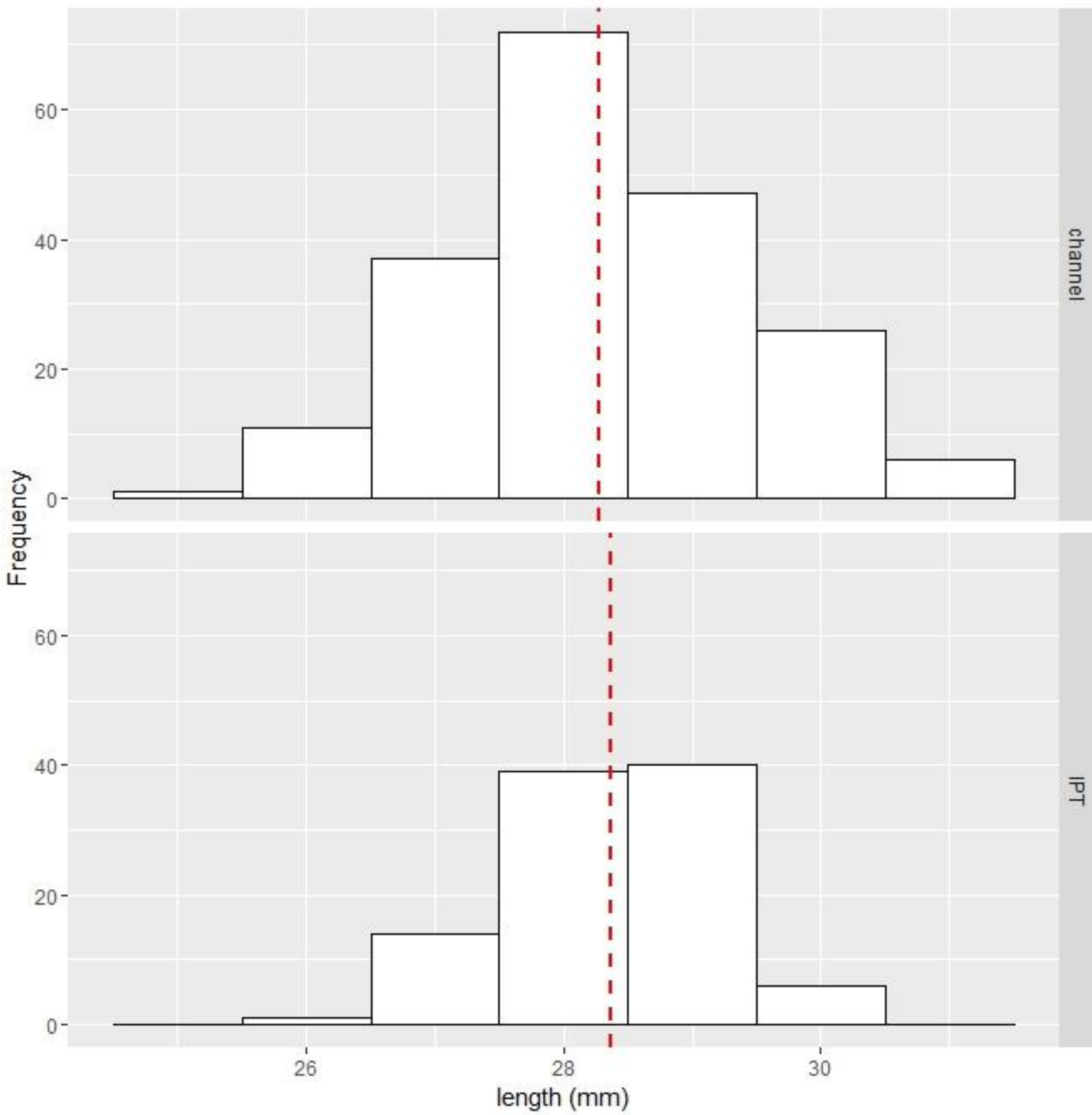

Figure 5. Frequency distribution of juvenile Sockeye Salmon fork lengths (mm) leaving Gates Creek spawning channel (top panel) and Gates Creek (bottom panel) in spring 2016. Red dotted line indicates sample mean.

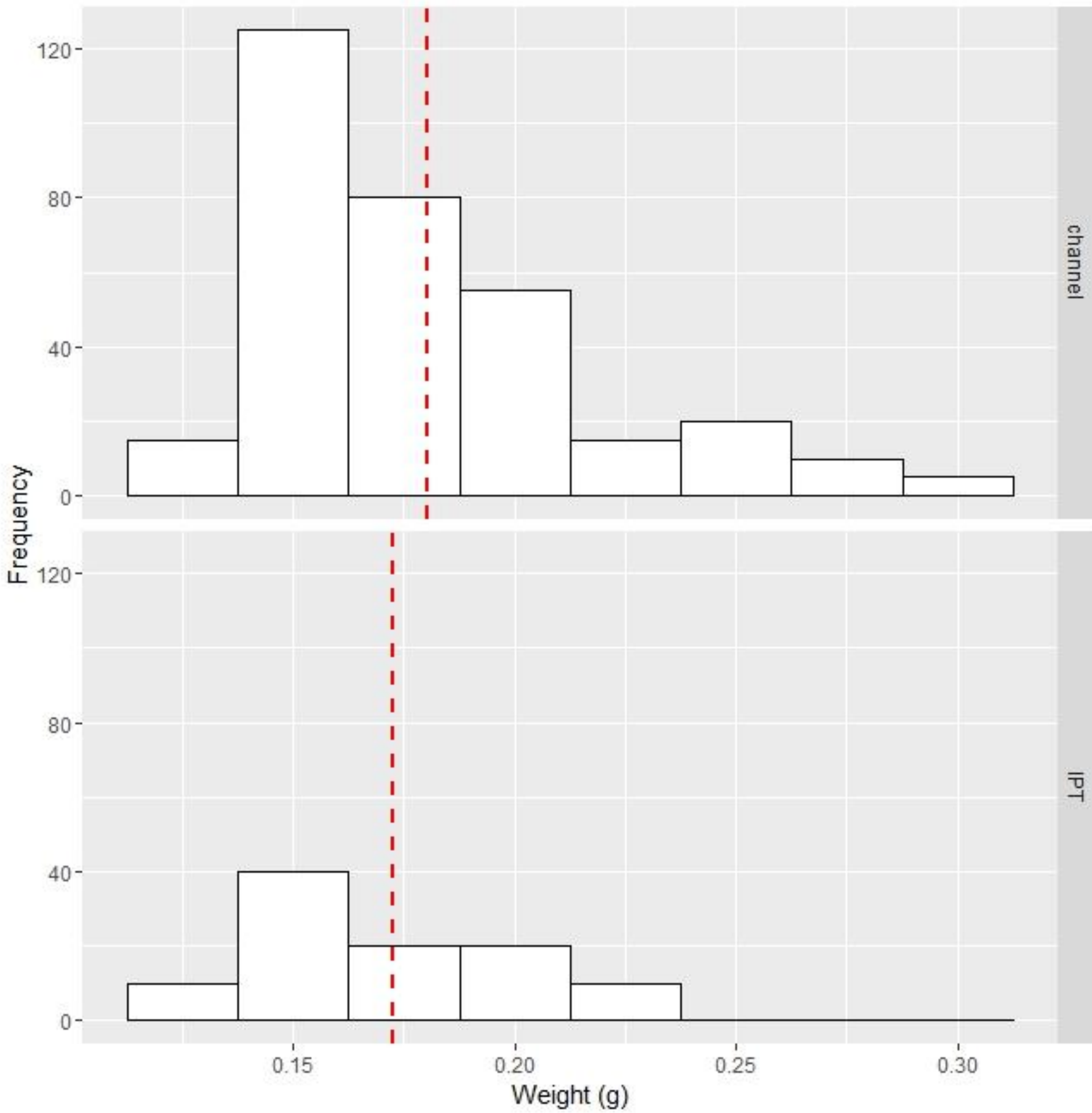

Figure 6. Frequency distribution of juvenile Sockeye Salmon weights (g) leaving Gates Creek spawning channel (top panel) and Gates Creek (bottom panel) in spring 2016. Red dotted line indicates sample mean.

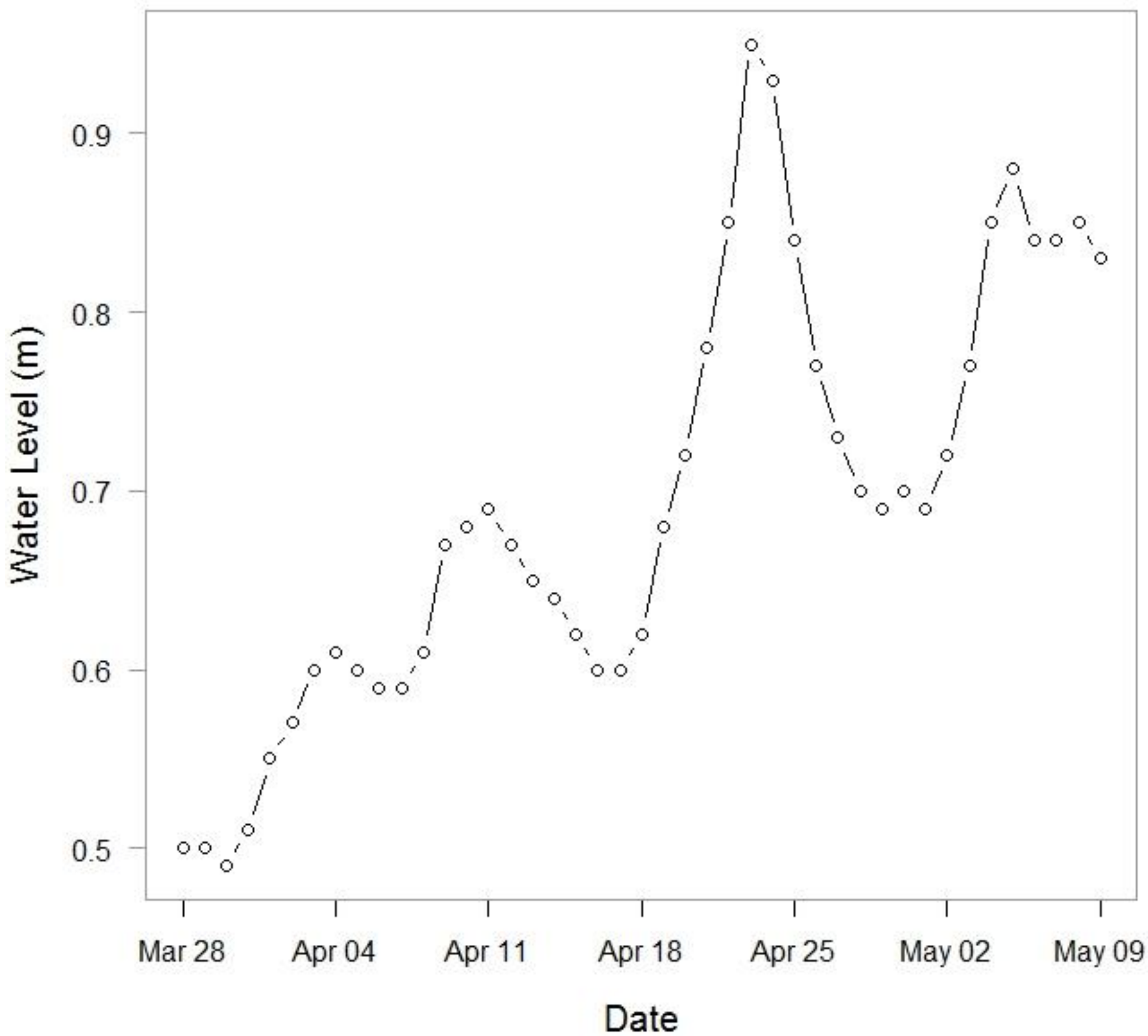

Figure 7. Daily water level (m) in Gates Creek (IPT site) in 2016.

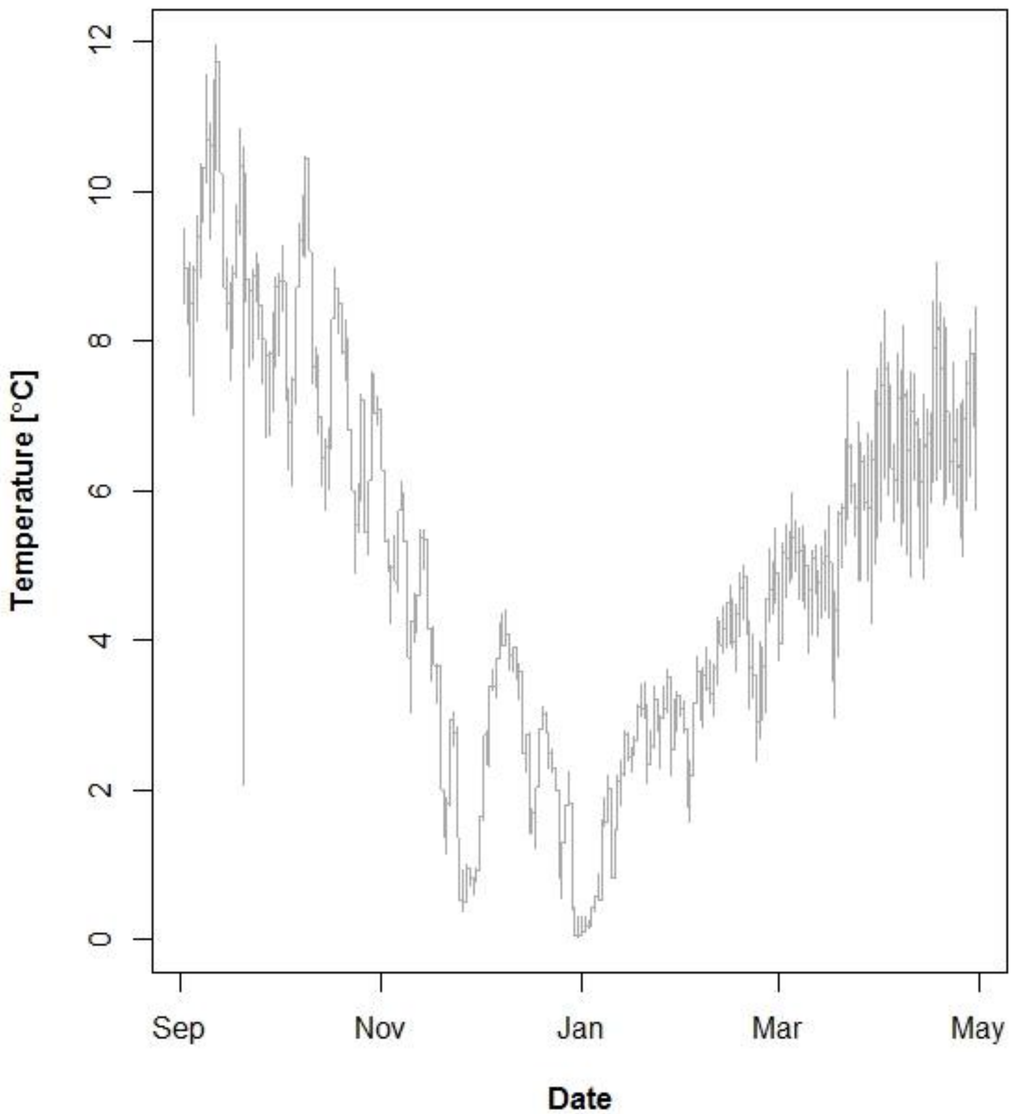

Figure 8. Daily water temperature in Gates Creek over the spawning, incubation and migration period (September 15, 2015 to May 1, 2016).

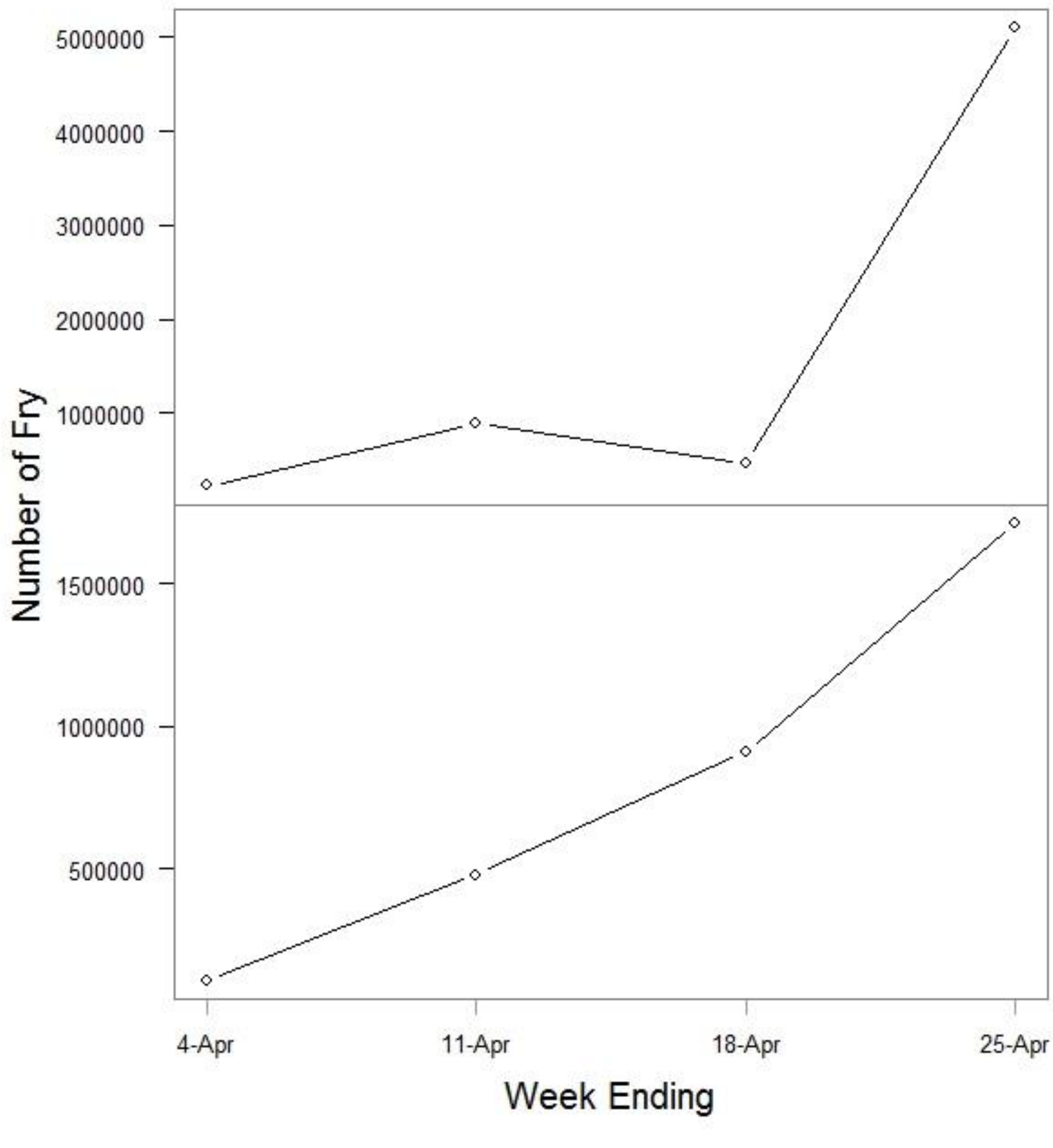

Figure 9. Number of Sockeye Salmon fry leaving Gates Creek (top) and the Gates Creek spawning channel (bottom) in 2016.

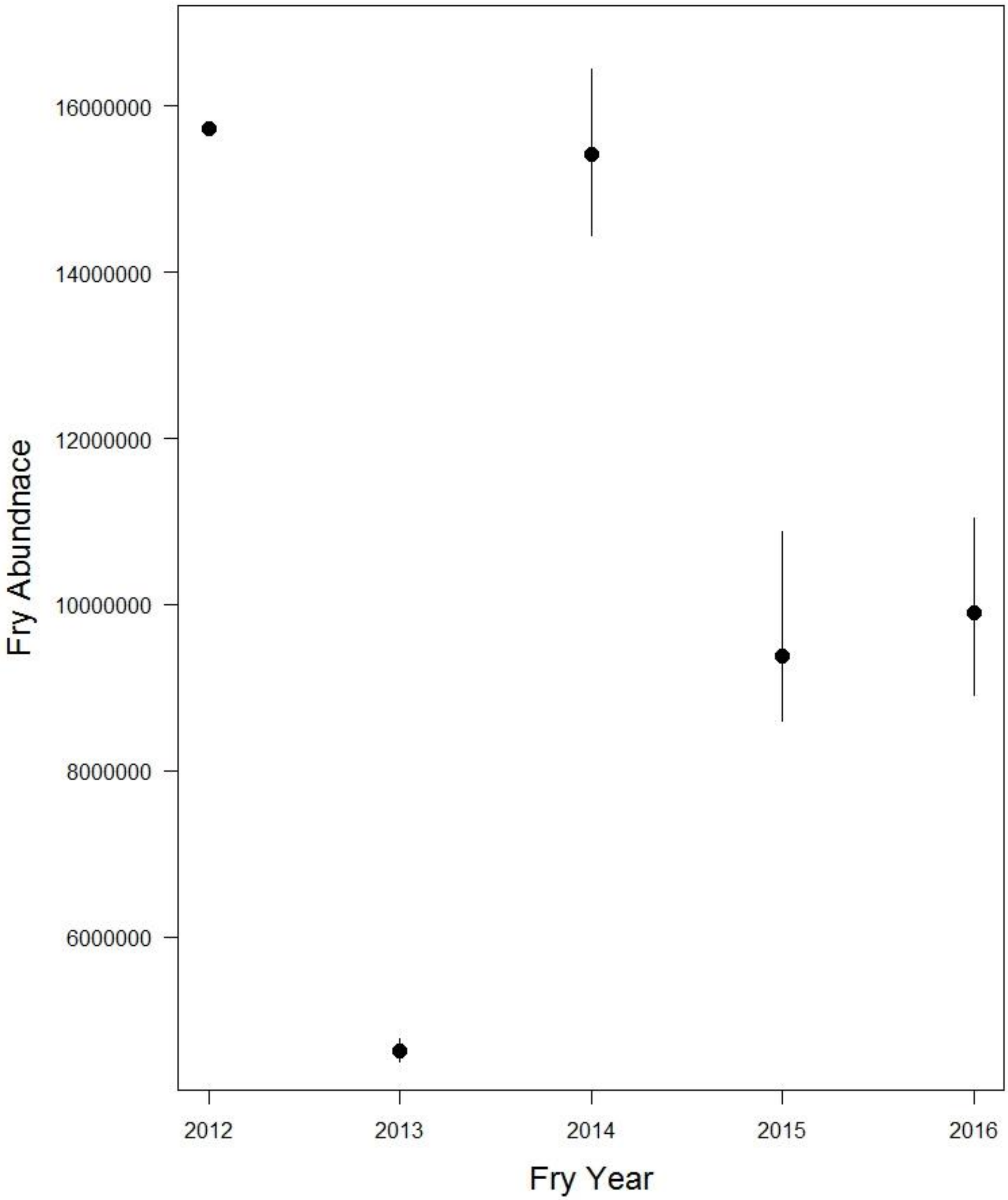

Figure 10. Annual estimates of Sockeye Salmon fry leaving the Gates Creek system from 2012 to 2016. Vertical lines represent 95% confidence intervals. Confidence intervals are not shown for 2012 because peak was estimated using alternate methods due traps not being operational (see Lingard et al. 2012 for explanation of methods). Estimates of fry abundance in 2016 are likely an underestimate of true abundance due a reduced sampling period.

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Chapter 2 Gates Creek Juvenile Standing Crop Assessment of Coho Salmon, Bull Trout and Rainbow Trout Juveniles

Executive Summary

The objective of this monitoring program is to obtain baseline population density estimates for rearing juvenile Coho Salmon, Rainbow Trout and Bull Trout in Gates Creek.

This report is the first in a proposed 4-year program to monitor juvenile salmonid density in Gates Creek. This data will provide valuable insight to the types of habitat used by juvenile salmonids in Gates Creek and identify opportunities for habitat restoration projects that will benefit salmonid populations in Gates Creek by increasing juvenile rearing capacity, abundance, survival.

The survey utilizes open-site electrofishing and mark-recapture techniques. Mark-recapture techniques were conducted to estimate capture probability, which was then used to expand counts from index sites sampled using single-pass electrofishing. A hierarchical Bayesian model was used to estimate site specific Age 0+ Rainbow Trout densities. Estimates of Rainbow trout density varied from 0.28 fish/m to 8.67 fish /m. Rainbow trout density was highest in reach 1 and lowest in reach 3.

Catches of juvenile Coho Salmon and Bull Trout were not sufficient to allow estimation of fish density. A total of 119 age 0+ Coho Salmon and 133 age 0+ Bull Trout were captured between mid- July and mid-August of 2016. Coho Salmon catch was highest in reach 3. Bull Trout catch was also highest in reach 3.

Low densities of Rainbow Trout as well as the low catch of Coho Salmon and Bull Trout suggest Gates Creek may not be as productive as similar sized drainages for these species of salmonids. Further years of study are necessary to capture the inter annual variation in each target species.

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9.0 INTRODUCTION

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. Due to the varying behaviour and life histories of juvenile Coho and Sockeye Salmon, the original objective of the study – to enumerate both species – was only partially successful. While a sufficient sample of sockeye was obtained to estimate the number of juveniles out-migrating (Lingard et al. 2015), very few Coho Salmon juveniles were collected and therefore the number of juvenile Coho Salmon could not be estimated.

In addition to the unknown status of the juvenile Coho Salmon population, the existing information about the habitat Bull Trout and Rainbow Trout use for spawning and rearing in the wider Seton-Anderson watershed is limited (BC Hydro 2012). In 2016, the Fish and Wildlife Compensation Program funded the first year of a proposed 4-year survey of juvenile salmonid densities in Gates Creek. This report summarizes the results of the first season of field work.

9.1 Study Objectives

The main objectives of this study were to assess the following biological parameters for Coho Salmon, Bull Trout and Rainbow Trout in Gates Creek:

4. Estimate the density of young of the year for Coho Salmon, Bull Trout and Rainbow Trout by reach.
5. Increase understanding of rearing habitats used by juvenile salmonids in Gates Creek

9.2 Study Area

The study area focuses on the 17 km length of Gates Creek running from Gates Lake in Birken to Anderson Lake in D'Arcy (Figure 1).

10.0 METHODS

This survey followed the methods outlined in Korman et al. (2010), for estimating species specific standing crop of young of the year (YOY) for salmonid species present in the Gates Creek (i.e. Coho Salmon, Rainbow Trout, Bull Trout). This survey method has been used to estimate densities and abundance of YOY Rainbow Trout and steelhead (anadromous form of Rainbow Trout) in the Seton (Ramos et al. 2015) and Cheakamus Rivers (Korman and Schick 2016). Capture probabilities can vary among age and size classes of fish. Korman et al. (2010), found capture probabilities for small juvenile steelhead trout (40-60 mm) to be as high as 0.6 and decline for each subsequent size class (10 mm size band) for fish over 60 mm. Capture probabilities of fish when electrofishing also differ by water depth and are higher in shallow water than deeper water (Korman et al. 2010). In this survey of Gates Creek, standing crop estimates were generated using open site electrofishing to sample shallow riffle and glide habitat along the length of Gates Creek. Capture probabilities were obtained for specific size classes of each species using mark-recapture methods at a sub-sample of the electrofishing sites.

A hierarchical Bayesian model was used to estimate fish abundance (Korman et al. 2010). This modeling approach incorporates variation in capture probabilities among sites for specific size classes, which are estimated from mark-recapture studies. From this method, site-specific and whole-river estimates of fish density and abundance can be generated for comparison with hydraulic and habitat conditions in Gates Creek.

10.1 Site Selection

Three reaches were identified during the 2015 Level 1 Fish Habitat Survey of Gates Creek (FHAP) (Lingard et al. 2015). Reach 1 extends from Anderson Lake to approximately two kilometres upstream of Spruce Creek (Figure 11). Reach 2 includes the portion of Gates Creek that has been most heavily impacted by land use and extends from the end of Reach 1 to approximately 2 km downstream of Seven Mile Creek (Figure 11). Reach 3 extends from the end of Reach 2 to Gates Lake, and is upstream of the major tributaries (Black Water Creek, Spruce Creek and Haylemore Creek) in the watershed (Figure 11).

Index sites were selected at random from the pool of habitat units identified through the level 1 FHAP. A total of 46 sites were surveyed out of a total of 511 habitat units. Sites were limited to glide and riffle habitats as cascade habitat is not suitable for electrofishing and pool habitat is limited in Gates Creek (less than 5% of the total area of Gates Creek) (Lingard et al. 2015).

A subsample of sites (5) were selected as mark-recapture sites to determine the capture efficiency of the field crew. A minimum catch of 25 fish per age class per species was chosen to be an adequate sample for the mark-recapture sites; this would ensure some fish were recapture even if capture probabilities were low. As a relatively high density of fish was needed in a site to qualify as a mark-recapture site and no previous data existed to guide selection of mark-recapture sites, sites were selected at random provided adequate number of samples (>25 per species). For example, if the crew began electrofishing a site and a sufficient number of juvenile salmonids (>25 per species) were captured it was designated as a mark-recapture site. A target of three sites in each reach was set prior to the survey. However, due to low densities of fish in many sites only 5 mark-recapture sites were completed between mid- July and mid- August, 2016 (Table 8).

10.2 Field Survey

The electrofishing survey was conducted by a three-person crew using a Smith-Root 12-B backpack electrofisher. At each site, a target of 100 m^2 was surveyed. Sites were contained within single habitat units (riffle or glide). In reach 3 of the river, where the stream is smaller, the entire habitat unit (up to 100 m^2) was surveyed. In the lower reaches of the creek where the river was wider and deeper, the crew measured off the 100 m^2 in the shallow margins of the habitat unit using a range finder. At each site, the length, width, and habitat type for the site was recorded as well as the seconds shocked.

Crew sampled each site moving in an upstream direction capturing stunned fish in a bucket fixed with an aerator. When the site was finished, fish were transferred to a larger bucket of aerated water. Fish were anesthetised in a bath of clove oil diluted 1:10 with ethanol prior to sampling. The length of each fish to the nearest mm was measured. For each species, up to 30 fish were weighed to the nearest gram and scale samples were collected.

At mark-recapture sites fish less than 80 mm were marked by immersion in Bismark Brown Y dye (Sigma-Aldrich, St. Louis, USA) diluted to a ratio of 1:10 000 with river water for 15 minutes. Fish over 80 mm were marked with half duplex 12 mm Passive Integrated Transponder (PIT) tags using a 12-gauge needle. Fish between 75 and 150 mm were tagged in the ventral stomach cavity and fish over 150 mm were tagged in the dorsal sinus.

In total, 46 sites were surveyed. At mark-recapture sites, target species were marked and released back into the creek they were collected. Mark-recapture sites were surveyed 24 hours later. For the second survey, the proportion of marked fish recaptured was used as a metric of capture probability. The remaining 41 sites surveyed were identified as index sites and were only surveyed once. Index sites were distributed throughout each of the 3 reaches (Figure 12 , Figure 13, Figure 14)

In the original study plan 27 sites were selected in reach 2; however, much of the reach is surrounded by private land and has been altered by land use with renders it either too deep (>1 m) for electrofishing or inaccessible. (Figure 13). Due to the conditions in reach 2 only 4 sites were completed.

10.3 Age Class Determination

Young of the year, or age 0+ fish were the target of this study as they are more susceptible to capture through electro-fishing than older larger fish (Korman et al. 2010). The budget did not permit aging of fin rays or scales therefore, we determined age classes using. The valley between modes in the size distribution plots was chosen as the division between size classes. Size data were then compared to age data from other populations and an age was assigned to each of the corresponding length classes. Ages are assigned for the number of winters a fish has survived.

10.4 Population Density Estimates

Density estimates were generated using a hierarchical Bayesian model (HBM) that incorporates the capture probability obtained at the mark-recapture sites and catch of each age class of each species at the index sites.

The HBM consists of two levels. The first level; the observation model, used data from the mark-recapture studies to estimate site-specific and hyper-distributions for capture probability. The hyper distribution for capture probability estimated from mark-recapture site *i* was then used in the second level of the model; the population model, to estimate density for index site *j* using catch data collected from the single pass, the site length, and the capture probability (Table 9).

Capture probability is the proportion of marked fish recaptured in the second pass at mark recapture site *i* (Table 9). The number of marked fish recaptured from a single pass in mark recapture site *i* were assumed to be binomial distributed and capture probabilities were assumed to follow a beta distribution. The only species/life stage with enough data to produce reliable estimates of capture probability was 0+ Rainbow Trout.

Catches from index sites were assumed to follow a binomial distribution and the abundance at index sites was assumed to follow a Poisson distribution. Densities were assumed to be lognormal-distributed.

All priors used in the observation model were uninformative (Table 9). In the population model we used informative priors for log density because convergence was not achieved with uninformative priors. The model was run with three chains and 10 000 iterations. The first half of the samples were discarded as the burn in and the remaining samples made up the posterior distributions. A convergence threshold of 1.1 was used.

11.0 RESULTS

11.1 Age Class Determination

The largest Bull Trout captured in this survey was 560 mm and was likely a mature adult. Juvenile Bull Trout ranged in length from 27 to 164 mm. The length distribution for Bull Trout was uni-modal with a peak at 40 mm (Figure 15). No Bull Trout were caught between 70 and 76 mm. Therefore, fish 70 mm and smaller were classified as age 0+. Age 0+ Bull Trout lengths ranged between 27 and 69 mm. Mean length of age 0+ Bull Trout captured between mid- July and mid- August of 2016 was 52 mm (Table 10). In the absence of fin ray analysis, it was not possible to confirm ages of large Bull Trout (> 69 mm) into age classes. Fish caught above the 70 mm cut off ranged from 78 to 112 mm.

The length distribution of Coho Salmon juveniles was uni-modal between 44 and 70 mm (Figure 15). There were 20 larger Coho Salmon juveniles captured ranging from 81 mm to 91 mm. Scales were not aged to verify or determine the ages of Coho juveniles; however, aging of juvenile Coho Salmon scales collected in July in the Seton River suggested an 80 mm length cut-off for age 0+ fish. Thus, Gates Creek Coho Salmon juveniles up to a length of 70 mm were classified as age 0+; and fish between 81 and 91 mm were classified as 1+. The mean length of age 0+ Coho Salmon caught between mid-July and mid-August, 2016 was 59 mm (Table 10).

Rainbow Trout length distribution was also uni-modal with a peak between 27 and 37 mm (Figure 15). Age 0+ Rainbow Trout juveniles ranged from 21 to 70 mm with a smaller group of older (possibly 1+ and 2+) fish starting at 71 mm and longer. The mean length of age 0+ Rainbow Trout captured was 36 mm and ranged from 21 to 70 mm (Table 10). The mean length of 1+ and older Rainbow Trout was 104 mm and ranged from 71 to 225 mm (Table 10). Rainbow Trout scales collected in July in the Seton River suggested a 70 mm cut-off for age 0+ fish.

11.2 Rainbow Trout Density

A total of 1 074 juvenile Rainbow Trout were caught between mid-July and mid-August 2016. Age 0+ Rainbow Trout (<70 mm) represented 95% of the total catch during the 2016 survey (Table 11). The catches of 0+ Rainbow Trout were large enough in the mark-recapture sites to permit estimation of fish density using the Bayesian model (Table 11).

In the mark-recapture sites, a total of 171 fish were marked and 24 were recovered. Mean recapture rate for the 5 sites was 0.14 with a range of 0.08 to 0.28. The posterior distributions of capture probabilities (θ) is shown in Figure 16.

Rainbow trout (0+) were found in all sites sampled between mid-July and mid-August. Across all sites, density of age 0+ Rainbow Trout ranged from 0.28 fish/m to 8.67 fish/m (Table 13, Figure 17). Mean density of Rainbow Trout was highest in Reach 1 (3.63 fish/m) and lowest in Reach 3 (1.31 fish/m) (Table 13). The coefficient of Variation (CV) for mean fish density in each reach was high (> 0.50) indicating fish density among sites in each reach was highly variable (Table 13, Figure 17).

Among sites density varied widely in all reaches, but was most variable in reach 1. Both the lowest (0.28 fish/m) and highest (8.67 fish/m) estimates of age 0+ Rainbow trout density were obtained in reach 1. Fish densities among sites in reach 3 also had a wide range (0.36 - 3.10 fish/m). Reach 2 had the smallest range of site specific density (0.59-2.10 fish/m); however, only four sites were sampled in reach 2 in 2016.

A total of 22 glides and 19 riffles were sampled. Mean densities of Age 0+ Rainbow Trout for the two habitats were similar (glides: 1.93 fish/m; riffles: 1.87 fish/m) (Table 14). Catches of larger Rainbow Trout juveniles (> 71 mm) were also similar between riffles (12 fish) and glides (13 fish).

11.3 Coho Salmon Catch

Too few Coho Salmon juveniles were captured in the mark-recapture sites to estimate capture probabilities for Coho Salmon. A total 125 Coho Salmon juveniles were captured in 23 of the 46 sites. Age 0+ Coho Salmon (≤ 70 mm) made up the majority (95%) of the catches (Table 15). The majority (72%) of age 0+ Coho Salmon were caught in reach 3 and the upper part of reach 2 (1 out of 4 sites). No

Coho Salmon juveniles were caught downstream of site 102 in the lower half of reach 1; Anderson Lake to Devine (Table 15).

11.4 Bull Trout Catch

Too few age 0+ Bull Trout (≤ 70 mm) were captured in the mark-recapture sites to generate estimates of Bull Trout capture efficiency and density. A total of 143 juvenile Bull Trout were captured in 29 of 46 sites. Of the total catch of Bull Trout juveniles, age 0+ (≤ 70 mm) made up the majority (93%) of the fish caught (Table 16). Ten Bull Trout over 70 mm were captured across all 46 index and mark recapture sites.

Captures of Bull Trout juveniles occurred in all reaches of Gates Creek, but where highest in reach 3 where 63% of Bull Trout fry were captured. Bull Trout fry were caught at 3 of the 4 sites surveyed in reach 2 and 13 out of 18 sites in reach 1 (Table 16).

12.0 DISCUSSION

Standing crop studies are conducted at base flows to ensure consistent conditions and maximize capture efficiency. High water levels in Gates Creek in the summer of 2016 delayed the start of the study from what was originally scheduled. In the proposed study plan, the survey was scheduled between the second week of July and August 1st. This time period was selected to ensure the survey was completed at base flows and before the arrival of the early-summer Sockeye Salmon in mid-August. To ensure electrofishing did not take place during the Sockeye Salmon spawning period, it was necessary to start the survey when river levels were elevated from base flows and as a result flows varied among survey sites. For example, during the study period the water level decreased by 10 cm (Figure 11).

Densities of age 0+ Rainbow Trout decreased moving upstream from Anderson Lake to Gates Lake. They were also found to be highly variable among sites (0.28 to 8.67 fish/m) and had broad confidence limits indicating low precision, which was likely due to the low capture probability estimated for mark-recapture sites. Stream conditions at the time of the survey (higher water levels) led to low capture probabilities. High discharge and water levels have been shown to negatively affect electrofishing capture probabilities (Lyon et al. 2014).

The densities for age 0+ Rainbow Trout suggest Gates Creek is not a productive Rainbow Trout stream and were similar to those observed in another stream with low Rainbow Trout standing crop, the Seton River (2014: 0.1 - 3.7 fish/m; 2015: 0.1 – 1.0 fish/m) (Ramos et al. 2015). Densities for age 0+ Rainbow Trout in Gates Creek and the Seton River both fall below estimates for the Cheakamus River (2.38 -5.15 fish/m) in 2008 (Korman and Schick. 2010), and the 2011 to 2015 average per reach estimates for the Bridge River (5.2 to 12.1 fish/ m) (Sneep and Korman 2016). Further years of assessment in Gates Creek coupled with ongoing assessments of Rainbow populations through BC Hydro Water Use Licencing monitors BRGMON 9 (Seton River) and BRGMON8 (Seton Lake) will inform on the abundance of Rainbow Trout populations in the watershed.

Rainbow Trout densities found in reach 2 are not likely representative of this reach as only 4 sites were surveyed due to limited access and unsuitable habitat for electrofishing. Unfortunately, even in during summer base flows, much of reach 2 is too deep or inaccessible due to overgrown brush to be sampled. Additional pre-survey reconnaissance in future years may identify additional sites suitable in reach 2.

Densities for Coho and Bull Trout could not be estimated using the hierarchical model because of parameter instability reflected in the lack of model convergence. Furthermore, there were too few Coho Salmon and Bull Trout to estimate capture probabilities from the mark and recapture sites. Although densities for Coho Salmon and Bull Trout could not be estimated, the catch data for juveniles of both species from this study are valuable information and provide insight into the abundances of these two species. The low catches of age 0+ Coho Salmon and Bull Trout indicate densities of both these species are likely lower than densities of age 0+ Rainbow Trout in in Gates Creek.

In addition to high water levels, low adult spawner abundances that gave rise to juveniles may have also been a factor in the low juvenile catches in 2016. Inter annual variation in the number of spawners will have large effects on the densities of juvenile salmonids. To deal with this uncertainty, we will include adult Coho Salmon escapement estimates from DFO to allow comparison of annual fluctuation in juvenile and adult abundances.

Each salmonid species has specific needs for both rearing and spawning habitat. Coho Salmon juveniles are known to prefer backwater habitats, side channels and flood plains for rearing (Sandercock 1991), while age 0+ Rainbow Trout have been found to prefer cobble/ boulder habitats with higher velocities and gradients than Coho Salmon (Beechie et al. 2005). Bull Trout juveniles are typically found in low bottom velocity habitats with ample instream cover such as boulder or cobble (McPhail and Baxter 1996.). These habitat preferences were mirrored in this survey. Rainbow Trout and Bull Trout juveniles were found in higher numbers than Coho Salmon in reach 1, which has limited side channel and slack water habitat, and is dominated by riffles with cobble and boulder substrate. Coho Salmon juveniles were found in higher numbers in reach 3 which contains the majority of side channel habitat in Gates Creek (Hillaby 2012; Lingard et al. 2015).

Of the three target species in this study, only Coho Salmon spawner abundance is monitored by DFO. Between 2001 and 2009 annual abundance of Coho Salmon spawners ranged from 1 900 to 13 000 (DFO unpublished data). In Gates Creek, the known spawning areas for Coho Salmon adults are located in reach 3, with a small number of spawners also distributing in the upper portions of reach 1 near Devine (Hillaby 2012). The distribution of known Coho Salmon spawners matches the location of spawning habitat observed in the level 1 FHAP with most of the spawning gravel was located in reaches 1 and 3, while less than 2% of reach 2 contained spawning gravel (Lingard et al. 2015).

The juvenile fish distributions paired with the data from the level 1 FHAP indicate that reach 2 is limited in both rearing and spawning habitat for Coho Salmon, Rainbow Trout and Bull Trout. Floodplain habitat and side channels have been cut off from the main river removing valuable rearing habitat. Reach 2 also lacks complexity and riparian vegetation and can be characterised as a deep (> 1 m), sandy glide (Lingard et al 2015). There are two BC Hydro owned properties (9523 and 9484 portage road) in reach 2 that provide valuable opportunities for fish habitat restoration projects such as re-connection/construction of side channels and flood plain habitat, adding spawning substrate, and replanting riparian vegetation for stream shading. Demonstration projects on these two properties may encourage neighbouring land owners to allow similar projects to occur on their properties.

The data from this study provide valuable site and reach specific indices of juvenile salmonids in Gates Creek. The data from 2016 provided the first year in creating a baseline understanding of population length and habitat use by juvenile salmonids in Gates Creek. This will be crucial to planning and evaluating restoration projects for the watershed in future years.

An additional benefit of this survey was the training and capacity building opportunity it provided to the N'Quatqua technicians. An additional 3 years of study will provide a stronger baseline of juvenile salmonid densities in Gates Creek to inform restoration planning. Lower water levels and increased efficiency in subsequent years, may improve mark-recapture results for Coho Salmon and Bull Trout and permit generation of density estimates for these species.

13.0 RECOMMENDATIONS

Salmonid populations can vary widely from year to year, and thus estimates of population length or densities from a single year do not provide enough information to judge the status of fish populations. This study is proposed as a 4-year project and continuation will allow evaluation of the variability of Coho Salmon, Bull Trout and Rainbow Trout populations in Gates Creek.

14.0 TABLES

Table 8. The number and habitat type of mark-recapture sites completed in Gates Creek electrofishing survey in summer 2016.

Reach	Riffle	Glide
1	2	0
3	1	2

Table 9. Equations, priors and transformations for the hierarchical model. The letters i and j represent the mark recapture and index sites, respectively.

Observation Model
$r_i \sim dbin(\vartheta_i, m_i)$
$\vartheta_i \sim dbeta(\alpha, \beta)$
Population Model
$\vartheta_j \sim dbeta(\alpha, \beta)$
$c_j \sim dbin(\vartheta_j, N_j)$
$N_j \sim dpois(\lambda_j, l_j)$
$\log(\lambda_j) \sim dnorm(\mu_\lambda, \tau_\lambda)$
Priors and Transformations
$\mu_\theta \sim dunif(-2, -0.5)$
$\sigma_\theta \sim dunif\ (0.2, 1)$
$\tau_\vartheta = \sigma_\theta^{-2}$
$\alpha \sim \mu_\vartheta\, \tau_\vartheta$
$\beta = (1 - \mu_\vartheta)\, \tau_\vartheta$
$\mu_\lambda \sim dnorm(0, 0.03)$
$\tau_\lambda \sim dnorm(1, 15)$
$\tau_\lambda = \sigma^{-2}$

Table 10. Mean lengthlength at age for Rainbow Trout, Bull Trout and Coho Salmon captured by open site electrofishing between mid-July and mid-August.

Species	N	Mean (mm)	Min (mm)	Max (mm)
Age 0+ Rainbow Trout	1005	36	21	70
Age 1+ and older Rainbow Trout	68	104	74	225
Age 0+ Bull Trout	133	52	27	69
Age 1+ and older Bull Trout	12	148	76	560
Age 0+ Coho Salmon	105	59	44	70
Age 1+ and older Coho Salmon	20	81	71	91

Table 11. Catch of juvenile Rainbow Trout in Gates Creek, using open site electrofishing between mid-July and mid-August, 2016.

Reach	Site Number	Rainbow Trout Fry (70 mm and smaller)	Rainbow Trout Parr (71 mm and larger)
1	2	1	2
1	12	5	
1	15	88	1
1	18	1	1
1	26	16	
1	39	20	
1	40	14	1
1	49	69	1
1	63	23	
1	65	5	
1	102	131	3
1	110	33	
1	119	55	2
1	133	38	4
1	143	31	1
1	168	13	2
1	184	5	3
1	192	6	4
1	196	11	4
1	201	19	3
2	217	16	2
2	239	21	
2	263	4	1
3	315	6	
3	327	7	
3	334	26	
3	340	3	
3	373	8	3
3	383	18	2
3	396	15	1
3	397	9	
3	409	12	4
3	410	2	1
3	414	11	
3	417	22	
3	429	5	
3	430	65	1
3	440	19	
3	441	6	
3	455	9	
3	476	52	5
3	479	19	1
3	480	23	2
3	486	5	1
3	493	8	2
3	506	30	10

Table 12. Density of 0+ Rainbow Trout (up to 70 mm) *per* m at each site sampled with open site electrofishing between mid-July and mid- August, 2016. Habitat Type: R= Riffle, G= Glide.

Site Number	Habitat Type	Density (fish/ m)	Density 95% Lower CI (fish/ m)	Density 95% Upper CI (fish/ m)
2	R	0.28	0.06	1.46
12	R	0.59	0.18	2.69
18	R	0.22	0.05	1.03
26	G	2.25	0.84	9.03
39	R	1.88	0.73	8.00
40	G	1.95	0.66	7.92
49	R	9.97	4.06	37.34
63	R	3.03	1.12	12.81
65	G	0.54	0.16	2.53
110	R	4.95	1.90	20.49
119	G	8.67	3.42	36.23
133	G	4.18	1.60	15.49
143	R	3.42	1.23	12.81
168	G	1.28	0.44	5.58
184	R	0.73	0.21	3.46
192	R	0.70	0.21	3.06
196	R	1.54	0.49	6.89
201	G	1.20	0.44	4.71
217	G	1.90	0.68	7.69
239	G	2.10	0.82	7.77
263	G	0.59	0.16	2.56
315	G	0.70	0.20	2.94
327	G	0.92	0.28	4.06
334	G	3.10	1.09	12.81
340	G	0.41	0.11	1.90
373	R	1.04	0.33	4.39
383	G	1.77	0.64	7.24
396	G	1.82	0.64	7.77
397	G	1.38	0.45	5.81
409	G	1.43	0.48	5.70
410	R	0.36	0.08	1.82
414	G	1.01	0.35	3.94
417	G	2.41	0.88	9.97
429	R	0.61	0.18	2.86
440	R	1.97	0.73	8.00
441	R	0.66	0.19	2.92
455	G	1.09	0.36	4.48
479	G	1.82	0.68	6.96
480	R	2.44	0.90	10.49
486	R	0.51	0.16	2.23
493	R	0.67	0.23	2.89

Table 13. Summary of mean fish density (fish/m) and coefficient of variation (CV) by reach in Gate Creek. Data collected between mid- July and mid- August, 2016 by open site electrofishing survey.

Reach	Number sites surveyed	Mean Density (fish/m)	CV
1	18	3.63	1.06
2	3	1.53	0.54
3	20	1.31	0.60

Table 14. Summary of mean fish density (fish/m) and coefficient of variation (CV) by habitat type in Gate Creek. Data collected between mid- July and mid- August, 2016 by open site electrofishing survey.

Habitat Type	Number of sites	Mean Density (fish/m)	CV
Glide	22	1.93	0.90
Riffle	19	1.87	1.24

Table 15. Catch of juvenile Coho Salmon in Gates Creek, using open site electrofishing, mid-July to mid-August, 2016.

Reach	**Site Number**	**Coho Salmon Fry (up to 70 mm)**	**Coho Salmon Parr (larger than 71 mm)**
1	102	2	
1	110	3	
1	119	5	
1	133	20	
1	143	2	
2	263	1	
3	315	1	
3	327	2	
3	334	3	
3	340	3	2
3	383	1	
3	409	1	
3	414	5	
3	429	13	1
3	430	18	1
3	440	9	
3	455	4	
3	476	6	1
3	479	4	
3	480	1	
3	486	1	
3	493	8	1
3	506	6	

Table 16. Catch of juvenile Bull Trout in Gates Creek using open site electrofishing, mid-July to mid-August, 2016.

Reach	Site Number	Bull Trout Fry (up to 70 mm)	Bull Trout Parr (larger than 70 mm)
1	12	1	
1	15	3	
1	26	8	
1	39	2	
1	40	2	
1	65	1	
1	102	10	
1	110	2	
1	119	7	1
1	143	1	
1	168	0	1
1	184	1	
1	192		1
1	201	4	
2	217		1
2	239	5	
2	263	2	
3	315	6	
3	327	7	
3	334	8	1
3	340	4	
3	383	1	1
3	396	4	1
3	397	3	1
3	409		1
3	414	6	
3	417	5	
3	429	11	1
3	430	10	
3	440	11	
3	441	6	
3	455	2	

15.0 FIGURES

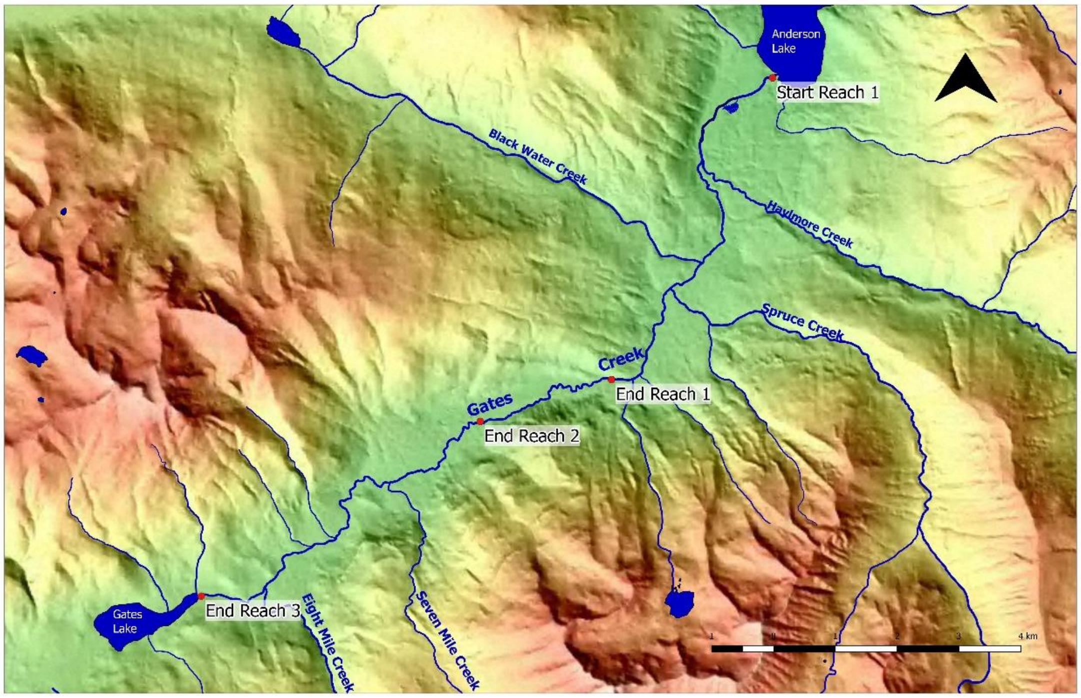

Figure 11. Overview of Gates Creek watershed running from Gates Lake in Birken to Anderson Lake in D'Arcy.

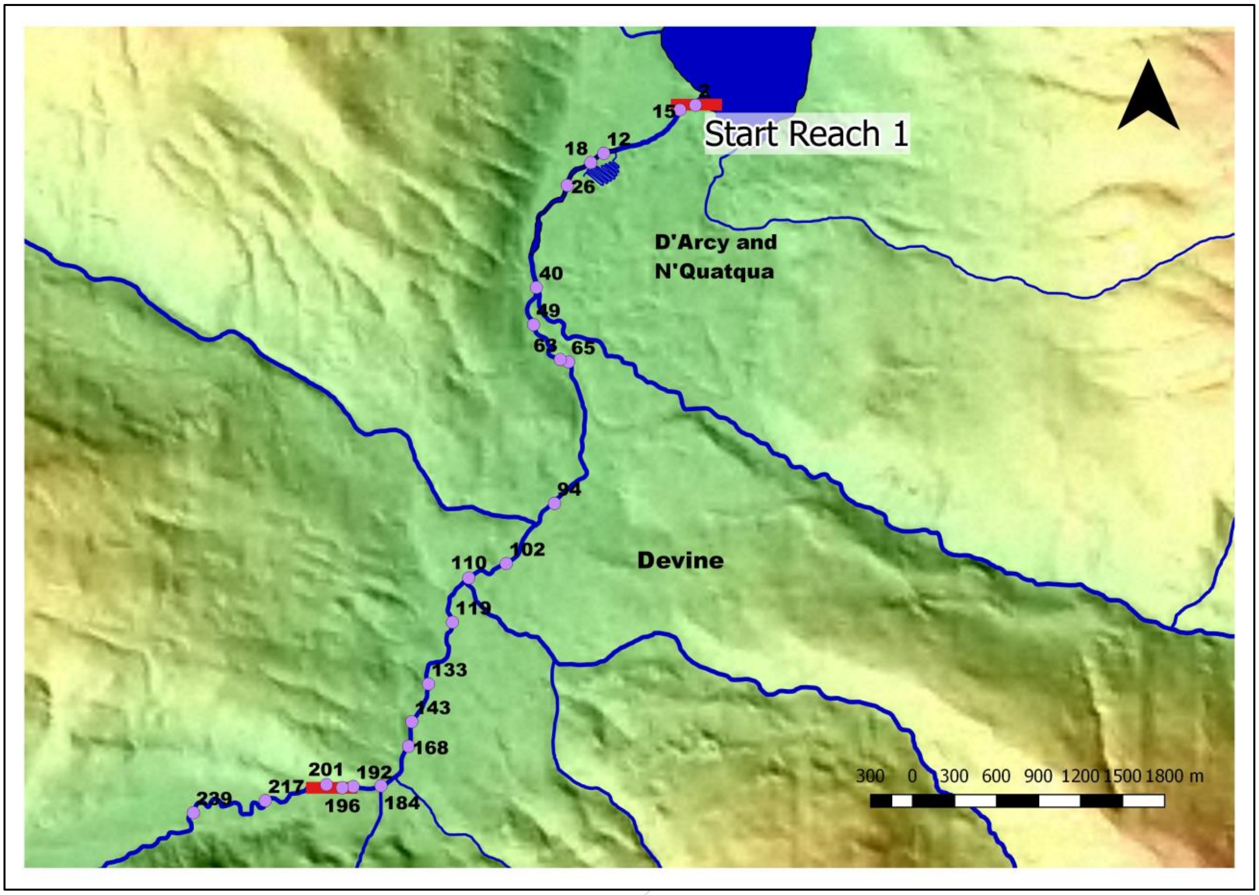

Figure 12. Map of electrofishing sites in reach 1 of Gates Creek for summer 2016. Purple dots indicate electrofishing sites.

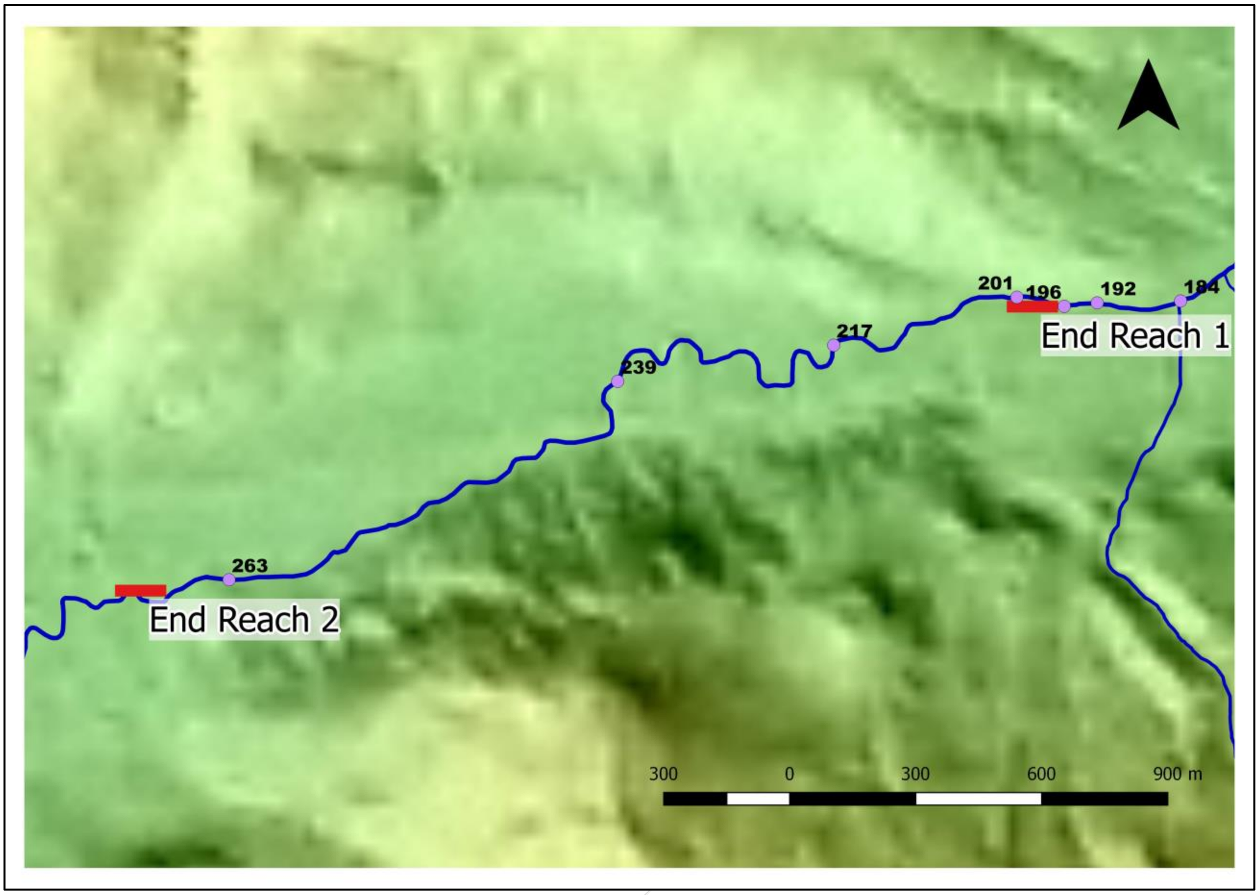

Figure 13. Map of electrofishing sites in reach 2 of Gates Creek for summer 2016. Purple dots indicate electrofishing sites.

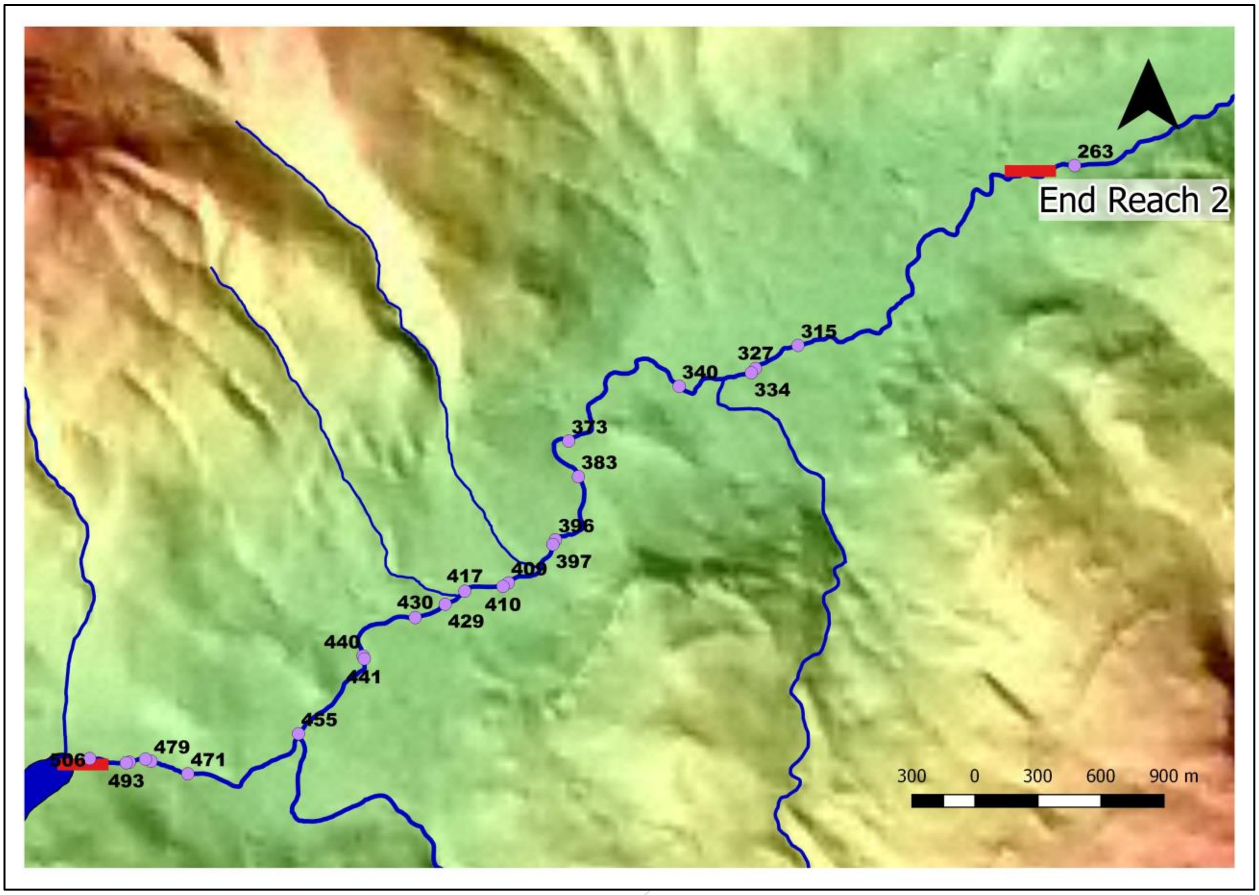

Figure 14. Map of electrofishing sites in reach 3 of Gates Creek for summer 2016. Purple dots indicate electrofishing sites.

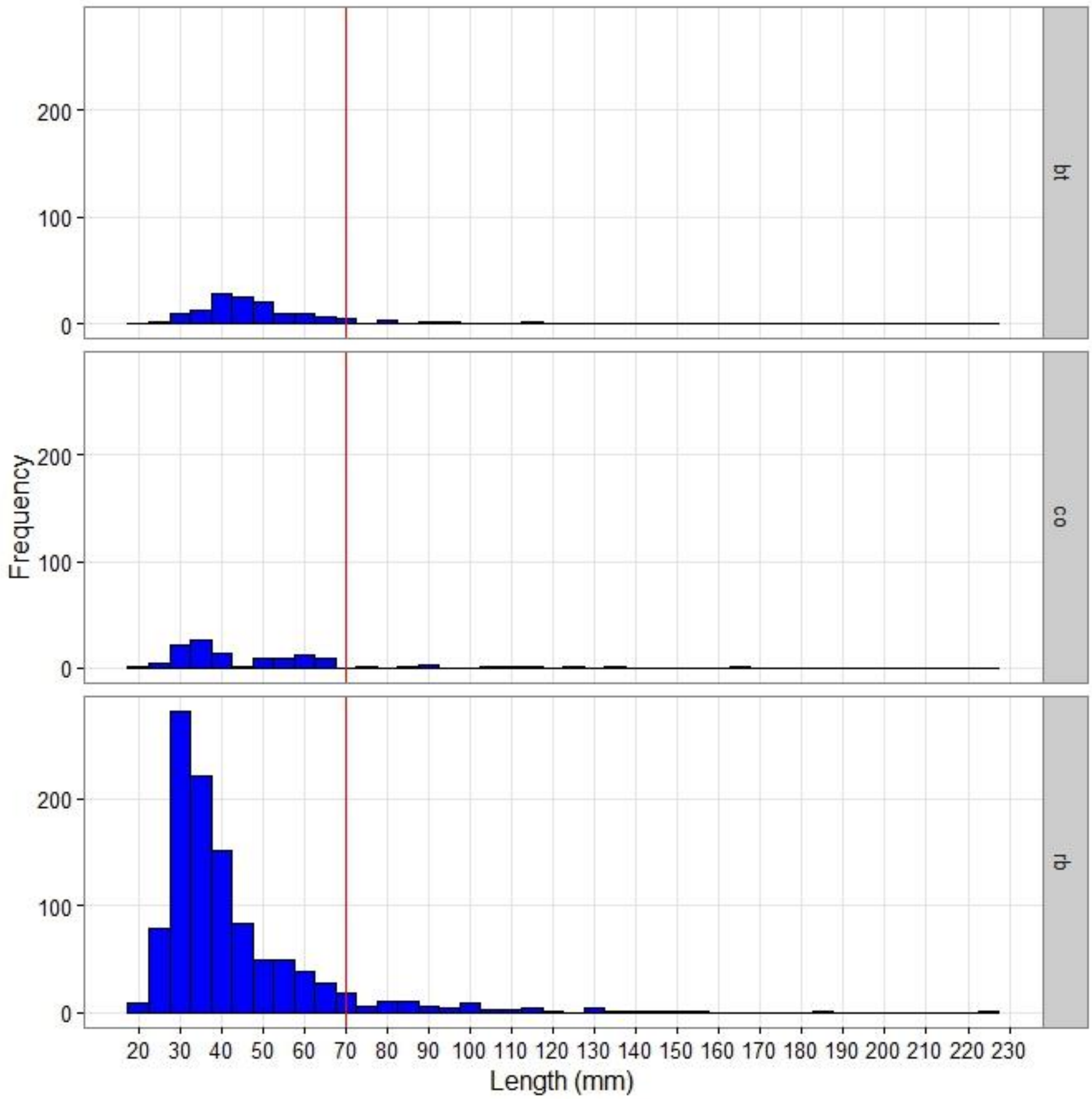

Figure 15. Length frequency plot for Bull Trout (top panel), Coho Salmon (middle panel) and Rainbow Trout (bottom panel) juveniles caught between mid-July and mid-August, 2016 in Gates Creek. The 70 mm length cut off for age 0+ fish is shown in red.

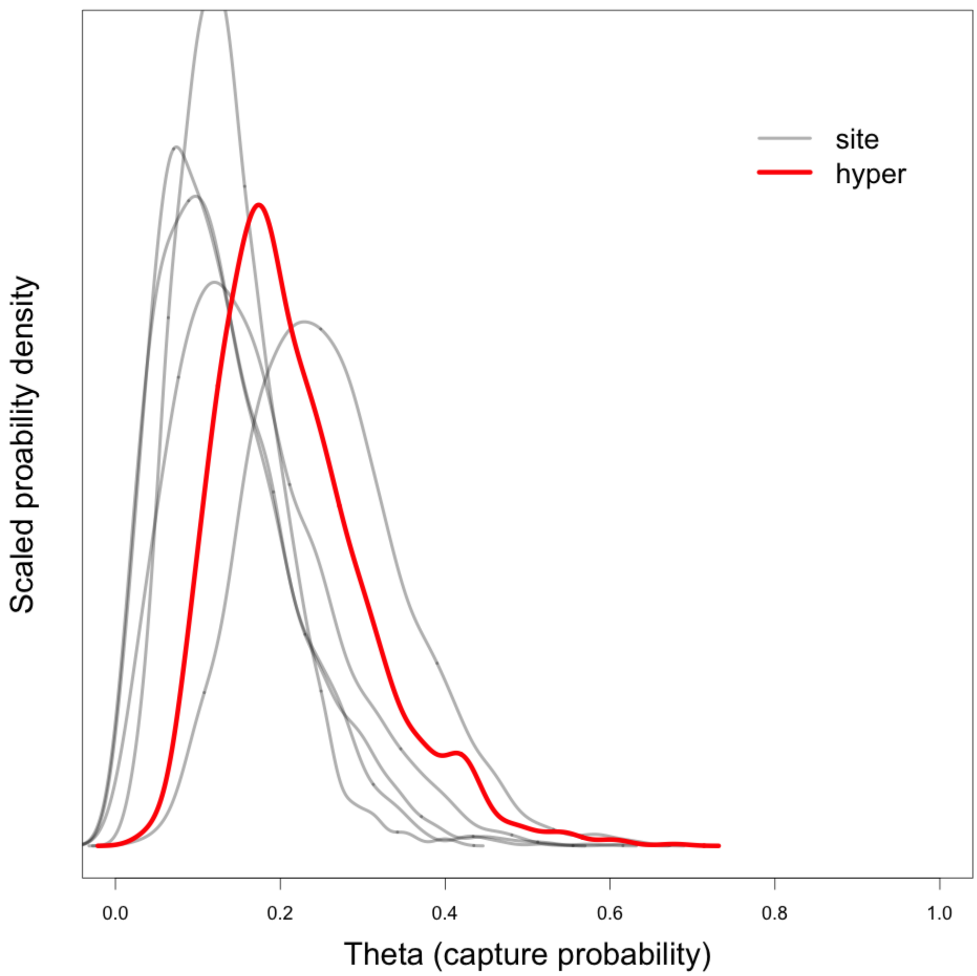

Figure 16. Posterior distributions for capture probability of age 0+ Rainbow Trout in Gates Creek for mid-July to mid-August, 2016.

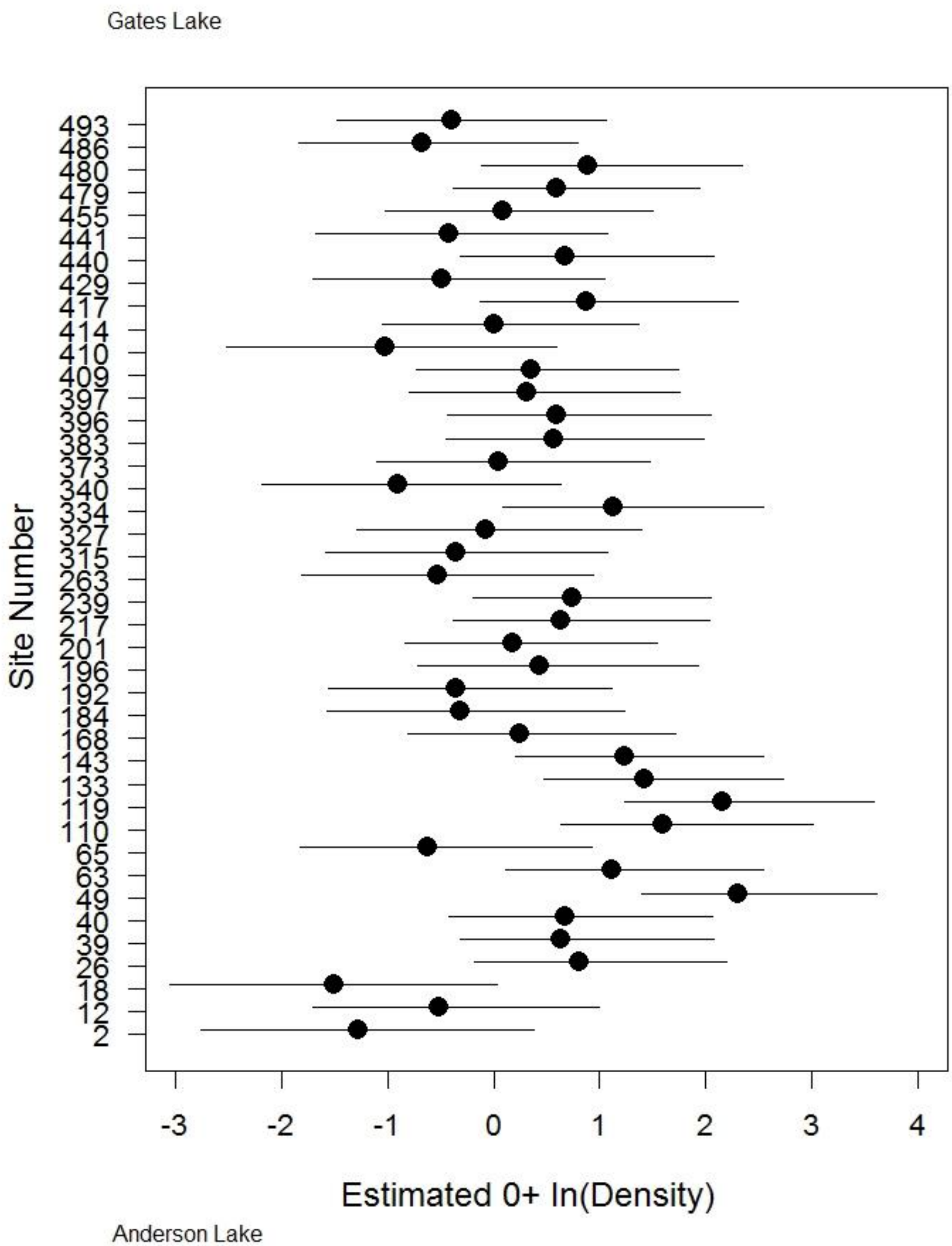

Figure 17. Plot of natural logarithm (ln) of fish density (fish/m) for age 0+ Rainbow Trout (up to 70 mm) estimated from open site electrofishing in Gates Creek, mid-July to mid-August, 2016.

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