Campbell River Project Water Use Plan

JHTMON-15 Elk Canyon Smolt and Spawner Abundance Assessment

Implementation Year 2

Reference: JHTMON-15

JHTMON-15 Year 2 Monitoring Report

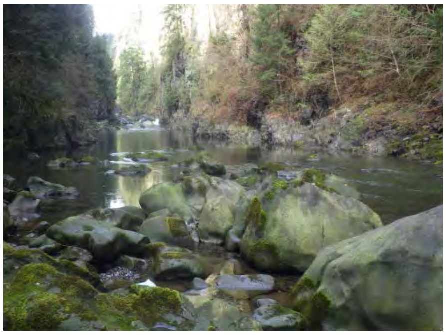
Study Period: 2015

Laich-Kwil-Tach Environmental Assessment Ltd. Partnership and Ecofish Research Ltd.

October 31, 2017

JHTMON-15: Smolt and Spawner Abundance Assessment

Year 2 Annual Monitoring Report




Prepared for:

BC Hydro Water License Requirements
6911 Southpoint Drive
Burnaby, BC, V3N 4X8

October 31, 2017

Prepared by:

Laich-Kwil-Tach Environmental Assessment Ltd. Partnership

Ecofish Research Ltd.

Published by Ecofish Research Ltd., Suite F, 450 8th St., Courtenay, B.C., V9N 1N5

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Citation:

Hocking, M.D., E. Smyth, K. Milburn, and T. Hatfield. 2017. JHTMON15 – Year 2 Annual Monitoring Report. Consultant's report prepared for BC Hydro by Laich-Kwil-Tach Environmental Assessment Ltd. Partnership and Ecofish Research Ltd., October 31, 2017.

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EXECUTIVE SUMMARY

The Elk Canyon on the lower Campbell River is used by seven salmonid species for at least part of their life history. The Campbell River Water Use Plan (WUP) prescribed a flow regime with the intent of maximizing fish habitat in Elk Canyon. However, there remains considerable uncertainty over the extent to which fish use of the canyon by juveniles and spawners is affected by the implemented flow regime. The *Elk Canyon Smolt and Spawner Abundance Assessment* (JHTMON-15) is designed to assess the extent to which fish production is driven by flow in Elk Canyon and how this relates to BC Hydro operations.

JHTMON-15 is scheduled for 10 years from 2014 to 2024 and is to be carried out as a series of interconnected parts, each focused on addressing a specific hypothesis and with different durations over the course of the monitor. Two of the main sampling techniques to be employed in the monitor are snorkel swim counts of spawning adults and rearing juveniles, and rotary screw trap (RST) enumerations of out-migrating fry and smolts. Year 2 was the first year that the Pulse Flow and Spawning Flow Assessments were conducted. In Year 3, an Instream Flow Study will be undertaken to determine the amount of available habitat for salmon rearing and spawning at different flows.

A broad diversity of fish species, including all BC coast salmonids, were observed using Elk Canyon for spawning and/or rearing during the second year of sampling (2015-2016) of the JHTMON-15 program. Although many of these species occur in low abundance, this nevertheless indicates that habitats in Elk Canyon are used by a diversity of salmon and trout.

The RST was in operation from the end of February to the end of July. In total, 24,009 fish were captured using the RST. The catches were primarily composed of Chum Salmon (84.1%), Chinook Salmon (6.9%), sculpin spp. (4.4%) and Coho Salmon (2.8%). Steelhead/Rainbow Trout and Sockeye Salmon catches were 0.4% and 0.3% of the total, respectively. The combined catch of all salmonids accounted for 95.5% of the total catch while the key target species - Chinook Salmon, Coho Salmon, and Steelhead/Rainbow Trout - accounted for 10.0% of the total catch.

Chum Salmon out-migration was the highest of all salmonid species with an estimated total out-migration of 271,301 fry. Coho Salmon total out-migration was estimated to be 6,042 fry, 871 age 0+ smolts, and 18 age 1+ smolts. Chinook Salmon total out-migration was estimated to be 17,554 fry and 1,819 age 0+ smolts. Steelhead/Rainbow Trout total out-migration was estimated to be 53 age 0+ fry, 145 age 1+ parr, and 835 age 2+ parr. Sockeye and Pink Salmon total out-migration was estimated at 884 and 846 fry, respectively.

Mark/recapture trials had an average recapture efficiency of 16.7% across all salmon species and life stages, which is similar to the average recapture efficiency from Year 1 of 20.8%. These average capture efficiencies exclude Coho Salmon fry that had recapture efficiencies of 2.5% in Year 1 and 1.2% in Year 2.

Out-migration timing information by life stage is evident within and across species from the RST data. All of the Chinook Salmon that were aged from the RST were 0+ fish, which indicates that they are exclusively 'ocean type'. However, two peaks in Chinook out-migration were observed, an early peak in March of Chinook fry, and a later peak in June of Chinook smolts.

Three Coho Salmon life history stages were evident in RST catch including an early migration of Coho fry in March and April, a later migration of larger 0+ Coho smolts from May through July, and a small cohort of 1+ smolts.

Three age classes of Steelhead/Rainbow Trout were identified in the RST catch, including 0+, 1+ and 2+ fish. A main peak in out-migration of age 2+ Steelhead/Rainbow Trout parr was observed in May. A smaller out-migration of 1+ parr occurred in May, June and July. Steelhead/Rainbow Trout fry were also caught in the RST in May, June and July.

For the overwintering assessment, night snorkeling mark/resight methods were adopted for the first time in Year 2 and these were successful at determining Steelhead/Rainbow Trout parr densities in both fall and early spring. Steelhead/Rainbow Trout parr abundance was similar between fall (September) and early spring (February) sampling seasons in Elk Canyon. Very few Coho Salmon were observed during the fall and spring marking swims, and therefore observer efficiencies could not be effectively calculated for Coho parr. These low numbers of observed Coho Salmon parr match the observations from the RST catch, which estimated a total of 18 out-migrating 1+ Coho Salmon smolts from Elk Canyon in spring 2016.

Snorkel surveys in Year 2 did not find strong evidence that the fall or spring pulse flows are attracting salmon into Elk Canyon. The abundance of all fall spawners in Elk Canyon did not differ the day after the 2-day 7 m^3/s fall pulse release compared to the day prior the pulse release. The rate of spawning salmonid in-migration per day also did not differ between periods of pulse flows and periods of base flows for all fall spawners. In the spring, the count of Steelhead in Elk Canyon was lower the day after the 2-day 10 m^3/s spring pulse releases compared to the day prior to the pulse releases, which is opposite to what was predicted. The rate of Steelhead in-migration per day did not differ between periods of pulse flows and periods of base/spawning flows.

The abundance of Steelhead in Elk Canyon was significantly higher prior to the two-week spawning flow release than during the release, which is opposite to what was predicted. No Steelhead redds were observed.

Snorkel surveys and area under the curve methods were used to estimate the abundance of Chinook, Coho, Pink, Chum, and Sockeye Salmon fall spawners in Elk Canyon. Chinook Salmon and Coho Salmon adult abundance was estimated to be 241 and 408 individuals, respectively; Chinook Salmon peaked in mid-October and Coho peaked in mid-November. Pink Salmon peaked in mid-September and had the highest estimated abundance of all species at 6,589 individuals. An estimated 953 Chum Salmon used the canyon and peaked in late October to early November; 1,149 Sockeye Salmon used the canyon and showed a subtle peak in late September. A maximum count of 11 adult Steelhead were observed in Elk Canyon in mid-October, while in spring, a maximum count of nine Steelhead were observed in mid-March. Chinook, Chum, Coho, Pink and Sockeye Salmon redds were observed, and the estimated fry and smolt production from these redds was compared to the estimated out-migration from the RST data. This analysis suggested that there was very low egg-to-fry survival for Pink Salmon. One explanation may be redd superimposition of the earlier spawning Pink Salmon by Chum, Chinook and Coho Salmon.

The following represents a summary of considerations for Year 3.

Smolt enumeration component:

1. The RST is an effective method to inventory juvenile salmonids (fry and smolts) that are migrating out of Elk Canyon. Due to high catches of wild fry in the RST, the mark-recapture experiment was expanded in Year 2 to include wild Coho, Chum, Pink and Sockeye fry in addition to Quinsam hatchery Chinook and Coho smolts. These experiments will continue with wild fry if sufficient catches are observed in Year 3. A synthesis analysis will also be conducted in Year 5 when the sample size is higher to integrate flow conditions (e.g., base flows versus pulse flows) and RST trap position into the estimates of recapture efficiency.
2. In the mark-recapture experiment, the first Chinook Salmon smolt release was marked with Bismark Brown. The next two smolt releases were marked with fin clips. The initial Bismark release faded quickly causing some potential confusion between wild/hatchery Chinook caught in the period after that release. Fin clip marks will be used for all subsequent Chinook parr mark recapture experiments.
3. The RST was effective at demonstrating run timing of out-migrating fry and smolts, including multiple age classes of Coho Salmon and Steelhead/Rainbow Trout. In Year 3, an increased sample size of Steelhead/Rainbow Trout age samples will be taken (20 to 30 individuals) across the full sampling period to more effectively identify the age breaks for Steelhead/Rainbow Trout.
4. There is some uncertainty as to the origin of Chinook and Coho Salmon smolts that are being caught in the RST in May and June. For example, it is unknown if any of the smolts released from Quinsam Hatchery swim up the Campbell River after their release and end up in the RST. Calibration snorkel swims will be conducted in late April in Year 3 in the six established survey sites from the overwintering assessment to confirm the size and density of age 0+ Chinook and Coho in the Elk Canyon and to calibrate the RST out-migration data. The hatchery fish also have a thermal mark that can be viewed through analyses of their otoliths. Otolith analyses will also be conducted on a subset of Chinook and Coho individuals >70 mm in length that are caught in the RST to confirm their origin.

Overwintering assessment component:

5. The night snorkeling mark/resight methods worked well in Year 2 and were used to test H_02 of the TOR for Steelhead/Rainbow Trout. Roughly equal numbers of Steelhead/Rainbow

Trout were observed in Elk Canyon in the fall and the early spring, which means that there is little evidence for net immigration or net emigration to or from Elk Canyon during this period. Very few Coho Salmon were observed during the fall and spring marking swims, so observer efficiencies could not be calculated for Coho parr. These low numbers of observed Coho Salmon parr match the observations from the RST, which estimated a total of 18 out-migrating 1+ Coho Salmon smolts from Elk Canyon in spring 2016. The mark/resight methods will continue in Year 3 and attempts will be made to mark and resight Coho Salmon parr if sufficient densities are observed.

Pulse flow assessment component:

6. Year 2 was the first year that pulse flow assessments were conducted. Snorkel surveys were successful in testing H_03 and H_05 of the TOR, although two more years are required to confirm results from Year 2. After Year 4 surveys, a synthesis analysis across years will be conducted that will provide a three-year baseline assessment of the effectiveness of the current pulse flow prescription for Elk Canyon.

Steelhead spawning flow component:

7. Year 2 was the first year that spawning flow assessments were conducted. Snorkel surveys were successful in testing H_06 of the TOR, although no Steelhead redds were observed, which prevented a test of H_07 and H_08. After Year 4 surveys, a synthesis analysis across years will be conducted that will provide a three-year baseline assessment of the effectiveness of the spawning flow prescription for Elk Canyon.

Spawner enumeration component:

8. Adult Steelhead and Chinook, Chum, Coho, Pink and Sockeye Salmon and were all observed in Elk Canyon; Chinook, Chum, Coho, Pink and Sockeye redds were also counted. Year 2 was the first year that estimates of production derived from RST catch were compared to estimates of production predicted from redd counts by species. This was a useful addition to the analysis that will be continued in Year 3. Snorkel surveys of adult spawners in the fall will estimate redd superimposition to support these analyses.

JHTMON-15 Objectives, Management Questions, Hypotheses and Status after Year 2.

<table>
<tr><th>Study Objectives</th><th>Management Questions</th><th>Management Hypotheses</th><th>Year 2 Status</th></tr>
<tr><td rowspan="2">The aim of JTHMON-15 is to assess the extent to which fish production is driven by flow in Elk Canyon and how this relates to BC Hydro operations.

The fish technical committee designed the following flow prescription:

1) Provide a minimum base flow of 4 m^3/s;
2) Provide two-day pulse flows of 10 m^3/s every two weeks in spring (Feb 15 to Mar 15) as an attraction flow primarily for spawning steelhead;
3) Provide a two-week spawning minimum flow of 7 m^3/s starting April 1-15; and
4) Provide two-day pulse flows of 7 m^3/s every week in the fall (Sept 15 to Nov 15) as an attraction flow for all fall spawners.

JTHMON-15 consists of a series of interconnected parts designed to test how the flow prescription affects salmon productivity in Elk Canyon</td><td>Is the prescribed 4 m^3/s base flow sufficient to increase juvenile rearing habitat to near maximum values? If not, by how much should the base release increase (or decrease) and what would be the expected gain in habitat area?</td><td>$H_0$1: Carrying capacity of the Elk Canyon reach, as measured by annual smolt out-migrant counts, does not vary as a function of discharge.

$H_0$2: The number of rearing residents deemed likely to smolt the following spring, as measured during late summer, is not significantly different from the abundance estimate obtained in late winter just prior to the onset of their out-migration.

$H_0$9: Annual abundance of ‘resident’ smolts is not correlated with an index of Steelhead spawner abundance.</td><td>Management question #1 and associated hypotheses are being addressed through several project components: a) an instream flow study (IFS), b) smolt enumeration, c) fall spawner abundance, d) spring spawner abundance, and e) juvenile over-wintering assessment.

The IFS will be conducted in Year 3.

The remaining components are being conducted each year to determine fish productivity of Elk Canyon.

Year 2 results confirm that we are on track to address $H_0$1, $H_0$2 and $H_0$9. A synthesis analysis for the first five years of JHTMON-15 will be conducted after Year 5 of sampling.</td></tr>
<tr><td>Does the 2-day 10 m^3/s pulse release every two weeks trigger the upstream migration of spring spawners as expected? If not, is this</td><td>$H_0$3: The rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation is not significantly different from</td><td>Management question #2 and associated hypotheses are being addressed through the spring pulse flow assessment component.</td></tr>
</table>

1230-14	the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulse attraction release unnecessary?	that during the base flow operation. $H_0$4: The rate of spawning salmonid in-migration (No./day) during the first day of the pulse flow release operation is not significantly different from that during the second day. $H_0$5: The estimated number of spawning salmonids following pulse flow release operation is not significantly different from that just prior to the release.	Year 2 results confirm that we are on track to address $H_0$3 and $H_0$5, although two more years are required to verify the result. Because the WUP pulse flow prescription does not vary in magnitude or duration, we will be unable to determine if upstream migration of spring spawners would be improved if an alternate flow pulse prescription is used. Hypothesis $H_0$4 is not testable using the current sampling method of snorkel surveys immediately prior to and after the pulse flows.
	Is the two-week long 7 m^3/s spawning flow effective at increasing available spawning habitat for spring spawners? If not, by how much should the spawning release increase (or decrease) and what would be the expected gain in habitat area?	$H_0$6: The estimated number of spawning steelhead during the two-week, 7 m^3/s spawning release period in spring is not significantly different from that observed just prior to the operation.	Management question #3 and associated hypothesis are being addressed through: a) the IFS, and b) the spring spawner abundance assessment. The IFS will be conducted in Year 3. Year 2 results confirm that we are on track to address $H_0$6, although two more years are required to verify the result.
	Does the resumption of base flows following the	$H_0$7: The number of redds found above the base flow	Management question #4 and associated

	spawning release keeps redds adequately wetted throughout the egg incubation period as expected? If not, what should the spawning release be to ensure all redds are wetted at the base flow?	water level (minus a nominal depth to take into account that Steelhead will not spawn in very shallow water, e.g., 10 cm) following the two-week spawning release is not considered significantly different when compared to the total number of redds in the reach. $H_0$8: Following resumption of base flow operations, the number of Steelhead redds found above the water line and therefore, at risk of egg mortality from stranding, is not considered significant compared to the total number of redds in the reach.	hypotheses are being addressed through: a) the IFS, and b) the spring spawner abundance assessments. The IFS will be conducted in Year 3. No Steelhead redds were observed during Year 2, which prevents a test of $H_0$7 and $H_0$8. Two more years of spawning flow assessment surveys will be conducted in Year 3 and Year 4.
	Does the 2-day 7 m^3/s pulse release every week trigger the upstream migration of fall spawners as expected? If not, is this the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulsed attraction release unnecessary?	$H_0$3: The rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation is not significantly different from that during the base flow operation. $H_0$4: The rate of spawning salmonid in-migration (No./day) during the first day of the pulse flow release operation is not significantly different from that during the second day. $H_0$5: The estimated number of spawning salmonids following pulse flow release operation is	Management question #5 and associated hypotheses are being addressed through the fall pulse flow assessment component. Year 2 results confirm that we are on track to address $H_0$3 and $H_0$5, although two more years are required to verify the result. Because the WUP pulse flow prescription does not vary in magnitude or duration, we will be unable to determine if upstream migration of fall

		not significantly different from that just prior to the release.	spawners would be improved if an alternate flow pulse prescription is used. Hypothesis H_04 is not testable using the current sampling method of snorkel surveys immediately prior to and after the pulse flows.
	Following implementation of the WUP flow prescription to the Elk Canyon reach, has the general fish productivity of the reach increased as expected? If a change is apparent, whether positive or negative, can it be attributed to WUP operations? Conversely, if no change is apparent, are some or all elements of the flow prescription still necessary?	This management question is a synthesis question associated with all of the hypotheses and project components listed above.	Since there are no fish population data available before the WUP was implemented it will not be possible to address these questions directly in terms of fish productivity. The IFS will address this management question using habitat availability metrics. Other components of JHTMON-15 (e.g., the RST study) will provide important measures of fish productivity that will allow informed discussions of the benefits of the WUP operations, and will establish a productivity reference point for these discussions.

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1. INTRODUCTION

1.1. Background to Water Use Planning

Water use planning exemplifies sustainable work in practice at BC Hydro. The goal is to provide a balance between the competing uses of water that include fish and wildlife, recreation and power generation. Water Use Plans (WUPs) were developed for many of BC Hydro's hydroelectric facilities through a consultative process involving local stakeholders, government agencies and First Nations. The framework for water use planning requires that a WUP be reviewed on a periodic basis and there is expected to be monitoring to address outstanding management questions in the years following the implementation of a WUP.

As the Campbell River Water Use Plan (BC Hydro 2012) process reached completion, a number of uncertainties remained with respect to the effects of BC Hydro operations on aquatic resources. A key question throughout the WUP process was "what limits fish abundance?" For example, are fish abundance and biomass in the Campbell system limited by flow? Resolving this uncertainty is an important step to better understanding how human activities in a watershed affect fisheries, and to effectively manage water uses to protect and enhance aquatic resources. To address this uncertainty, monitoring programs were designed to assess whether fish benefits are being realized under the WUP operating regime and to evaluate whether limits to fish production could be improved by modifying operations in the future.

The Elk Canyon on the lower Campbell River is used by all salmonid species for at least part of their life history. The WUP prescribed a flow regime with the intent of maximizing fish use in the canyon. However, there remains considerable uncertainty over the extent to which fish use of the canyon by juveniles and spawners is affected by the implemented flow regime. The *Elk Canyon Smolt and Spawner Abundance Assessment* (JHTMON-15) is part of wider monitoring of the Campbell River WUP. JTHMON-15 is designed to assess the extent to which fish production is driven by flow in Elk Canyon and how this relates to BC Hydro operations. This report presents results from Year 2 of the JHTMON-15 study.

1.2. BC Hydro Infrastructure, Operations and the Monitoring Context

The Campbell River WUP project area is complex and includes facilities and operations in the Campbell, Quinsam and Salmon watersheds. In addition to the mainstem rivers, there are three large reservoirs, nine diversion lakes influenced by water diverted from the Quinsam and Salmon rivers, and many tributaries and small lakes in these watersheds that are not directly affected by operations (Map 1). Details of BC Hydro's Campbell River infrastructure and operations are provided in the Campbell River System WUP report (BC Hydro 2012).

1.2.1. Elk Canyon

The Elk Canyon consists of a reach of the Lower Campbell River from Elk Falls below the John Hart Dam to the John Hart generating station (Map 2). Water in John Hart Reservoir is diverted via three 1,767 m long penstocks to the John Hart Generating Station, with water returning to the Lower Campbell River below Elk Canyon; flows to the canyon are released through the John Hart Dam spillway gates. The value of Elk Canyon as fish habitat was not fully appreciated until a base flow of 3.5 m^3/s was provided as part of an interim flow management strategy developed in 1997 (Campbell River Hydro/Fisheries Advisory Committee). Field investigations since the flow release have shown an increase in the use of the canyon as juvenile rearing and salmonid spawning habitat. Despite this increase in canyon use by salmonids, it was hypothesized that further habitat increases were possible with additional flow releases. Therefore, during the Campbell River WUP process, a flow prescription was developed for Elk Canyon based primarily on the professional opinion of several biologists (all members of the Fish Technical Subcommittee or FTC). Recognizing that the release of water to the canyon reach comes at considerable cost in terms of lost generation, the FTC recommended that the flow prescription be the start of a long term 'titration' study with the aim of modifying the prescription at regular intervals (i.e., WUP Review intervals) based on the results of the preceding interval's monitoring program.

Based on the available information at the time, the FTC recommended that the following flow prescription be implemented as an attempt to maximize fish use in the canyon;

1) A minimum base flow of 4 m^3/s.
2) 2-day pulse flows of 10 m^3/s every two weeks in spring (February 15 to March 15) as an attraction flow primarily for spawning Steelhead (though other spring spawners may benefit).
3) A two week spawning minimum flow of 7 m^3/s starting April 1-15.
4) 2-day pulse flows of 7 m^3/s every week in the fall (September 15 to November 15) as an attraction flow for all fall spawners that could potentially use this reach.

The prescription above was considered by the FTC as a starting point in a titration type study that would progressively change the flow regime as new information is gathered; alterations are only to be considered during WUP reviews when trade-offs with other values in the system can be examined. To successfully conduct this titration approach to flow setting, it was recommended that a monitoring program be developed and implemented to track the success or failure of the flow prescription in meeting its management objectives. JHTMON-15 is the monitoring study program implemented to increase the knowledge and understanding of flow relationships with fish in the Elk Canyon reach.

1.3. Management Questions and Hypotheses

There are six key management questions (or sets of questions) to be addressed by JHTMON-15:

1) Is the prescribed 4 m^3/s base flow sufficient to increase juvenile rearing habitat to near maximum values? If not, by how much should the base release increase (or decrease) and what would be the expected gain in habitat area?

2) Does the 2-day 10 m^3/s pulse release every two weeks trigger the upstream migration of spring spawners as expected? If not, is this the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulse attraction release unnecessary?
3) Is the two-week long 7 m^3/s spawning flow effective at increasing available spawning habitat for spring spawners? If not, by how much should the spawning release increase (or decrease) and what would be the expected gain in habitat area?
4) Does the resumption of base flows following the spawning release keeps redds adequately wetted throughout the egg incubation period as expected? If not, what should the spawning release be to ensure all redds are wetted at the base flow?
5) Does the 2-day 7 m^3/s pulse release every week trigger the upstream migration of fall spawners as expected? If not, is this the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulsed attraction release unnecessary?
6) Following implementation of the WUP flow prescription to the Elk Canyon reach, has the general fish productivity of the reach increased as expected? If a change is apparent, whether positive or negative, can it be attributed to WUP operations? Conversely, if no change is apparent, are some or all elements of the flow prescription still necessary?

The following hypotheses were developed to answer these management questions:

$H_0$1: Carrying capacity of the Elk Canyon reach, as measured by annual smolt out-migrant counts, does not vary as a function of discharge.

$H_0$2: The number of rearing residents deemed likely to smolt the following spring, as measured during late summer, is not significantly different from the abundance estimate obtained in late winter just prior to the onset of their out-migration.

$H_0$3: The rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation is not significantly different from that during the base flow operation.

$H_0$4: The rate of spawning salmonid in-migration (No./day) during the first day of the pulse flow release operation is not significantly different from that during the second day.

$H_0$5: The estimated number of spawning salmonids following pulse flow release operation is not significantly different from that just prior to the release.

$H_0$6: The estimated number of spawning steelhead during the two-week, 7 m^3/s spawning release period in spring is not significantly different from that observed just prior to the operation.

$H_0$7: The number of redds found above the base flow water level (minus a nominal depth to take into account that Steelhead will not spawn in very shallow water, e.g., 10 cm) following the two-week spawning release is not considered significantly different when compared to the total number of redds in the reach.

$H_0$8: Following resumption of base flow operations, the number of Steelhead redds found above the water line and therefore, at risk of egg mortality from stranding, is not considered significant compared to the total number of redds in the reach.

$H_0$9: Annual abundance of 'resident' smolts is not correlated with an index of Steelhead spawner abundance.

1.4. Scope of the JHTMON-15 Study

1.4.1. Overview

The study area for JHTMON-15 consists of the Elk Canyon reach of the Lower Campbell River from its entrance by the John Hart generating station (at the first riffle above the pedestrian bridge) to Elk Falls below John Hart Dam. The species of primary concern are Steelhead, Chinook Salmon and Coho Salmon, though other salmonid species known to use the system will also be considered.

JHTMON-15 is scheduled for 10 years and is to be carried out as a series of interconnected parts, each focused on addressing a specific hypothesis and with different durations over the course of the monitor. Two of the main sampling techniques to be employed in the monitor are snorkel swim counts of spawning adults and rearing juveniles and rotary screw trap enumerations of out-migrating smolts. The basic data requirements of the TOR include:

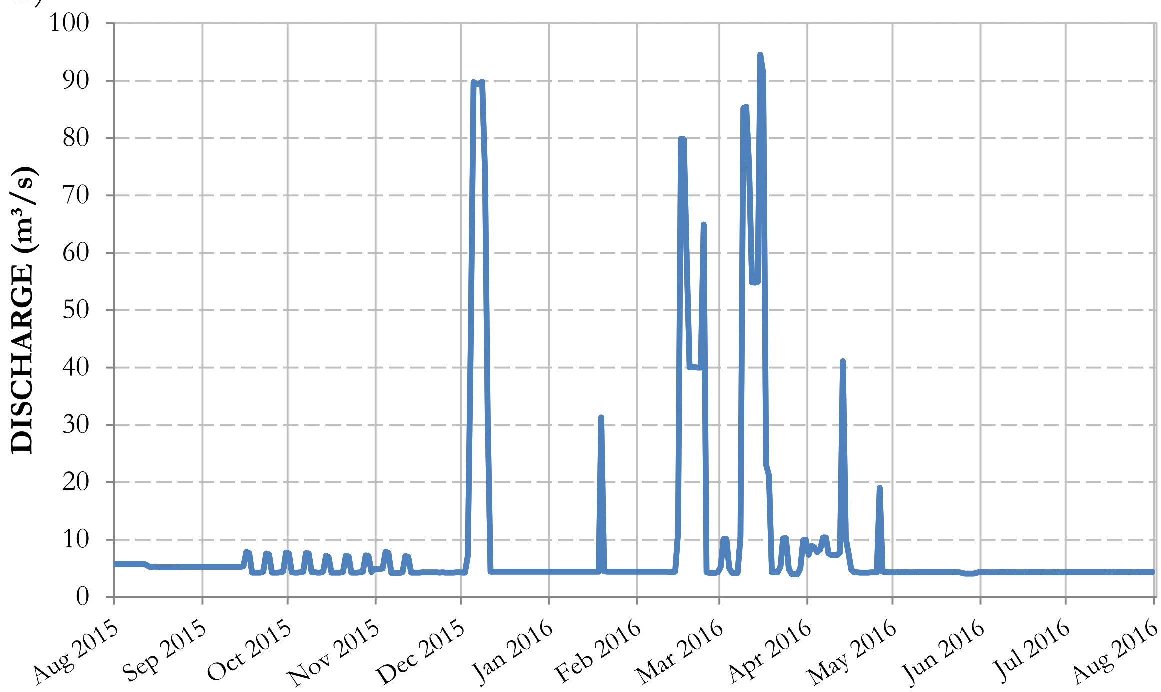
- Instream flow study (2016-2017); once in Year 3;
- Smolt enumeration (Mar-July); annually for 5 years;
- Juvenile over-wintering assessment (Sep and Feb); annually for 5 years;
- Fall pulse flow assessments (Sep-Nov); annually for 3 years;
- Spring pulse flow assessments (Feb-Apr); annually for 3 years;
- Steelhead spawning flow assessments (Mar-Apr); annually for 3 years;
- Spring spawner abundance (Feb-Apr); annually for 10 years; and
- Fall spawner abundance (Sep-Nov); annually for 10 years.

The Instream Flow Study will be completed in Year 3 of the study and is therefore not discussed further in this Year 2 report. The remaining components of JHTMON-15 were all part of the data collection for Year 2.

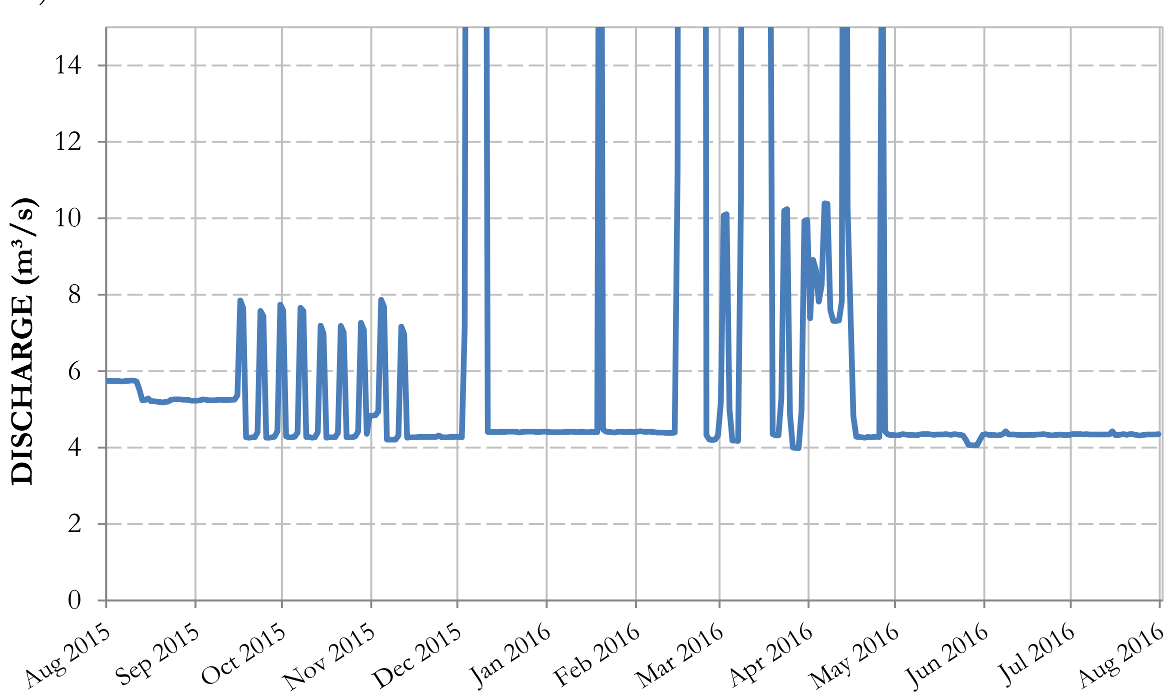
Figure 1A and B show the measured flow in Elk Canyon from August 2015 through to the end of July 2016. The 7 m^3/s pulse flows in September through November are evident, as well as the 10 m^3/s pulse flows and 7 m^3/s spawning flow in March and April, respectively. Also evident are the dam safety and blasting spills that occurred intermittently from December through May of up to 95 m^3/s.

Figure 1. Discharge (m^3/s) in Elk Canyon from August 2015 to July 2016. Note the different y-axis scales in A and B.

A)



B)



1.4.2. Smolt Enumeration

The carrying capacity of the Elk Canyon reach is hypothesized to be affected by the magnitude of base flows (e.g., 4 m^3/s) provided in the flow prescription (H_01). This hypothesis will be addressed in part by monitoring salmon fry and smolt production from Elk Canyon using a rotary screw trap (RST) from February to July each year. Priority species for monitoring are Steelhead Trout, Chinook Salmon and Coho Salmon. The RST was used successfully in Year 1 to enumerate out-migrating fry and smolts of all salmon species and was continued in Year 2.

1.4.3. Overwintering Assessment

The carrying capacity of Elk Canyon can be viewed as containing two components; the first consisting of fish that complete their life cycle from egg to smolt within the reach (here referred to as residents) and the other consisting of immigrant juveniles that enter the reach (immigrants). For Steelhead and Coho Salmon, there is potential for estimates of carrying capacity to differ during late summer and late winter based on abundance of overwintering immigrants to Elk Canyon (H_02). Therefore, snorkel swim counts of resident juveniles were conducted late in the growing season (September) and prior to smolt out-migration (February) to test if juvenile fish abundance differs between seasons as a result of immigration to Elk Canyon.

The Chinook Salmon using the canyon reach are thought to be ocean-type, meaning that fry will spend two to five months in freshwater after emergence, and then move into the estuary. Because the in-river rearing period for these Chinook is relatively short and their first migration takes them to the estuary (Healey 1991), there is little risk that out-migrant counts collected in the canyon will include over-wintering immigrants of this species.

1.4.4. Pulse Flow Assessment

Part of the flow prescription for Elk Canyon is to provide 2-day pulse flows of 7 m^3/s every two weeks in the fall (September 15 to November 15) and 2-day pulse flows of 10 m^3/s every two weeks in spring (February 15 to March 15) as an attraction flow primarily for spawning salmonids. Hypotheses H_03, H_04 and H_05 were developed to test the effectiveness of these pulse flows in attracting spawning salmonids and attracting and retaining Steelhead in Elk Canyon. Hypotheses H_03 and H_04 test the rate of spawning migration to the canyon during the pulse flows. The preliminary work done by Bruce *et al.* (2003) showed that the fall spawners that migrated into the canyon during a pulse release did not necessarily stay in the reach following the resumption of base flow operations. The reason for this behaviour is uncertain, and it is unknown whether the response would be similar among spring spawners. This leads to hypothesis H_05 that tests the change in Steelhead abundance before and after the 2-day pulse flows.

The fall and spring pulse flow assessments are to be conducted in Year 2, 3 and 4 of JHTMON-15. Year 2 thus represents the first year of data collection for the fall and spring pulse flow assessments. In the JHTMON-15 Year 1 pilot study we conducted an options analysis to determine the best method to test the hypotheses associated with the fall and spring pulse flows. It was determined that options such as DIDSON are not likely to be viable in the canyon environment. Instead, snorkel surveys were found to be a viable method to enumerate adult salmon in Elk Canyon.

1.4.5. Steelhead Spawning Flow Assessment

The flow prescription for Elk Canyon also includes a two-week long 7 m^3/s spring spawning flow (April 1-15) aimed at increasing available spawning habitat for Steelhead. Hypotheses H_06, H_07 and H_08 were developed to test the effectiveness of the spawning flow at increasing the numbers of spring spawners as well as available spawning habitat. The Steelhead spawning flow assessment will be completed using snorkel surveys and redd surveys prior to, during and after the spawning flows in Year 2, 3 and 4 of the JHTMON-15 program. Year 2 thus represents the first year of the Steelhead Spawning Flow Assessment.

1.4.6. Spawner Enumeration

Spawner counts in both fall and spring are to be conducted annually for the full JHTMON-15 program. Area under the curve estimates of abundance are calculated and used to test if the annual abundance of 'resident' smolts is correlated with spawner abundance (H_09). This is a final check to make sure that the assumption of 'full seeding' needed to test Hypothesis H_01 is satisfied. Note that the hypothesis is concerned only with that portion of the total smolt count that has spent their entire freshwater lifecycle in the Elk Canyon reach.

2. METHODS

The Elk Canyon smolt and spawner abundance program involves a series of interconnected parts, each focused on addressing a specific hypothesis. The two main sampling techniques employed in Year 2 of the monitor were snorkel swim counts and rotary screw trap enumerations. The Year 1 data collection was considered to be a baseline study to verify the proposed methods. In Year 2, a more detailed work plan was developed.

2.1. Smolt Enumeration

2.1.1. RST Setup and Operation

Smolt enumeration was carried out using a single 1.2 m rotary screw trap (RST) located near the base of the canyon, in the first run type mesohabitat (Figure 2), just around the corner and upstream from the powerhouse at JHT-DVRST (Map 2). Use of the RST followed standard protocol (U.S. Fish and Wildlife Service 2008).

The RST was secured with the help of a qualified rigging professional. The rigging allowed adjustment of fishing position and included a mechanism for moving the trap if necessary (e.g., in the event of a planned spill) and a breakaway mechanism for recovering the trap safely in the event that it broke free. Operators were trained during the install to manage the rigging under a range of flow conditions.

The trap was installed February 25, 2016 and fished, 5 days a week Monday – Friday, continuously until July 27, 2016. Crews serviced the trap daily each morning. On Fridays the trap was serviced, the cone raised and secured to the bank in a non-fishing position. On Mondays the cone was lowered and the trap was placed back into fishing position. In Year 2 there were 3 fishing positions for the trap. Position #1 was for base flows of 4 m^3/s and the prescribed spawning flow of 7 m^3/s (Figure 2). Position #2 was for prescribed migration flows of 10 m^3/s (Figure 3). Position #2 was added in Year 2 in order to minimize impacts to fish catches as well as damage to the RST during prescribed 10 m^3/s pulse flow events. Position #3 was added in Year 2 in order to account for lower water conditions at the trap location due to the summer rampdown to minimum Preferred Discharge Range into the Lower Campbell River from the John Hart project (Figure 4).

Daily trap servicing consisted of a crew of two accessing the trap to record trap orientation and rotation, water velocity at the trap and the debris present in the trap. The trap was cleaned, serviced, and all fish were removed for sampling.

All fish caught in the trap were documented and sampled. A small semi-permanent fish sampling station was constructed to increase sampling efficiency and allow for fish to be sampled on shore, outside of the active channel. A maximum of ten fish per species and size class were sampled for measurement of fork length, wet weight and DNA. If more than ten fish per size class and species were captured, the surplus fish were identified to species in a fish viewer. All fish were released back to the river downstream of the trap.

The condition of the trap was also monitored continuously by remote camera, which took a series of still pictures each morning (at first light) and afternoon. Pictures were emailed automatically to the trapping crew so they were aware of any potential issues with the trap prior to arriving onsite. Afternoon pictures were emailed sufficiently early in the day so that any issues could be resolved prior to sunset. For site security, the camera was also programmed to be motion activated to detect tampering or vandalism.

Figure 2. Rotary Screw Trap (RST) during operation at base of Elk Canyon at 4 m^3/s (Position #1).

Figure 3. Rotary Screw Trap (RST) during operation at base of Elk Canyon at 10 m^3/s (Position #2).

Figure 4. Rotary Screw Trap (RST) during operation at base of Elk Canyon at 4 m^3/s low water conditions (Position #3).

2.1.2. Age Analysis

Scale samples were collected for age analysis from RST captured Steelhead/Rainbow Trout, Chinook Salmon and Coho Salmon that were >50 mm fork length. In total, 79 scale samples from Steelhead/Rainbow Trout, 153 scale samples from Chinook Salmon and 67 scale samples from Coho Salmon were collected. Of these, 10 Steelhead/Rainbow Trout, 15 Chinook Salmon and 14 Coho Salmon scales were aged.

In the Ecofish laboratory, scales were examined under a dissecting microscope to determine age. Three representative scales from each sample were photographed and annuli were noted on a digital image. Scales were aged by two independent observers, following Ecofish in-house QA protocols. Where discrepancies were noted, they were discussed and a final age determination was made based on professional judgment of the senior biologist.

2.1.3. Mark Recapture Experiment

Mark-recapture experiments were completed to measure RST catch efficiency and ultimately to estimate total out-migration from Elk Canyon (Table 1). A total of 26 mark recapture trials were completed over 12 release days from March 5 to May 31, 2016. The trials included: 21 trials of wild Chinook, Chum, Coho, Pink, and Sockeye Salmon fry (average fork length = 40 mm, weight = 0.5 g), and three trials of Chinook smolts (average fork length = 75 mm, weight = 5.0 g) and three trials of Coho smolts (average fork length = 140 mm, weight = 28 g) from the Quinsam hatchery.

All wild fry were marked by immersion in Bismarck Brown (0.8 g in 38 L of water) for 1.25 hrs. Coho and Chinook Salmon smolts were marked using a unique ventral fin clip for each individual trial. The number of fish that were targeted to be released per trial (200 fish) was determined by an efficiency analysis conducted for the Year 1 report (Hocking *et al.* 2015). This analysis determined that with 200 fish released the RST catch efficiency is not expected to vary by more than 5% if an additional fish is captured during a given trial (U.S. Fish and Wildlife Service 2008).

The hatchery Chinook and Coho Salmon smolts were driven to the powerhouse from the Quinsam hatchery and then transported into the canyon in buckets with battery-powered bubblers. The wild fry were captured from the RST and held on site in a mesh box secured in the river. No wild fish were held longer than 3 days prior to release. All fish were released approximately 225 m upstream of the RST in batches of ten fish. The release site was consistent through all trials and was located at the top of a cascade which flowed into a pool, run, riffle and then into the RST.

In total, 1,515 Chum Salmon fry, 384 Chinook Salmon fry, 34 Pink Salmon fry, 172 Coho Salmon fry, and 9 Sockeye Salmon fry were released over the course of the wild release days. For hatchery releases, 589 Chinook Salmon smolts and 556 Coho Salmon smolts were released over the course of three release days for each species (Table 1).

Two different capture efficiency estimates were calculated based on recaptures of the marked and released fish. First, the trial capture efficiency was based on recapture rates calculated for each trial:

$$CE_t = \frac{\sum_{i=0}^{3} RR_x}{r_x} \qquad \text{Equation 1}$$

where CE_t is the trial capture efficiency, RR_x is the total number of recent recaptured fish of trial x, and r_x is the number of released fish at trial x.

Second, because some marked and released fish may not immediately leave Elk Canyon, an overall capture efficiency was calculated based on combining all trials for each species and life stage:

$$CE_o = \frac{R}{r} \qquad \text{Equation 2}$$

where CE_o is the overall capture efficiency, R is the total number of recaptured fish, and r is the total number of released fish.

To estimate the total out-migration for each salmon species and life stage, it was necessary to calibrate the RST catch by the proportion of days that the RST was open relative to the days that it was closed (i.e., on the weekend and during the dam safety spills). To do this, the average CPUE measured as catch per sampling day for half month periods (e.g., March 1 to March 15 and March 16 to March 31) was calculated as the average of RST catch divided by the number of sampling days that the RST was open during that time period.

Using estimates of overall capture efficiency and CPUE per half month period, total out-migration by fish species and life stage in Elk Canyon can be calculated by:

$$Total\ Outmigration = \frac{\sum CPUE_{ij} \times T_j}{CE_{oi}} \qquad \text{Equation 3}$$

where $CPUE_{ij}$ is the average catch per day of a given species and life stage i in half month j, T_j is the number of days each half month j, and CE_{oi} is the overall capture efficiency for each species and life stage i.

For Chinook, Chum, and Pink Salmon, the capture efficiencies for each species and life stage were used to calculate the total out-migration. For species and life stages with low capture efficiencies (i.e., Coho Salmon fry, Steelhead/Rainbow Trout, and Sockeye Salmon fry with capture efficiencies ≤0.1) the overall capture efficiency of all other species and life stages combined was used to calculate outmigration. Similarly, the capture efficiency of combined Coho Salmon age 0+ and 1+ smolts was used to calculate their outmigration because of low captures of each age class.

Table 1. Mark-recapture experiment release date and fish numbers.

Release Species	Life Stage	Origin	Release Date	Number of Fish Marked	Number of Fish Released[1]
Chinook Salmon	Fry	Wild	5-Mar-16	129	129
	Fry		21-Mar-16	75	75
	Fry		28-Mar-16	38	38
	Fry		5-Apr-16	66	66
	Fry		11-Apr-16	54	54
	Fry		19-Apr-16	22	22
	Smolt	Hatchery	26-Apr-16	195	195
	Smolt		3-May-16	197	195
	Smolt		10-May-16	200	199
Chum Salmon	Fry	Wild	5-Mar-16	325	325
	Fry		21-Mar-16	256	255
	Fry		28-Mar-16	260	260
	Fry		5-Apr-16	268	265
	Fry		11-Apr-16	254	250
	Fry		19-Apr-16	159	159
Coho Salmon	Fry	Wild	5-Mar-16	15	15
	Fry		21-Mar-16	56	56
	Fry		28-Mar-16	31	31
	Fry		5-Apr-16	11	11
	Fry		11-Apr-16	38	38
	Fry		19-Apr-16	21	21
	Smolt	Hatchery	17-May-16	206	164
	Smolt		24-May-16	200	199
	Smolt		31-May-16	200	193
Pink Salmon	Fry	Wild	5-Mar-16	32	32
	Fry		28-Mar-16	2	2
Sockeye Salmon	Fry	Wild	28-Mar-16	3	3
	Fry		11-Apr-16	6	6

[1] Not all fish survived the marking and/or transport procedure. Only live marked fish were released.

2.2. Overwintering Assessment

2.2.1. Mark-resight Assessment

The overwintering assessment was designed to test if juvenile salmonids used Elk Canyon during their entire rearing period or if a significant proportion of the population consisted of immigrant juveniles from below the canyon. This was done by contrasting late summer (mid-September) parr abundance in the canyon with winter (early February) counts of parr just before onset of out-migration. For example, Coho Salmon are hypothesized to rear in Elk Canyon for over a full year after hatching and begin juvenile out-migration as 1+ smolts in mid-March (Table 3). Snorkel survey sampling occurred before this out-migration period. The periodicity chart shown in Table 3 was adopted from the WUP for the Lower Campbell River and will be updated with Elk Canyon specific data as the JHTMON-15 program progresses. For Chinook Salmon, it is currently hypothesized that all Chinook juveniles leave the Campbell watershed by July and are thus an 'Ocean type" life history. This would predict that no Chinook parr would be observed in the fall or winter snorkel surveys.

The overwintering assessment snorkel surveys completed in Year 1 were highly variable and resulted in no fish being observed during daytime winter snorkels. A single night snorkel confirmed fish presence during the winter, and that day snorkels were not effective for reliably enumerating juvenile fish in the winter. Therefore, Year 2 overwintering assessment methods were modified from Year 1 to consist of two night snorkel mark resight trials. The first trial was conducted on September 12 and 13, 2015 and the second trial was conducted on February 3 and 4, 2016. The mark-resight snorkels followed methods established in the Cheakamus River WUP and Puntledge River WUP Steelhead monitoring projects (Korman 2008, Faulkner *et al.* 2011).

On September 9, 2015 a crew of two established 6 sites in the lower 1.0 km of Elk Canyon (sites CBR-NSK01 to CBR-NSK06 in Map 2). Sites were approximately 100 m long and encompassed a variety of habitat types (riffles, runs, pools) that parr would utilize. The portion of riffle/run/pool was delineated within each site in order to assess habitat specific preferences. Representative photographs and waypoints were collected, along with habitat data including: habitat type, length, stream width, depth, primary and secondary cover type, substrate and gradient.

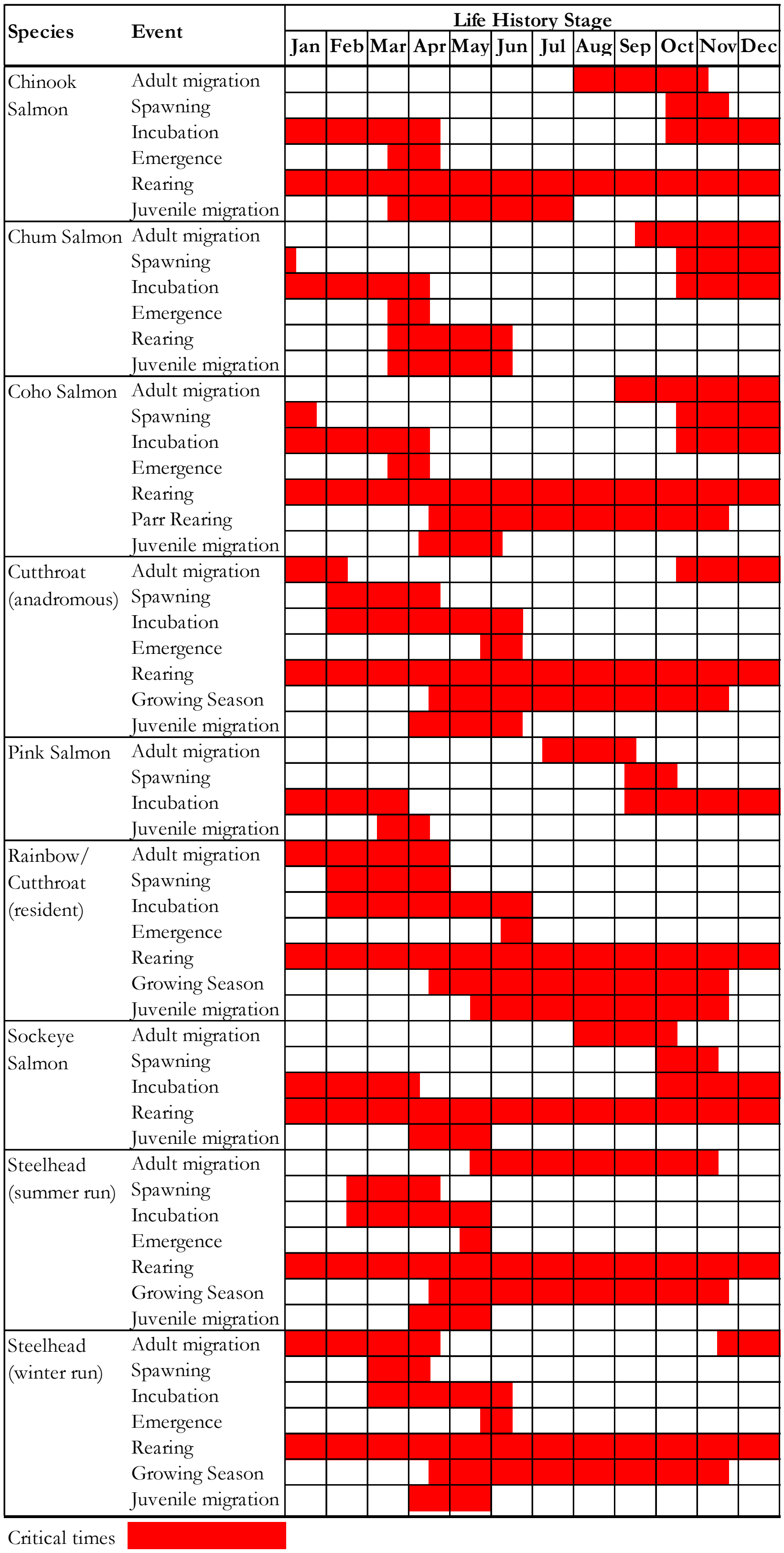
Fish were marked at each site using a crew of four on September 12, 2015 and February 3, 2016. Crews started at the upstream site (CBR-NSK01) and finished at the downstream end of the canyon. Within each site, two snorkelers traversed the site in an upstream direction with two underwater dive lights and a handheld dip net. Individual parr were captured using the dip net and were passed to the third and fourth crew members on shore. A hook tag consisting of a size 12-16 dry fly hook with a coloured piece of chenille was inserted into each fish at the base of dorsal fin. The estimated fork length was recorded as well as the tag colour. A ruler was placed in the bottom of the holding bucket to visually estimate fork length without excessive handling or use of anaesthetic. The tag colours used in the study are listed in Table 2. Once tags were applied, the parr were released within 5 m of where they were captured. Crews avoided conducting multiple passes through the site to avoid excessive disturbance prior to conducting the recapture snorkel the following day.

Table 2. Size bins and corresponding tag colour and hook size used during the Steelhead/Rainbow Trout, and Coho parr mark-recapture study in the Campbell River in 2016.

Size Range (mm)	Colour	Hook Size
80-100	Blue	16
100-120	Red	16
120-140	Orange	15
140-160	Green	14
160-180	Sparkle Pink	13
180-190	Plain Pink	12

On September 13 and February 4, two crews of two conducted resight snorkels in each of the six sites that were marked the previous night. The mark resight crews accessed the canyon before dark and started surveys one hour after sunset at the most upstream sites (CBR-NSK01, CBR-NSK02). Each crew of two snorkelled three sites each, and covered all available habitat >20 cm deep by traversing from each bank and meeting at the centre of the stream, slowly working their way upstream. Each crew member was equipped with two underwater dive lights, one on their wrist and one attached to the dive mask strap. All fish observed were recorded on underwater dive slates in 10 mm size bins. Prior to conducting the surveys, underwater fish models of known sizes were examined underwater to calibrate size estimates. All tagged fish were noted, along with tag colour. In addition, approximately 20 m of habitat above and below the site boundaries were snorkelled to determine if any tagged fish moved out of the site. No untagged fish were enumerated outside of the site boundaries, although any tagged fish were noted.

Table 3. Draft periodicity chart for salmonid species using Elk Canyon (Source = BC Hydro John Hart Water Use Plan)



2.2.1.1. Data Analysis

The population estimate of overwintering fish at each of the six sites was calculated based on the observer efficiency of marked individuals:

$$Observer\ Efficiency\ (OE) = \frac{R}{(M - O)}$$

where R is the number of marked individuals observed during the resight swim (resights), M is the number of marked individuals during the mark swim, and O is the number of marked individuals observed outside of the site during the resight swim. The mean observer efficiency for the fall and spring sampling was calculated and used to estimate the population density at each site:

$$Population\ Density = \frac{M}{OE} \times A$$

where OE is the observer efficiency and A is the site area in m^2.

In addition to the observer efficiency, the population density was estimated using the Peterson estimator with Chapman modification calculation as outlined in Krebs (2014). Population density was calculated from the two approaches and compared.

The population densities of Steelhead/Rainbow Trout and Coho Salmon were compared between the two seasons (early fall and winter) across all six sites using a paired t-test in the open access software program R (R Core Team 2013).

2.3. Pulse Flow Assessment

2.3.1. Fall Pulse Flow Assessment

Fall pulse flow assessments were initiated in Year 2. There were nine fall pulse flow releases conducted weekly through Elk Canyon between September 14 and November 15, 2015 (Table 4). Each pulse lasted 48 hours and occurred at least three days apart on Wednesday and Thursday of each week. Full canyon snorkel surveys were used to assess migration response for fall spawning salmon pre and post pulse. The snorkel counts were carried out by a crew of two swimmers swimming in tandem, with a third crew member recording data on shore. For each pulse a snorkel survey was conducted the day before the pulse and the day after the pulse (one exception occurred September 19). The next pre-pulse survey (3-4 days later) was used to determine the baseline fish count prior to the next pulse as well as to assess if fish stayed or moved back downstream between the pulses. Additionally, weekly snorkels were conducted during the two weeks preceding the first pulse and one week after the last pulse, for a total of 21 fall snorkel surveys.

Table 4. Elk Canyon pulse flow and snorkel survey schedule in fall 2015 including overwintering assessment mark resight snorkels.

September

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE
								Snorkel						Snorkel	Pulse	Pulse		Snorkel			Snorkel	Pulse	Pulse	Snorkel				Snorkel	Pulse
											Overwintering	Overwintering																	

October

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA
Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel	

November

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	MO
		Snorkel	Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel			Snorkel									Snorkel					

2.3.1.1. Data Analysis

The effect of pulse flows on salmon in-migration to Elk Canyon was determined with paired t-tests in an approach similar to the fish passage assessment analysis conducted for the Ash River WUP (Lewis *et al.* 2010). Analyses were conducted separately for Coho Salmon, Chinook Salmon, Chum Salmon, Sockeye Salmon and Steelhead. For each salmon species, two separate tests were completed that address the hypotheses $H_0 3$ and $H_0 5$. The null hypothesis for $H_0 5$ states: The estimated number of spawning salmonids following pulse flow release operation is not significantly different from that just prior to the release. To address this hypothesis, paired t-tests were used to determine if the number of salmon observed in Elk Canyon was higher in the post pulse snorkel compared to the pre pulse snorkel.

The null hypothesis for $H_0 3$ states: The rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation is not significantly different from that during the base flow operation. To address this hypothesis, the pre pulse count of salmon for each pulse was subtracted from the post pulse count of salmon to derive the change in salmon abundance pre versus post pulse ($\Delta salmon_{pulse\ flow}$). Each value for $\Delta salmon_{pulse\ flow}$ was divided by the number of days between snorkel surveys (usually 3 days) to derive the rate of salmon in-migration per day for each pulse event ($\Delta salmon/day_{pulse\ flow}$). The post pulse snorkel for each pulse and the pre pulse snorkel for the subsequent pulse were also separated by three to four days, except they were not divided by a pulse event and instead had consistent base flows. Therefore, these two surveys were assigned as pre base flow and post base flow respectively and acted as a paired control to the pre versus post pulse data. The rate of salmon in-migration per day during base flow (Δsalmon/day$_{base\ flow}$) was computed in the same fashion and paired with each measure of Δsalmon/day$_{pulse\ flow}$ from only a few days before. This yielded nine base flow versus pulse flow pairs that were analyzed using paired t-tests to address $H_0$3. All analyses were conducted using the open source program R (R Core Team 2013).

A test of $H_0$4 was not possible using this snorkel design because daily salmon count data was not collected during the pulse flow releases. The null hypothesis for $H_0$4 states: The rate of spawning salmonid in-migration (No./day) during the first day of the pulse flow release operation is not significantly different from that during the second day.

2.3.2. Spring Pulse Flow Assessment

Spring spawning pulse flow assessments were initiated in Year 2. There were 4 spring pulse flow events conducted through the Elk Falls Canyon between February 15 and April 15 (Table 5). Each pulse lasted 48 hours and occurred at least three days apart. Full canyon snorkel surveys were used to assess migration response for Steelhead pre and post pulse. The snorkel count methods were the same as those used for the Fall Pulse Flow Assessment (Section 2.3.1). For each pulse a snorkel survey was conducted the day before the pulse and the day after the pulse and a third snorkel survey two to three days later to asses if fish stayed or moved back down stream. Additionally, weekly snorkels were conducted during the two weeks preceding the first pulse and one week after the last pulse were complete, for a total of 15 spring snorkel surveys.

Table 5. Elk Canyon pulse flow, snorkel survey and RST schedule in spring 2016 including dam safety spills (dark grey), blasting spills (chartreuse), 7 cms spawning flow (light grey), overwintering assessments, and mark recapture releases.

February

1	MO	
2	TU	Snorkel
3	WE	Overwintering
4	TH	Overwintering
5	FR	
6	SA	
7	SU	
8	MO	
9	TU	Snorkel
10	WE	
11	TH	
12	FR	
13	SA	
14	SU	
15	MO	
16	TU	Dam safety spill
17	WE	Dam safety spill
18	TH	Dam safety spill
19	FR	Dam safety spill
20	SA	Dam safety spill
21	SU	Dam safety spill
22	MO	Dam safety spill
23	TU	Dam safety spill
24	WE	Dam safety spill
25	TH	Snorkel, RST Install
26	FR	RST Install
27	SA	
28	SU	
29	MO	RST

March

1	TU	Snorkel, RST
2	WE	Pulse, RST
3	TH	Pulse, RST
4	FR	Snorkel, RST
5	SA	RST, Wild Fry
6	SU	RST
7	MO	RST
8	TU	Snorkel, RST
9	WE	Dam safety spill
10	TH	Dam safety spill
11	FR	Dam safety spill
12	SA	Dam safety spill
13	SU	Dam safety spill
14	MO	Dam safety spill
15	TU	Dam safety spill
16	WE	Dam safety spill
17	TH	Dam safety spill
18	FR	Dam safety spill
19	SA	RST
20	SU	RST
21	MO	RST, Wild Fry
22	TU	Snorkel, RST
23	WE	Pulse, RST
24	TH	Pulse, RST
25	FR	Snorkel, RST
26	SA	
27	SU	
28	MO	RST, Wild Fry
29	TU	Snorkel, RST
30	WE	Pulse, RST
31	TH	Pulse, RST

April

1	FR	7 cms Spawning Flow; Snorkel, RST
2	SA	7 cms Spawning Flow
3	SU	7 cms Spawning Flow
4	MO	7 cms Spawning Flow; Snorkel, RST
5	TU	7 cms Spawning Flow; RST, Wild Fry
6	WE	7 cms Spawning Flow; Pulse, RST
7	TH	7 cms Spawning Flow; Pulse, RST
8	FR	7 cms Spawning Flow; RST
9	SA	7 cms Spawning Flow
10	SU	7 cms Spawning Flow
11	MO	7 cms Spawning Flow; RST, Wild Fry
12	TU	7 cms Spawning Flow; Snorkel, RST
13	WE	blasting spill; RST
14	TH	7 cms Spawning Flow; Pulse, RST
15	FR	7 cms Spawning Flow; Snorkel, RST
16	SA	
17	SU	
18	MO	Snorkel, RST
19	TU	RST
20	WE	RST
21	TH	RST
22	FR	RST
23	SA	
24	SU	
25	MO	Snorkel, RST
26	TU	blasting spill; RST, CN Parr
27	WE	RST
28	TH	RST
29	FR	RST
30	SA	

May

1	SU	
2	MO	RST
3	TU	RST, CN Parr
4	WE	RST
5	TH	RST
6	FR	RST
7	SA	
8	SU	
9	MO	RST
10	TU	RST, CN Parr
11	WE	RST
12	TH	RST
13	FR	RST
14	SA	
15	SU	
16	MO	RST
17	TU	blasting spill; RST, CO Parr
18	WE	RST
19	TH	RST
20	FR	RST
21	SA	
22	SU	
23	MO	RST
24	TU	RST, CO Parr
25	WE	RST
26	TH	RST
27	FR	RST
28	SA	
29	SU	
30	MO	RST
31	TU	RST, CO Parr

June

1	WE	RST
2	TH	RST
3	FR	RST
4	SA	
5	SU	
6	MO	RST
7	TU	RST
8	WE	RST
9	TH	RST
10	FR	RST
11	SA	
12	SU	
13	MO	RST
14	TU	RST
15	WE	RST
16	TH	RST
17	FR	RST
18	SA	
19	SU	
20	MO	RST
21	TU	RST
22	WE	RST
23	TH	RST
24	FR	RST
25	SA	
26	SU	
27	MO	RST
28	TU	RST
29	WE	RST
30	TH	RST

July

1	FR	RST
2	SA	
3	SU	
4	MO	RST
5	TU	RST
6	WE	RST
7	TH	RST
8	FR	RST
9	SA	
10	SU	
11	MO	RST
12	TU	RST
13	WE	RST
14	TH	RST
15	FR	RST
16	SA	
17	SU	
18	MO	RST
19	TU	RST
20	WE	RST
21	TH	RST
22	FR	RST
23	SA	
24	SU	
25	MO	RST
26	TU	RST
27	WE	RST
28	TH	RST Removal
29	FR	RST Removal
30	SA	
31	SU	

2.3.2.1. Data Analysis

The effect of the spring pulse releases on Steelhead in-migration to Elk Canyon was determined using the same methods as described for the fall pulse flow assessment. Paired t-tests were used to address $H_0$3 and $H_0$5 relating to the number of Steelhead observed in the canyon pre versus post pulse and the rate of Steelhead in-migration per day during the pulse release compared to in-migration during base flows. One difference of note is that two of the four contrasts of flow were influenced by the 7 m^3/s spawning release flow from April 1 to April 15 (Table 5). The rate of Steelhead in-migration per day during pulse flows was thus compared to the rate of Steelhead in-migration per day during base/spawning flows.

2.4. Steelhead Spawning Flow Assessment

A spring spawning flow of 7 m^3/s was maintained through the Elk Falls Canyon from April 1 to April 15, 2016. Four full canyon snorkel surveys were conducted on April 1, 4, 12, and 15 to assess the response by spawning Steelhead to the 7 m^3/s spawning flow. The snorkel counts were conducted using the same methods as those used during the Fall and Spring Pulse Flow Assessments (Section 2.3).

Two-sample t-tests were used to address $H_0$6 relating to the number of Steelhead observed in the canyon prior to and during the two-week, 7 m^3/s spawning release period in spring. To minimize the effect of periodicity on Steelhead counts, the results from the three sampling events prior to the spawning release (March 22, 25, and 29, 2016) were compared to the counts of adult Steelhead during the spawning flow release.

2.5. Spawner Enumeration

2.5.1. Spawner Surveys

2.5.1.1. Fall Surveys

Snorkel surveys were used to enumerate fall spawners in reaches one to seven of the Campbell River (Map 2); however, data from reach seven were excluded as recommended in Year 1 because of the large number of fish that hold in the pool at the base of the canyon that are not actively spawning. In total, 21 snorkel surveys were conducted on September 9, 15, 19, 22, 25, 29, October 2, 6, 9, 13, 16, 20, 23 27, 30, November 3, 6, 10, 13, 16, and 25, 2015, to inventory fall spawners in Elk Canyon including Coho Salmon, Chinook Salmon, Chum Salmon, Pink Salmon, Sockeye Salmon and Steelhead. In each reach total counts of all species, their spawning condition and the presence of redds were recorded. Spawning areas were also marked for future data collection. The snorkel count methods were the same as those used for the Fall and Spring Pulse Flow Assessments (Section 2.3).

2.5.1.2. Spring Surveys

Snorkel surveys were used to enumerate spring spawners in reaches 1-7 of the Campbell River (Map 2); however, data from reach 7 were excluded because these fish are generally holding in the pool at the base of the canyon and are not actively spawning. In total 15 snorkel surveys were conducted on

February 2, 9, 25, March 1, 4, 8, 22, 25, 29, April 1, 4, 12, 15, 18, and 25, 2016, to inventory Steelhead in Elk Canyon. In each reach total counts of Steelhead, their spawning condition and the presence of redds were recorded. Redd count surveys were carried out concurrently. As each redd was encountered, its location relative to water level was recorded. The snorkel count methods were the same as those used for the Fall and Spring Pulse Flow Assessments (Section 2.3).

2.5.2. Spawner Abundance

Spawner abundance for each species was estimated using an area under the curve (AUC) analysis for salmon species or, when observations were too low (i.e., <25 for Steelhead), peak observed estimates were used. For salmon, the DFO AUC calculator tool was used. The AUC calculator uses the survey abundance estimates, along with estimates of fish residence time and observer efficiency to estimate the total spawner abundance. Estimates of fish residence times are provided in Perrin and Irvine (1990) (Table 6). Observer efficiency was assumed to be 100%. During the spring, the maximum number of Steelhead observed in a single survey day was used as the spawner abundance estimate rather than using area under the curve.

Table 6. Fall spawner residence times (source Perrin and Irvine 1990).

Fish Species	Residence Time (days)
Coho Salmon	11.4
Chum Salmon	11.9
Pink Salmon	17.3
Chinook Salmon	12.1
Sockeye Salmon	13.2

2.5.3. Productivity of Fall Salmon Spawners

The production of fry and smolts was estimated based on the maximum number of redds observed for Chinook, Coho, Chum, Pink and Sockeye Salmon spawners. Assuming that a female would spawn in a single redd, we estimated the number of eggs produced per redd based on average female fecundity by salmon species (Bradford 1995). We then estimated fry and smolt production by salmon species based on the egg to fry and egg to smolt survival rates provided in Quinn (2005). These estimates of fry and smolt production from observed salmon redds were compared against the fry and smolt out-migration estimates generated from the RST data.

3. RESULTS

3.1. Smolt Enumeration

3.1.1. RST Capture Data

The rotary screw trap (RST) was operational for 83 days from February 26, 2016 to July 28, 2016. RST operation was halted from March 9 to March 18, 2016 due to dam safety spill of over 10 m^3/s, and the RST was removed from the river. Once operational spill levels decreased, the RST was reset and operations continued until July 28, 2016.

In total, 24,009 fish were captured using the RST (Figure 5 and Figure 6). The catches were primarily composed of Chum Salmon (84.1%), Chinook Salmon (6.9%), sculpin spp. (4.4%) and Coho Salmon (2.8%). Steelhead/Rainbow Trout and Sockeye Salmon were 0.4% and 0.3%, respectively. The combined catch of all salmonids (22,881 fish) accounted for 95.5% of the total catch while the catch of the key target species of Chinook Salmon, Coho Salmon, and Steelhead/Rainbow Trout (2,406 fish) accounted for 10.0% of the total catch.

Clear periods of peak out-migration were observed for Chinook Salmon, Coho Salmon, Chum Salmon, Pink Salmon, Sockeye Salmon and Steelhead/Rainbow Trout based on the RST catches (Figure 7, Figure 8, Figure 9). Chinook Salmon out-migration increased throughout early March, peaked in mid-March and declined in mid-April. A second, smaller peak in out-migration occurred in late May to mid-June. Coho Salmon out-migration occurred later with a peak in late March until mid-April. Following the first peak in out-migration, Coho Salmon were continuously captured in the RST but in lower numbers. Steelhead/Rainbow Trout out-migration peaked starting in early May and decreased by early June. Chum Salmon out-migration began to increase in early March and peaked at the beginning of April. Catches of Chum Salmon decreased until May 3, 2016, after which no other Chum Salmon were observed. Pink Salmon out-migration had a narrow peak at the beginning of March and ended on April 1. Sockeye Salmon out-migration had a very narrow peak that occurred at the very end of March and beginning of April. Catches of Sockeye Salmon were sporadic beyond this two week period and no Sockeye were observed after mid-April.

It is important to note that the Quinsum hatchery releases sub yearling Chinook Salmon smolts into the Quinsam River, which subsequently enters the Campbell River downstream of the RST. There is some uncertainty around whether the Chinook released from the hatchery could swim upstream and become captured in the RST. In 2016, there were seven groups released from the hatchery across four different days: May 2, May 4, May 5, and May 16, 2016. The average length of these individuals ranged from 81 mm to 85 mm. The number of Chinook Salmon captured in the RST were plotted during and following the period of hatchery releases (Figure 10). Chinook Salmon catches in the RST were relatively low during the period of hatchery releases and increased during a second pulse of out-migration in late May and June. Fish origin could not be determined in the field; however, these results suggest that hatchery fish do not make up a significant proportion of the Chinook out-migration from Elk Canyon.

Of the 22,830 salmonids caught in the RST, 1,053 fish were measured. The fork lengths of these fish were compared over time to determine if out-migration timing varied by the size and/or age cohort of fish (Figure 11). Chum, Pink, and Sockeye Salmon fry were captured throughout February, March, and April within a narrow range of fork length of roughly 30 to 40 mm (Figure 11, Figure 12, Figure 13, Figure 14).

Chinook Salmon and Coho Salmon exhibited two main peaks in out-migration timing and size (Figure 11). Recently emerged Chinook and Coho fry were caught in the RST from March to mid-April, which ranged in fork length from 40 to 44 mm and 36 to 42 mm, respectively. A second peak in out-migration composed of larger individuals was observed for both species starting in May until the end of the sampling period. From late May to the end of July, the majority of the Chinook and Coho caught in the RST ranged from 70 to 100 mm in length (for Chinook) and 55 to 90 mm in length (for Coho) (Figure 11, Figure 15, Figure 16). The fork length of Chinook Salmon caught in the RST was similar through May, June and early July, while the fork length of Coho Salmon generally increased through this period. All of these fish are assumed to be age 0+ smolts that have reared for several months in Elk Canyon prior to their out-migration. One exception is that two Coho Salmon >120 mm were captured in April and May, which suggests that a small cohort of age 1+ Coho Salmon out-migrants also were present.

Steelhead/Rainbow Trout had one main peak in out-migration timing and size (Figure 17). The majority of Steelhead/Rainbow Trout were caught in the RST in May and ranged from 140 mm to 213 mm in length. These were aged as 2+ parr. A few smaller individuals <140 mm were also caught in the RST in May, June and July indicating that there may be a smaller and later pulse of age 1+ parr.

Figure 5. **Total RST catch by species from February 26 to July 28, 2016. ST/RB = Steelhead/Rainbow Trout, CO = Coho Salmon, CH = Chinook Salmon, CM = Chum Salmon, PK = Pink Salmon, CT = Cutthroat Trout, CAL = Coastrange Sculpin, CAS = Prickly Sculpin, CC = sculpin (*Cottus* spp.), CCG = Slimy Sculpin, L = lamprey spp., SA = Salmon spp., SK = Sockeye Salmon, TSB = Threespine Stickleback, TR = unknown trout spp.**

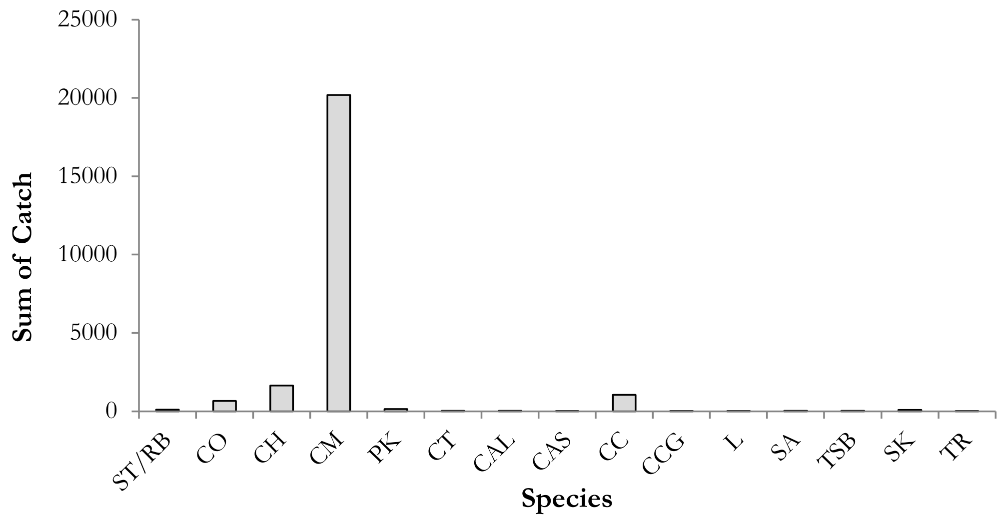


Figure 6. **Total RST catch by species from February 26 to July 28, 2016 excluding Chum Salmon. ST/RB = Steelhead/Rainbow Trout, CO = Coho Salmon, CH = Chinook Salmon, PK = Pink Salmon, CT = Cutthroat Trout, CAL = Coastrange Sculpin, CAS = Prickly Sculpin, CC = sculpin (*Cottus* spp.), CCG = Slimy Sculpin, L = lamprey spp., SA = Salmon spp., SK = Sockeye Salmon, TSB = Threespine Stickleback, TR = unknown trout spp.**

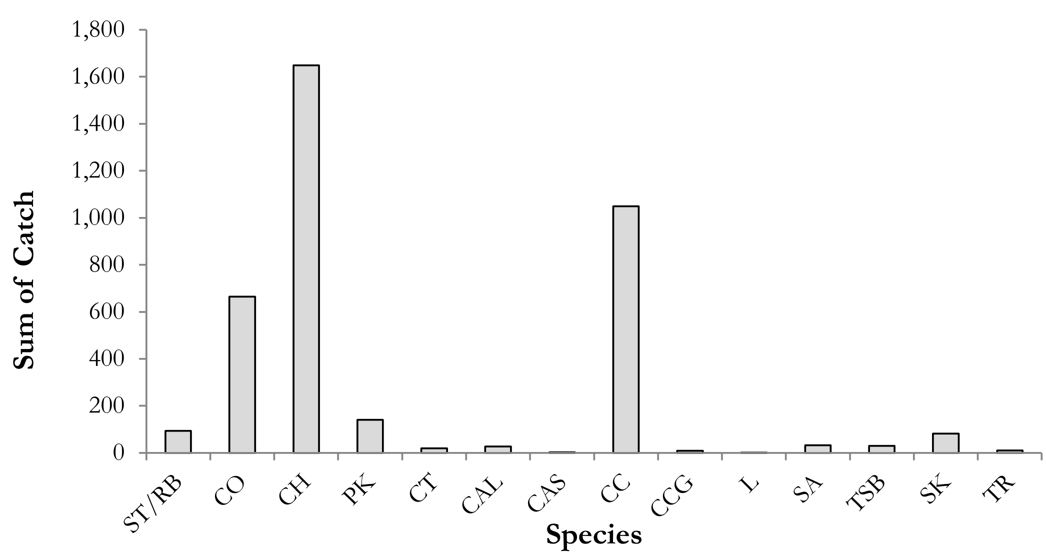


Figure 7. RST catch per-unit-effort of key salmonid species from February 26 to July 28, 2016.

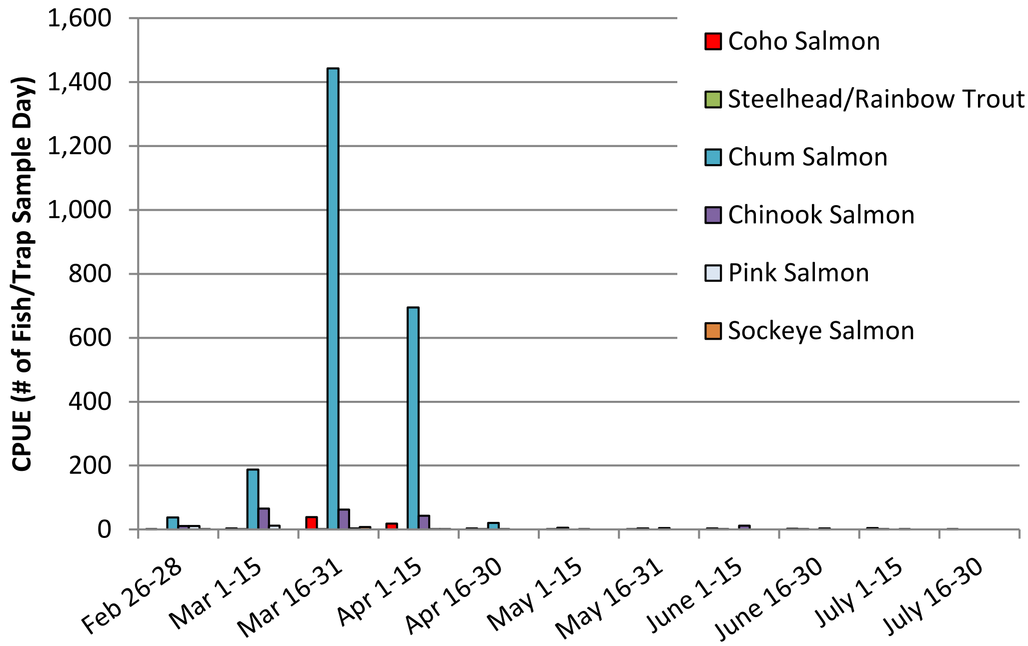


Figure 8. RST catch per-unit-effort of key salmonid species (excluding Chum Salmon) from February 26 to July 30 2016.

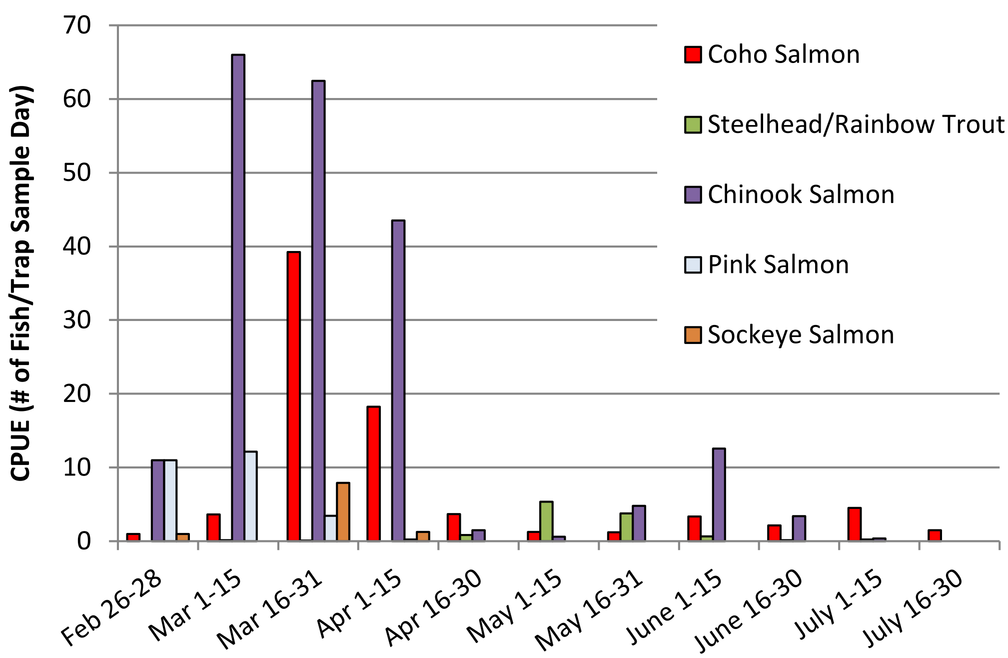


Figure 9. RST catches of a) Chinook Salmon, b) Coho Salmon, c) Steelhead/Rainbow Trout, d) Chum Salmon, e) Pink Salmon, and f) Sockeye Salmon.

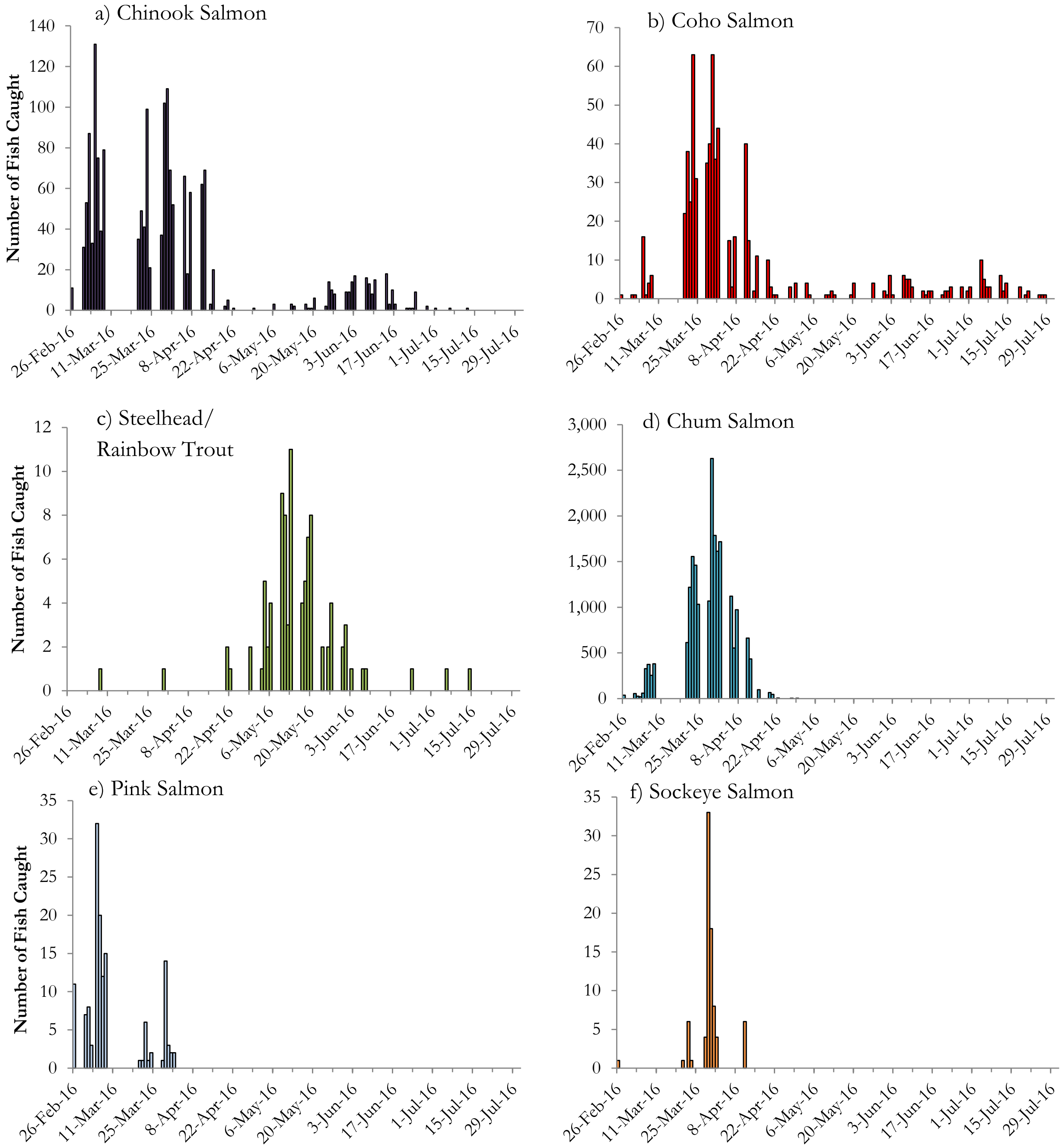


Figure 10. **RST catches of Chinook Salmon from April 15 to June 15, 2016 (purple bars) in relation to dates of hatchery releases of Chinook Salmon (hatched bars).**

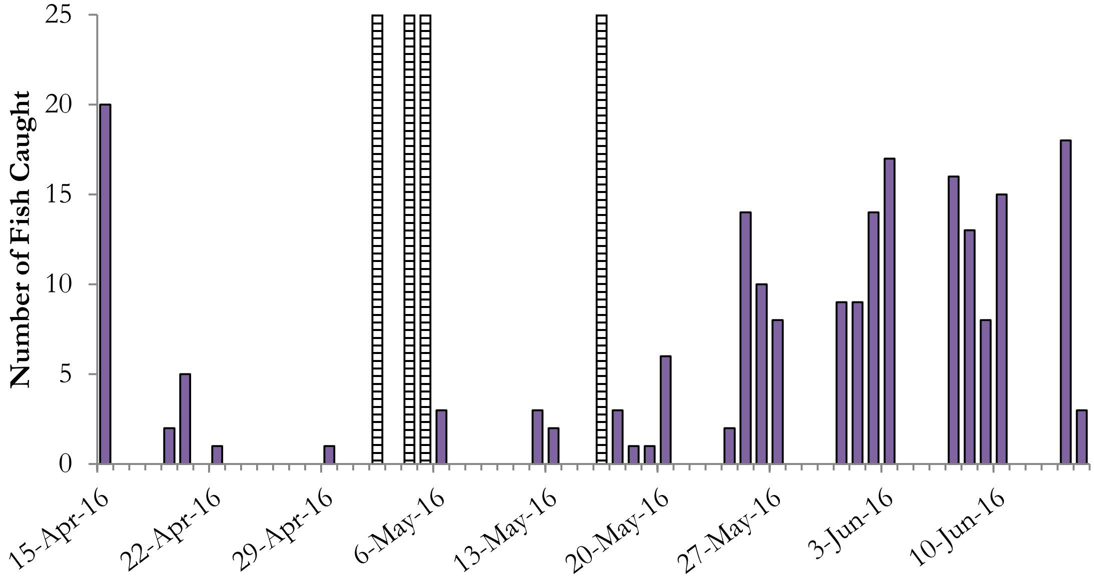


Figure 11. **Average fork length of Coho Salmon, Steelhead/Rainbow Trout, Chum Salmon, Chinook Salmon, Pink Salmon, and Sockeye Salmon during RST sampling period.**

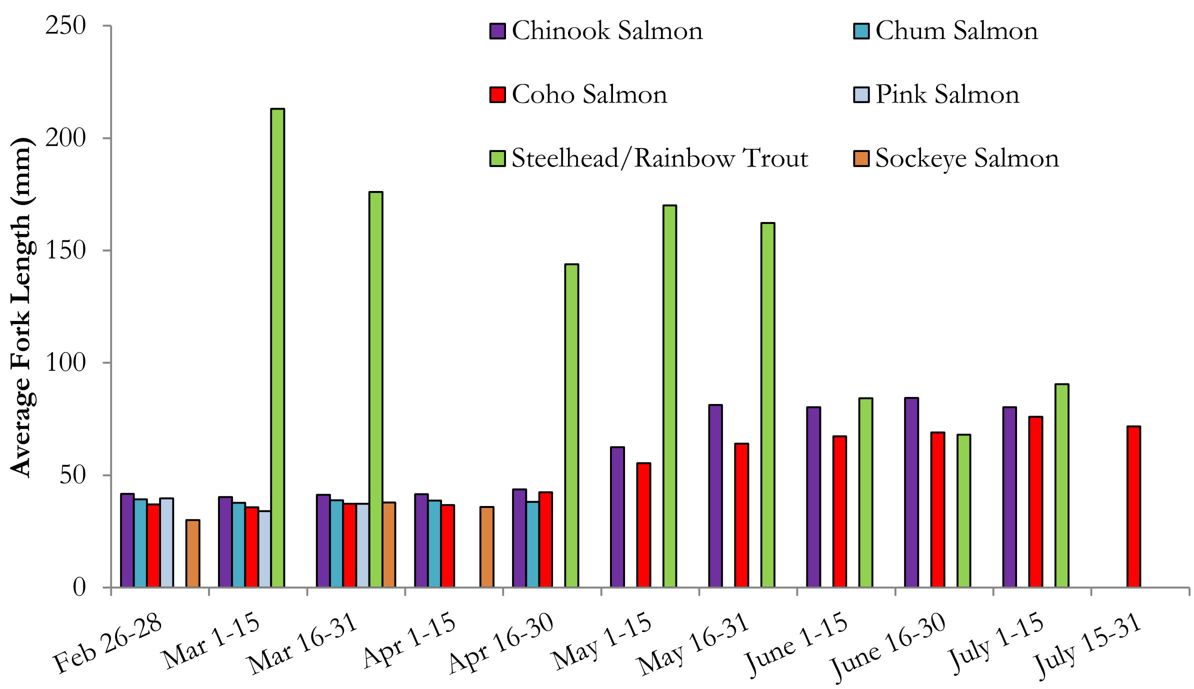


Figure 12. Length frequency histogram of Pink Salmon captured in the RST by month.

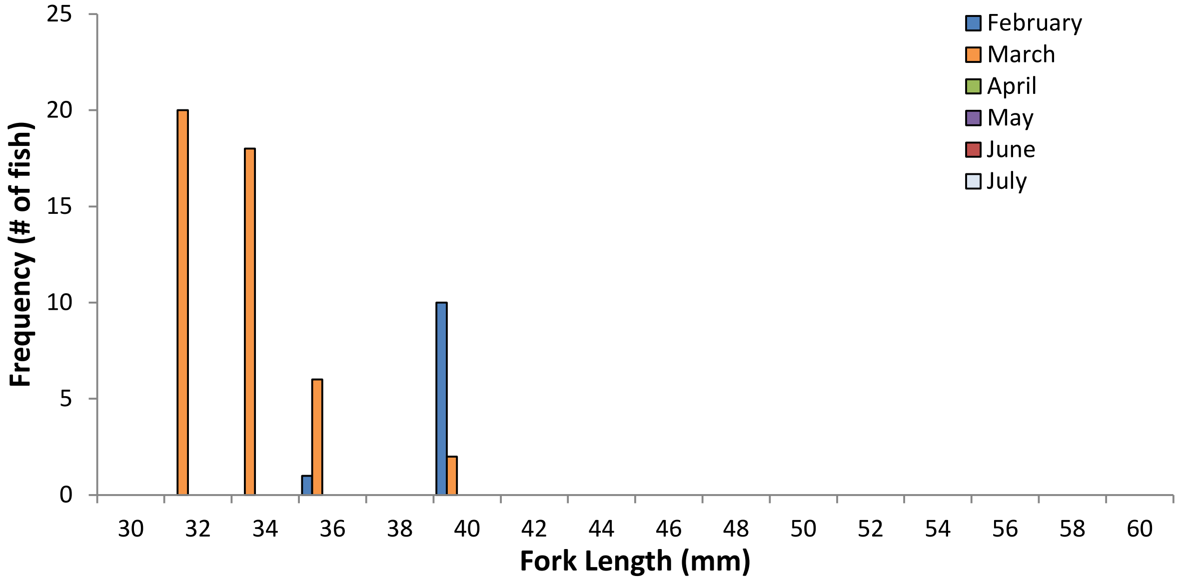


Figure 13. Length frequency histogram of Sockeye Salmon captured in the RST by month.

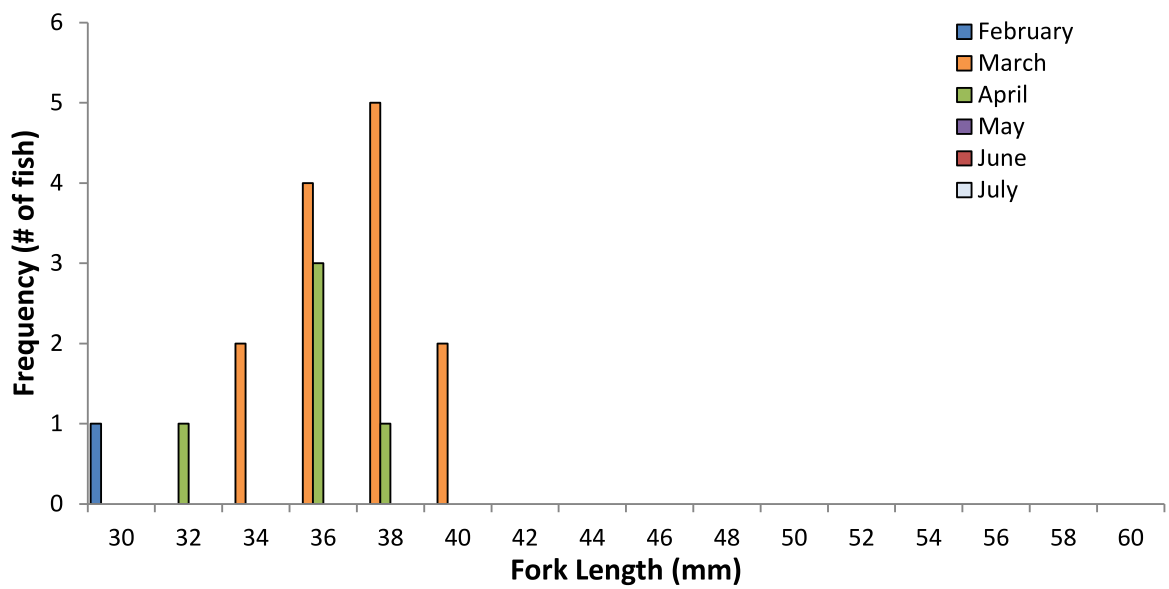


Figure 14. Length frequency histogram of Chum Salmon captured in the RST by month.

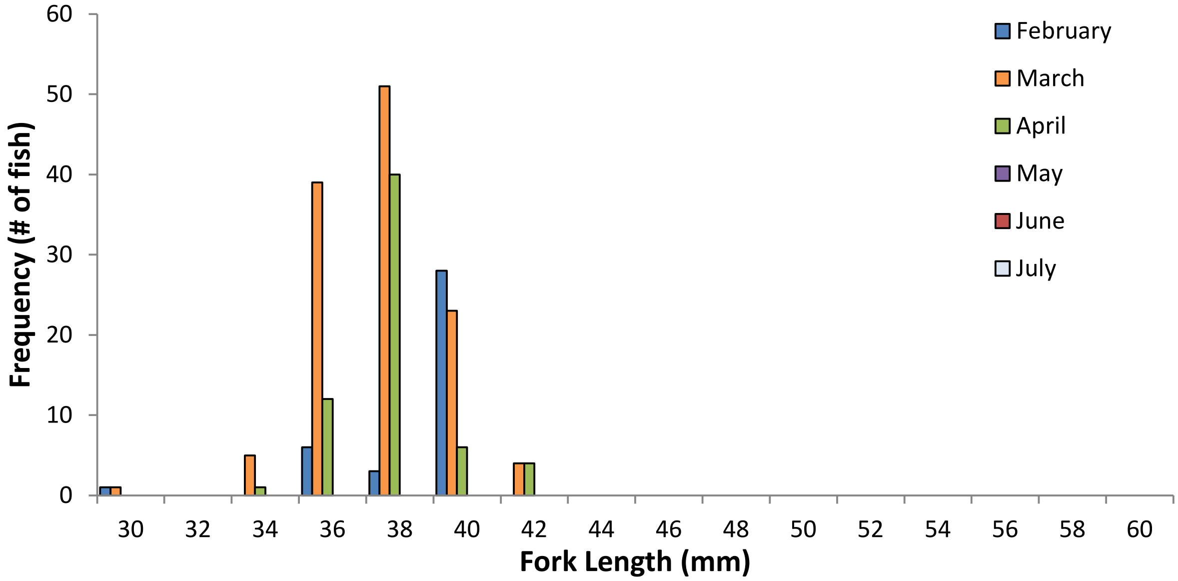


Figure 15. Length frequency histogram of Chinook Salmon captured in the RST by month.

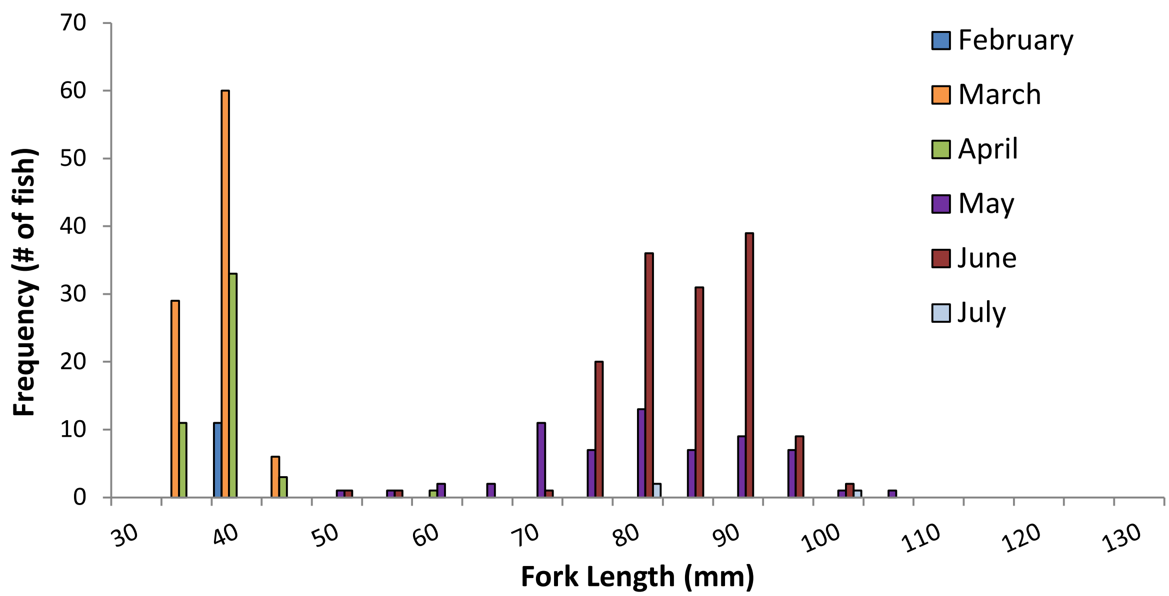


Figure 16. Length frequency histogram of Coho Salmon captured in the RST by month.

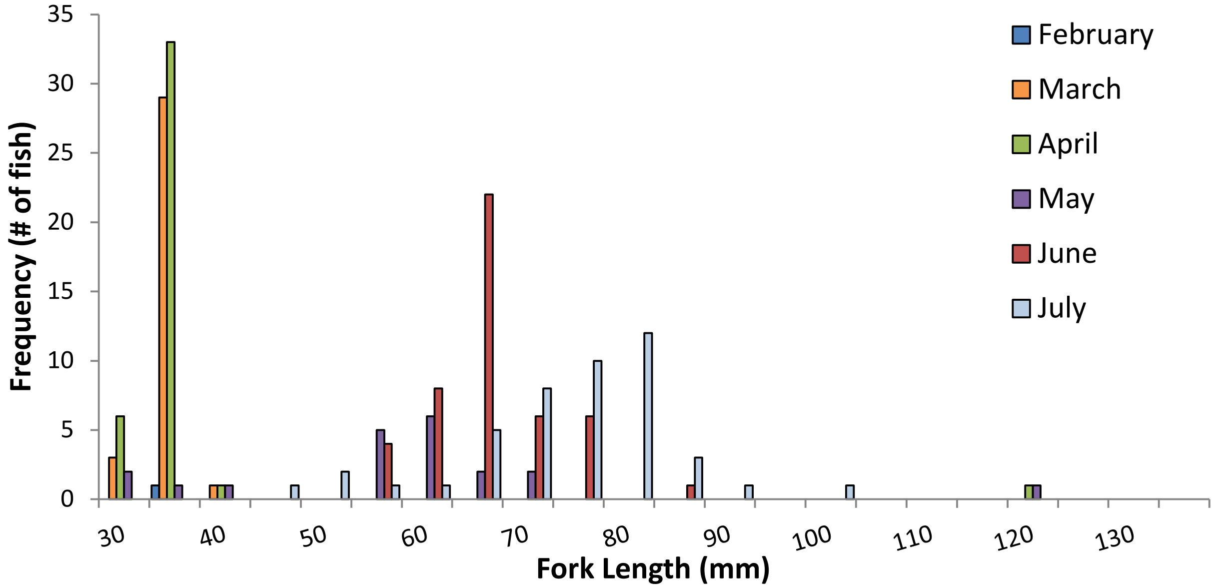
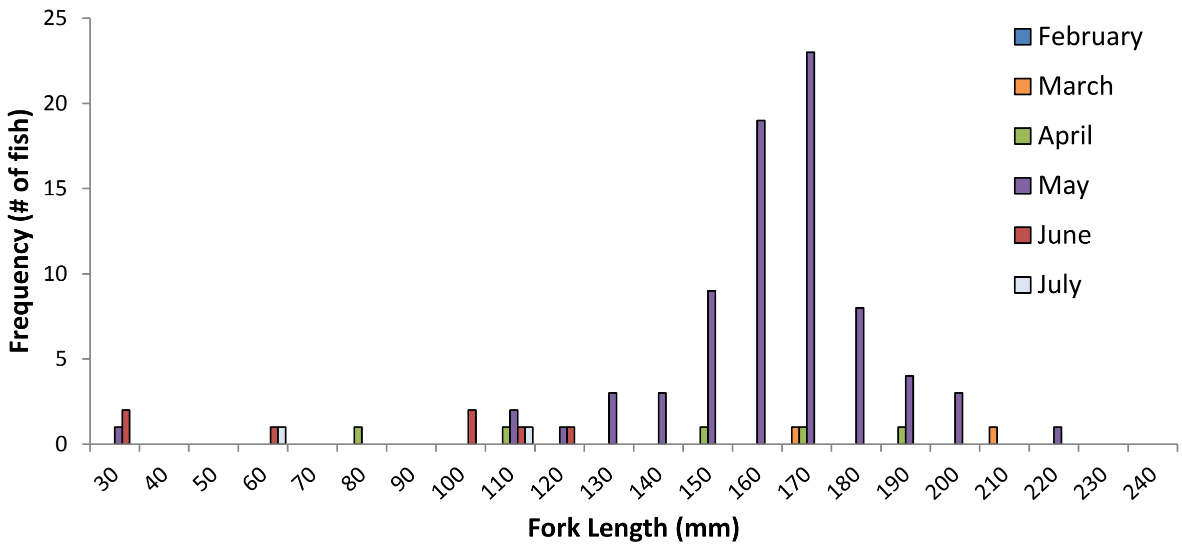


Figure 17. Length frequency histogram of Steelhead/Rainbow Trout captured in the RST by month.



3.1.2. RST Fish Age Data

Of the 15 Chinook Salmon scales that were aged, all were aged as 0+ fish (Figure 18, Table 7). Chinook individuals caught in the RST that were aged ranged in fork length from 64 mm to 95 mm. Based on the size distribution of Chinook Salmon caught in the RST, it is concluded that all Chinook Salmon juveniles are 'ocean type' and leave Elk Canyon by the end of July.

Of the 14 Coho Salmon scales that were aged, 13 were aged as 0+, and one was aged as a 1+ (Figure 18). Based on this limited data we assume that all Coho >115 mm are 1+ smolts (Table 7). Using that age break, only two 1+ Coho smolts were caught in the RST.

Of the 10 Steelhead/ Rainbow Trout scales that were aged, two were aged as 1+, and the remaining eight were aged as a 2+ fish (Figure 18). Based on this aging data, and the length-frequency histograms from RST catch, all fish <81 mm are assumed 0+, fish 81 to 136 mm assumed 1+, and all fish >136 mm assumed 2+ (Table 7).

There is uncertainty associated with these age break classifications for Coho Salmon and Steelhead/Rainbow Trout fry and parr given the low sample sizes of fish that were aged, and the relatively narrow range in fork length and date of age sample collection.

Figure 18. **Length at age graphs for a) Chinook Salmon, b) Coho Salmon, and c) Steelhead/Rainbow Trout.**

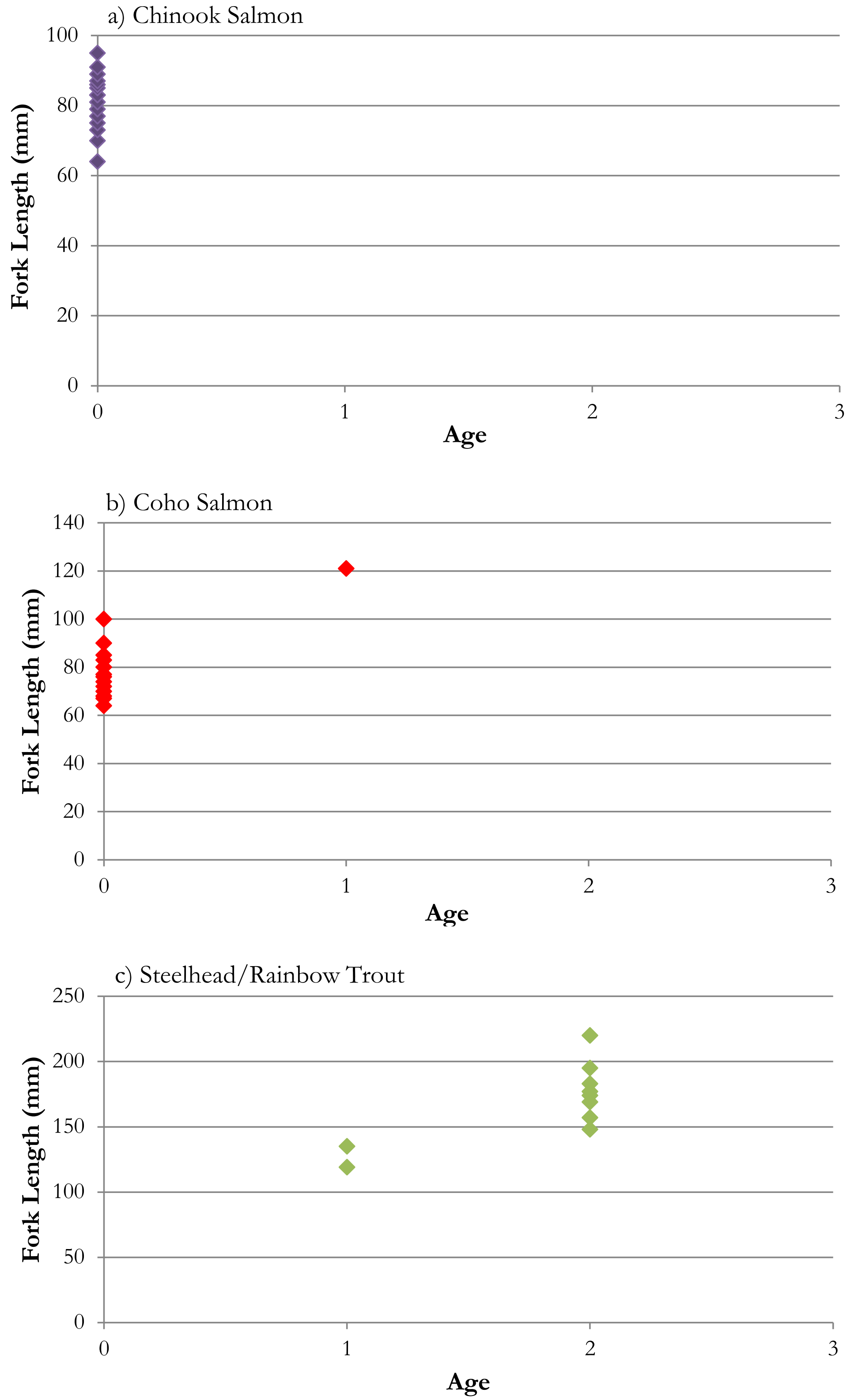


Table 7. Estimated size at age classification for juvenile Chinook Salmon, Coho Salmon, and Steelhead/Rainbow Trout.

Species	Age Class	Length bins (mm)
Chinook Salmon	0+	≤105
Coho Salmon	0+	≤115
	1+	>115
Steelhead/	0+	≤80
Rainbow Trout	1+	81-136
	≥2+	>136

3.1.3. RST Mark-Recapture Data

The mark-recapture trials for salmon fry and smolts were used to estimate the capture efficiency of the RST and to ultimately generate out-migration abundance estimates from Elk Canyon.

Of the 3,258 released fish, 517 fish (16%) were recaptured (Table 8 and Table 9). The capture efficiencies were comparable across species and life stages except for Coho Salmon fry, Pink Salmon Fry, and Sockeye Salmon fry (Table 8 and Table 9). Only two Coho Salmon fry were recaptured which resulted in low recapture rates. This is similar to the results from 2015, which may be because the released Coho fry choose to stay in Elk Canyon after their release. The relatively high capture efficiency observed for Pink Salmon fry and low efficiency observed for Sockeye Salmon fry are likely due to their low release numbers.

The trial capture efficiency estimates were based on recent recapture rates within the Year 2 release periods (Table 8). Chinook Salmon fry trial capture efficiencies ranged from 0.000 to 0.202 and the Coho Salmon fry trial capture efficiencies ranged from 0.000 to 0.036. The Chum Salmon fry trial capture efficiencies ranged from 0.064 to 0.188 and the Pink Salmon fry trial capture efficiencies ranged from 0.000 to 0.344; no Sockeye Salmon fry were recaptured.

The Chinook Salmon smolt capture efficiencies ranged from 0.149 to 0.241 and the Coho Salmon smolt capture efficiencies ranged from 0.218 to 0.271 (Table 8).

The overall capture efficiency estimates varied from 0.000 to 0.324 and were based on grouping the releases and recaptures for each species and life stage (Table 9). Excluding Coho Salmon fry, the overall capture efficiency across all species and life stages was 0.167, which is similar to the average capture efficiency from 2015 of 0.208.

Table 8. Trial capture efficiency estimates for each corresponding release date during the mark-recapture study.

Fish Species	Fish Lifestage	Release Date	Total Released Fish	Total Recaptured Fish	Trial Capture Efficiency
Chinook Salmon	Fry	5-Mar-16	129	26	0.202
		21-Mar-16	75	15	0.200
		28-Mar-16	38	4	0.105
		5-Apr-16	66	6	0.091
		11-Apr-16	54	8	0.148
		19-Apr-16	22	0	0.000
		Total	*384*	*59*	*0.154*
	Smolt	26-Apr-16	195	30	0.154
		3-May-16	195	29	0.149
		10-May-16	199	48	0.241
		Total	*589*	*107*	*0.182*
Chum Salmon	Fry	5-Mar-16	325	58	0.178
		21-Mar-16	255	48	0.188
		28-Mar-16	260	44	0.169
		5-Apr-16	265	26	0.098
		11-Apr-16	250	16	0.064
		19-Apr-16	159	13	0.082
		Total	*1,514*	*205*	*0.135*
Coho Salmon	Fry	5-Mar-16	15	0	0.000
		21-Mar-16	56	2	0.036
		28-Mar-16	31	0	0.000
		5-Apr-16	11	0	0.000
		11-Apr-16	38	0	0.000
		19-Apr-16	21	0	0.000
		Total	*172*	*2*	*0.012*
	Smolt	17-May-16	164	37	0.226
		24-May-16	199	54	0.271
		31-May-16	193	42	0.218
		Total	*556*	*133*	*0.239*
Pink Salmon	Fry	5-Mar-16	32	11	0.344
		28-Mar-16	2	0	0.000
		Total	*34*	*11*	*0.324*
Sockeye Salmon	Fry	28-Mar-16	3	0	0.000
		11-Apr-16	6	0	0.000
		Total	*9*	*0*	*0.000*

Table 9. Overall capture efficiency estimates for the mark-recapture study.

Release Species	Total Number of Released Fish	Total Number of Recaptured Fish	Overall Capture Efficiency
Chinook Salmon Fry	384	59	0.154
Chinook Salmon Smolt	589	107	0.182
Chum Salmon Fry	1,514	205	0.135
Coho Salmon Fry	172	2	0.012
Coho Salmon Smolt	556	133	0.239
Pink Salmon Fry	34	11	0.324
Sockeye Salmon Fry	9	0	0.000
Overall Capture Efficiency[1]	3,086	515	0.167

[1] Excludes Coho Salmon fry

3.1.4. Estimates of Salmonid Out-migration

Estimates of RST CPUE by half month (Table 10) and total out-migration (Table 11) of salmon smolts and fry were generated for Elk Canyon. Chum Salmon out-migration was the highest of all salmonid species with an estimated out-migration of 271,301 fry. Coho Salmon out-migration was estimated to be 6,042 fry, 871 age 0+ smolts, and 18 age 1+ smolts. Chinook Salmon out-migration was estimated to be 17,554 fry and 1,819 age 0+ smolts. It is likely these Chinook smolts are all ocean type Chinook. Steelhead/Rainbow Trout out-migration was estimated to be 53 age 0+ fry, 145 age 1+ smolts, and 835 age 2+ smolts. Sockeye and Pink Salmon out-migration was estimated at 884 and 846 fry individuals, respectively.

Table 10. RST catch per-unit-effort (number of fish/day) by half month, salmon species and age class.

Date	Chinook Salmon		Coho Salmon			Steelhead/Rainbow Trout			Chum Salmon	Pink Salmon	Sockeye
	Fry 0+	Smolt 0+	Fry 0+	Smolt 0+	Smolt 1+	0+	1+	2+	Fry 0+	Fry 0+	Salmon Fry 0+
Feb 26-28	11.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	38.0	11.0	1.0
Mar 1-15	66.0	0.0	3.6	0.0	0.0	0.0	0.0	0.1	187.3	12.1	0.0
Mar 16-31	62.4	0.0	39.2	0.0	0.0	0.0	0.0	0.1	1,442.6	3.4	7.9
Apr 1-15	43.5	0.0	18.3	0.0	0.0	0.0	0.0	0.0	694.8	0.3	1.3
Apr 16-30	1.5	0.0	3.5	0.0	0.2	0.0	0.3	0.5	20.7	0.0	0.0
May 1-15	0.0	0.6	0.0	1.1	0.1	0.0	0.1	5.3	0.0	0.0	0.0
May 16-31	0.0	4.8	0.0	1.2	0.0	0.1	0.6	3.1	0.0	0.0	0.0
June 1-15	0.0	12.6	0.0	3.3	0.0	0.2	0.4	0.0	0.0	0.0	0.0
June 16-30	0.0	3.4	0.0	2.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
July 1-15	0.0	0.4	0.0	4.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0
July 16-30	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 11. Estimates of salmonid out-migration from Elk Canyon by salmon species and life stage based on RST catch.

Species	Life Stage	Total Catch (# of fish)	Capture Efficiency	Estimated Outmigration (# of fish)
Chinook Salmon	0+ Fry	1,458	0.154	17,554
	0+ Smolt	191	0.182	1,819
Coho Salmon	0+ Fry[1]	550	0.167	6,042
	0+ Smolt	112	0.239	871
	1+ Smolt	2	0.239	18
Steelhead/ Rainbow Trout	0+ Fry	5	0.167	53
	1+ Parr	13	0.167	145
	2+ Parr	75	0.167	835
Chum Salmon	-	20,201	0.135	271,301
Pink Salmon	-	141	0.324	846
Sockeye Salmon	-	82	0.167	884

[1] The overall capture efficiency of the RST was used to estimate outmigration for Coho and Sockeye Salmon 0+ fry and all age classes of Steelhead/Rainbow Trout.

3.2. Overwintering Assessment

3.2.1. Snorkel Survey Data

Steelhead/Rainbow Trout parr abundance was similar between fall (September) and early spring (February) sampling seasons in Elk Canyon (Figure 19, Table 12, paired t-test: $t_5 = 0.2317$, $p = 0.826$ for abundances calculated based on observer efficiency and $t_5 = -0.3384$, $p = 0.7488$ for abundances calculated based on the Peterson estimator). In total, 95 and 105 Steelhead/Rainbow Trout were observed and marked during day one of snorkel sampling in fall and spring, respectively (Table 12). In fall 2015, 116 Steelhead/Rainbow Trout were observed during the resight sampling, 29 of which were previously marked fish. The site specific observer efficiency ranged from 0.17 to 0.50 with a mean of 0.30. In spring 2016, 109 Steelhead/Rainbow Trout were observed during the resight sampling, 27 of which were previously marked fish. The site specific observer efficiency ranged from 0.17 to 0.33 with a mean of 0.25.

The population density estimates of Steelhead/Rainbow Trout in fall and spring were similar using the observer efficiency method versus the Peterson estimator with Chapman modification (Figure 19). The fall site population density estimates ranged from 3.2 fish/100 m^2 to 7.8 fish/100 m^2 based on the observer efficiency and 2.2 fish/100 m^2 (±0.2 95% CI) to 6.6 fish/100 m^2 (±0.5 95% CI) based on the Peterson estimator. The spring site population density estimates ranged from 2.6 fish/100 m^2 to 8.1 fish/100 m^2 based on the observer efficiency and 1.6 fish/100 m^2 (±0.1 95% CI) to 8.5 fish/100 m^2 (±1.2 95% CI) based on the Peterson estimator.

Very few Coho Salmon parr were observed in either season of sampling in Elk Canyon (Table 13). In total, 35 Coho Salmon were observed in the fall across all sampling sites and only three were observed in the early spring. None of the Coho Salmon were marked and therefore observer efficiencies and estimates of population abundance were not calculated. The low numbers of Coho Salmon parr observed in the overwintering snorkel surveys match predictions from the RST of low out-migration of 1+ Coho (only 18 individuals predicted).

The habitat conditions for the six monitoring sites that were established in Elk Canyon are shown in Table 14. Sampling conditions and sampling effort were comparable between sampling days and seasons.

Table 12. Observed Steelhead/Rainbow Trout parr during overwintering snorkel surveys.

Season	Site	Captures/Observations[1]				Observer Efficiency
		M	C	R	O	
Fall 2015	CBR-NSK01	22	22	5	0	0.23
	CBR-NSK02	18	36	9	0	0.50
	CBR-NSK03	12	11	2	0	0.17
	CBR-NSK04	16	21	4	0	0.25
	CBR-NSK05	11	9	2	0	0.18
	CBR-NSK06	16	17	7	1	0.47
					Average	0.30
					Standard Deviation	0.15
					Standard Error	0.06
Spring 2016	CBR-NSK01	12	11	2	0	0.17
	CBR-NSK02	32	44	9	0	0.28
	CBR-NSK03	15	14	4	0	0.27
	CBR-NSK04	12	13	3	0	0.25
	CBR-NSK05	16	10	3	1	0.20
	CBR-NSK06	18	17	6	0	0.33
					Average	0.25
					Standard Deviation	0.06
					Standard Error	0.02

[1] M = number of marked fish, C = number of observed fish, R = number of tagged fish observed, O = number of tagged fish observed outside of site

Table 13. Observed Coho Salmon during overwintering snorkel surveys. No Coho Salmon were marked.

Date	Season	Site	Captures/ Observations
13-Sep-15	Fall 2015	CBR-NSK01	9
		CBR-NSK02	3
		CBR-NSK03	3
		CBR-NSK04	10
		CBR-NSK05	2
		CBR-NSK06	8
4-Feb-16	Spring 2016	CBR-NSK01	0
		CBR-NSK02	0
		CBR-NSK03	1
		CBR-NSK04	0
		CBR-NSK05	2
		CBR-NSK06	0

Figure 19. Estimated population density of Steelhead/Rainbow Trout parr in fall 2015 and spring 2016. Error bars represent 95% confidence intervals.

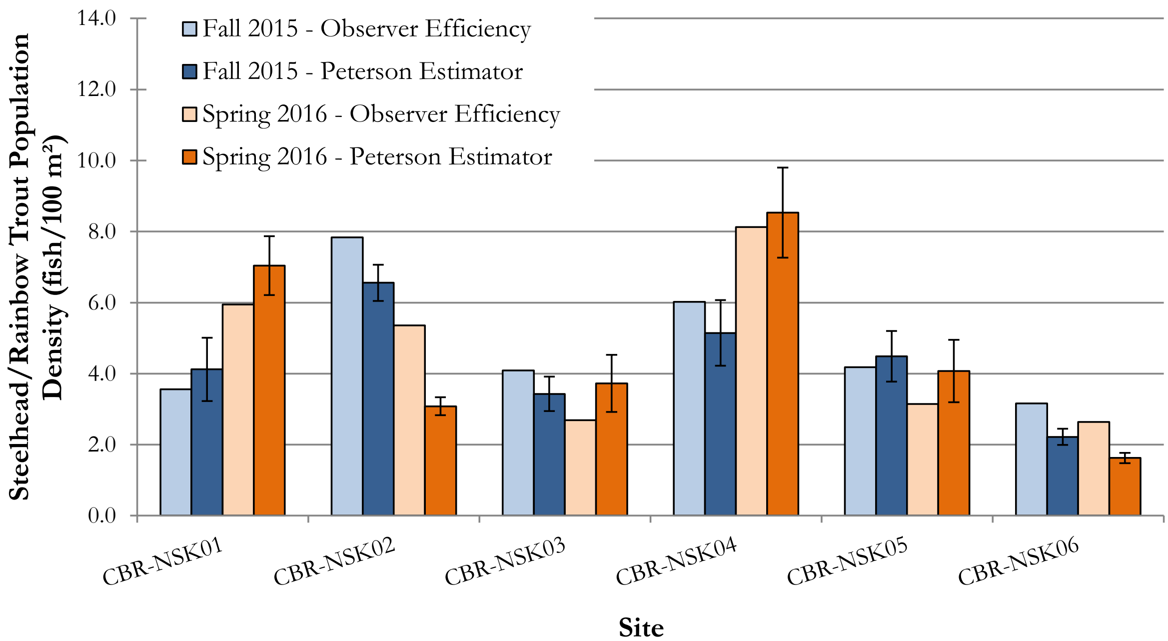


Table 14. Overwintering snorkel site habitat data.

Site	Site Length (m)	Average Wetted Width (± SD) (m)	Site Area (m^2)	Gradient (%)	Max Depth (m)	Cover Type[1]		Substrate Composition (%)[2]						
						Dominant	Sub-Dominant	BR	BO	LC	SC	LG	SG	F
CBR-NSK01	62.0	20.0 ± 3.8	1,238.1	0.5	3.0	BO	DP	10	40	15	5	25	5	0
CBR-NSK02-1	29.9	20.2 ± 2.3	604.9	5.0	1.5	BO	CO	5	50	35	5	5	0	0
CBR-NSK02-2	32.2	16.1 ± 0.4	518.4	6.0	1.5	BO	CO	5	70	20	5	0	0	0
CBR-NSK02-3	35.0	17.7 ± 2.2	619.5	1.0	2.5	BO	DP	20	50	10	10	10	0	0
CBR-NSK02-4	38.6	13.1 ± 0.5	506.8	0.5	2.2	BO	DP	20	60	8	2	10	0	0
CBR-NSK03	75.0	18.3 ± 0.7	1,370.3	2.5	2.0	BO	DP	10	48	20	5	10	5	2
CBR-NSK04	40.6	21.3 ± 1.6	864.8	0.5	2.5	BO	DP	5	60	15	5	10	5	0
CBR-NSK05	46.5	20.6 ± 1.4	957.9	0.5	1.2	BO	CO	5	40	30	10	15	0	0
CBR-NSK06	98.0	22.0 ± 3.6	2,156.0	2.0	2.2	BO	DP	5	60	15	5	10	3	2

[1] BO = Boulder, CO = Cobble, DP = Deep Pools

[2] BR = Bedrock, BO = Boulder, LC = Large Cobble, SC = Small Cobble, LG = Large Gravel, SG = Small Gravel, F = Fines

3.3. Pulse Flow Assessment

3.3.1. Fall Pulse Flow Assessment

The abundance of Coho Salmon, Chinook Salmon, Chum Salmon, Steelhead and Sockeye Salmon in Elk Canyon did not differ the day after the 2-day 7 m^3/s fall pulse release compared to the day prior the pulse release (paired t-tests: all $t_8 < |0.87|$, all p-values > 0.40). The snorkel count of salmon was both higher and lower pre and post pulse release, with no consistent positive trend present for any of the target salmon species (Figure 20). Therefore, based on Year 2 data, the null hypothesis of H_05 of no difference in the number of spawning salmonids following pulse flow release compared to just prior to the release was retained.

The rate of spawning salmonid in-migration per day did not differ between periods of pulse flows (Δsalmon/day$_{pulse\ flow}$) and periods of base flows (Δsalmon/day$_{base\ flow}$) (paired t-tests: all $t_8 < |1.23|$, all p-values > 0.25). The average rate of salmon in-migration per day was near zero for all species and was similar to the average rate of salmon in-migration per day during base flows, which acts as the control (Figure 21). Therefore, based on Year 2 data, the null hypothesis of H_03 of no difference in the rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation compared to during base flow operation was retained.

There were several salmon counts that provide some evidence that the pulse flow release was a success. During week 1 (September 16-17 pulse), the count of Coho Salmon, Sockeye Salmon and Steelhead increased post pulse release (Figure 20). Coho Salmon abundance in Elk Canyon gradually increased through the fall of 2015, with a peak occurring at the beginning of November. A significant proportion of later component of the Coho Salmon run entered Elk Canyon during the November 11-12 pulse release.

Figure 20. Fall salmon count in Elk Canyon pre and post the 2-day 7 m^3/s pulse release on Wednesday and Thursday of each week from September 14 to November 15 2015. Target species include A) Coho Salmon, B) Chinook Salmon, C) Chum Salmon, D) Steelhead and E) Sockeye Salmon.

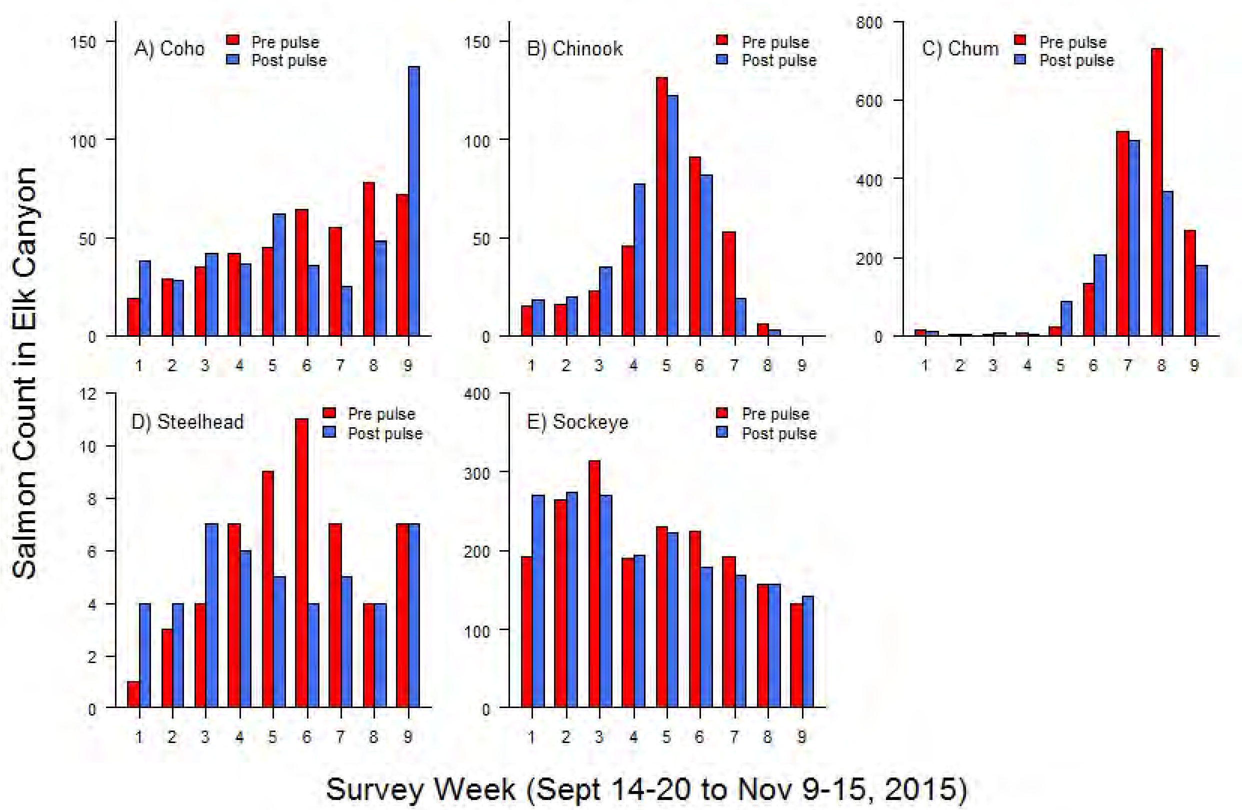
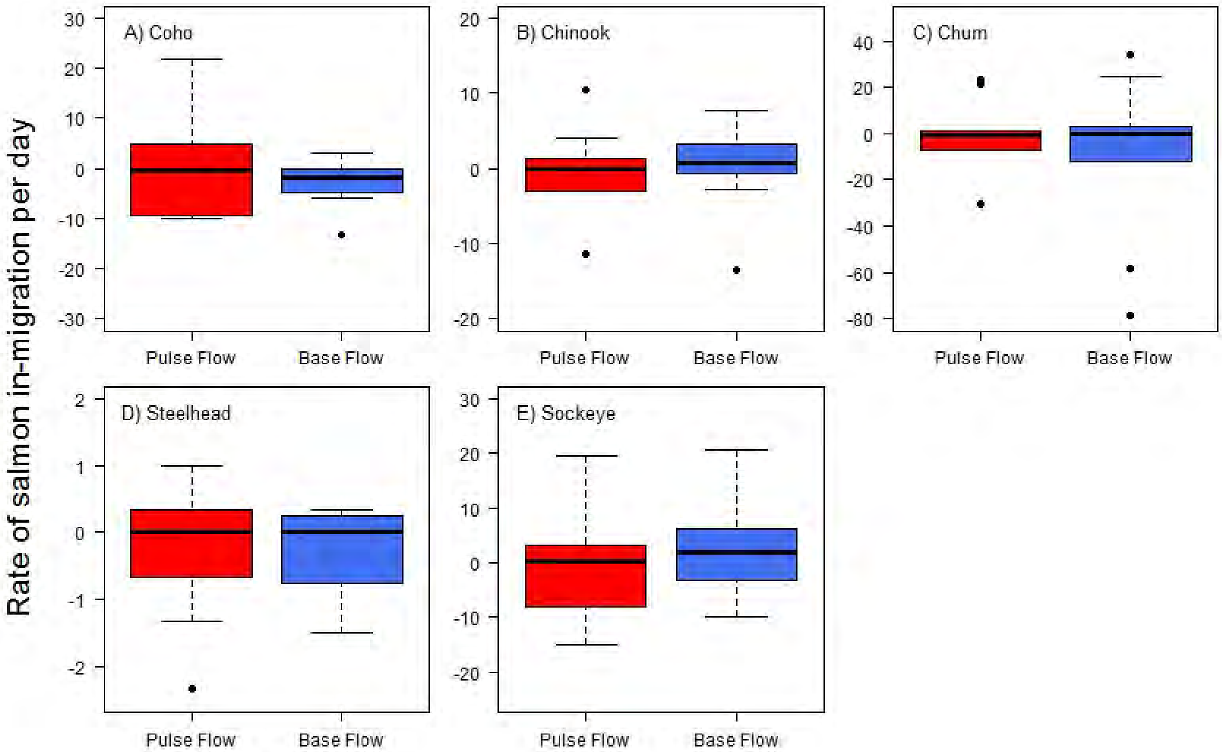


Figure 21. Rate of salmon in-migration per day during the pulse flow release and during base flows for A) Coho Salmon, B) Chinook Salmon, C) Chum Salmon, D) Steelhead and E) Sockeye Salmon. Boxplots show the median (solid line) of the nine tests, the middle 50% of the data (box), the outer quartiles (whiskers), and outliers (solid points).



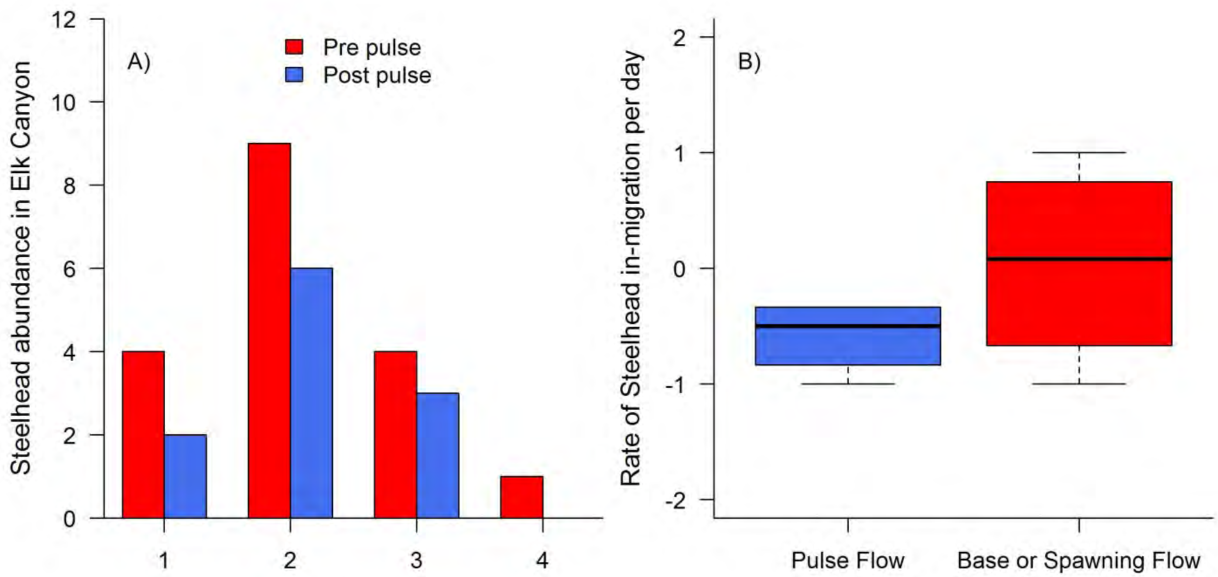
3.3.2. Spring Pulse Flow Assessment

The count of Steelhead in Elk Canyon was lower the day after the 2-day 10 m^3/s spring pulse releases compared to the day prior to the pulse releases (paired t-test: $t_3 = 3.66$, p-value = 0.035). All four counts of Steelhead immediately after the spring pulse release were lower than the day prior to the pulse release although counts of Steelhead were low (maximum = 9) (Figure 22A). Based on Year 2 data, the null hypothesis of H_05 of no difference in the number of spawning salmonids following pulse flow release compared to just prior to the release was rejected. However, these preliminary data suggest that the pulse release may cause Steelhead to leave Elk Canyon during the spring period instead of attracting fish into the canyon.

The rate of Steelhead in-migration per day did not differ between periods of pulse flows ($\Delta salmon/day_{pulse\ flow}$) and periods of base/spawning flows ($\Delta salmon/day_{base\ flow}$) (paired t-test: $t_3 = -1.35$, p-value = 0.27). The average rate of Steelhead in-migration during the pulse was between 0 and -1 fish per day, which was similar to the average rate of in-migration during base/spawning flows, which acts as the control (Figure 22B). Therefore, based on Year 2 data, the null hypothesis of $H_0 3$ of no difference in the rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation compared to during base flow operation was retained.

At present there is no evidence to suggest that spring pulse flows attract Steelhead into Elk Canyon.

Figure 22. Spring pulse flow assessment: A) Steelhead count in Elk Canyon pre and post the 2-day 10 m^3/s pulse; and B) Rate of Steelhead in-migration per day during the pulse flow release and during base/spawning flows in Elk Canyon.



3.4. Steelhead Spawning Flow Assessment

The abundance of Steelhead in Elk Canyon was higher prior to the two-week spawning flow release than during the flow release (independent t-test: $t=3.3$, $p=0.047$). The count of adult Steelhead decreased steadily from nine to four individuals prior to the spawning flow release, and remained at or below three individuals during the spawning flow release (Table 15). Therefore, based on Year 2 data, the null hypothesis of $H_0 6$ of no difference in the number of spawning Steelhead during the two-week spawning release period compared to just prior to the release was rejected. However, the direction of the effect is opposite to what was predicted. Further years are required to confirm this result as this assessment is challenged by the small numbers of Steelhead individuals that spawn in Elk Canyon.

Table 15. Counts of Adult Steelhead prior to and during the spawning flow release.

Spawning Flow Condition	Date	Count of Adult Steelhead
Pre Spawning Flow Release	22-Mar-16	9
	25-Mar-16	6
	29-Mar-16	4
	Average	*6.3*
During Spawning Flow Release	1-Apr-16	3
	4-Apr-16	0
	12-Apr-16	1
	15-Apr-16	0
	Average	*1.0*

3.5. Spawner Enumeration

3.5.1. Fall Spawners

Chinook and Coho Salmon adult abundance were estimated to be 241 and 408 individuals, respectively, using the area under the curve method (Table 16). Pink Salmon had the highest estimated abundance of 6,589 individuals. A population of 953 Chum Salmon and 1,149 Sockeye Salmon were also estimated (Table 16). Few Steelhead were observed in fall and an abundance of 11 Steelhead was estimated based on maximum observed fish.

The peak spawning time was variable across salmon species. Pink Salmon had the earliest peak and appeared to have hit peak spawning shortly after surveys began in mid-September during the second 2-day pulse release (September 23 and 24) (Figure 23). Sockeye Salmon had the next peak in counts, which was observed in late September; however the peak was not as clear as other species (Figure 24). Chinook Salmon had a peak in mid-October during the fifth 2-day pulse release (October 14 and 15) (Figure 24). Finally, Chum Salmon had a peak in spawning in late October/early November during the eighth 2-day pulse release (November 4 and 5) (Figure 24), while Coho Salmon had the latest peak in mid-November after the final 2-day pulse release on November 11 and 12 (Figure 24). A maximum of 11 Steelhead were observed in mid-October between the fourth and fifth 2-day pulse release (Figure 25).

Not all observed adults spawned in Elk Canyon. The number of redds was also recorded during the fall spawner surveys (Table 17). The maximum number observed of redds varied across species, where Pink Salmon had the highest number of 484 redds, followed by Chum Salmon with 160 redds, Sockeye Salmon with 48 redds, Chinook Salmon with 14 redds, and finally Coho Salmon with 12 redds. No Steelhead redds were observed.

3.5.1.1. Productivity of Fall Salmon Spawners

Salmon fry and smolt production from Elk Canyon was estimated based on the fall 2015 redd counts (Table 18). These estimates were compared to the 2016 out-migration predicted from RST catch. Based on the mean fecundity by salmon species and the maximum number of redds observed for each species, Pink Salmon had the greatest number of estimated eggs produced with 871,200. After correcting for egg-to-fry and egg-to-smolt survival, the estimated fry and smolt production from redd counts was greater than the out-migration estimate derived from RST catch, with the exception of Chum Salmon. The largest differences between the redd and RST out-migration estimates were for Chum Salmon and Pink Salmon (Table 18). Chum Salmon out-migration was estimated to be ~270,000 fish but only ~66,000 fry were estimated to be produced based on the maximum number of redds observed. An opposite result was found for Pink Salmon where Pink out-migration was estimated to be 846 fish but ~100,200 fry were estimated to be produced based on the maximum number of redds observed.

These differences in production estimates derived from redd surveys and RST catch could be attributed to multiple factors, including our coarse estimates of fecundity and survival by species. The large difference in estimates between Chum and Pink Salmon suggests that Pink Salmon have very low egg-to-fry survival in Elk Canyon. One possible explanation is redd superimposition, where redds constructed from early spawners are superimposed by later spawners. Redd superimposition by Chum Salmon over Pink Salmon redds has been repeatedly demonstrated in other systems, and can be a cause for substantial egg loss for Pink Salmon (Fukushima *et al.* 1998).

3.5.2. Spring Spawners

Steelhead abundance in Elk Canyon peaked at a maximum count of nine individuals in mid-March (Table 17). Steelhead counts declined in April to a maximum of two individuals. Due to the few adults observed, area under the curve method was not used to estimate total abundance. No Steelhead redds were observed during this period.

Table 16. Fall adult salmon counts by species and estimates of abundance.

Date	Count of Fish Species[1]					
	ST	CH	CM	CO	PK	SK
9-Sep-15	2	10	17	8	3,367	100
15-Sep-15	1	15	16	19	3,140	192
19-Sep-15	4	18	12	38	4,205	270
22-Sep-15	3	16	3	29	4,645	264
25-Sep-15	4	20	4	28	3,957	274
29-Sep-15	4	23	5	35	2,100	314
2-Oct-15	7	35	9	42	1,915	271
6-Oct-15	7	46	7	42	519	189
9-Oct-15	6	77	5	37	164	193
13-Oct-15	9	131	21	45	18	230
16-Oct-15	5	122	86	62	0	223
20-Oct-15	11	91	135	64	2	224
23-Oct-15	4	82	205	36	0	179
27-Oct-15	7	53	519	55	1	192
30-Oct-15	5	19	497	25	0	168
3-Nov-15	4	6	731	78	0	157
6-Nov-15	4	3	368	48	0	158
10-Nov-15	7	0	269	72	0	133
13-Nov-15	7	0	178	137	0	143
16-Nov-15	6	1	75	132	0	124
25-Nov-15	5	0	11	88	0	59
Abundance Estimate[2]	**11**	**241**	**953**	**408**	**6,589**	**1,149**

[1] ST = Steelhead, CH = Chinook, CM = Chum Salmon, CO = Coho Salmon, PK = Pink Salmon, and SK = Sockeye Salmon

[2] Abundance estimate of salmon species are based on an area under the curve analysis while the abundance estimate of trout species are based on maximum observed fish.

Figure 23. Adult Pink Salmon counts in Elk Canyon by date.

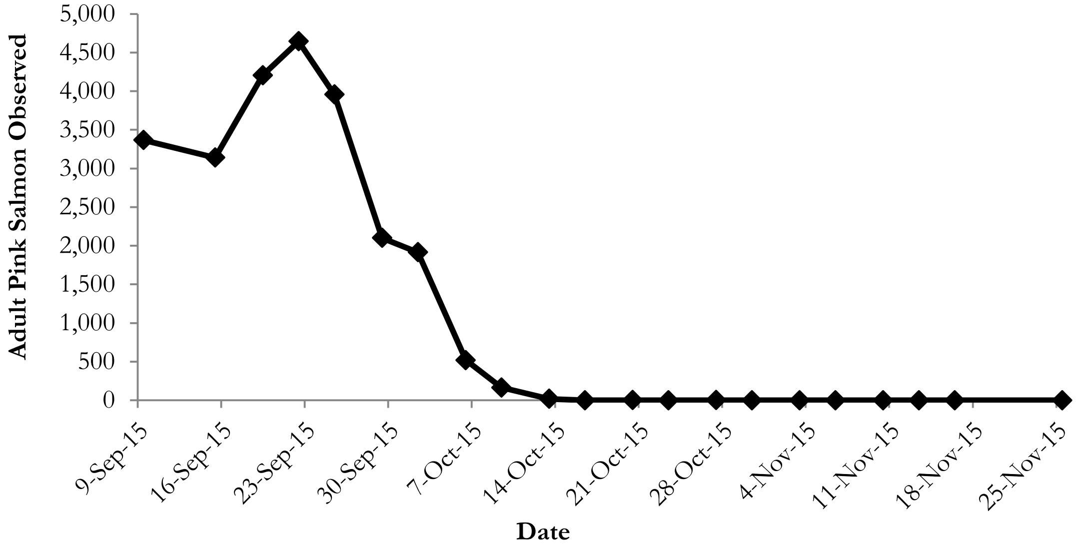


Figure 24. Adult Chinook, Coho, Chum, and Sockeye Salmon counts in Elk Canyon by date.

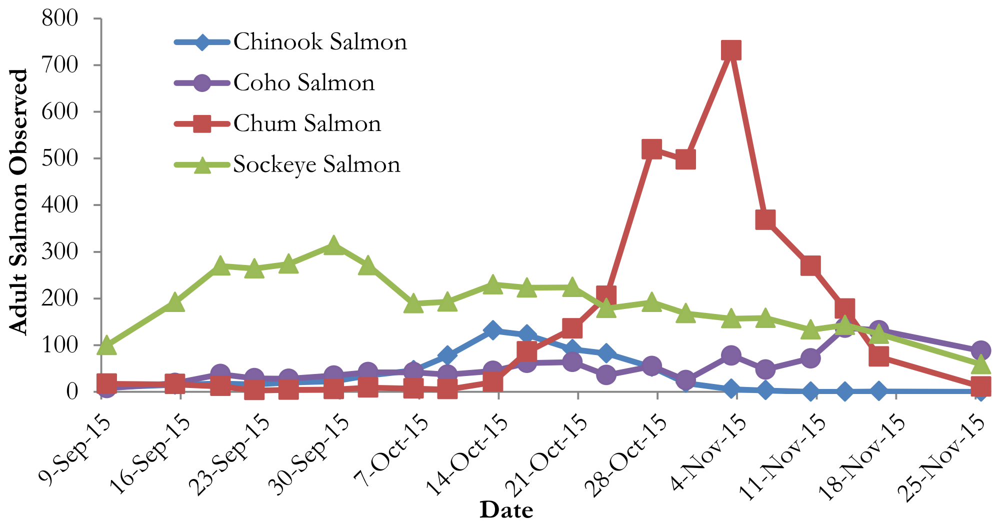


Figure 25. Adult Steelhead counts in Elk Canyon by date.

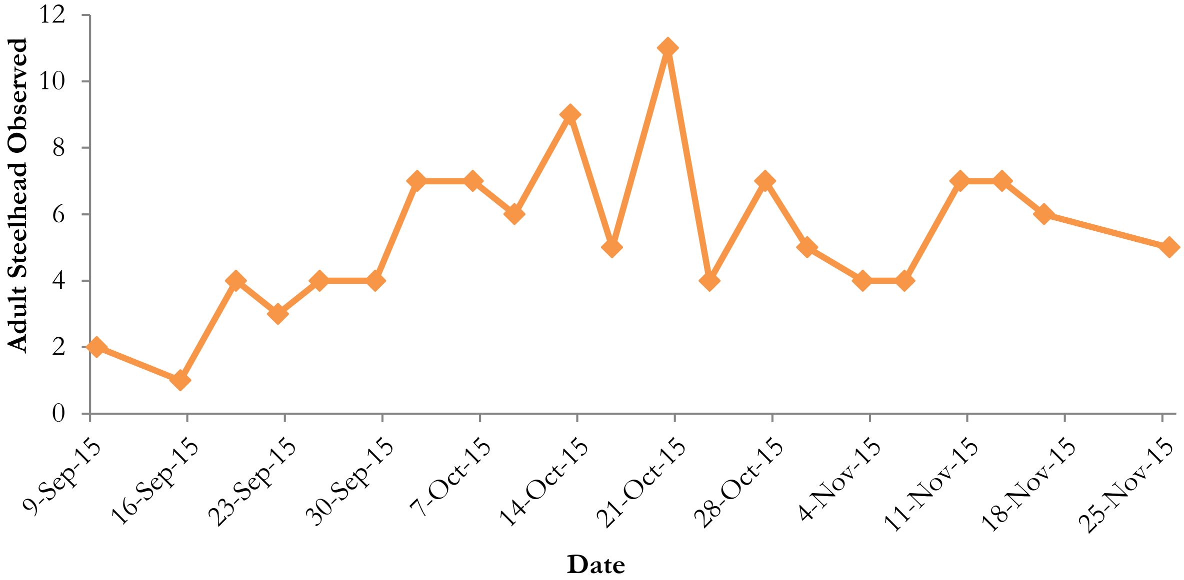


Table 17. Fall counts of salmon redds by species.

Date	Count of Fish Redds[1]					
	ST	**CH**	**CM**	**CO**	**PK**	**SK**
9-Sep-15	0	0	0	0	15	0
15-Sep-15	0	0	0	0	326	0
19-Sep-15	0	0	0	0	283	0
22-Sep-15	0	0	0	0	298	0
25-Sep-15	0	0	0	0	484	7
29-Sep-15	0	0	0	0	420	20
2-Oct-15	0	0	0	0	422	42
6-Oct-15	0	0	0	0	207	48
9-Oct-15	0	0	0	0	222	25
13-Oct-15	0	5	0	0	30	30
16-Oct-15	0	14	13	0	0	37
20-Oct-15	0	14	27	0	0	26
23-Oct-15	0	9	41	0	0	20
27-Oct-15	0	7	145	0	0	17
30-Oct-15	0	0	103	0	0	10
3-Nov-15	0	0	160	1	0	10
6-Nov-15	0	0	73	0	0	8
10-Nov-15	0	0	67	2	0	10
13-Nov-15	0	0	43	3	0	2
16-Nov-15	0	0	3	5	0	9
25-Nov-15	0	0	0	12	0	7
Max Observed	**0**	**14**	**160**	**12**	**484**	**48**

[1] ST = Steelhead, CH = Chinook Salmon, CM = Chum Salmon, CO = Coho Salmon, CT = Cutthroat Trout, PK = Pink Salmon, SK = Sockeye Salmon

Table 18. Comparisons of estimated production from Elk Canyon derived from redd counts and RST catch.

Species	Mean Fecundity[1]	Max Redds Observed	Total Estimated Eggs	Egg-Fry Survival[2]	Egg-Smolt Survival[2]	Estimated Redd Production[3]		Estimated Outmigration[4]	
						Fry	Smolt	Fry[5]	Smolt[6]
Pink	1,800	484	871,200	0.12		100,188		846	
Chum	3,200	160	512,000	0.13		66,048		271,301	
Sockeye	3,500	48	168,000	0.13		21,336		884	
Coho	3,000	12	36,000	0.25	0.17	9,108	5,940	6,042	889
Chinook	4,300	14	60,200	0.38	0.10	22,876	6,080	17,554	1,819

[1] Information from Bradford (1995).

[2] Information from Quinn (2005).

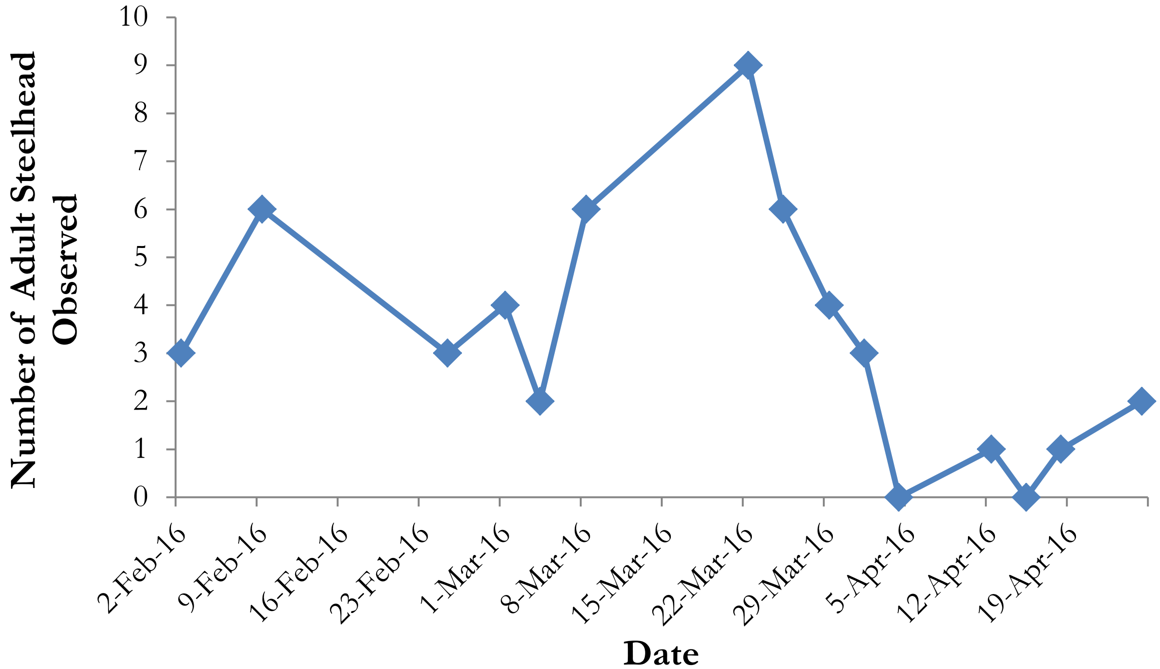
[3] Estimated redd production based on the total estimated eggs and literature survival rates.

[4] Estimated outmigration of fish based on the RST sampling results.

[5] Sockeye Salmon fry RST outmigration estimates are based on overall Capture efficiency of all species combined as no Sockeye Salmon fry were recaptured.

[6] Coho smolt RST outmigration estimates are based on the sum of the 0+ and 1+ smolt outmigration estimates.

Figure 26. Steelhead adult counts during the spring spawner survey.



4. CONCLUSIONS

4.1. Overview

All BC coast salmonid species were observed using Elk Canyon for spawning and/or rearing during the Year 2 of sampling of the JHTMON-15 program. Although many of these species occurred in low abundance, this nevertheless indicates that habitats in Elk Canyon are used by a diversity of salmon and trout.

The first management question of JHTMON-15 centres on the base flow of 4 m^3/s in Elk Canyon and whether it is sufficient to provide juvenile rearing habitat to near maximum values. At present, the base flows of 4 m^3/s are fixed by the WUP as a single treatment for 10 years, with no experimental comparisons to other base flows. This limits the ability of the study to test the efficacy of different flow prescriptions. A TOR revision was conducted in summer 2015 and the Instream Flow Study component was added. The Instream Flow Study will be conducted in Year 3 and will address management question one of the TOR in terms of habitat availability. The smolt and adult spawner enumeration work will provide important measures of fish productivity that will allow informed discussions of the benefits of the WUP operations, and will establish a fish productivity reference point for these discussions.

The following sections highlight the main conclusions for each component of the study conducted in Year 2.

4.2. Smolt Enumeration

The RST worked well during its second year and remains a viable technique for enumerating juvenile fish that are out-migrating from Elk Canyon. All salmonid species recruited from Elk Canyon in Year 2 of the program with Chum Salmon having the highest outmigration.

Mark/recapture trials had an overall recapture efficiency of 16.7% across all salmon species and life stages, which is similar to the average recapture efficiency from Year 1 of 20.8%. These capture efficiencies exclude Coho Salmon fry that had recapture efficiencies of 2.5% in Year 1 and 1.2% in Year 2. The fact that the Coho Salmon fry capture efficiencies were very low in both years indicates that most Coho Salmon fry released upstream do not immediately re-emigrate from Elk Canyon. Trial capture efficiencies were variable for all species and life stages, which may reflect instream flow and/or trap position during the trial.

Out-migration timing information by life stage is evident within and across species from the RST data. For example, several life history stages of Chinook Salmon, Coho Salmon and Rainbow Trout/Steelhead were captured in the RST. All of the Chinook Salmon that were caught in the RST are likely to be 0+ fish, which indicates that they are exclusively 'ocean type', meaning that they rear for a few months in freshwater and then migrate to the estuary to continue rearing. However, two peaks in Chinook out-migration were observed, an early peak in March of Chinook fry that may rear lower down in the Campbell River system, and a later peak in June of larger individuals that have likely reared for a few months in Elk Canyon. This last statement assumes that Chinook fry >70 mm that originate from the Quinsam Hatchery or from natural populations downstream of Elk Canyon do not swim upstream in later spring and get caught in the RST. Three Coho Salmon life history strategies were evident including an early migration of Coho fry in March and April, a later migration of larger 0+ Coho smolts from May through July, and a small cohort of 1+ smolts. Three age classes of Steelhead/Rainbow Trout were identified in the RST catch, including 0+, 1+ and 2+ fish. A main peak in out-migration of age 2+ Steelhead/Rainbow Trout parr was observed in May. A smaller out-migration of 1+ parr occurred in May, June and July. Steelhead/Rainbow Trout fry were also caught in the RST in May, June and July.

Based on the catch results of the target fish species, it remains appropriate for the RST sampling period to remain open until the end of July to ensure that the Coho and Chinook Salmon and Steelhead/Rainbow Trout out-migration peaks are captured. In Year 2, a clear second peak in out-migration was observed for Chinook in June, steady but low out-migration of Coho throughout May, June, and July, and outmigration of various Steelhead/Rainbow Trout life stages in May, June and July.

4.3. Overwintering Assessment

The overwintering assessment component of JHTMON-15 is designed to test if juvenile fish rear for their entire life history in Elk Canyon or if a significant proportion of the population consists of immigrant juveniles. Night snorkeling mark/resight methods were adopted for the first time in Year

2 and these were successful at determining Steelhead/Rainbow Trout parr densities in six standardized sites in both fall and early spring.

Steelhead/Rainbow Trout parr density was similar between fall (September) and early spring (February) sampling seasons in Elk Canyon. Therefore hypothesis $H_0 2$ for Steelhead/Rainbow Trout parr is not rejected, which suggests that the majority of the population of Steelhead/Rainbow Trout is resident in the canyon during the winter months with little immigration or emigration during this period.

Very few Coho Salmon were observed during the fall and spring marking swims so observer efficiencies could not be effectively calculated for Coho parr. These low numbers of observed Coho Salmon parr match the observations from the RST catch, which estimated a total of 18 out-migrating 1+ Coho Salmon smolts from Elk Canyon in spring 2016.

4.4. Pulse Flow Assessment

This was the first year that fall and spring pulse flow assessments were conducted. The snorkel survey methods for these components of the monitor were a success and should be continued in future years.

The abundance of Coho Salmon, Chinook Salmon, Chum Salmon, Sockeye Salmon and Steelhead in Elk Canyon did not differ the day after the 2-day 7 m^3/s fall pulse releases compared to the day prior the pulse releases. Therefore, based on Year 2 data, we did not reject the null hypothesis of $H_0 5$ of no difference in the number of spawning salmonids following pulse flow release compared to just prior to the release.

The rate of spawning salmonid in-migration per day also did not differ between periods of pulse flows and periods of base flows for all fall spawning species. Therefore, based on Year 2 data, the null hypothesis of $H_0 3$ of no difference in the rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation compared to during base flow operation was also retained.

On average, there was no effect of the fall pulse releases across all of the pulses. However, there were several salmon counts that provide some evidence that the pulse flow releases were a success. During week 1 (September 16-17 pulse), the count of Coho Salmon, Sockeye Salmon and Steelhead increased post pulse release. Additionally, a large proportion of the later component of the Coho Salmon run entered Elk Canyon during the November 11-12 pulse.

The count of Steelhead in Elk Canyon was lower the day after the 2-day 10 m^3/s spring pulse releases compared to the day prior to the pulse releases. Based on Year 2 data, the null hypothesis of $H_0 5$ of no difference in the number of spawning salmonids following pulse flow release compared to just prior to the release was rejected. These preliminary data suggest that the pulse release may cause Steelhead to leave Elk Canyon during the spring period instead of attracting fish into the canyon.

The rate of Steelhead in-migration per day did not differ between periods of pulse flows and periods of base/spawning flows. The average rate of Steelhead in-migration during the pulse was between 0 and -1 fish per day, which was similar to the average rate of in-migration during base/spawning flows, which acts as the control. Therefore, based on Year 2 data, the null hypothesis of H_03 of no difference in the rate of spawning salmonid in-migration (No./day) during the 2-day pulse flow release operation compared to during base flow operation was retained. At present there is no evidence to suggest that spring pulse flows attract Steelhead into Elk Canyon.

These conclusions should be considered preliminary until two more years of pulse flow assessments are completed, including a synthesis analysis across all years.

4.5. Steelhead Spawning Flow Assessment

The abundance of Steelhead in Elk Canyon was significantly higher prior to the two-week spawning flow release than during the release, which is opposite to what was predicted. However, the relatively low numbers of Steelhead that spawn in Elk Canyon in the spring limit the effectiveness of this test. Another confounding factor is the spring safety spills and blasting spills that resulted in up to 95 m^3/s of discharge through Elk Canyon for several days at a time (Figure 1). The large fluctuations in flows in February, March and April have relatively unknown consequences for Steelhead migration and spawning. Overall, at least two more years of assessment are required to confirm observations from 2016.

4.6. Spawner Enumeration

Snorkel surveys are an appropriate method to enumerate adult fish in Elk Canyon. Adults of all target species were observed in Elk Canyon. Overall, Pink Salmon had the highest estimated abundance and Steelhead observations were very low. Redds were also observed for all species with the exception of Steelhead.

The peak spawning time was variable across salmon species. Pink Salmon spawned the earliest peaking in mid-September, followed consecutively by Sockeye Salmon, Chinook Salmon and Chum Salmon. Coho Salmon spawned the latest and had a peak in mid-November.

The estimated production of salmon fry and smolts from counts of redds was compared to estimates of salmon out-migration determined from RST catch. Production estimates were comparable for Coho and Chinook Salmon fry. It appears that there was very low egg-to-fry survival for Pink Salmon. One possible explanation is redd superimposition by the later spawning Chum Salmon over Pink Salmon redds.

5. CONSIDERATIONS FOR YEAR 3

The following represents a summary of considerations for Year 3.

5.1. Smolt Enumeration Component

1. The RST is an effective method to inventory juvenile salmonids (fry and smolts) that are migrating out of Elk Canyon. Due to high catches of wild fry in the RST, the mark-recapture experiment was expanded in Year 2 to include wild Coho, Chum, Pink, and Sockeye fry in addition to Quinsam hatchery Chinook and Coho smolts. These experiments should be continued with wild fry if sufficient catches are observed in Year 3. A synthesis analysis should be conducted in Year 5 when the sample size is higher to integrate flow conditions (e.g., base flows versus pulse flows) and RST trap position into the estimates of recapture efficiency.
2. In the mark-recapture experiment, the first Chinook Salmon smolt release was marked with Bismark Brown. The next two smolt releases were marked with fin clips. The initial Bismark release faded quickly causing some potential confusion between wild/hatchery Chinook caught in the period after that release. Fin clip marks should therefore be used for all subsequent Chinook parr mark recapture experiments.
3. The RST was effective at demonstrating run timing of out-migrating fry and smolts, including multiple age classes of Coho Salmon and Steelhead/Rainbow Trout. In Year 3, an increased sample size of Steelhead/Rainbow Trout age samples should be considered (20 to 30 individuals) across the full sampling period to more effectively identify the age breaks for Steelhead/Rainbow Trout. If larger Coho Salmon are caught they could also be aged to confirm the 1+ age breaks.
4. There is some uncertainty as to the origin of Chinook and Coho Salmon smolts that are being caught in the RST in May and June. For example, it is unknown if any of the smolts released from Quinsam Hatchery swim up the Campbell River after their release and end up in the RST. It is recommended that calibration snorkel swims be conducted in late April in Year 3 in the six established survey sites from the overwintering assessment to confirm the size and density of age 0+ Chinook and Coho in the Elk Canyon and to calibrate the RST out-migration data. The hatchery fish also have a thermal mark that can be viewed through analyses of their otoliths. Otolith analyses should also be conducted on a subset of Chinook and Coho individuals >70 mm in length that are caught in the RST to confirm their origin.

5.2. Overwintering Assessment Component

1. The night snorkeling mark/resight methods worked well in Year 2 and were used to test $H_0 2$ of the TOR for Steelhead/Rainbow Trout. Roughly equal numbers of Steelhead/Rainbow Trout were observed in Elk Canyon in the fall and the early spring, which means that there is little evidence for net immigration or net emigration to or from Elk Canyon during this period. Very few Coho Salmon were observed during the fall and spring marking swims, so observer efficiencies could not be calculated for Coho parr. These low numbers of observed Coho Salmon parr match the observations from the RST, which estimated a total of 18 out-

migrating 1+ Coho Salmon smolts from Elk Canyon in spring 2016. The mark/resight methods should be continued in Year 3 and attempts should be made to mark and resight Coho Salmon parr if sufficient densities are observed.

5.3. Pulse Flow Assessment Component

1. Year 2 was the first year that pulse flow assessments were conducted. Snorkel surveys were successful in testing $H_0$3 and $H_0$5 of the TOR, although two more years are required to confirm results from Year 2. After Year 4 surveys, a synthesis analysis across years should be conducted to provide a three-year baseline assessment of the effectiveness of the current pulse flow prescription for Elk Canyon.

5.4. Steelhead Spawning Flow Component

1. Year 2 was the first year that spawning flow assessments were conducted. Snorkel surveys were successful in testing $H_0$6 of the TOR, although no Steelhead redds were observed, which prevented a test of $H_0$7 and $H_0$8. After Year 4 surveys, a synthesis analysis across years will be conducted that will provide a three-year baseline assessment of the effectiveness of the spawning flow prescription for Elk Canyon.

5.5. Spawner Enumeration Component

1. Adult Steelhead and Chinook, Chum, Coho, Pink and Sockeye Salmon were all observed in Elk Canyon; Chinook, Chum, Coho, Pink and Sockeye redds were also counted. Year 2 was the first year that estimates of production derived from RST catch were compared to estimates of production predicted from redd counts by species. This was a useful addition to the analysis that should be continued in Year 3. Snorkel surveys of adult spawners in the fall should be used to estimate redd superimposition to support these analyses.

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PROJECT MAPS

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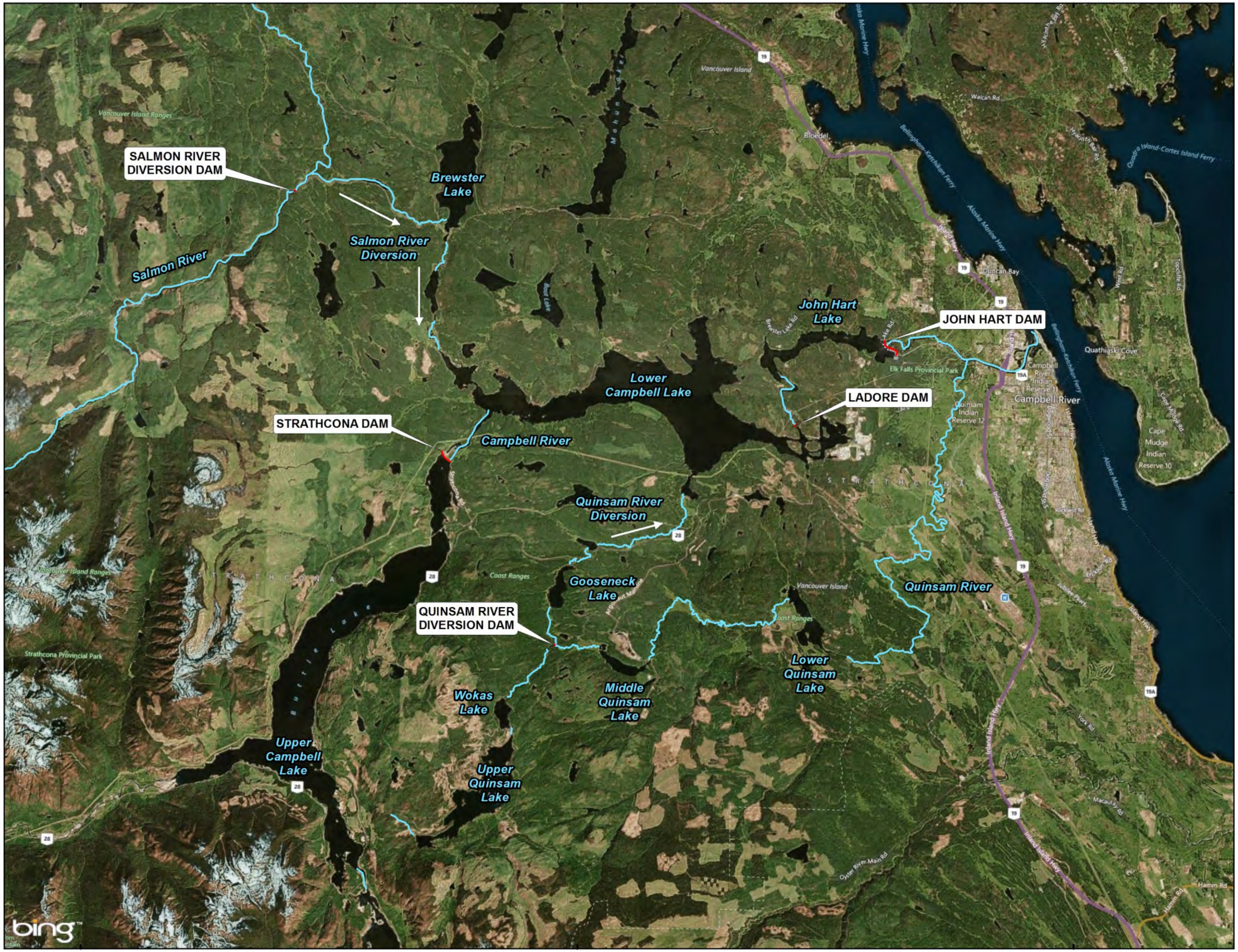

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JHTMON Campbell River Water Use Plan

BC Hydro
Campbell River Facilities

Legend

- Dam
- Stream

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 0.5 1 2 3 4 5 km

Scale: 1:150,000

NO.	DATE	REVISION	BY
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2			
3			
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Date Saved: 2/24/2015
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 1

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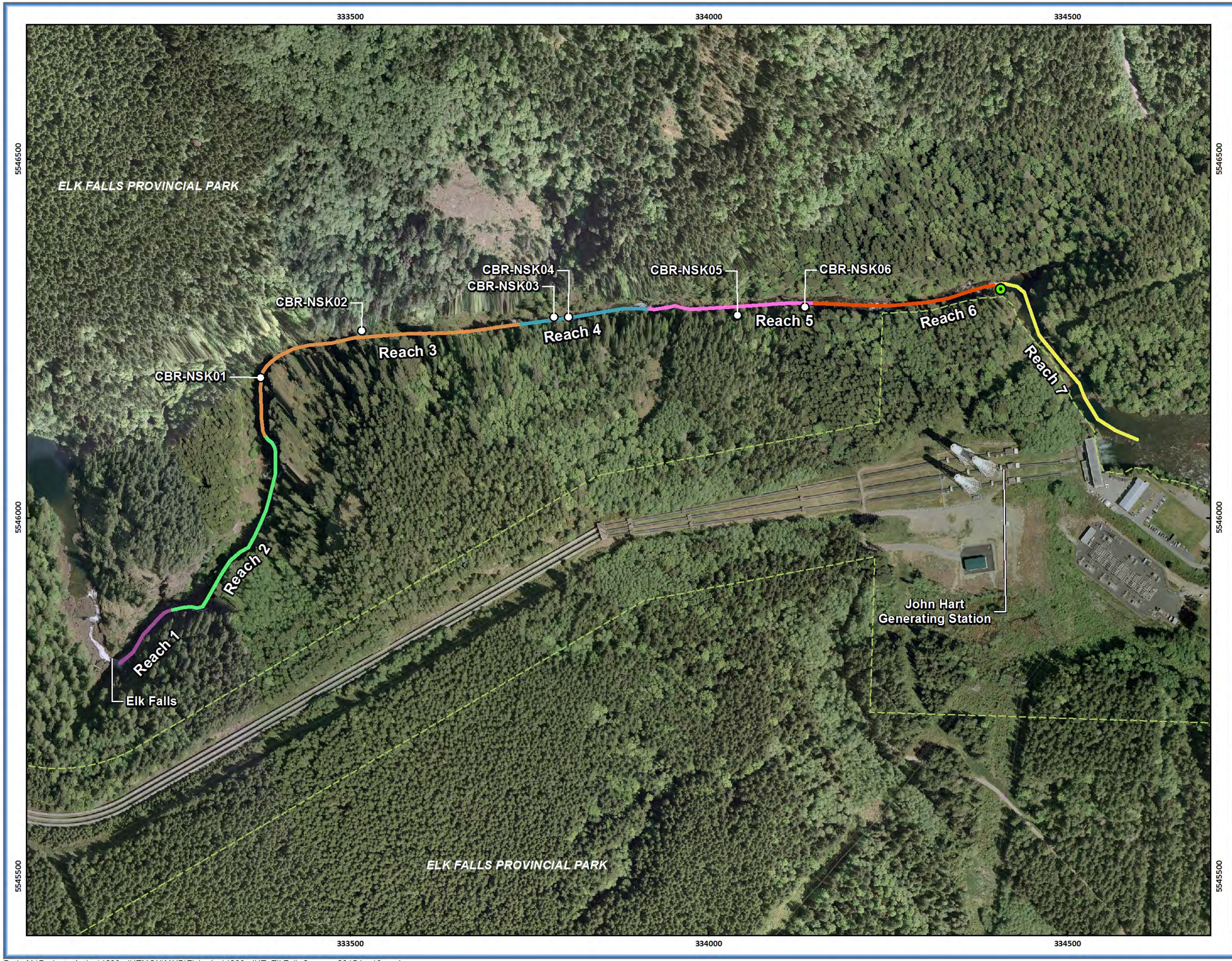
JHTMON Campbell River Water Use Plan

Elk Falls Canyon



Legend

- Overwintering Night Snorkel Sites
- Rotary Screw Trap

Canyon Snorkel Reach Breaks

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6
- Reach 7

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 50 100 200 m

Scale: 1:5,000

NO.	DATE	REVISION	BY
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ECOFISH RESEARCH

Map 2

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