

Gates Creek Salmon Project
Juvenile Salmonid Outmigration
Enumeration Assessment

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Prepared for:

Lillooet Tribal Council

By

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Executive Summary

This report presents the results of the 2012 salmonid outmigration and adult escapement study on Gates Creek. This was the first year of an anticipated 4 year study of juvenile sockeye production from Gates Creek and Gates Creek spawning channel, as well as Gates Creek production of out-migrant coho juveniles.

For the sockeye component of this study two traps, a partial river incline plane or rotary screw trap on Gates Creek and a full channel weir on Gates Creek spawning channel, were operated from March 27th until June 8th, 2012. For the coho component of this study the same rotary screw trap on Gates Creek served as both a mark and recapture trap operating from May 1st to June 8th, 2012. Bayesian P-Splines were used to generate estimates of total production and migration timing for both sockeye fry (*Oncorhynchus nerka*) and coho smolts (*O. kisutch*) from the mark-recapture data collected during trap operations.

A total estimated 15,792,991 sockeye fry were produced from Gates Creek and Gates Creek spawning channel combined, in the spring of 2012. Of this total migration, 10,214,909 fry (or 65%) were produced by Gates Creek and 5,515,083 fry (35% of total) were produced by Gates Creek spawning channel. Egg to fry survival for Gates Creek spawning channel was an estimated 37%, with an estimated 1206 fry produced per effective female in 2012. Estimated egg to fry survival for Gates Creek was 14.7%, with an estimated 480 fry produced per effective female.

A total of 17,259 1+ migrating coho smolts are estimated to have passed the trapping site on Gates Creek in the spring of 2012.

Challenges to study design were experienced due to variability observed in trap efficiencies for coho and sockeye at the downstream recapture trap on Gates Creek. Modifications to trap design, and/or the use of additional traps and trapping locations will need to be considered in subsequent years if both the sockeye and coho enumeration components are to provide estimates with high precision.

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Contents

1.0 INTRODUCTION	1
1.1 Study Objectives	2
1.2 Study Area and Trapping Locations	2
2.0 METHODS	2
2.1 Fish Trap Operations	2
2.1.1 Rotary Screw and Incline Plane Traps	2
2.1.2 Channel Trap	3
2.2 Fish Marking	3
2.2.1 Sockeye Fry Marking	3
2.2.2 Coho Smolt Marking	4
2.3 Bio- sampling	4
2.3.1 Data Collection	4
2.4 Biophysical Monitoring	5
2.5 Population Estimate Methods	5
2.5.1 Coho Smolt and Total Sockeye Fry Production	5
2.5.2 Gates Creek Spawning Channel Sockeye Fry Production	6
2.5.3 Gates Creek Sockeye Fry Production	7
2.5.4 Egg to Fry Survival and Fry per Effective Female	7
3.0 RESULTS	7
3.1 Trap Operations	7
3.1.1 Rotary Screw and Incline Plane Traps	7
3.1.2 Channel Trap	7
3.2 Bio- sampling	8
3.2.1 Sockeye bio-sampling	8
3.2.2 Coho bio-sampling	8
3.3 Biophysical Monitoring	8
3.3.1 Temperature	8
3.3.2 Water Level	8
3.4 Sockeye Population Estimates	8
3.4.2 Total Production of Sockeye Fry	8
3.4.1 Gates Creek Spawning Channel Sockeye Fry Production	9
3.4.3 Gates Creek Sockeye Fry Migration	9
3.4.4 Egg to Fry Survival and Fry per Effective Female	10

3.5 Coho Smolt Migration	10
4.0 DISCUSSION.....	10
4.1 Trap Operations	10
4.1.1 Rotary Screw and Incline Plane Traps.....	10
4.1.2 Channel Trap	11
4.2 Sockeye Migration.....	11
4.3 Coho Production	12
5.0 Summary and Recommendations	12
6.0 TABLES	14
7.0 FIGURES	20
8.0 REFERENCES	27

LIST OF TABLES

Table 1. Start and end dates for all traps operated on Gates Creek, Spring 2012	14
Table 2. Fecundity data for 2011 Gates Creek sockeye salmon brood year. (Source: DFO unpublished data)	14
Table 3. Trap dates in 2012 at Gates Creek for which trap operation was limited or suspended (1 day = 24 hrs)	14
Table 4. Performance (%) of Gates Creek spawning channel proportional sampler with original funnel and with custom funnel, spring 2012.....	15
Table 5. Summary of length & weight data from fish captured at Gates Creek spawning channel and Gates Creek RST site, spring 2012.	16
Table 6. Weekly totals of marked, recaptured, and unmarked sockeye fry at the Gates Creek enumeration site with weekly capture efficiency for both IPT and RST traps, spring 2012.	16
Table 7. Estimated total weekly emigration of sockeye fry passing the Gates Creek juvenile salmon enumeration site, spring 2012. Shaded week represents the strata trap was operated only 2 of 7 days, and back calculation of creek and total emigration was estimated from ratio of channel to total emigration from adjacent strata.	17
Table 8. Total estimated weekly emigration of sockeye fry from Gates Creek, spring 2012.	17
Table 9. Weekly strata totals of marked, recaptured and unmarked 1+ coho smolts at the Gates Creek RST site with weekly capture efficiency for both IPT and RST traps, spring 2012	18
Table 10. Total weekly estimated emigration of 1+ coho smolts at Gates Creek RST site, spring 2012. Total weekly migration is combined weekly mean unmarked population generated from spline model and weekly marked population.	19

LIST OF FIGURES

Figure 1. Overview of study Gates Creek watershed extending from Gates lake to Anderson Lake. Sites of spawning channel (10 U 536706 5599716) and IPT/RST (10 U 537151 5599978) are indicated with arrows.....	20
Figure 2. Overview of Seton- Anderson watershed. Red and orange lines indicate roadways.	21
Figure 3. Schematic of study area including relative locations of spawning channel, creek, recapture site and confluence of Gates Creek with Anderson Lake.	22
Figure 4. Rotary screw trap (RST) in operation on Gates Creek. Cable way visible across middle of figure.	22
Figure 5. Visual Implant Elastomer (VIE) mark on lower caudal lobe of Gates Creek Coho.	23
Figure 6. Length frequency distribution of Gates Creek Sockeye caught at RST (a) spawning channel (b) RST.....	23
Figure 7 Length frequency distribution of Gates Creek Coho (1+) Juveniles, 2012.	23
Figure 8. Average daily water temperature (°C) at the Gates creek RST site, spring 2012.	24
Figure 9. Gates Creek water level recorded at channel entrance, March 27, 2012 to June 6, 2012.....	24
Figure 10. Total weekly abundance estimates of Sockeye fry (SKF) at the Gates Creek RST site (solid line, diamonds) related to temperature in °C (broken line, squares,) and water level (solid line, triangles, values above, spring 2012.	25
Figure 11. Weekly abundance of SKF from Gates Creek spawning channel (dashed line), and Gates Creek (solid line) related to weekly average water level (m) (solid line, squares) and temperature (°C) (dotted line, triangles). .	26
Figure 12. Weekly abundance estimates of Coho smolts (solid line, diamonds) related to temperature in °C (broken line, triangles) and water level (m) (solid line, squares) from Gates Creek.	26

1.0 INTRODUCTION

Gates Creek, a major salmon bearing tributary of the Seton- Anderson Watershed, runs 12 kilometres from Gates Lake to Anderson Lake draining approximately 34,300 hectares (Komori 1997) (Figure 1). The Seton Basin, which feeds the Seton- Anderson watershed, is located approximately 200 km north of Vancouver in the rain shadow of the southern Coast Mountains (Anon. 2000). There are no glaciers in the watershed; however, Gates and Anderson Lake provide ample storage with-in the Seton basin. Anderson Lake is connected to Seton Lake via the Portage River, and Seton Lake drains into the Fraser River via Seton River (Figure 2).

Gates Creek supports a large population of sockeye salmon (*Onchorynchus nerka*), as well as smaller populations of coho Salmon (*O. kisutch*), and pink Salmon (*O. gorbushuca*). Prior to the construction of the Seton Dam, Gates Creek and other Fraser salmon stocks upstream of Hell's Gate 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 Seton Creek 750m 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 the impacts of hydro development, and earlier Hell's Gate slides on fish populations in the Anderson-Seton watershed, fish 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 Commission (IPSC) on Gates Creek 800m upstream of Anderson Lake to enhance sockeye escapement in the Seton-Anderson watershed. The spawning channel was originally overseen by the IPSC and the Department of Fisheries and Oceans Canada (DFO). In 1987, responsibility for channel maintenance and monitoring was turned over to the N'Quat Qua 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 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 production and adult escapement are available for Gates Creek spawning channel, detailed assessment of the gravel replacement activities has yet to be undertaken. Additionally, quantitative data regarding sockeye egg to fry survival and production from Gates Creek has never been collected. Enumeration of coho juvenile production in Gates Creek has 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 Gates Creek 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 Fish and Wildlife Compensation Program. The following report summarizes the findings of field work conducted on 2012 juvenile production.

1.1 Study Objectives

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

1. Derive population estimates for out migrant sockeye fry for both Gates Creek and 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. Derive a population estimate for out migrant coho juveniles from Gates Creek

1.2 Study Area and Trapping Locations

The study area consists of two sites, a full weir on the spawning channel (10 U 536706 5599716, 800m upstream of the mouth of Gates Creek at Anderson Lake), and an incline plane trap (IPT)/rotary screw trap (RST) (10 U 537151 5599978, 280m upstream of the mouth of Gates Creek at Anderson Lake) downstream of the channel outlet on Gates Creek (Figure 1 & 3).

2.0 METHODS

Two methods were used to enumerate out migrant juvenile sockeye and coho on Gates Creek in 2012.

- 1) Partial traps: rotary screw traps (RSTs) or incline plane traps (IPTs) which rely on mark-recapture methods to evaluate juvenile outmigration.
- 2) Complete channel traps: which allows enumeration of all out migrant sockeye fry from the Gates Creek spawning channel.

Study design was developed to ensure methodologies minimized stress and risk of mortality on fish, as well as considered the life-history stage of targeted species (i.e fry or smolt). The population estimate generated from the partial river trap (RST or IPT) which sampled only a portion of the total out migrating juvenile sockeye and coho population, required the use of mark-recapture techniques and analysis using the BTSPAS spline model (Bonner and Schwarz 2011).

2.1 Fish Trap Operations

2.1.1 Rotary Screw and Incline Plane Traps

Two types of traps were utilized as the downstream recapture trap in this study. Initially, March 27th to April 26th an IPT was used, but as discharge and debris loads increased due to spring snow melt the IPT became inoperable. A four foot diameter RST was used for the second half of the study, May 1st to June, 8th (Table 1). Both traps were oriented on a cableway pulley system allowing the 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 IPT or RST was set out fishing between 6 pm and 8 pm each evening depending on the timing of dusk. The trap was then checked at 8

am the following day for manual counting of captured fish. Restriction of trap operations to night hours was deemed adequate because it is known, from channel trap operations, that minimal numbers of fry migrate during daylight hours. During times of high water the trap was brought to shore and operations had to be suspended to ensure safety of crew and equipment.

2.1.2 Channel Trap

The full channel trap at the downstream end of the spawning channel guided all out migrating sockeye fry to a single trough where a proportional sampler, designed by Red Fish Services (here after referred to as the proportional sampler), divided out migrants into two separate capture boxes, “sample” and “full channel”. The proportional sampler was installed in 2011, and was designed to sample approximately 5% of fish into the “sample” box; however, the past two years of data have shown that the proportional sampler efficiency is highly variable (2011 to 2012, data on file). An accurate assessment of channel production is integral to assess the channel vs. Gates Creek production; therefore, rather than sub-sampling out-migrant fry all fish leaving the channel were manually counted using weight sub-samples. In addition to assessing fry production from the spawning channel, a portion of the sockeye fry captured at the channel trap were marked and were subsequently captured at the downstream IPT/RST site, allowing for a population estimate of Gates Creek sockeye to be derived using the mark-recapture methods as described in Section 2.5

In an effort to reduce the variability in the proportional sampler on April 27th the funnel was replaced with a custom funnel with a longer neck. The new funnel was designed to match the one utilized at the DFO Weaver Creek sockeye spawning channel. Additionally, the trough on the weir was outfitted with perforated screens which were designed to lower the water level in the trough and reduce the amount of water entering the proportional sampler.

The changes to the Gates Creek proportional sampler were evaluated by enumerating both the sample and full boxes. The comparative data was then analysed using ANOVA and Welch’s t-test to determine whether the modifications reduced the variability in the sampled proportion of fry over the remainder of the study period.

2.2 Fish Marking

2.2.1 Sockeye Fry Marking

On marking days, sockeye fry collected at the channel trap were not sampled in the morning of capture but held in the trap boxes until late afternoon. A maximum of 2,500 fry were marked each day by immersion in Bismark Brown Y (BB) at a concentration 1:100,000. 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 due to the marking/holding process on fry (Melville and McCubbing 2002b). Daily fry catch data represented a 24 hour sample period beginning at 8 am each morning.

Marking and enumeration were timed such that each release of marked fry would coincide with dusk. This procedure was undertaken for four days each week (Monday through Thursday). A three-day break between marking periods has been assessed in similar studies (i.e Melville and McCubbing 2001-2011) as sufficient to allow all marked fry from each four-day marking period to pass by the enumerator trap (IPT/RST), thus requiring only one mark type. This assumption was validated by the capture data at the

IPT/RST site as there were zero re-captures of marked sockeye fry on Sunday night/Monday morning during our study period.

2.2.2 Coho Smolt Marking

Coho juveniles have varied freshwater life histories prior to migration to salt water. For the purpose of field marking and enumeration of fish it is necessary to use discrete length intervals to identify which life stage a coho juvenile is at when captured during the spring migration period. 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 (1+ migrating). Beginning May 1st, unmarked coho smolts captured in the RST were marked daily with a caudal fin clip, and Visual Implant Elastomer (VIE) tag (Northwest Marine Technology, Inc.) (Figure 5). To allow for temporal stratification of capture efficiency, mark patterns were changed on Sunday of each week. Thus, mark groups for coho ran from Monday through Sunday from May 1st to June 8th. Fish were marked in the morning after the RST catch had been enumerated. The marked coho were then placed in a holding box in the channel flow, downstream of the channel trap and released at dusk. The daily coho catch was defined as the 24 hour period beginning at 8 am.

To reduce stress to fish and ensure successful marking, fish were anaesthetized using a water bath with clove oil diluted in ethanol. Caudal fin clips consisted of a dorso-ventral cut approximately ¼ the distance from the caudal peduncle to the tip of either the upper or lower caudal lobe. VIE was injected sub-dermal along fin rays in either caudal lobe (Figure 6). Temperature stress was minimized by frequent changes of anaesthetic baths, and by marking early in the morning in shade.

2.3 Bio- sampling

2.3.1 Data Collection

Bio-sampling of fish was undertaken at the channel and the IPT/RST site. Throughout the study period 25 unmarked sockeye fry were sampled twice a week. Coho juveniles were only sampled at the IPT/RST site as none were captured in the channel trap. To ensure accuracy of measurements and reduce handling stress fish were anaesthetized in water baths with clove oil diluted in ethanol. Fork lengths were taken to the nearest millimetre. Coho were weighed individually to the nearest tenth of a gram. Sockeye fry were weighed in groups of five to the nearest tenth of a gram.

2.3.2 Data Analysis

Length and weight data for sockeye fry from Gates Creek spawning channel and the RST site were analysed for significant differences in sample mean and sample variance using the single factor one way ANOVA and Welch's t-test functions.

2.4 Biophysical Monitoring

Two temperature loggers were maintained and data collected in the Gates Creek spawning channel and Gates Creek in 2012.

The temperature loggers were operated for the juvenile study period, and were downloaded once every month. The temperature data recorded at the RST/IPT site were used for analysis in this study. Mean weekly water level (WL) over the survey period was computed from daily staff gauge reading taken in the main creek above the intake for the spawning channel.

2.5 Population Estimate Methods

2.5.1 Coho Smolt and Total Sockeye Fry Production

The Bayesian P-SPLINE model developed by Bonner and Schwarz (2011) was utilized for mark-recapture data analysis. The analysis is carried out using the R computer program (R Development Core Team, 2012), with the R2OpenBUGS (Sturtz *et al.* 2005) package for interfacing with Open Bugs (Lunn *et al.* 2009), as well as the BTSPAS (Schwarz and Bonner 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 (eg. Ricker, 1975, Arnason *et al.*, 1996) methods have been the preferred analysis method for mark re-capture 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.

As well, we assume that:

- 7) Marked and unmarked fish have similar movement patterns from the release site to the downstream trap.
- 8) Fish can pass the downstream trap only once and all marked fish pass trap 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 no fish leave the system without passing trap.

Due to fluctuating flow and subsequent changes in catchability, an estimator like the Pooled Petersen (which relies on an assumption of homogenous catchability over the study period) can introduce bias into the population estimate. Additionally, in the presence of heterogeneous catchability over a study the Pooled Peterson estimator will overestimate the precision of the estimate (Seber 2002). An estimator which addresses heterogeneity in catchability throughout a study, for example through the use of temporal strata is likely to be more accurate than an estimator based on an assumption of homogeneity (Seber 1982). Such an estimator requires that a study be designed where strata can be differentiated by mark group. The stratified Peterson estimator was introduced by (Darroch 1961), and was further refined by

Seber (1982, Chapter 13), Plante et al. (1998), Schwarz and Taylor (1998), Arnason et al. (1996) and Bjorkstedt (2000). While, in theory, these methods are more accurate there are some downfalls to their use because the matrix of recoveries will be sparse with some strata having small counts. Because this estimator relies on the inversion of sparse low count data, the estimates generated from these estimators can be subject to high levels of uncertainty and imprecision. Additionally, these stratified methods do not take into account strata that have sparse data, but are likely to have similar abundance and movement patterns and thus catchability as adjacent strata. Due to sparse data, pooling of strata is often required. However, there is no statistically defensible method to choose the strata to pool, and pooling decisions are not included into the estimates of uncertainty (Bonner and Schwarz 2012).

Bonner and Schwarz (2011) developed an alternate method (Bayesian spline model) for calculating population estimates that has many advantages over existing methods which are discussed further in (Bonner and Schwarz 2012). It takes into account the temporal stratification and shares information among neighboring strata to help alleviate problems caused by small counts. The key features of this method are the use of splines to model the general shape of the run and Bayesian hierarchical methods to share information on catchability and the shape of the spline among strata. The method is self-calibrating in the sense that if the data are sparse, the equivalent of simple-Petersen methods where the catchability is assumed to be roughly the same over the study are fit, but when the data are rich, more complex models are fit. Estimates of abundance are provided for each recapture stratum and so it is relatively simple to also estimate derived 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 features of the model also deal with problems (such as no sampling in some strata) in a straightforward fashion – 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.

Despite its complexity, the spline model 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 potentially to other stratified models (Bonner and Schwarz 2012). These potential problems are more fully described in Schwarz and Bonner (2012).

During the week of April 24th to April 30th where trapping occurred only 2 days out of 7 alternate methods were used to generate an estimate of total weekly abundance at the RST site. For this week of sparse data (strata 5) total weekly abundance was calculated by dividing the channel production estimate by the averaged ratio of weekly channel production to the spline estimate for the adjacent two weeks (strata 4 and 6). To estimate a weekly abundance of sockeye fry from Gates Creek, the channel production was then subtracted from the estimated total weekly abundance. No confidence intervals are available for this data.

2.5.2 Gates Creek Spawning Channel Sockeye Fry Production

Production of sockeye fry from Gates Creek spawning channel was estimated using counts and volume sampling. Monitoring of the migration began on March 27th and ended June 8th. For daily catches of 3000 or less, fry were counted using dip nets and hand tallies. Volume sampling was used when daily catches exceeded 3000 fry. The volume sampling technique utilized at Gates Creek spawning channel consists of dip netting live fry from the capture boxes and letting it drain for approximately 20 seconds (or until water stops dripping out). The fish are then added to a container of water on a scale. Water is changed between each weighing. Weight sampling was completed between 0800 hours and 1200 hours daily. During the peak of the migration a technician also weighed out the fish in the full channel box between 2300 and 2400 hours to prevent mortality caused by overcrowding in the trap box. The weights for the full channel box done at night were recorded and added to the morning totals.

To convert the weights of fry to number of fry, a sub sample of 500 fish was removed from one of the boxes and weighed. The number of fry per gram was then calculated and multiplied by the weight of fry in each box.

Daily channel production was the summed total of fry enumerated from both the sample box and full channel box. For days on which the full channel box was not in use (April 24th-29th, May 1st and May 24th), the average sample proportion from the proportion sampler for the study period was used to calculate daily production.

2.5.3 Gates Creek Sockeye Fry Production

Gates Creek production was assumed to be the difference between the total fry production estimate derived at the IPT/RST and Gates Creek spawning channel estimate.

2.5.4 Egg to Fry Survival and Fry per Effective Female

Egg to fry survival was estimated by dividing fry production by egg deposition. Egg deposition for Gates Creek channel was estimated using fecundity data for the 2011 brood year obtained from DFO (DFO unpublished data). Fry *per* effective female¹ was calculated by dividing the number of fry into the number of effective females for 2011. Mean Fecundity, effective females, and egg deposition figures for 2011 are summarized in Table 2 for both the spawning channel and creek.

3.0 RESULTS

3.1 Trap Operations

3.1.1 Rotary Screw and Incline Plane Traps

The IPT/RST trap was operational 65 days (or 86%) of the 74 day study period. Due to high water trapping was suspended from April 26th – April 30th, May 17th – May 18th, and June 1st – June 2nd - a total of 9 days (Table 3). The IPT had higher mean capture efficiency for sockeye (7.0%, SD 1.1%) than the RST (1.2%, SD 1.0%). However, even though the IPT was operational during a portion (April 1st to April 26th) of the typical run timing of coho smolt migration (Melville and McCubbing, 2012 and McCubbing and Ward 2008) it did not catch an adequate amount of coho smolts (< 5 per day, or 69 total over 25 days) to allow for marking and subsequent calculation of a population estimate. The RST in comparison functioned with a mean capture efficiency of 15.6% (SD 5.1%) for coho smolts from May 1st to June 8th.

3.1.2 Channel Trap

The average sampling efficiency of the proportional sampler over the entire period was 4.2% (SD 3.45). Performance of the proportional sampler was evaluated both before and after modifications (Table 4). No significant difference was found; Welch's t-test ($P = 0.389$), or single factor one way ANOVA ($F(43) = 1.32$, $P = 0.2567$) between mean sampled proportion with the original funnel (mean 3.74, SD 1.66) or with the custom funnel (mean 4.71, SD 4.98).

¹ Effective female refers to a female which successfully spawned

On May 23rd the motor in the proportional sampler broke and was not operated for the remainder of the study. All fry migrating out of channel after May 23rd were captured and weight sampled in the full channel box.

3.2 Bio- sampling

3.2.1 Sockeye bio-sampling

Length frequency data, for both the channel and the IPT/RST, were uni-modal at between 28 and 30mm (Table 5, Figure 6). The mean length (mm) for sockeye caught at the channel and IPT/RST sites were 30mm (SD 3) and 29mm (SD 1), respectively. A significant difference between channel and IPT/RST fry length data was calculated by both Welch's t-test ($P = 0.003$) and single factor ANOVA ($F(1,664) = 8.28, P = 0.004$). Channel fry were more variable in size ranging from 25 to 54mm, while fry caught at the IPT/RST ranged from 26- 40 mm.

Mean sockeye fry weight (g) for both the channel and RST sites was 0.3g (SD 0.1), respectively over the same period. No significant variation in mean fry weight, among the channel and IPT/RST samples, was found using single factor ANOVA ($F(1,662) = 1.57, P = 0.21$), or Welch's t-test ($P = 0.21$).

3.2.2 Coho bio-sampling

Gates Creek 1+ migrating coho had a mean length of 96 mm (SD 10.0), and a mean weight of 11.3 g (SD 9.8) (Table 5). Length frequency data was uni-modal peaking between 86 and 100mm with 45.0% of the fish sampled falling within this range (Figure 7).

3.3 Biophysical Monitoring

3.3.1 Temperature

Average daily water temperature at the RST data logger ranged from 4.6°C to 15.2°C from April 3rd to June 8th (Figure 8)

3.3.2 Water Level

Average daily river water level, measured at the channel intake, ranged from 0.6 m to 1.6 m from March 27th – June 8th, (Figure 9). Increased water levels on April 26th (0.95m), May 17th (1.60m), and June 2nd (1.40m) resulted in temporary suspension of trap operations.

3.4 Sockeye Population Estimates

3.4.2 Total Production of Sockeye Fry

The total number of sockeye fry captured at the IPT/RST site over the period March 27th to June 8th, was 533,393 fish (Table 6). A total of 93,117 marked sockeye fry were released at the channel weir, of which 2,889 were recaptured giving an estimated total migration of 15,729,991 sockeye fry passing the IPT/RST site between March 27th and June 8th, 2012. This was calculated utilizing the BTSPAS- spline model with an adjusted weekly total for April 24th to April 30th, (Figure 9). A total 25,709 mortalities (included in production estimates) representing 6.6% of total catch, or 0.2 % of total estimate were incurred from the IPT (22,922 of 331,672 captures) and RST (2,787 of 53,149 captures) combined. Trap efficiencies for the

IPT ranged from 6.2% to 8.0% (mean 7.0%, SD 1.1%), while trap efficiency for the RST (installed May 1st) ranged from 0.1% to 2.8% (mean 1.2%, SD 1.1%) (Table 6).

Based on estimated weekly abundance, it appears the run of sockeye fry had commenced just prior to trap operations. In the first week, March 27th to April 2nd, 175,248 fry or 1.1% of the total estimated emigration passed the trap (Table 7). Overall the run timing of sockeye fry passing the IPT/RST site was bi-modal (Figure 10). The first peak in estimated weekly migration of 5,863,824 fry (or 37.3% of total migration) occurred in the week of April 24th to April 30th, which is also the week the run reached the 50% mark. A second smaller peak of 2,490,885 fry (or 15.8% of total migration) occurred in the week of May 8th to May 14th, by the end of which more than 90% of the fry had migrated had (Table 7). The first peak in the migration coincided with an increase in average weekly temperature from 5.8 °C the week previous to 6.2 °C, as well as an increase in average weekly water level from 0.75m in the week previous to 0.92m. The second peak in sockeye fry migration did not correspond to an increase in either water level or temperature.

3.4.1 Gates Creek Spawning Channel Sockeye Fry Production

Gates Creek spawning channel produced an estimated total 5,567,583 sockeye fry between March 27th and June 8th. Of this total there were 5,515,083 were live migrants, and 52,500 mortalities (1.2% of total estimated channel production) from handling and channel trap operations. The migration of fry out of the channel was uni-modal with a peak weekly emigration of 2,593,636 fry (46.1% of total channel migration) in the week of April 24th to April 30th (Table 8, Figure 11). Specifically, the channel peaked on April 24th with a total nightly migration of 1,271,179.

Fry migration from the channel had likely just started when trapping commenced as less than 1% of the total run was captured in the first week. The channel reached the 10%, 50% and 90% points of the migration in the weeks ending of April 23rd, April 30th and May 14th, respectively. In the three week period between April 17th and May 7th, 82% of the estimated fry production had migrated out of the channel, after which migration dropped off sharply with only 11% of fish emigrating over the remaining 5 weeks (May 8th to June 8th).

3.4.3 Gates Creek Sockeye Fry Migration

By subtraction, Gates Creek produced an estimated total migration of 10,214,909 sockeye fry over the period March 27th to June 8th, 2012 (Table 8, Figure 11). The creek migration was bi-modal. The first larger peak occurred in the week of April 23rd to April 30th with a total of 3,324,188 fry, or 32.5% of the total creek production. The second smaller peak occurred in the week of May 8th to May 14th with a total of 2,007,956 fry, or 19.7% of the total creek production (Table 8, Figure 11).

In the first week of trapping an estimated 155,078 fry from Gates Creek (1.5% of creek total) migrated past the IPT/RST site. The creek reached the 10%, 50% and 90% points of the migration in the weeks ending April 16th, April 30th and May 14th, respectively. The run timing of the creek sockeye fry was longer than the channel run with 90% of the run being spread over the 5 week period April 10th to May 14th. In the 4 weeks following the second peak, (May 15th to June 8th) the migration dropped off sharply with only 6.4% of the fish emigrating.

3.4.4 Egg to Fry Survival and Fry per Effective Female

Egg to fry survival for Gates Creek spawning channel and Gates Creek were estimated to be 37.0%, and 14.7% respectively for the 2011 brood year. The number of fry produced per effective female was 1206 for Gates Creek spawning channel, and 480 for Gates Creek (Table 2).

3.5 Coho Smolt Migration

A total of 1,554 live coho smolts from 6 weekly strata were marked at the RST site on Gates Creek in the spring of 2012 (Table 9). From this number of marked fish, an estimated 17,294 (SD 1,232, 95% CI [15,170, 20,012]) coho smolts migrated past the RST site between May 1st and June 8th (Table 11, Figure 12). Only 5 mortalities representing >0.3% of total estimated abundance were incurred at the RST over the same period.

RST capture efficiency among weekly strata for coho smolts ranged from 10.2% to 21.2 % with a mean of 15.2% (SD 5.2%) (Table 9).

Peak emigration of coho smolts from Gates Creek occurred in the week of May 21st to May 27th with a total of 6,067 (or 35.1% of the total smolt migration) smolts. This same peak week was also the week the 60% migration mark was reached. The migration for coho smolts likely started prior to the commencement of our marking activities on May 1st. In the first week of RST operation May 1st, to May 7th, 543 coho smolts were caught resulting in a total estimated emigration of 1,768 smolts (or 10.2% of the total smolt migration) (Table 9 & 10). However, it is likely we captured the end of the run as less than 8.0% of the estimated total smolt migration passed in the final two weeks May 28th to June 8th (Table 10).

4.0 DISCUSSION

4.1 Trap Operations

4.1.1 Rotary Screw and Incline Plane Traps

In general, the IPT was more efficient than the RST at capturing sockeye fry (IPT 7.0% on average vs. 1.1% for RST on average). However, while the IPT functioned better at lower water levels, it did not perform well under increased flows and debris loads.

A possible explanation for reduced capture efficiency of the RST may be that there was no longer a central channel of focused flow where the IPT had previously been situated. Initially, during low water (< 0.8 m) the IPT was situated in the main flow of the creek which had been restricted to a narrow channel by a log and large boulders, but as river discharge increased flow was dispersed into a wider area and it was not possible to situate the RST in a way that it would capture the same percentage of flow as the IPT had under lower water conditions. McDonald (1956) observed that traps placed in areas of heavy flow captured the highest percentage of sockeye fry in William Creek (McDonald 1956). In McDonald's study, traps placed on the margins of flow captured very few fish.

Some relatively minor design modifications could improve the ability of the IPT to handle higher flows and debris loads period include:

- 1) Additional flotation to allow the trap to fish during high flow events
- 2) A second stage box to create refuge from turbulence for fish.

Regardless, of suggested modifications to the IPT the trap type is not efficient for capturing 1+ coho smolts. If juvenile coho enumeration is to be continued as part of the project in subsequent years, it will be necessary to switch out the IPT for the RST at the beginning of May or earlier (when it appears coho begin to migrate), run both trap simultaneously or use an alternate location for coho smolt evaluations.

4.1.2 Channel Trap

The proportional sampler at the channel outfall captured a wide range of sample percentages. The mean percentage sampled over the whole period March 27, 2012 to June 8, 2012 was 4.1%; however, the standard deviation for the proportional sampler was 3.4%. The mean sampling percentage in 2011 was 4.8% with a standard deviation of 3.5%. Results from Welch's t-test and ANOVA indicate the modifications made to the proportional sampler have not improved the consistency of the proportional sampler.

The inconsistency of the proportional sampler is an issue that requires immediate attention. Due to the inconsistency of the proportional sampler, it has been necessary to capture and expose all juveniles leaving the spawning channel to handling stress. Use of the proportional sampler without modification is not advised because accurate estimates of fry production from Gates Creek spawning channel are integral to the calculation of Gates Creek fry migration in addition to estimates of channel production and survival.

4.2 Sockeye Migration

An estimated 15,792,991 sockeye fry emigrated from Gates Creek and Gates Creek spawning channel in the spring of 2012. Of the total production, 65% of the fish were produced by Gates Creek and 35% were produced by the channel. While the creek had higher total production of fry in the spring of 2012, egg to fry survival in Gates Creek was actually markedly lower (14.7%) than the spawning channel (37.0%).

Part of this study's objectives were to provide estimates of sockeye fry production in both Gates Creek and Gates Creek spawning channel which would enable DFO advisory staff to evaluate the effectiveness of the gravel replacement activities. While the the proportional sampler was installed in 2011, and fry production data for Gates Creek spawning channel were available (data on file), calculation of survival was not possible due to scarcity of fecundity data for the 2010 brood year. Prior to 2011, fecundity data had not been collected since 1988 (DFO unpublished data in O'Donahey *et al.* 1999). At other DFO operated spawning channels, annual estimates of egg to fry survival can span a wide range of percentages. Weaver Creek, a highly productive sockeye channel, egg to fry survival figures fluctuate from 35-87%, (DFO unpublished data). With out additional data points it is impossible to infer whether Gates Creek spawning channel functions within, below or above this range of survival.

Although egg to fry survival for sockeye salmon in Gates Creek is lower than in the spawning channel, our estimate for 2012 is actually higher than the estimated average literature values. In a review of the few published studies of juvenile sockeye survival, Quinn (2005) calculated an average wild egg to fry survival of 12.4%. While the estimate of survival for sockeye from egg to the fry stage in Gates Creek appears to be slightly higher than the average for known populations calculated by Quinn (2005), it is only one data point and does not confer enough information at present to evaluate how survival in Gates Creek may fluctuate in years of lower/ higher adult escapement or in response to varying water temperature and flow conditions.

The inability to fish the IPT during higher flows with associated debris loads, which ultimately resulted in the replacement of the IPT with the RST, impacted the precision of our sockeye fry estimates. It was especially untimely to have the IPT fail during the peak of the fry emigration from the channel. It resulted in the channel emigration estimate being higher than total estimated emigration (channel and creek) calculated from the spline model for the 5th strata (April 24th to April 30th). As negative emigration from the creek is not possible, we resorted to alternate methods to estimate emigration from Gates Creek for this week. Our back calculation method for the missing strata however, has some weaknesses including the inability to calculate standard deviation and confidence intervals. The ratio of channel emigration to total emigration increased from the 4th strata to the 6th strata meaning the channel production was likely increasing in contribution to the weak 5th strata as well. Due to the use of this back calculation method, our estimated weekly and total migration of sockeye from Gates Creek are likely either slightly over or under estimating the true total migration past the site. Therefore, it would be prudent to complete recommended modifications to the IPT for next year to ensure more precise estimates of sockeye migration.

4.3 Coho Production

The total estimate of 17,294 (SD 1,232, 95% CI [15,170, 20,012]) out migrant 1+ coho smolts for the spring of 2012 is the first quantitative assessment of juvenile coho production in Gates Creek. It is likely we have underestimated the total population of (1+) out-migrant juvenile coho by not being able to derive an estimate for the beginning of the migration. Therefore, the true population of total out-migrant 1+ coho smolts is likely higher than the total presented here. Estimates of egg-smolt survival for coho are not possible due to a vacuity of fecundity data for the Gates Creek coho population. In their draft Fisheries Implementation Plan, the State of British Columbia has identified improvement of fish habitat as a key focus for Gates Creek in future years (Anon. 2012). Preliminary assessments have been made along the extent of Gates Creek identifying possible locations of improved fish rearing habitat (Anon. 2001) as well as areas currently used by rearing juvenile coho (Hillaby 2012).

The data presented here represent the first enumeration of Gates Creek juvenile coho smolt emigration. While this is an important first assessment, continuation of the project to develop a model of juvenile coho migration behaviour during varying water level and temperature patterns would compliment surveys of habitat use by juvenile coho (Hillaby 2012), as well as allow assessment of future restoration activities. Furthermore, a life cycle time series of juvenile production for this population could be linked to the adult escapement data collected annually by DFO to serve as a rough indicator of ocean survival for this stock.

5.0 Summary and Recommendations

The objectives for this first year of the study have largely been accomplished.

1. We obtained total estimates of 10,222,607 out migrant sockeye fry from Gates Creek, and 5,515,083 fry from Gates Creek spawning channel.
2. We obtained an estimated egg to fry survival of 14.7% for Gates Creek, and 37.0% for Gates Creek Spawning channel.
3. We estimated sockeye fry production per effective female to be 1,206 for Gates Creek spawning channel and 480 for Gates Creek.
4. We obtained a total estimated emigration of 17,259 coho smolts for Gates Creek in the spring of 2012.

For future years of this study, should it be continued, we recommend that the IPT be modified to have sufficient flotation to handle increased flows as well as debris loads. This will enable fishing during a wider range of conditions and improve data quality and precision of estimates. Additionally the box of the trap will require modifications for improved fish health. The box at present can become overwhelmed with debris and turbulence resulting in fish mortality.

The study design will have to be modified should both the sockeye and coho components of the study be continued. A complication to the study that will need to be evaluated is that the RST is efficient only for coho smolts, while the IPT is only efficient for sockeye fry. Separate sites for smolt and fry assessments could be considered, or modifications to the existing site could be undertaken.

There are several important reasons for continuation of this study. Since the construction of the spawning channel, it has generally been accepted that Gates Creek has limited suitable habitat for salmon spawning and the best operating regime for safe guarding the valuable Gates Creek sockeye stock has been to load the spawning channel to maximum capacity (Doug Lofthouse, pers. comm.). However, these assumptions have never been validated as juvenile production and survival data have not been collected for Gates Creek to date. Continuation of this study will help to build a knowledge base upon which channel loading decisions could be based. In addition to improving channel loading decisions, this study provides preliminary estimates of fry production from Gates Creek for both sockeye fry and coho smolts and is also one of very few estimates of wild egg to fry survival for sockeye in BC.

Several study linkages exist with the now ongoing expanded monitoring of sockeye and coho salmon adult escapement through the Seton dam fishway (BC Hydro WLR requirement). These include but are not limited to; migration survivorship, escapement/loading forecasts, adult migration timing and relative distribution of spawners. There also exist significant opportunity for capacity building in staff resources for the N'Quat'Qua, by continuation of these studies and through the Sta'at'imc Government Services fisheries technician program (Anon. 2012).

6.0 TABLES

Table 1. Start and end dates for all traps operated on Gates Creek, Spring 2012

Trap/Counter Name	Start Date	End Date	Comments
Channel Weir	March 27	June 8	Sampler funnel piece replaces April 27, 2012. Sampler stopped functioning June
IPT	March 27	April 26	Water level increased April, 26, 2012 suspending operation of trap
RST	April 30	June 8	Installed in place of IPT

Table 2. Fecundity data for 2011 Gates Creek sockeye salmon brood year. (Source: DFO unpublished data)

	Channel	Creek
Total Female Spawners	4,574	21,297
Eggs <i>per</i> Female	3,260	3,260
Egg Deposition	14,911,240	69,428,220
Total Emigration of Fry, Spring 2012	5,515,083	10,222,607
% Survival	37.0%	14.7%
Fry <i>per</i> Effective Female	1,206	480

Table 3. Trap dates in 2012 at Gates Creek for which trap operation was limited or suspended (1 day = 24 hrs)

River	Trap_Code	Date	Comments
Gates	IPT	24-Apr	high water
Gates	IPT	25-Apr	high water
Gates	IPT	26-Apr	high water
Gates	IPT	27-Apr	high water
Gates	IPT	28-Apr	high water
Gates	IPT	29-Apr	high water
Gates	RST	16-May	high water
Gates	RST	17-May	high water
Gates	RST	01-Jun	high water
Gates	RST	02-Jun	high water
Gates	Proportional	23-May- 8- Jun	Motor Broke

Table 4. Performance (%) of Gates Creek spawning channel proportional sampler with original funnel and with custom funnel, spring 2012.

Date	Original Funnel	Date	Custom Funnel
27-Mar	3.96	30-Apr	4.35
28-Mar	1.34	2-May	3.74
29-Mar	3.35	3-May	6.16
30-Mar	3.00	4-May	4.46
31-Mar	3.86	5-May	2.58
1-Apr	4.53	6-May	4.95
2-Apr	4.89	7-May	4.02
3-Apr	1.29	8-May	2.57
4-Apr	4.51	9-May	2.54
5-Apr	2.29	11-May	1.91
6-Apr	5.35	12-May	6.28
7-Apr	3.82	13-May	4.63
8-Apr	4.63	14-May	5.16
9-Apr	4.23	15-May	25.40
10-Apr	1.64	16-May	1.50
11-Apr	1.64	17-May	2.73
12-Apr	3.87	18-May	2.59
13-Apr	2.81	19-May	1.47
14-Apr	4.87	20-May	6.01
15-Apr	7.14	21-May	1.77
16-Apr	4.11	22-May	4.21
17-Apr	2.91		
18-Apr	2.09	Original Funnel	
19-Apr	1.69	Mean	3.74
20-Apr	3.85	SD	1.66
21-Apr	3.99		
22-Apr	3.80	Custom Funnel	
23-Apr	8.86	Mean	4.72
24-Apr	4.23	SD	4.98

Table 5. Summary of length & weight data from fish captured at Gates Creek spawning channel and Gates Creek RST site, spring 2012.

Species		Length (mm)	Weight (g)
Sockeye Fry at RST	N	465	465
	Range	35-45	0.28-0.62
	Mean	39	0.42
	SD	1.44	0.06
Sockeye Fry at channel	N	340	340
	Range	25-54	0.12-0.80
	Mean	30	0.31
	SD	3.4	0.13
Coho Smolts	N	747	747
	Range	70-218	4-114
	Mean	96	11
	SD	6.0	5.8

Table 6. Weekly totals of marked, recaptured, and unmarked sockeye fry at the Gates Creek enumeration site with weekly capture efficiency for both IPT and RST traps, spring 2012.

Week Ending	Marks	Recaptures	Unmarked	Mortalities ²	ECE%	Trap
2-Apr	6,969	416	10,818	413	6.0%	IPT
9-Apr	7,439	593	20,876	622	8.0%	IPT
16-Apr	9,386	741	111,916	2331	7.9%	IPT
23-Apr	7,496	464	210,247	19421	6.2%	IPT
30-Apr ¹	7,293	31	1,926	287	0.4%	IPT
7-May	10,111	280	48,600	1657	2.8%	RST
14-May	9,941	14	4,771	912	0.1%	RST
21-May	7,500	9	511	33	0.1%	RST
28-May	7,696	109	769	31	1.4%	RST
4-Jun	10,893	140	670	2	1.3%	RST
11-Jun	8,393	102	564	0	1.2%	RST
Total	93,117	2,899	411,668	25,709		

¹ Shaded week of April 24th to April 30th, 2012 was first week of high water where only two days were fished. Following this week the IPT was replaced with RST.

² Mortalities included in weekly unmarked totals for spline calculations

Table 7. Estimated total weekly emigration of sockeye fry passing the Gates Creek juvenile salmon enumeration site, spring 2012. Shaded week represents the strata trap was operated only 2 of 7 days, and back calculation of creek and total emigration was estimated from ratio of channel to total emigration from adjacent strata.

Week Ending	Mean	SD	Relative SD ¹	-97.5%	97.5%	Temp (°C)	Water Level (m)
2-Apr	175,248	8,516	0.05	159,190	192,178	6.46	0.68
9-Apr	255,016	10,096	0.04	235,796	275,364	6.20	0.68
16-Apr	1,389,993	48,940	0.04	1,296,980	1,487,303	6.12	0.71
23-Apr	3,085,914	137,342	0.04	2,827,088	3,370,827	5.75	0.75
30-Apr	5,863,824	-	-	-	-	6.19	0.92
7-May	1,698,578	100,334	0.06	1,512,466	1,911,654	6.25	0.85
14-May	2,490,885	649,348	0.26	1,524,281	4,032,335	5.91	0.87
21-May	527,942	170,169	0.32	286,802	937,801	6.36	1.21
28-May	53,294	5,483	0.10	43,569	65,230	6.16	0.97
4-Jun	84,196	7,708	0.09	70,207	100,301	7.96	1.09
11-Jun	105,101	10,860	0.10	86,023	128,376	-	0.92
Total	15,729,991						

¹ Mean is the mean estimated weekly emigration past the RST site from the spline model

² Relative SD is a measure of precision. Values > than 0.3 indicate low precision.

Table 8. Total estimated weekly emigration of sockeye fry from Gates Creek, spring 2012.

Creek production is calculated as the difference between estimated channel production, and total weekly emigration in the Creek estimated from the spline model. Shaded week represents the strata trap was operated only 2 of 7 days, and back calculation of creek and total emigration was estimated from ratio of channel to total emigration from adjacent strata

Week Ending	Channel	Creek	Total weekly migration	Cumulative % of Total Emigration	Temp (°C)	Water Level (m)
2-Apr	20,170	155,078	175,248	1.1	6.46	0.68
9-Apr	41,698	213,318	255,016	2.7	6.20	0.68
16-Apr	327,673	1,062,320	1,389,993	11.6	6.12	0.71
23-Apr	1,134,612	1,951,302	3,085,914	31.2	5.75	0.75
30-Apr	2,539,636	3,324,188	5,867,676	68.5	6.19	0.92
7-May	846,793	851,786	1,698,578	79.3	6.25	0.85
14-May	482,929	2,007,956	2,490,885	95.1	5.91	0.87
21-May	94,824	433,118	527,942	98.5	6.36	1.21
28-May	19,095	34,199	53,294	98.8	6.16	0.97
4-Jun	6,955	77,240	84,196	99.3	7.96	1.09
11-Jun	698	104,402	105,101	100.0	-	0.92
Total	5,515,083	10,214,909	15,792,991			

Table 9. Weekly strata totals of marked, recaptured and unmarked 1+ coho smolts at the Gates Creek RST site with weekly capture efficiency for both IPT and RST traps, spring 2012

Week Ending	Marks	Recaptures	Unmarked	Mortalities¹	ECE	Trap
06-May-12	251	53	292	0	21.1%	RST
13-May-12	549	112	648	1	20.4%	RST
20-May-12	372	38	452	3	10.2%	RST
27-May-12	312	34	459	1	10.9%	RST
03-Jun-12	69	11	119	0	15.9%	RST
08-Jun-12	1	0	12	0	00.0%	RST
Total	1,554	248	1,982	5		

¹ Mortalities included in weekly unmarked totals for spline calculations

Table 10. Total weekly estimated emigration of 1+ coho smolts at Gates Creek RST site, spring 2012. Total weekly migration is combined weekly mean unmarked population generated from spline model and weekly marked population.

Week Ending	Mean¹	SD	-97.5%	+97.50%	Relative SD²	Marks	Total Weekly Emigration	Cumulative % of Total Emigration	Temp (°C)	Water Level (m)
06-May-12	1,517	203.10	1,170	1,954	0.13	251	1,768	10.2	6.0	0.8
13-May-12	3,361	305.04	2,816	4,005	0.09	549	3,910	32.8	6.3	0.9
20-May-12	5,712	808.55	4,408	7,536	0.14	372	6,084	68.0	6.0	1.2
27-May-12	3,898	578.64	2,941	5,197	0.15	312	4,210	92.4	6.4	1.0
03-Jun-12	1,131	245.89	751	1,710	0.22	69	1,200	99.3	6.2	1.1
08-Jun-12	120	138.30	41	337	1.15	1	121	100	7.5	0.9
Total	15,740					1,554	17,294			-

¹Mean is the mean estimated weekly emigration past the RST site from the spline model

²Relative SD is a measure of precision. Values > than 0.3 indicate low precision.

7.0 FIGURES

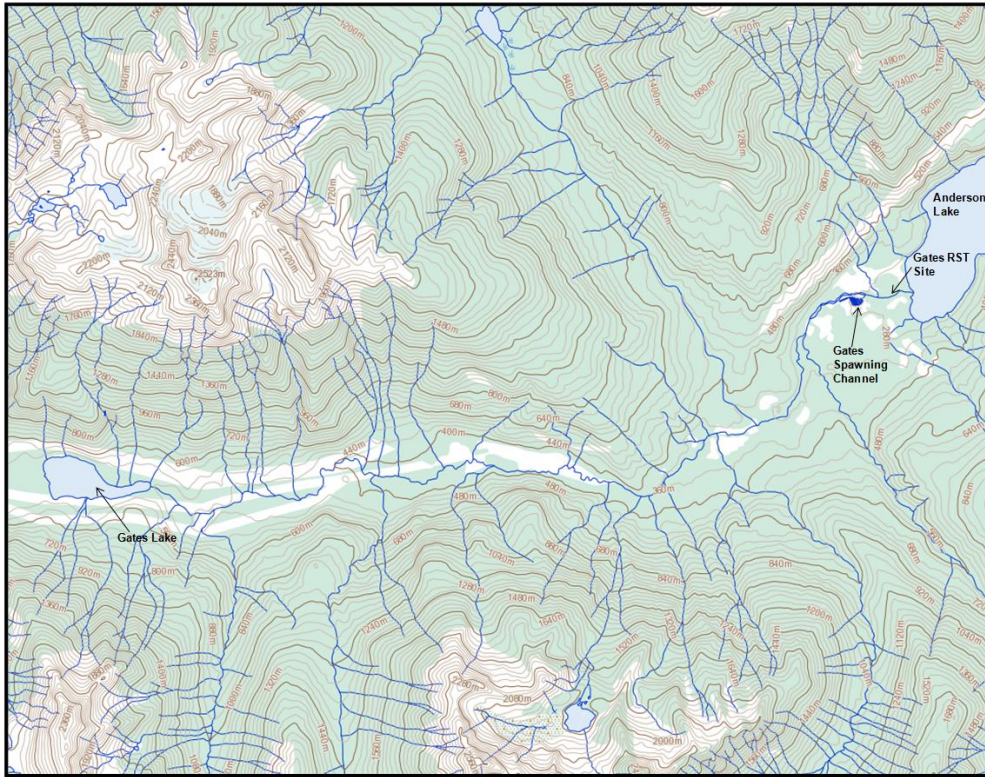


Figure 1. Overview of study Gates Creek watershed extending from Gates lake to Anderson Lake. Sites of spawning channel (10 U 536706 5599716) and IPT/RST (10 U 537151 5599978) are indicated with arrows.

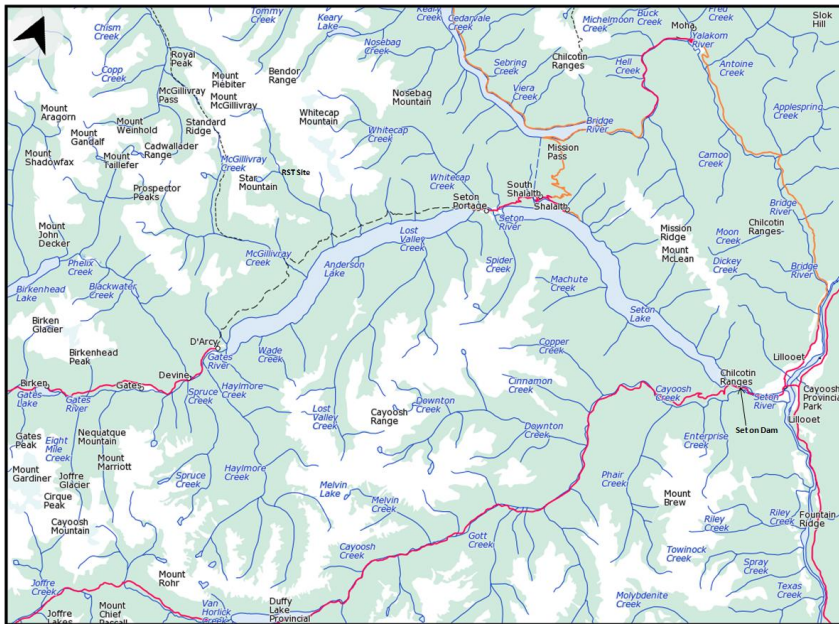


Figure 2. Overview of Seton- Anderson watershed. Red and orange lines indicate roadways.

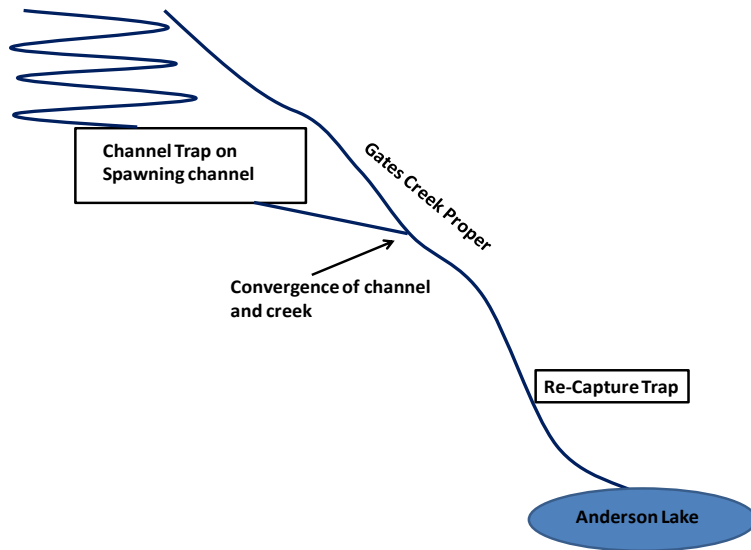


Figure 3. Schematic of study area including relative locations of spawning channel, creek, recapture site and confluence of Gates Creek with Anderson Lake.



Figure 4. Rotary screw trap (RST) in operation on Gates Creek. Cable way visible across middle of figure.

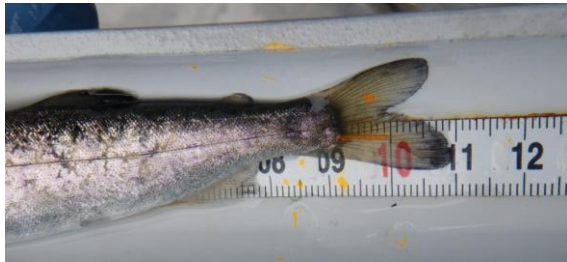


Figure 5. Visual Implant Elastomer (VIE) mark on lower caudal lobe of Gates Creek Coho.

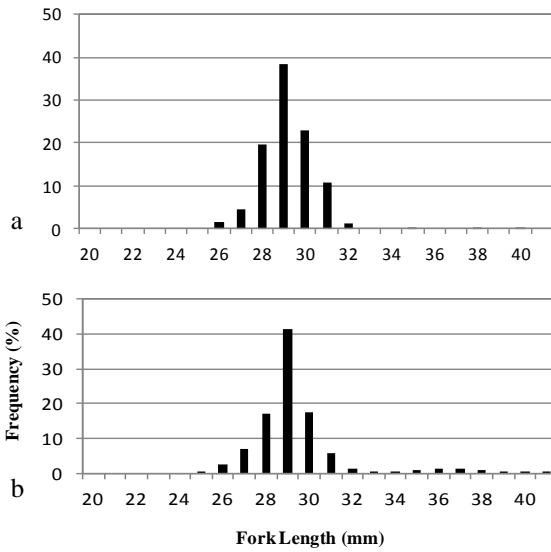


Figure 6. Length frequency distribution of Gates Creek Sockeye caught at RST (a) spawning channel (b) RST.

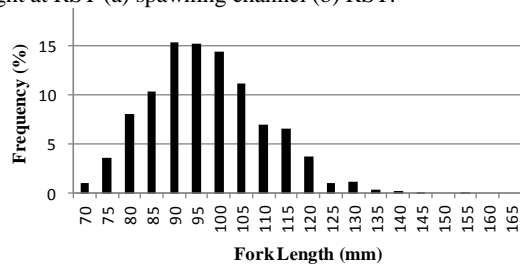


Figure 7 Length frequency distribution of Gates Creek Coho (1+) Juveniles, 2012.

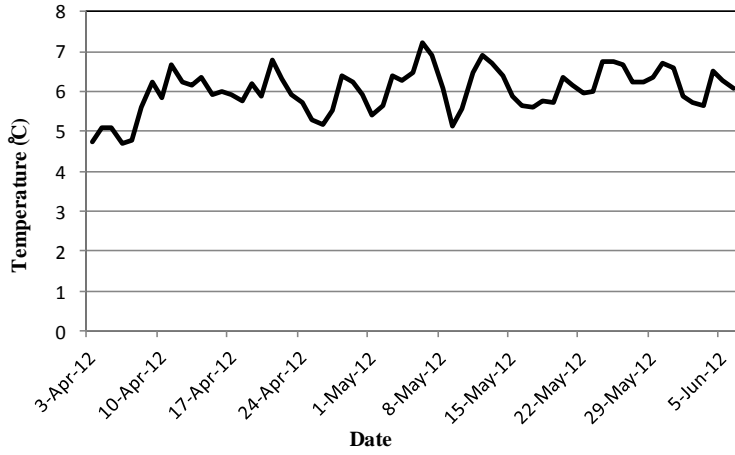


Figure 8. Average daily water temperature (°C) at the Gates creek RST site, spring 2012.

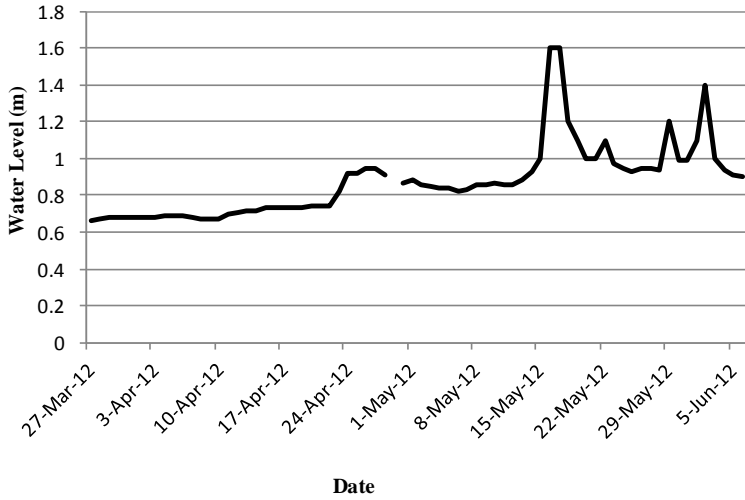


Figure 9. Gates Creek water level recorded at channel entrance, March 27, 2012 to June 6, 2012.

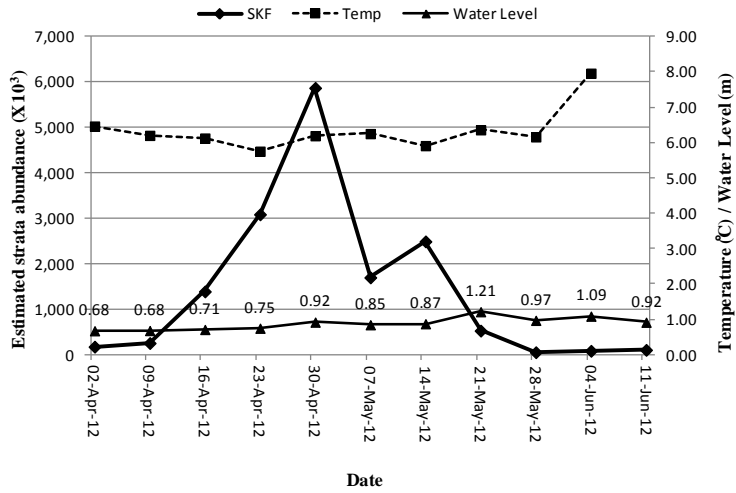


Figure 10. Total weekly abundance estimates of Sockeye fry (SKF) at the Gates Creek RST site (solid line, diamonds) related to temperature in °C (broken line, squares,) and water level (solid line, triangles, values above, spring 2012.

Deleted:

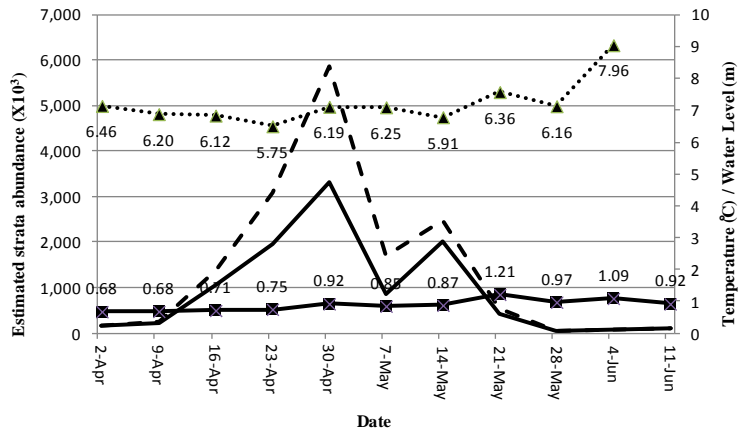


Figure 11. Weekly abundance of SKF from Gates Creek spawning channel (dashed line), and Gates Creek (solid line) related to weekly average water level (m) (solid line, squares) and temperature (°C) (dotted line, triangles).

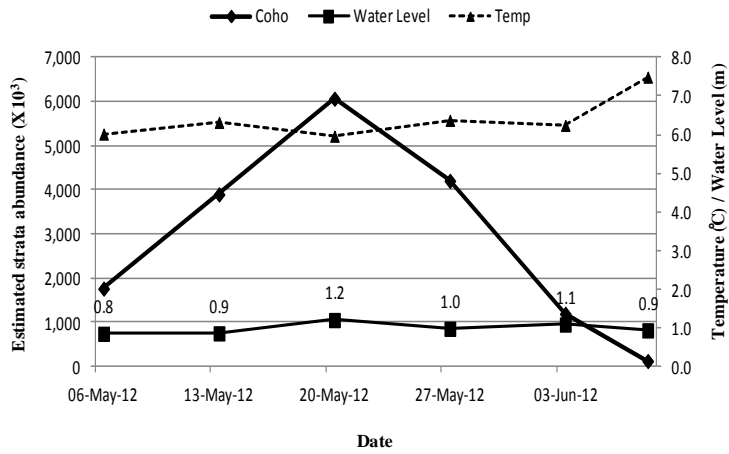


Figure 12. Weekly abundance estimates of Coho smolts (solid line, diamonds) related to temperature in °C (broken line, triangles) and water level (m) (solid line, squares) from Gates Creek.

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