Campbell River Project Water Use Plan

JHTMON-15 Elk Canyon Smolt and Spawner Abundance Assessment

Implementation Year 3

Reference: JHTMON-15

JHTMON-15 Year 3 Monitoring Report

Study Period: 2016

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

October 22, 2018

JHTMON-15: Smolt and Spawner Abundance Assessment

Year 3 Annual Monitoring Report




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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. This report presents Year 3 of monitoring in Elk Canyon, which includes the third year of adult spawning enumeration, the third year of RST smolt enumeration, the third year of the overwintering assessment, and the second year of the pulse flow and spawning flow assessments. In Year 3, an Instream Flow Study (IFS) was also undertaken to determine the amount of available habitat for salmon rearing and spawning at different flows. The IFS results will be presented in a separate report to BC Hydro.

A broad diversity of fish species, including all BC coast salmonids, were observed using Elk Canyon for spawning and/or rearing during the third year of sampling (2016-2017) of the JHTMON-15 program. Although many of these species occur in low abundance, this corroborates the same findings in years 1 and 2 of sampling, indicating that habitats in Elk Canyon are used by a diversity of salmon and trout. This includes the key species Chinook Salmon, Coho Salmon and Steelhead.

The RST was in operation from the end of February to the end of July, 2017. In total, captures in Year 3 of sampling were far lower than in Year 2, with only 3,738 fish captured in the RST, which is roughly 15.5 % of the catch in 2016 (24,009). As in Year 2, the catches were primarily composed of Chum Salmon (74.5%), Chinook Salmon (6.2%), sculpin spp. (13.2%) and Coho Salmon (2.0%). Steelhead/Rainbow Trout, Sockeye Salmon and Pink Salmon catches were the rarest catches at only 0.8%, 0.5% and 0.05% of the total, respectively. The combined catch of all salmonids accounted for 85.7% of the total catch while the key target species - Chinook Salmon, Coho Salmon, and Steelhead/Rainbow Trout - accounted for 8.9% of the total catch.

Total salmonid out-migration by species was estimated by standardizing the RST catch by the capture efficiency of the RST, which was determined from mark recapture experiments. As in Year 2, Chum Salmon out-migration was the highest of all salmonid species, with an estimated total out-migration of 29,997 fry. Coho Salmon total out-migration was estimated to be 121 fry and 446 age 0+ smolts, and zero age 1+ smolts. Chinook Salmon total out-migration was estimated to be 199 fry and 1,823 age 0+ smolts. Steelhead/Rainbow Trout out-migration was estimated to be 28 age

0+ fry, 72 age 1+ parr, 74 age 2+ parr, and 54 ≥3+ smolts. Pink Salmon and Sockeye Salmon total out-migration was estimated at only 15 and 133 fry, respectively.

Estimated salmonid out-migration was considerably lower than in 2016 with Chum, Coho, Chinook, Pink, and Sockeye Salmon fry out-migrations estimated to be only 8%, 2%, 1%, 2%, and 16%, respectively of those in 2016. In contrast, Steelhead/Rainbow Trout fry out-migration was estimated to be 53% lower than in 2016. Differences in out-migration estimates between years were less pronounced for Coho Salmon and Chinook Salmon smolts and Steelhead/Rainbow Trout parr. Estimated out-migration for Coho 0+ smolts in 2017 was 51% lower than in 2016, while 0+ Chinook Salmon smolt out-migrations were very similar between the two years. Similarly, Steelhead/Rainbow Trout parr out-migration estimates were 50%, and 9% of those in 2016 for 1+ parr and 2+ parr, respectively. It is likely that these exceptionally low estimates relative to 2016 for fry result from the large spill event between November 4 and 24, 2016, which caused considerable gravel movement in Elk Canyon and low egg-to-fry survival.

Mark/recapture trials had an average capture efficiency across all species and life stages (excluding Coho Salmon fry and Parr) of 13.5%, which is lower than the average capture efficiencies from 2015 and 2016 of 20.8% and 16.7%, respectively. These average capture efficiencies exclude Coho Salmon fry and smolts, which seem to not immediately emigrate from Elk Canyon after release. This was corroborated by calibration swims in May that found numerous Coho fry still holding upstream of the RST.

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'. Two peaks in Chinook out-migration were observed, an early peak in March of Chinook fry, and a later peak in June of Chinook 0+ smolts.

Two Coho Salmon life 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. In contrast to 2016, no 1+ smolt cohort was evident in RST catches.

Four age classes of Steelhead/Rainbow Trout were identified in the RST catch, including 0+, 1+, 2+ and 3+ fish. Steelhead/Rainbow Trout did not have a clear peak in out-migration timing suggesting that catches represent more localized movements rather than out-migration. Only three 0+ individuals (e.g., < 79 mm fork length) were captured in the RST, all in June. The majority of Steelhead/Rainbow Trout were 1+ (28%), 2+ (31%), and ≥3+ fish (24%), which were captured between March and July throughout the period of RST deployment.

Night snorkeling mark/resight methods were used to estimate Steelhead/Rainbow Trout and Coho Salmon parr densities in fall and in early spring, which were then compared to determine the extent of parr overwintering in Elk Canyon. Steelhead/Rainbow Trout parr abundance in the overwintering monitoring sites was similar between fall (September) and early spring (February) sampling seasons in 2016-2017, which was also similar to results from 2015-2016. The fall population density estimates of Coho Salmon parr in 2016 ranged from 1.7 fish/100 m^2 to 3.4 fish/100 m^2. In contrast, no Coho Salmon parr were observed in the early spring. The zero counts of Coho Salmon parr in the February overwintering snorkel surveys match the output from the RST, which indicated that no 1+ Coho overwintered in Elk Canyon.

Year 3 snorkel surveys 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. The count of Steelhead in Elk Canyon in the spring was similar the day after the 2-day 10 m^3/s spring pulse releases compared to the day prior to the pulse releases, which was further confirmed when both years of data were analyzed together. The rate of Steelhead in-migration per day also did not differ between periods of pulse flows and periods of base/spawning flows. A final year of pulse flow assessments will be completed in Year 5, which will be followed by synthesis analyses across all three years.

The abundance of Steelhead in Elk Canyon was not significantly different prior to the two-week spawning flow release than during the release. However, when this analysis was conducted with both years of data, it was found that the Steelhead abundance was significantly higher prior to the spawning flow release than during the spawning flow release. Given the low numbers of fish observed, there remains uncertainty in this conclusion. A third year of spawning flow assessment will be completed in Year 5, which will be followed by synthesis analyses across all three years. Similar to Year 2, no Steelhead redds were observed during these spring surveys in 2017.

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 and Coho Salmon adult abundance were estimated to be 275 and 249 individuals respectively. Chum Salmon had the highest estimated abundance of 1,094 individuals. Pink Salmon estimated abundance was much lower in Year 3 relative to Year 2 at only 763 individuals. 89 Sockeye Salmon were also estimated.

The period of peak spawning varied by salmon species. Similar to Year 2, Pink and Sockeye Salmon spawned the earliest, with counts peaking in late September. Chinook Salmon had a peak in mid-October, while Coho Salmon and Chum Salmon had the latest peaks in early November. However, Chum and Coho Salmon counts were at a maximum in the last snorkel survey prior to the large spill event that occurred throughout the majority of November, and therefore it is possible that the peak would have been higher for both species if the spill had not occurred. Once spawning surveys resumed at the end of November and early December, no adults of any species were observed.

Chinook, Chum, Coho, Pink and Sockeye Salmon redds were counted during fall spawning surveys, 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 all species. While red superimposition is possible, in particular for Pink Salmon, a more likely explanation for low egg-to-fry survival is the scouring of redds during the large spill event of up to

480 m^3/s that occurred in November 2016. This is also explained by significant movement of gravel and the few redds that were observed during snorkels following the spill event.

The following represents a summary of considerations for Year 4.

Smolt enumeration component:

1. The RST is an effective method to inventory juvenile salmonids (fry and smolts) that are migrating out of Elk Canyon and obtain valuable life history information. In Year 3, the mark-recapture experiments included wild Chum fry in addition to Quinsam hatchery Chinook and Coho fry and smolts. These experiments with wild fry will continue if sufficient catches are observed in Year 4.
2. In the mark-recapture experiment, fry releases were marked with Bismarck Brown. These marks fade after several days causing some potential confusion between wild versus hatchery rearing Coho and Chinook fry caught in the period after that release if they choose to remain in the canyon for an extended period of time. We recommend that for the remainder of the program that no Coho or Chinook fry be included in mark-recapture experiments. Mark recapture experiments should continue with hatchery Coho and Chinook smolts that are clearly marked with a fin clip or with wild Chum, Pink and Sockeye fry where the expectation is for the fry to move downstream immediately upon release.
3. There is still some uncertainty as to the origin of Chinook and Coho Salmon fry and smolts that are being caught in the RST in May, June and July. Smolts released from Quinsam Hatchery may swim up the Campbell River after their release and end up in the RST. Wild Chinook and Coho juveniles may also swim upstream and get caught in the RST. One of 29 Chinook Salmon smolts sampled for otolith analysis had a thermal mark, indicating that a small proportion of RST catch are hatchery-origin fish. These analyses should be conducted again in Year 4 to confirm the proportion of hatchery releases being captured in the RST.
4. Calibration snorkel swims were conducted in early May in Year 3 in the six index sites from the overwintering assessment to provide further calibration to the RST out-migration data. A large number of Coho fry were observed, which matches the later catch of Coho 0+ smolts in June and July. However, in contrast to the results for Coho Salmon, no Chinook Salmon juveniles were observed during the calibration swims. These calibration swims were conducted during the day when Coho and Chinook Salmon fry were just beginning to become active during the day. The lack of Chinook Salmon fry observations during these swims may thus have been due to these fish still hiding within the substrate during the swims. To better quantify the numbers of juvenile salmon holding upstream of the RST, and to support comparisons between seasons, we recommend that the two calibration swims be conducted later in the growing season in Year 4 during early to mid-June. We also recommend that the calibration swims use the night snorkel mark/resight methodology so that the data can be compared between the fall, winter and late spring periods.

Overwintering assessment component:

5. The night snorkeling mark/resight methods worked well again in Year 3 and were used to test $H_0$2 of the TOR for Steelhead/Rainbow Trout and Coho Salmon. As in Year 2, similar numbers of Steelhead/Rainbow Trout were observed in Elk Canyon in the fall and the early spring, providing little evidence for net immigration or net emigration to or from Elk Canyon during this period. Coho Salmon were observed during the fall in Elk Canyon, although none were observed during the spring mark/resight swims. These low numbers of observed Coho Salmon parr match the observations from the RST, in which no 1+ Coho Salmon smolts were captured from Elk Canyon in spring 2017. The mark/resight methods will continue in Year 4, and attempts will be made to mark and resight Coho Salmon parr in early spring if sufficient densities are observed.

Pulse flow assessment component:

6. Year 3 was the second year that pulse flow assessments were conducted. Snorkel surveys were successful in testing $H_0$3 and $H_0$5 of the TOR, and results were similar to those in Year 2. A third year of pulse flow assessment will be completed in Year 5 of the program, after which, a synthesis analysis across years will be conducted that will provide a three-year assessment of the effectiveness of the current pulse flow prescription for Elk Canyon.

Steelhead spawning flow component:

7. Year 3 was the second 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 5 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 3 was the second year that estimates of production derived from RST catches were compared to estimates of production predicted from redd counts by species. This was a useful component of the analysis, which showed that the large spill event in November 2017 likely reduced egg-to-fry survival of all species.

JHTMON-15 Objectives, Management Questions, Hypotheses and Status after Year 3.

Study Objectives	Management Questions	Management Hypotheses	Year 3 Status
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	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?	$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.	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 field work was completed in Year 3 and will be presented in an upcoming report. The remaining components (b, c, d and e) are being conducted each year to determine fish productivity of Elk Canyon. Year 3 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.
	Does the 2-day 10 m^3/s pulse release every two weeks trigger the	$H_0$3: The rate of spawning salmonid in-migration (No./day) during the 2-day	Management question #2 and associated hypotheses are being

Study Objectives	Management Questions	Management Hypotheses	Year 3 Status
	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?	pulse flow release operation is not significantly different from that during the base flow operation. H_04: 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_05: The estimated number of spawning salmonids following pulse flow release operation is not significantly different from that just prior to the release.	addressed through the spring pulse flow assessment component. Year 3 results confirm that we are on track to address H_03 and H_05, although one more year is required to complete the study. 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_04 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_06: 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 field work was conducted in Year 3. Year 3 results confirm that we are on track to

Study Objectives	Management Questions	Management Hypotheses	Year 3 Status
			address $H_0$6, although one more year is required to complete the study.
	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?	$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.	Management question #4 and associated hypotheses are being addressed through: a) the IFS, and b) the spring spawner abundance assessment. The IFS field work was conducted in Year 3 and results will be presented in an upcoming report. Again, no Steelhead redds were observed during Year 3, which prevents a test of $H_0$7 and $H_0$8. One more year of spawning flow assessment surveys will be conducted in Year 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	$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	Management question #5 and associated hypotheses are being addressed through the fall pulse flow assessment component. Year 3 results confirm that we are on track to address $H_0$3 and $H_0$5, although one more year is required to complete

Study Objectives	Management Questions	Management Hypotheses	Year 3 Status
	attraction release unnecessary?	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.	the study. Because the WUP pulse flow prescription does not vary in magnitude or duration, we will be unable to determine if upstream migration of fall 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.
	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-flow relationships. Other components of JHTMON-15 (e.g., the RST study) will provide important measures of fish productivity that will allow informed

Study Objectives	Management Questions	Management Hypotheses	Year 3 Status
			discussions of the benefits of the WUP operations, and will establish a productivity reference point for these discussions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

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 managing water uses to protect and enhance aquatic resources. To address this uncertainty, monitoring programs were designed to assess whether benefits to fish 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 the use of the canyon by juvenile and spawning fish 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 WUPand is designed to assess the extent to which fish production is driven by flows in Elk Canyon, and how this relates to BC Hydro operations. This report presents results from Year 3 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 1997). Field investigations since the flow release have shown an increase in the use of the canyon by fish as both juvenile rearing and salmonid spawning habitat. Despite this increase in the use of the canyon by salmonids, it was hypothesized that further increases in habitat 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 minimum spawning flow of 7 m^3/s (April 1-15); and
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 keep 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.

All of these components of JHTMON-15 were part of the data collection for Year 3. The Instream Flow Study results will be presented in a separate report to BC Hydro.

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_0$1). 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 and 2 to enumerate out-migrating fry and smolts of all salmon species and was continued in Year 3.

1.4.3. Overwintering Assessment

The carrying capacity of Elk Canyon can be viewed as consisting of two components; 1) those fish that complete their life cycle from egg to smolt within the reach (here referred to as residents), and 2) juveniles that immigrate into 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_0$2). 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 week in the fall (September 15 to November 15) and 2-day pulse flows of 10 m^3/s every two weeks in the spring (February 15 to March 15) as an attraction flow primarily for spawning salmonids. Hypotheses $H_0$3, $H_0$4, and $H_0$5 were developed to test the effectiveness of these pulse flows in attracting spawning salmonids and attracting and retaining Steelhead in Elk Canyon. Hypotheses $H_0$3 and $H_0$4 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_0$5 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 5 of JHTMON-15. Year 3 thus represents the second 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_0$6, $H_0$7, and $H_0$8 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 5 of the JHTMON-15 program. Year 3 thus represents the second 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 (AUC) estimates of abundance are calculated and used to test if the annual abundance of 'resident' smolts is correlated with spawner abundance ($H_0$9). This is a final check to make sure that the assumption of 'full seeding' needed to test Hypothesis $H_0$1 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

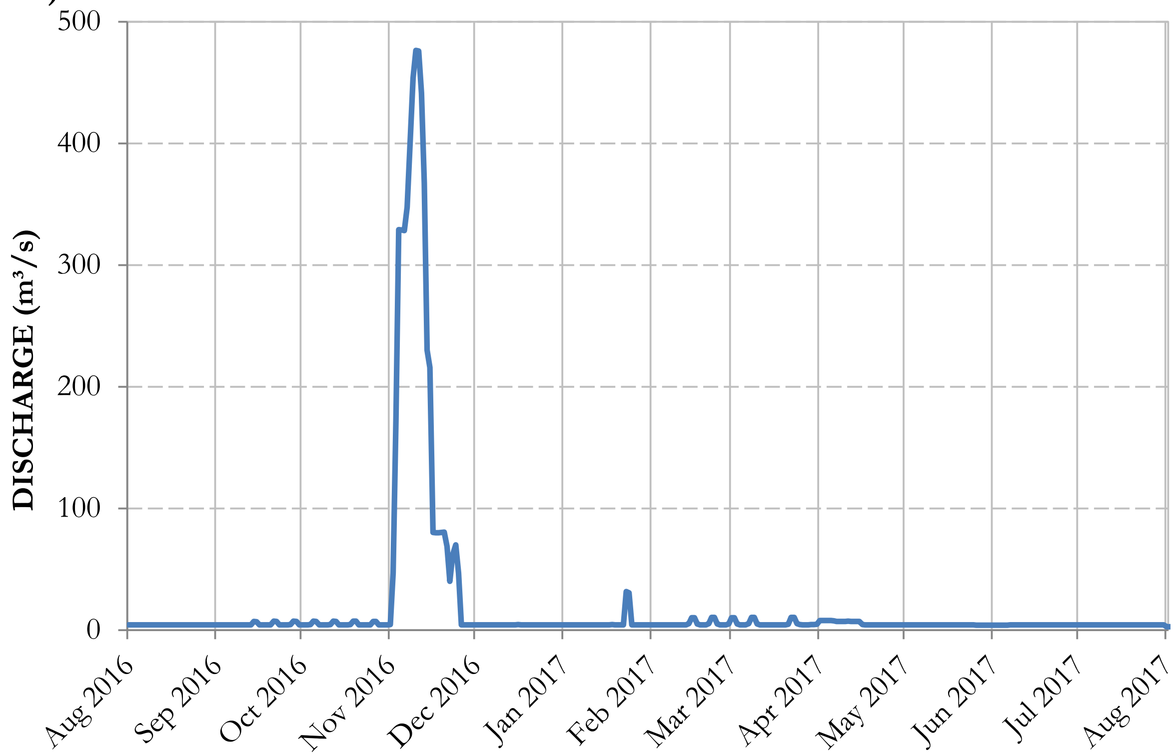
2.1. Overview of Conditions in Year 3

The Elk Canyon smolt and spawner abundance program involves a series of interconnected components, each focused on addressing a specific hypothesis. The two main sampling techniques employed in Year 3 of the monitor were snorkel swim counts of adults and juveniles and rotary screw trap enumerations of out-migrating juveniles.

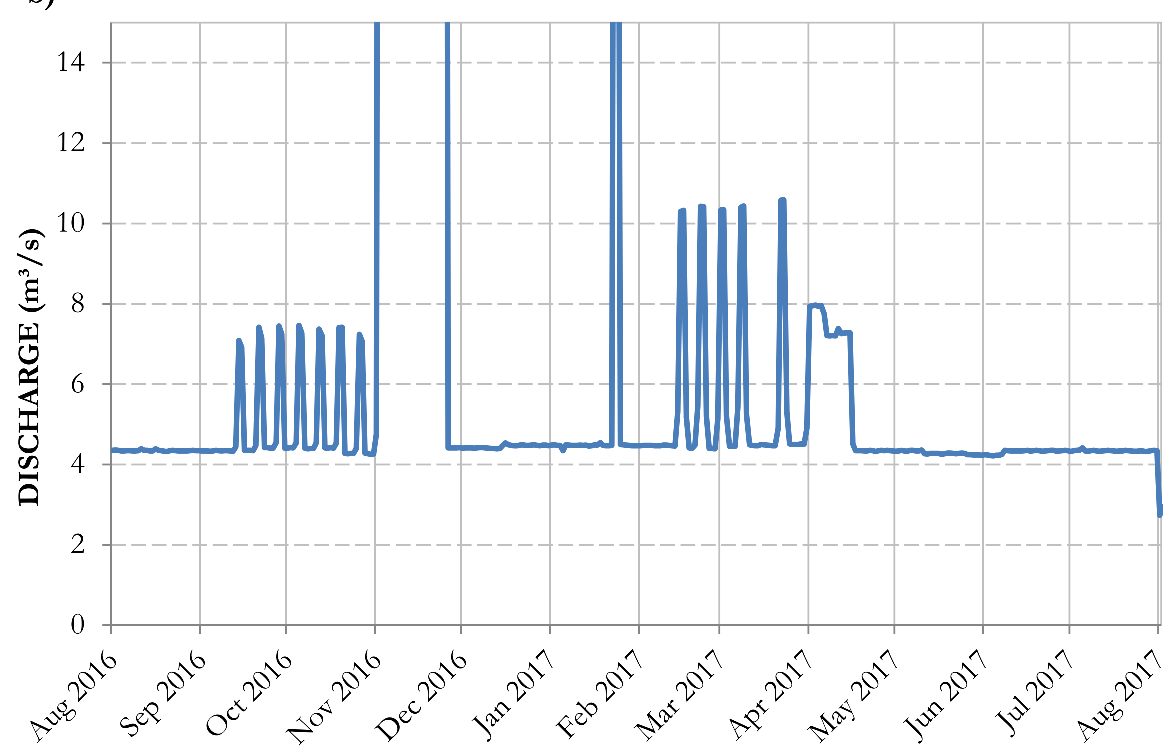
Figure 1a and b show the measured flow in Elk Canyon from August 2016 through to the end of July 2017. The 7 m^3/s pulse flows in September through November are evident, as well as the 10 m^3/s pulse flows and 7 m^3/s spawning flow in March and April. Also evident is the large spill of almost 500 m^3/s that occurred during a period of significant precipitation in November 2016.

Figure 1. Discharge (m^3/s) in Elk Canyon from August 2016 to July 2017. Note the different y-axis scales in panels a and b.

a)



b)



2.2. Smolt Enumeration

2.2.1. 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 a 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 24, 2017 and fished 7 days a week, continuously until July 27, 2017. Crews serviced the trap daily each morning. In Year 3 there were 3 fishing positions for the trap. Position #1 was for base flows of 4 m^3/s (Figure 2) and Position #2 was for the prescribed spawning flow of 7 m^3/s (Figure 3) as well as the prescribed migration flows of 10 m^3/s (Figure 4). Position #2 was added in Year 2 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 and maintained in Year 3 to account for lower water conditions at the trap location due to the summer rampdown to the minimum Preferred Discharge Range into the Lower Campbell River from the John Hart project (Figure 5).

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 removed and identified to species prior to release. 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. On each catch date, a maximum of ten fish per species and size class were measured for fork length and wet weight, and sampled for 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 a 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 7 m^3/s (Position #2).

Figure 4. Rotary Screw Trap (RST) during operation at base of Elk Canyon at 10 m^3/s (Position #2).

Figure 5. Rotary Screw Trap (RST) during operation at base of Elk Canyon at 4 m^3/s low water conditions (Position #3).

2.2.2. 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, 24 scale samples from Steelhead/Rainbow Trout, 110 scale samples from Chinook Salmon, and 22 scale samples from Coho Salmon were collected. Of these, 23 Steelhead/Rainbow Trout and 14 Coho Salmon scales were aged. No Chinook Salmon scales were aged; however, 29 Chinook Salmon were aged through otolith analysis conducted by DFO (Section 2.2.4).

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.

2.2.3. 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 14 mark recapture trials were completed over 13 release days from March 6 to May 29, 2017. The trials included: three trials of wild Chum fry, two trials of hatchery Coho smolts, three trials of hatchery Coho fry, three trials of hatchery Chinook fry, and three trials of hatchery Chinook smolts. Chum, Chinook and Coho Salmon fry were marked by immersion in Bismarck Brown (0.8 g of in 38 L of water) for 1.25 hrs and Coho and Chinook Salmon smolts were marked using a unique ventral fin clip for each individual trial.

The number of fish targeted for release 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, a quality criterion described in U.S. Fish and Wildlife Service (2008).

The hatchery Chinook and Coho Salmon were driven to the powerhouse from the Quinsam hatchery and then transported into the canyon in buckets with battery-powered bubblers. 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, 620 hatchery Coho Salmon fry, 400 hatchery Coho Salmon smolts, 672 hatchery Chinook Salmon fry, 596 hatchery Chinook Salmon smolts and 482 wild Chum Salmon fry were released over the course of three release days for each species and each life stage, excluding Coho Salmon smolts which were released over two days (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.

2.2.4. Otolith Analyses

In Year 1 and Year 2, almost all Chinook and Coho smolts >70 mm in length were caught in the RST after May 1st. It is assumed that these fish (exception: 1+ Coho Salmon) hatched in Elk Canyon, reared in Elk Canyon for two or more months, and then migrated downstream as 0+ smolts. However, there was some uncertainty as to the origin of these fish; it is possible that some Coho and Chinook may originate from the Quinsam hatchery or from natural populations in the lower Campbell River and have swum upstream into Elk Canyon. For example, RST catch results in Year 2 that included some large individuals led to the question of whether Chinook Salmon juveniles reared in the Quinsam hatchery may be being caught in the RST. To help support the analytical conclusions of the RST work two 'calibrations' were completed in Year 3: 1) otolith analyses, and 2) spring calibration snorkel swims. Both calibrations will be completed in Years 3 to 5 of the program.

A large number of Chinook and Coho Salmon are released from the Quinsam Hatchery each spring. Of these some fish are marked with coded wire tags (CWT), some were marked with adipose fin clips, some were marked with both CWT and adipose fin clips, and others were not marked. A CWT reader was used for the final week of the RST deployment (July 19-27); however, prior to this any hatchery raised CWT-marked smolts captured in the RST would not be discernible from wild fish, and unmarked fish would not be discernible from wild fish throughout the RST deployment. Similarly, those marked with adipose fin clips would not be discernible from those released by Ecofish during the mark-recapture study. Therefore, to assess whether some fish originate from the hatchery, otoliths from 29 Chinook Salmon smolts caught in the RST were shipped to the Fisheries and Oceans Canada Fish Ageing Lab and analysed for a hatchery thermal mark on their otolith. The proportion of hatchery to wild fish in this sample was then used to correct the estimated total out-migration of Chinook and Coho Salmon described in section 2.2.6.

2.2.5. Calibration Snorkels

Two calibration snorkel swims were completed on May 8 and 9, 2017 when the water temperatures of Elk Canyon had risen above 8°C and the juvenile Coho and Chinook Salmon had become active. These calibration snorkels occurred during the day and were limited to the six standardized sites that were established in the Year 2 over-wintering assessment. Calibration snorkel swims were conducted by a crew of three over two successive days using methods described in Thurow (1994). Snorkel surveys began at the upstream site and continued downstream until all six sites were assessed. Two swimmers traversed each site, while the third recorded data. Twelve minnow traps were also set overnight on day 1 in locations where higher densities of Coho and/or Chinook Salmon were observed. On day 2, the minnow traps were checked prior to snorkel surveys, and individuals that were caught were processed and released prior to beginning the snorkels. After the snorkel survey was completed, each site was pole seined to catch individuals that were present in the site. If high densities of Coho and/or Chinook were observed in locations outside of the six monitoring sites then these areas were also pole seined. All captured fish were measured for fork length and wet weight, and DNA and age samples were taken from them prior to release.

2.2.6. Estimating Salmonid Out-migration

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:

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

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*. These total estimates of out-migration for Chinook and Coho Salmon were then corrected to account for hatchery-reared fish by multiplying estimates by the proportion of hatchery reared to wild fish in the sub-sample of captured Chinook Salmon smolts from which otoliths analysed for thermal markers (Section 2.2.4), and subtracting this value from the original estimate.

Where possible, the capture efficiencies for each species and life stage were used to calculate the total out-migration. If this was not possible, the mean capture efficiency was used based on the number of released and recaptured fish from all trials. Coho fry were excluded from estimates of mean capture efficiency because their overall capture efficiency was much lower than that of other species and life stages. This lower capture efficiency likely reflects a tendency for Coho fry to remain in the canyon after their release rather than moving downstream past the RST. Total out-migration of Coho fry was thus also calculated based on the mean capture efficiency from all other species.

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

Species	Origin	Life Stage	Release Date	Number of Fish Marked	Number of Fish Released[1]
Chinook Salmon	Hatchery	Fry	6-Mar-17	203	199
			13-Mar-17	274	273
			20-Mar-17	200	200
		Smolt	1-May-17	200	200
			8-May-17	200	200
			15-May-17	196	196
Chum Salmon	Wild	Fry	18-Apr-17	202	197
			24-Apr-17	200	199
			1-May-17	88	86
Coho Salmon	Hatchery	Fry	10-Apr-17	200	200
			17-Apr-17	219	218
			24-Apr-17	202	202
		Smolt	22-May-17	200	200
			29-May-17	200	200

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

2.3. Overwintering Assessment

2.3.1. 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, some Coho Salmon may 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 and Year 3 overwintering assessment methods were modified from Year 1 to consist of two night snorkel mark/resight trials. The first trial was conducted on

September 10 and 11, 2016 and the second trial was conducted on February 2 and 3, 2017. 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).

The same 6 sites that were established in Year 2 in the lower 1.0 km of Elk Canyon (sites CBR-NSK01 to CBR-NSK06 in Map 2) were utilized again in Year 3. 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 10, 2016 and February 2, 2017. 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 2016/2017.

Size Range (mm)	Colour	Hook Size
80-99	Pink	16
100-119	Orange	16
120-139	Red	15
140-159	Sparkle Purple	14
160-179	Sparkle Green	13
>180	Sparkle Pink	12

On September 11 and February 3 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 observed fish were recorded on underwater dive slates in 20 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.

2.3.1.1. 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. Population densities were also compared using both years of data across all six sites using linear mixed-effects models with year and site as random effects. Both paired t-tests and multi-year mixed-effects models were performed in the open access software program R (R Core Team 2013).

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

Species	Event	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Life History Stage											
Chinook Salmon	Adult migration								■	■	■	■	
	Spawning										■	■	
	Incubation	■	■	■	■						■	■	■
	Emergence			■	■								
	Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile migration			■	■	■	■	■					
Chum Salmon	Adult migration									■	■	■	■
	Spawning	■									■	■	■
	Incubation	■	■	■	■						■	■	■
	Emergence			■	■								
	Rearing			■	■	■	■						
	Juvenile migration			■	■	■	■						
Coho Salmon	Adult migration									■	■	■	■
	Spawning	■									■	■	■
	Incubation	■	■	■	■						■	■	■
	Emergence			■	■								
	Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Parr Rearing				■	■	■	■	■	■	■	■	
	Juvenile migration				■	■	■						
Cutthroat (anadromous)	Adult migration	■	■								■	■	■
	Spawning		■	■	■								
	Incubation		■	■	■	■	■						
	Emergence					■	■						
	Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Growing Season				■	■	■	■	■	■	■	■	
	Juvenile migration				■	■	■						
Pink Salmon	Adult migration							■	■	■			
	Spawning									■	■		
	Incubation	■	■	■						■	■	■	■
	Juvenile migration			■	■								
Rainbow/ Cutthroat (resident)	Adult migration	■	■	■	■								
	Spawning		■	■	■								
	Incubation		■	■	■	■	■						
	Emergence						■						
	Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Growing Season				■	■	■	■	■	■	■	■	
	Juvenile migration					■	■	■	■	■	■	■	
Sockeye Salmon	Adult migration								■	■	■		
	Spawning										■	■	
	Incubation	■	■	■	■						■	■	■
	Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile migration				■	■							
Steelhead (summer run)	Adult migration					■	■	■	■	■	■	■	
	Spawning		■	■	■								
	Incubation		■	■	■	■							
	Emergence					■							
	Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Growing Season				■	■	■	■	■	■	■	■	
	Juvenile migration				■	■							
Steelhead (winter run)	Adult migration	■	■	■	■							■	■
	Spawning			■	■								
	Incubation			■	■	■	■						
	Emergence					■	■						
	Rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Growing Season				■	■	■	■	■	■	■	■	
	Juvenile migration				■	■							

Critical times ■

2.4. Pulse Flow Assessment

2.4.1. Fall Pulse Flow Assessment

Fall pulse flow assessments were initiated in Year 2 and continued in Year 3. There were eight fall pulse flow releases conducted weekly through Elk Canyon between September 13 and November 4, 2016 (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 onshore. For each pulse a snorkel survey was conducted the day before the pulse and the day after the pulse. 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.

From November 4 to November 24 a high precipitation event necessitated a large spill of up to 476 m^3/s through Elk Canyon (Figure 1), which prevented pulse flow assessment on the final two pulses (Table 4). A total of seven pulse events were assessed pre and post pulse in Year 3. Three snorkel surveys were added to the schedule in late November and early December after the large spill event, for a total of 21 fall snorkel surveys including the overwintering assessment.

Table 4. Elk Canyon pulse flow and snorkel survey schedule in fall 2016 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
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
						Snorkel			Overwintering	Overwintering		Snorkel	Pulse	Pulse	Snorkel			Snorkel		Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel

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
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	SU	MO
		Snorkel		Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel			Snorkel		Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel			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
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
	Pulse	Pulse	Snorkel				Snorkel	Pulse	Pulse	Snorkel			Snorkel									Snorkel						Snorkel	

December

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
	Snorkel			Snorkel																										

Spill event work not completed

2.4.1.1. 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 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 ($\Delta salmon/day_{base\ flow}$) was computed in the same fashion and paired with each measure of $\Delta salmon/day_{pulse\ flow}$ from only a few days before. This yielded seven base flow versus pulse flow pairs that were analysed using paired t-tests to address $H_0$3. All analyses were conducted using 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.

2.4.2. Spring Pulse Flow Assessment

Spring spawning pulse flow assessments were initiated in Year 2 and continued in Year 3. There were 5 spring pulse flow events conducted through the Elk Falls Canyon between February 14 and March 24 (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 2.4.1). For each pulse a snorkel survey was conducted the day before and the day after the pulse, with a third snorkel survey conducted two to three days later to assess if fish stayed or moved back down stream. Additionally, seven extra weekly snorkels for the two weeks preceding the first pulse and five weeks after the last pulse were completed, for a total of 18 spring snorkel surveys.

Table 5. Elk Canyon pulse flow, snorkel survey and RST schedule in spring 2017 including, overwintering assessments, calibration snorkels and mark recapture releases.

February

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

March

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

April

Date	Day	Flow	Snorkel	RST
1	SA	7 cms Spawning Flow		RST
2	SU	7 cms Spawning Flow		RST
3	MO	7 cms Spawning Flow	Snorkel	RST
4	TU	7 cms Spawning Flow		RST
5	WE	7 cms Spawning Flow		RST
6	TH	7 cms Spawning Flow		RST
7	FR	7 cms Spawning Flow		RST
8	SA	7 cms Spawning Flow		RST
9	SU	7 cms Spawning Flow		RST
10	MO	7 cms Spawning Flow	Snorkel	RST CO Fry
11	TU	7 cms Spawning Flow		RST
12	WE	7 cms Spawning Flow		RST
13	TH	7 cms Spawning Flow		RST
14	FR	7 cms Spawning Flow		RST
15	SA	7 cms Spawning Flow		RST
16	SU			RST
17	MO		Snorkel	RST CO Fry
18	TU			RST CM Fry
19	WE			RST
20	TH			RST
21	FR			RST
22	SA			RST
23	SU			RST
24	MO		Snorkel	RST CO & CM Fry
25	TU			RST
26	WE			RST
27	TH			RST
28	FR			RST
29	SA			RST
30	SU			RST

May

Date	Day	RST	Other
1	MO	RST CH Parr & CM Fry	
2	TU	RST	
3	WE	RST	
4	TH	RST	
5	FR	RST	
6	SA	RST	
7	SU	RST	
8	MO	RST CH Parr	Calibration Snorkel
9	TU	RST	Calibration Snorkel
10	WE	RST	
11	TH	RST	
12	FR	RST	
13	SA	RST	
14	SU	RST	
15	MO	RST CH Parr	
16	TU	RST	
17	WE	RST	
18	TH	RST	
19	FR	RST	
20	SA	RST	
21	SU	RST	
22	MO	RST CO Parr	
23	TU	RST	
24	WE	RST	
25	TH	RST	
26	FR	RST	
27	SA	RST	
28	SU	RST	
29	MO	RST CO Parr	
30	TU	RST	
31	WE	RST	

June

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

July

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

2.4.2.1. 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 (Section 2.4.1). 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. These analyses were also conducted with both years of data through linear mixed-effects models including year as a random effect. Both paired t-tests and multi-year mixed-effects models were performed in R using the "base-R" and the "lme4" packages, respectively.

2.5. 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, 2017. Two full canyon snorkel surveys were conducted on April 3 and April 10 to assess spawning response for Steelhead to the 7 m^3/s spawning flow. The snorkel count methods were the same as those used for the fall and spring pulse flow assessments (Section 2.4).

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 21, 24, and 28, 2017) were compared to the counts of adult Steelhead during the spawning release (April 3 and 10, 2017). These analyses were also conducted with both years of data through linear mixed-effects models including year as a random effect. Both paired t-tests and multi-year mixed-effects models were performed in R using the "base-R" and the "lme4" packages, respectively.

2.6. Spawner Enumeration

2.6.1. Spawner Surveys

2.6.1.1. Fall surveys

Snorkel surveys were used to enumerate fall spawners in reaches one to six of the Campbell River (Map 2). 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 19 snorkel surveys were conducted on September 7, 13, 16, 19, 23, 27, 30, October 3, 7, 11, 14, 17, 21, 25, 28, 31, November 29, December 2, and 5, 2016, to inventory fall spawning Coho Salmon, Chinook Salmon, Chum Salmon, Pink Salmon, Sockeye Salmon, and Steelhead in Elk Canyon. 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 2.4).

2.6.1.2. Spring surveys

Snorkel surveys were also used to enumerate spring spawning Steelhead in reaches one to six of the Campbell River (Map 2). Data from reach 7 were again excluded because the large number of fish holding in the pool at the base of the canyon and are not actively spawning. In total 18 snorkel surveys were conducted on February 1, 7, 14, 17, 21, 24, 28, March 3, 6, 10, 13, 21, 24, 28, April 3, 10, 17, and 24, 2017 following the same methods used in the pulse flow assessments and fall spawner surveys (Sections 2.4 and 2.6.1.1, respectively).

2.6.2. Spawner Abundance

Spawner abundance for each species was estimated using an area under the curve (AUC) analysis for salmon species or peak observed estimates for Steelhead. 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

2.6.3. 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 operated continuously for 151 days from February 27, 2017 to July 27, 2017.

In total, 3,738 fish were captured in the RST (Figure 6, Figure 7), which is roughly 15.5% of the catch in spring 2016 (24,009 fish). The catches were primarily composed of Chum Salmon (74.5%), Chinook Salmon (6.2%), sculpin spp. (13.2%) and Coho Salmon (2.0%). Steelhead/Rainbow Trout and Sockeye Salmon were 0.8% and 0.5%, respectively. The combined catch of all salmonids (3,203 fish) accounted for 85.7% of the total catch while the catch of the key target species of Chinook Salmon, Coho Salmon, and Steelhead/Rainbow Trout (334 fish) accounted for 8.9% of the total catch.

Clear periods of out-migration were observed for Chinook Salmon, Coho Salmon, Chum Salmon, and Sockeye Salmon based on the RST catches (Figure 8, Figure 9, Figure 10). Chinook Salmon out-migration had three peaks, including a smaller peak of recently emerged fry in late March, a second brief peak over three days in mid-May following hatchery releases, and a third, large peak of out-migrating 0+ smolts in June. Coho Salmon out-migration occurred later than Chinook, with two main peaks; the first in mid-May consisting of newly emerged fry, and the second beginning in late June through late July consisting of 0+ smolts. Steelhead/Rainbow Trout out-migration was low and relatively consistent from mid-March through to late July. Chum Salmon out-migration began in early March and peaked in mid to late April. Catches of Chum Salmon occurred until June 1, after which none were captured in the RST. Only two Pink Salmon individuals were caught, including one in late March and one in late April. Sockeye Salmon out-migration had a very narrow peak that occurred at the end of April, with none captured after April 30th.

It is important to note that the Quinsam hatchery releases sub yearling Chinook and Coho Salmon smolts into the Quinsam River, which enters the Campbell River downstream of the RST. There is some uncertainty around whether the Chinook and Coho released from the hatchery could swim upstream and become captured in the RST. In 2017, Chinook Salmon smolts were released from the hatchery March 6, April 10, 13, and 24, and May 1, 2, 3, 4, 8, 9, and 11. Hatchery reared Coho smolts were also released on seven different dates: May 8, 23, 24, 30, 31, and June 1, and 6. The number of Chinook Salmon and Coho Salmon captured in the RST were plotted during and following the period of hatchery releases of each species (Figure 11 and Figure 12, respectively). 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 because very few Chinook were caught in the RST during the period of hatchery releases. Although most captures of Coho

Salmon occurred during an initial pulse in early May prior to hatchery releases and in a second pulse in July, the highest capture of Coho Salmon in the RST did correspond to the first date of hatchery releases of this species (May 8) (Figure 12). The majority of these Coho Salmon caught in the RST at this time were fry at a size of ~35 mm, so it is unlikely that these fish were of hatchery origin. However, three abnormally large Coho (84-109 mm fork length) were captured later in May, which were aged as 0+ fish and could have originated from the Quinsam hatchery.

Of the 3,203 salmonids caught in the RST, 915 fish were measured for fork length. 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 13, Figure 14, Figure 15, Figure 16, Figure 17). Chum Salmon fry were captured throughout February through to April, and Pink and Sockeye Salmon were captured in March and April within a narrow range of fork lengths between roughly 30 to 40 mm.

Chinook Salmon and Coho Salmon exhibited two main peaks in out-migration timing and size (Figure 15, Figure 16). Recently emerged Chinook and Coho fry were caught in the RST from March to early May, and ranged in fork length from 30 to 40 mm and 30 to 35 mm, respectively. A second peak in out-migration composed of larger individuals was observed for both species starting in mid-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 in fork length from 70 to 100 mm and 55 to 90 mm, respectively (Figure 13, 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. The exception to this is three large 0+ Coho Salmon (84 mm to 109 mm fork length) that were captured in May, which, given their larger relative size, may have been hatchery reared fish.

Steelhead/Rainbow Trout did not have a clear peak in out-migration timing in 2017 (Figure 17). Only three 0+ individuals (e.g., < 63 mm fork length) were captured in the RST, all in June. The majority of captured Steelhead/Rainbow Trout were 1+ (28%) (79-145 mm) and 2+ (31%) (158-191 mm), which were captured between March and July throughout the period of RST deployment. Larger ≥3+ fish (>200 mm) made up a considerable proportion of RST captures (24%), which were also captured throughout the RST deployment between March and July.

Figure 6. Total RST catch by species from February 27 to July 27, 2017. ST/RB = Steelhead/Rainbow Trout, CO = Coho Salmon, CH = Chinook Salmon, CM = Chum Salmon, PK = Pink Salmon, SK = Sockeye Salmon, CT = Cutthroat Trout, TR = unknown trout spp., CAL = Coastrange Sculpin, CC = sculpin (*Cottus* spp.), L = lamprey spp., SB = Stickleback spp., TSB = Threespine Stickleback , UNK = unknown fish species (fry mortalities that were too damaged to identify to species in the field).

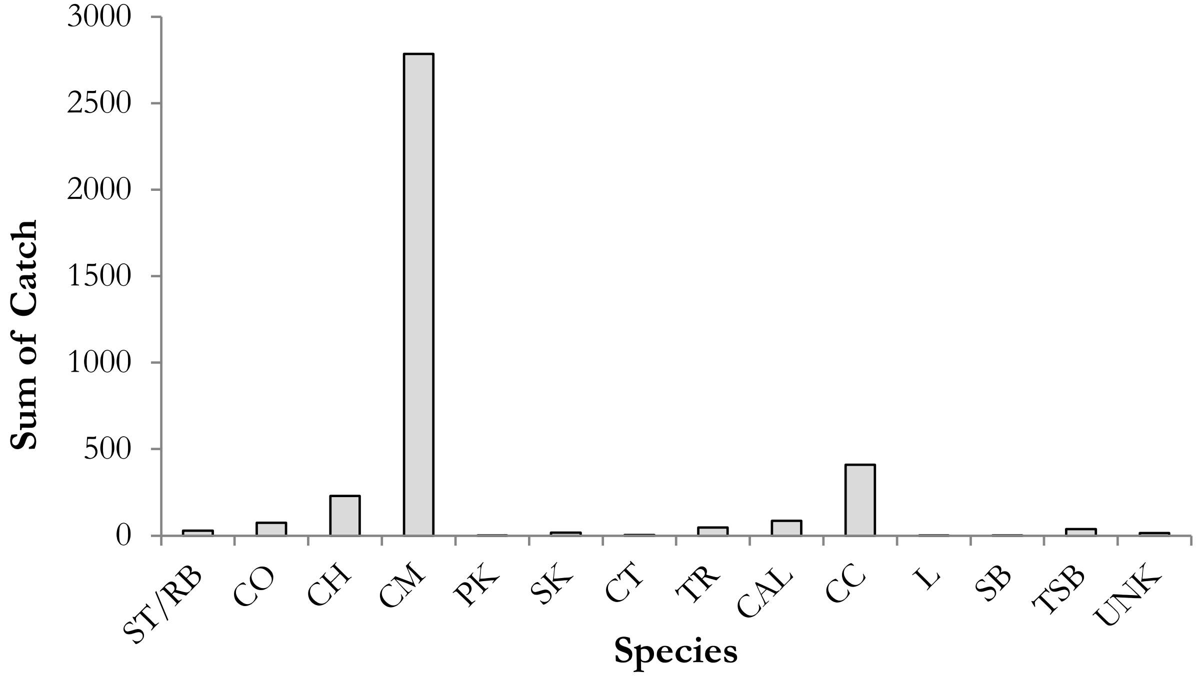


Figure 7. **Total RST catch by species from February 27 to July 27, 2017 excluding Chum Salmon. ST/RB = Steelhead/Rainbow Trout, CO = Coho Salmon, CH = Chinook Salmon, PK = Pink Salmon, SK = Sockeye Salmon, CT = Cutthroat Trout, TR = unknown trout spp., CAL = Coastrange Sculpin, CC = sculpin (*Cottus* spp.), L = lamprey spp., SB = Stickleback spp., TSB = Threespine Stickleback, UNK = unknown fish species (fry mortalities that were too damaged to identify to species in the field).**

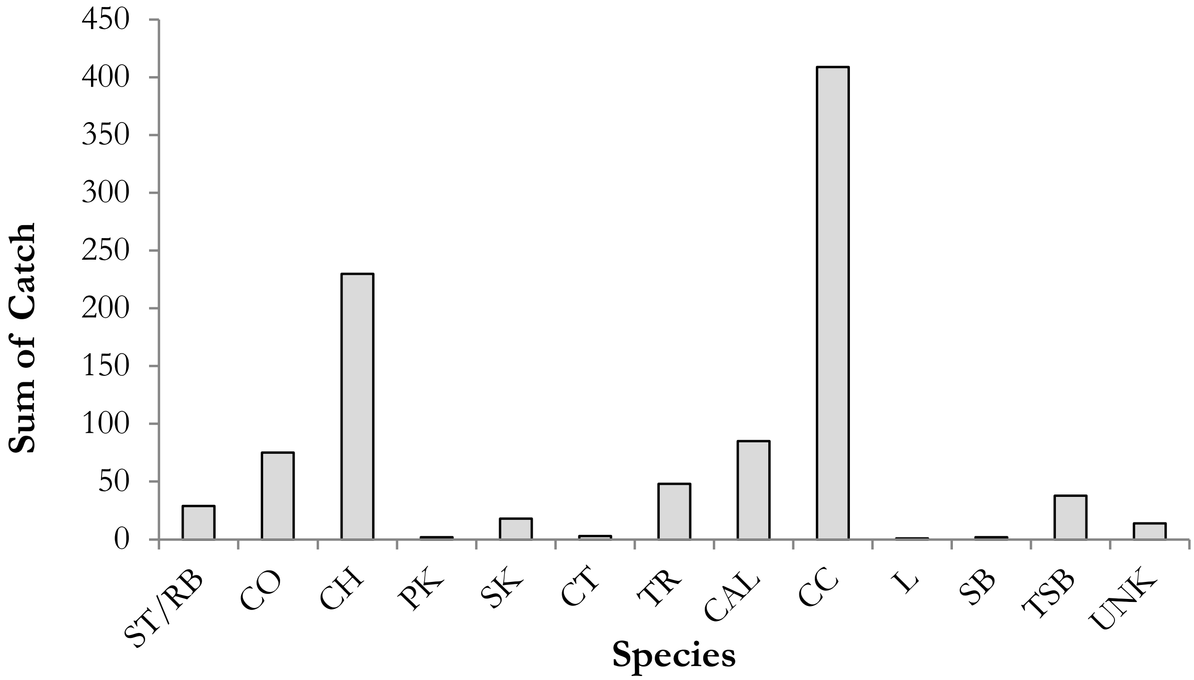


Figure 8. RST catch per-unit-effort of key salmonid species from February 27 to July 27, 2017.

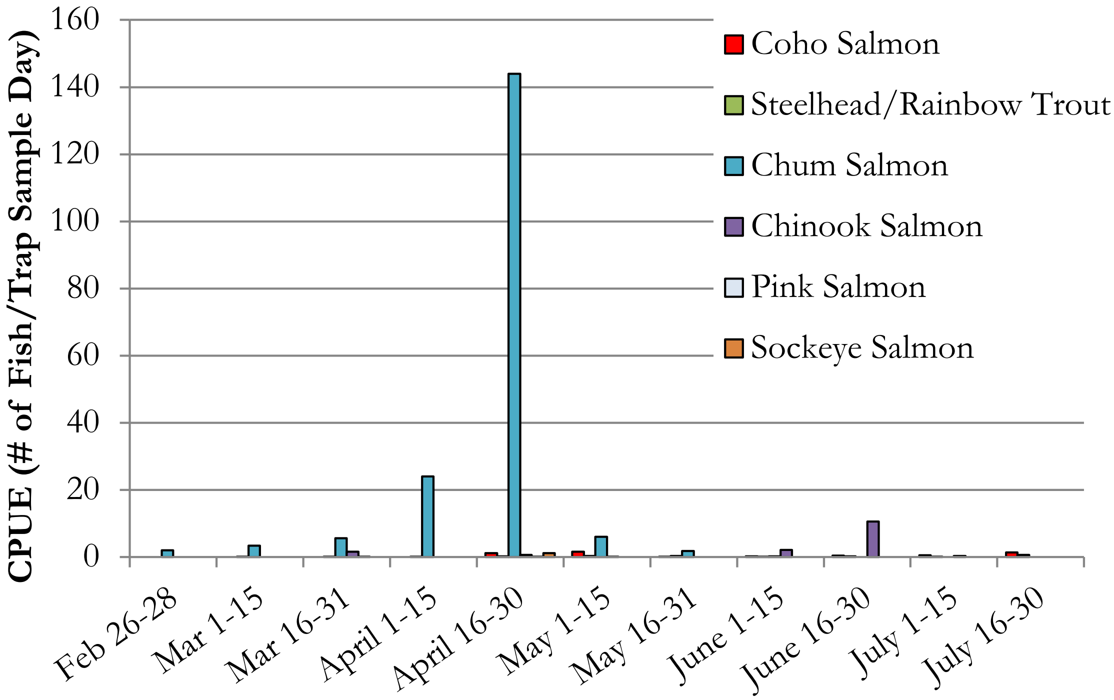


Figure 9. RST catch per-unit-effort of key salmonid species (excluding Chum Salmon) from February 27 to July 27, 2017.

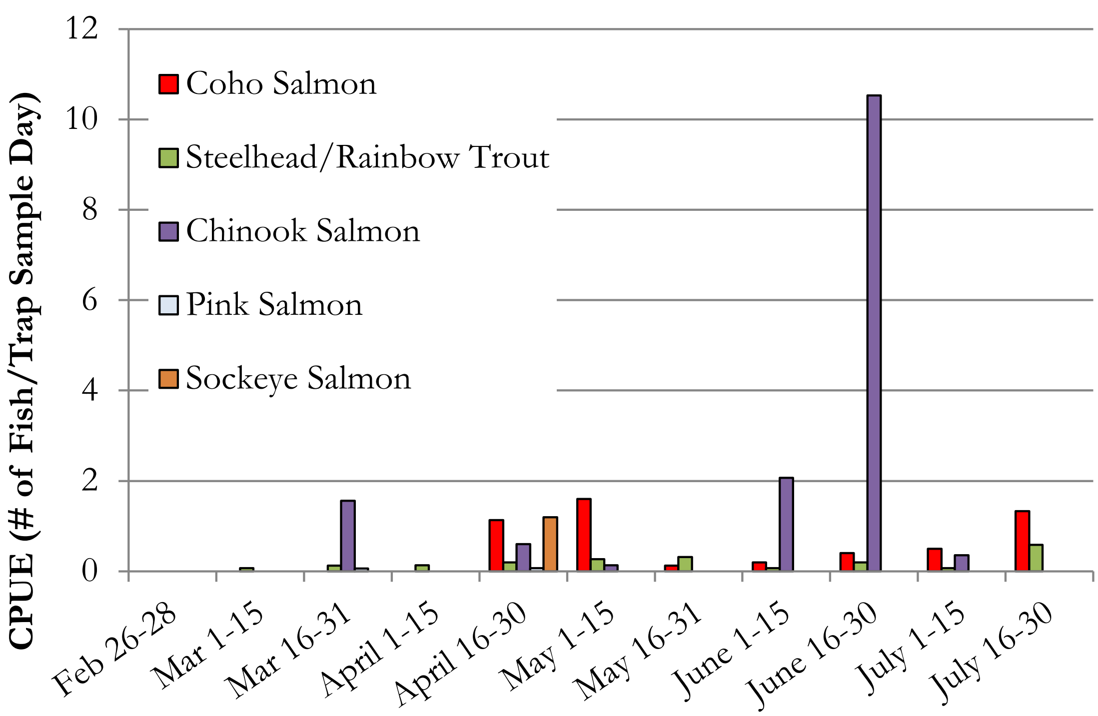


Figure 10. RST catches of a) Chinook Salmon, b) Coho Salmon, c) Steelhead/Rainbow Trout, d) Chum Salmon, e) Pink Salmon, and f) Sockeye Salmon.

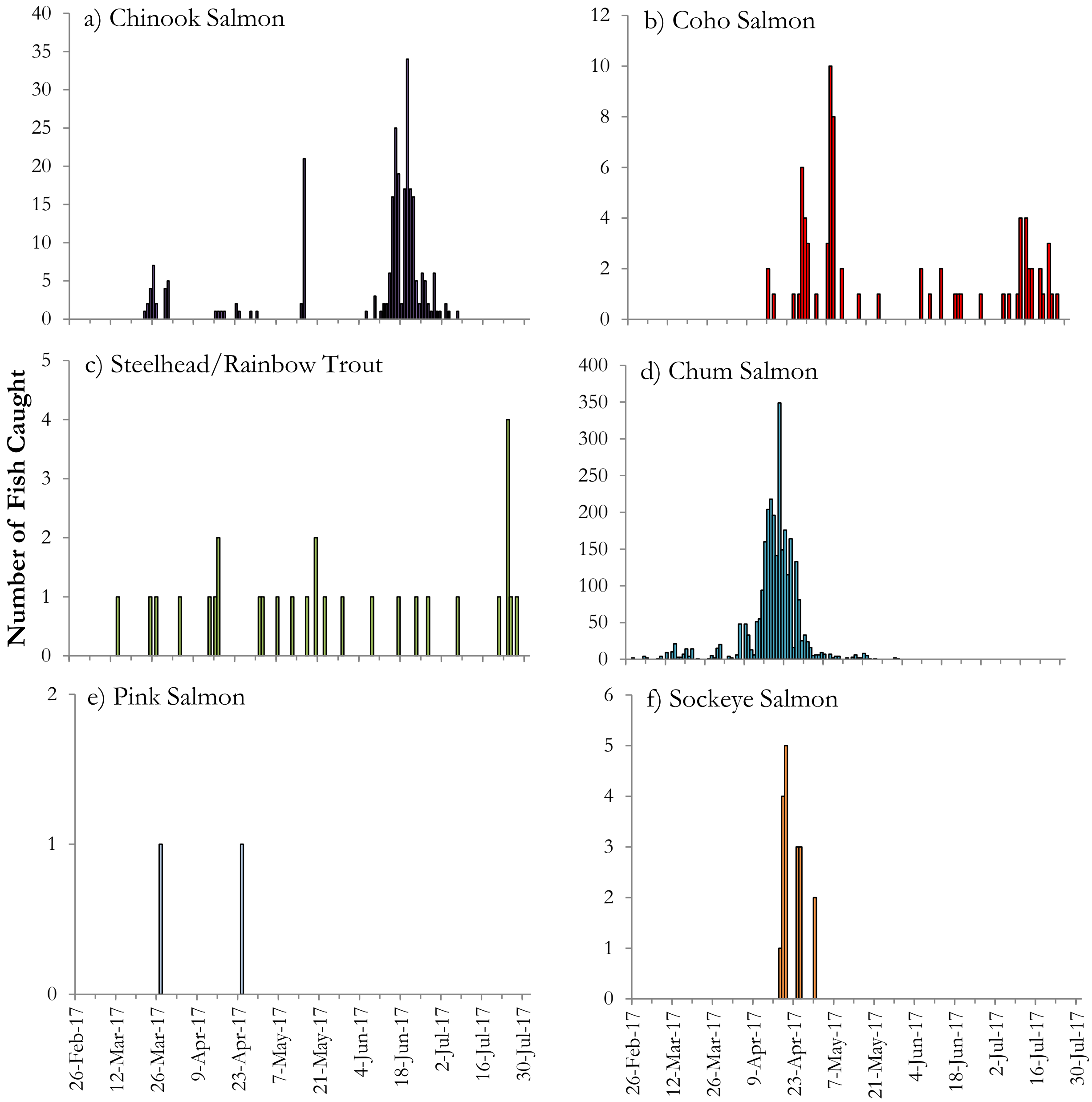


Figure 11. RST catches of Chinook Salmon (purple bars) in relation to dates of releases of marked hatchery-reared Chinook Salmon (hatched bars).

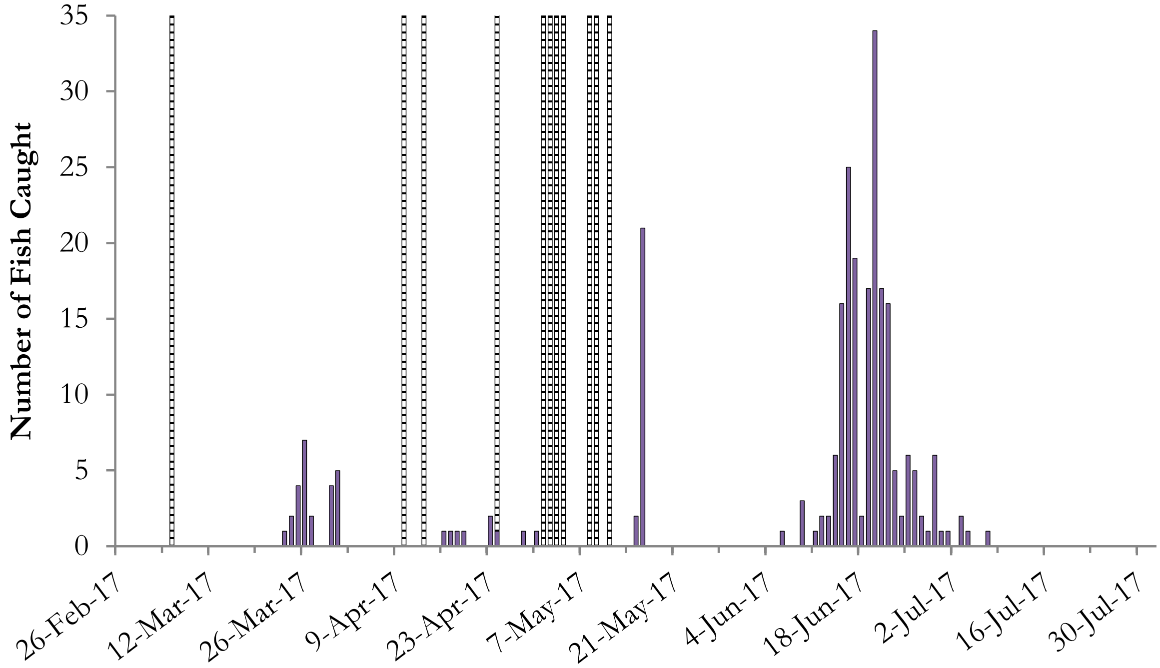


Figure 12. RST catches of Coho Salmon (purple bars) in relation to dates of releases of marked hatchery reared Coho Salmon (hatched bars).

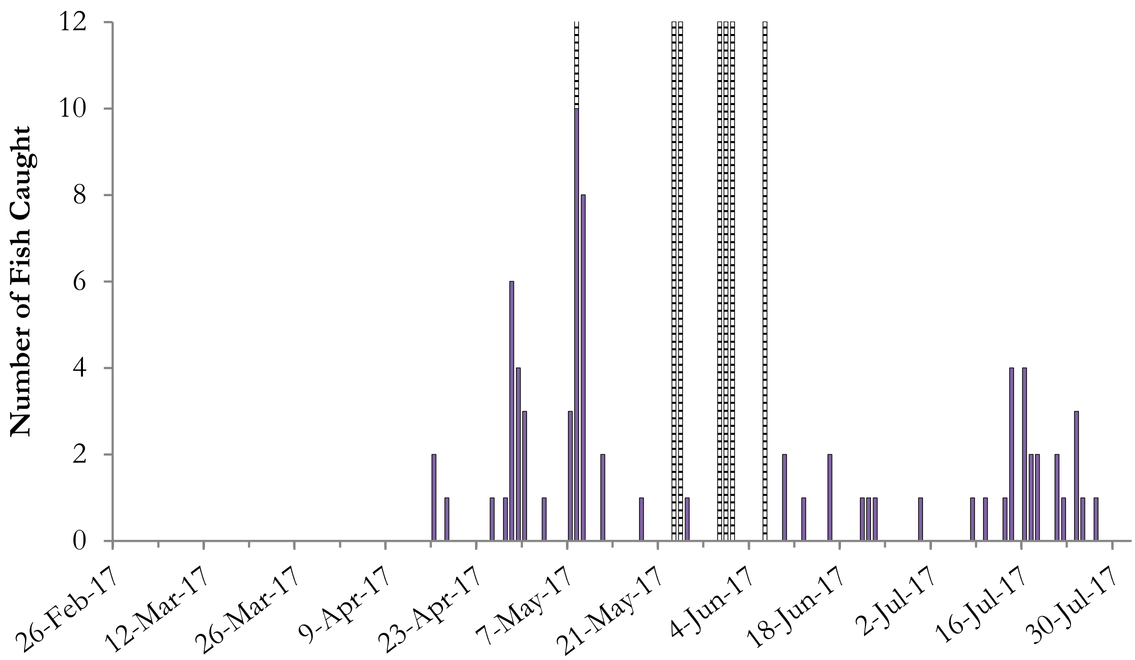


Figure 13. Average fork length of Coho Salmon, Steelhead/Rainbow Trout, Chum Salmon, Chinook Salmon, Pink Salmon, and Sockeye Salmon during RST sampling period.

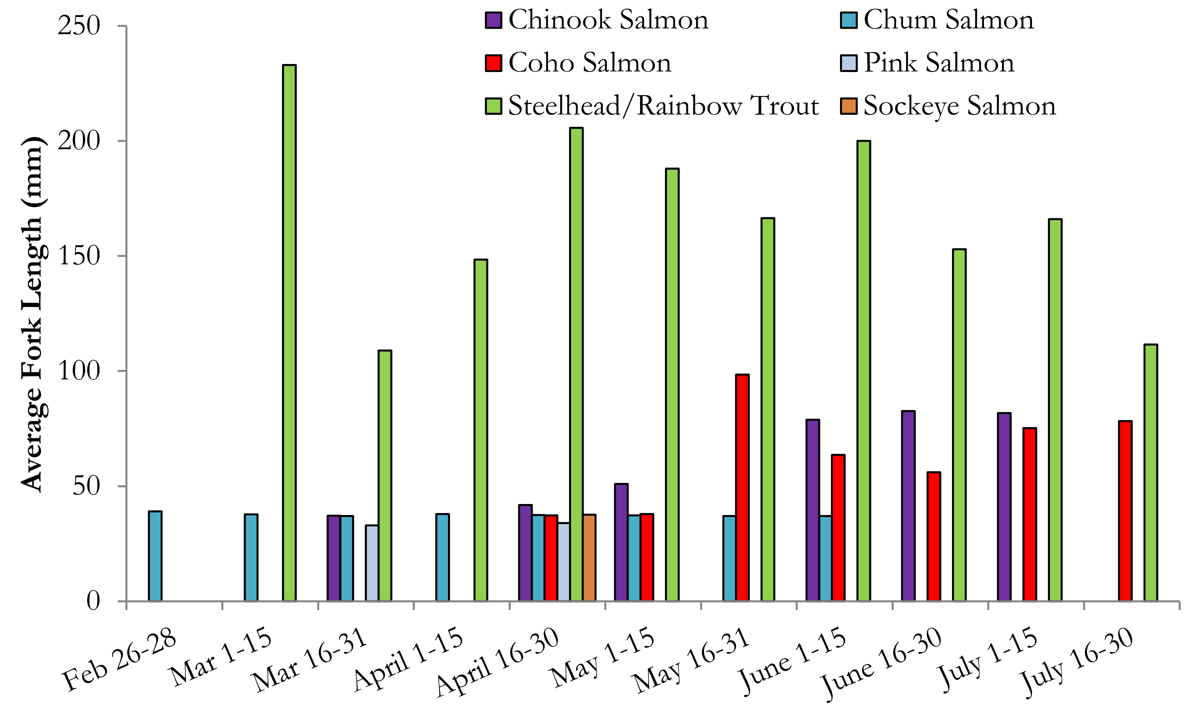


Figure 14. Length frequency histogram of Chum Salmon captured in the RST by month.

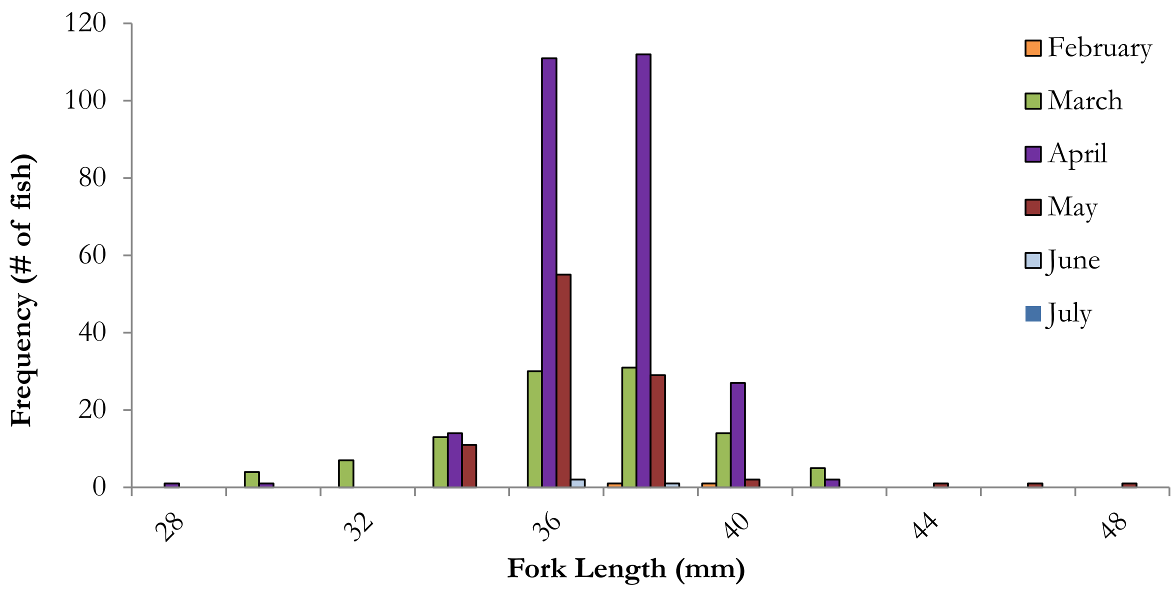


Figure 15. Length frequency histogram of Chinook Salmon captured in the RST by month.

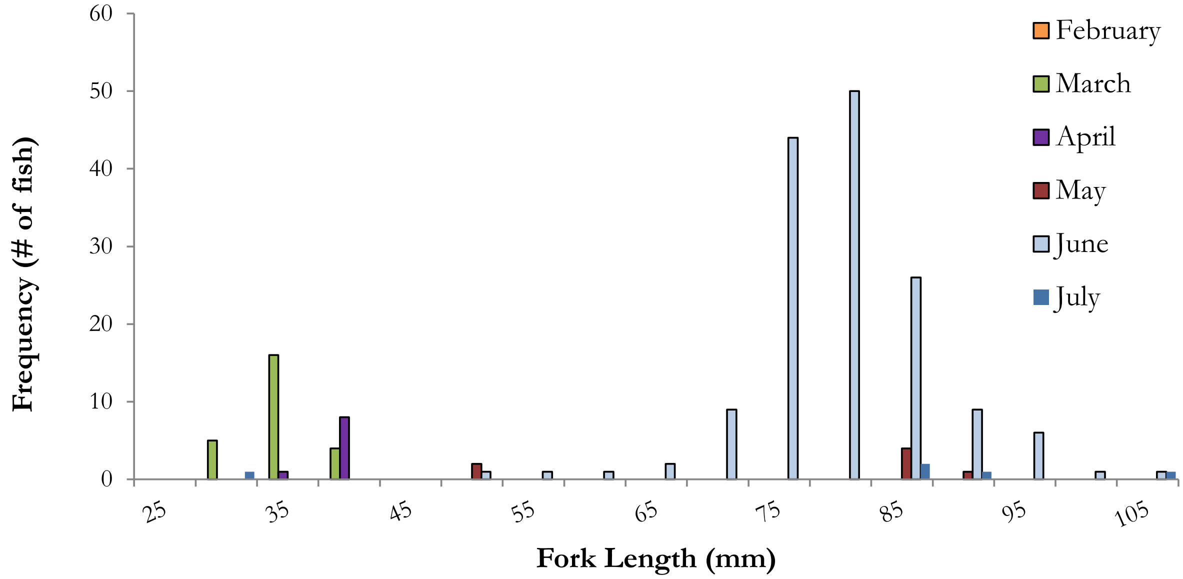


Figure 16. Length frequency histogram of Coho Salmon captured in the RST by month.

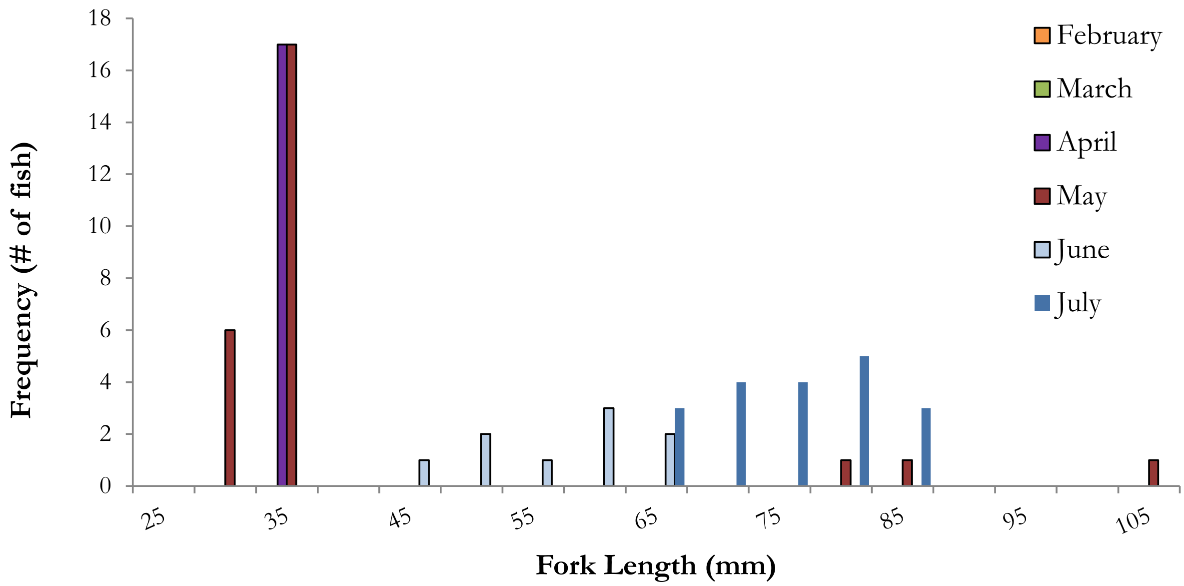
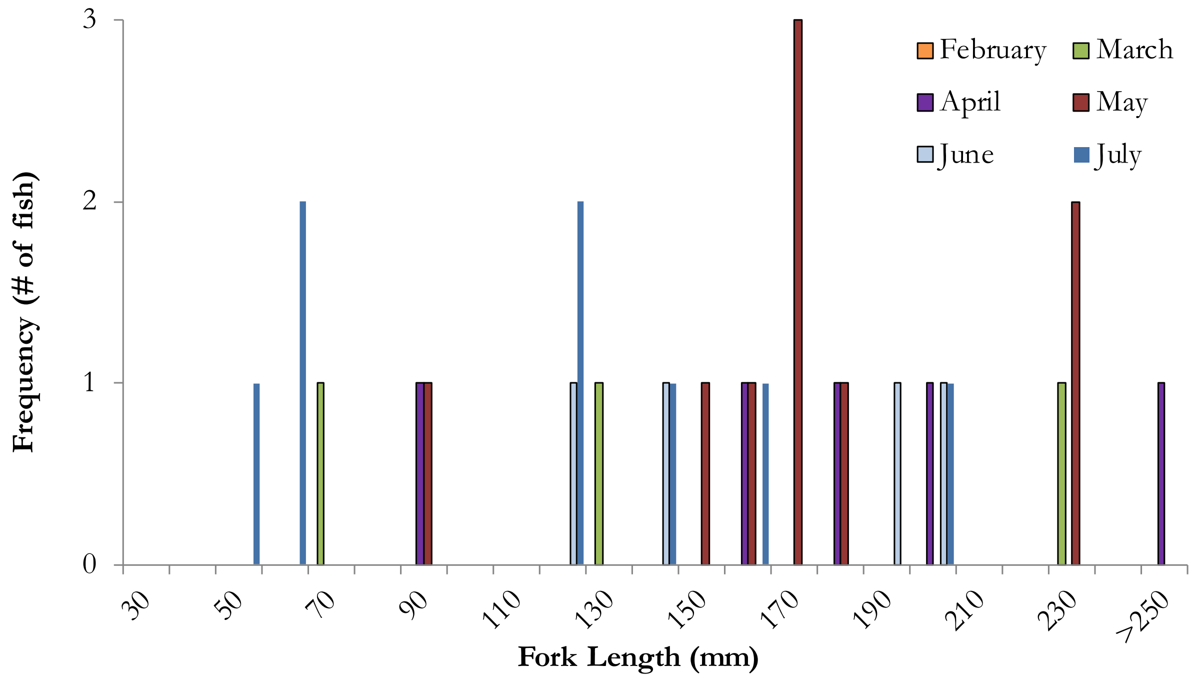


Figure 17. Length frequency histogram of Steelhead/Rainbow Trout captured in the RST by month.



3.1.2. RST Fish Age Data

Of the 29 Chinook Salmon otolith samples 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 68 mm to 102 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 likely leave Elk Canyon by the end of July.

Of the 10 Coho Salmon scales that were aged, all were aged as 0+ fish (Figure 18, Table 7). Coho individuals caught in the RST that were aged ranged in fork length from 66 mm to 109 mm. Based on the size distribution of Coho Salmon caught in the RST, it is concluded that all Coho Salmon juveniles caught in the RST in 2017 were 0+ fish. No 1+ Coho were caught that overwintered in Elk Canyon.

Of the 23 Steelhead/ Rainbow Trout scales that were aged, seven were aged as 1+, eleven were aged as a 2+ fish, and five were aged as ≥3+ (Figure 18). Based on this aging data, and the length-frequency histograms from RST catch, all fish <63 mm are assumed 0+, fish 79 to 145 mm assumed 1+, fish 158 to 191 mm assumed 2+, and all fish >200 mm assumed ≥3+ (Table 7). There is uncertainty associated with these age break classifications for Steelhead/Rainbow Trout based on the low sample size 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 (otoliths), b) Coho Salmon, and c) Steelhead/Rainbow Trout (scales).

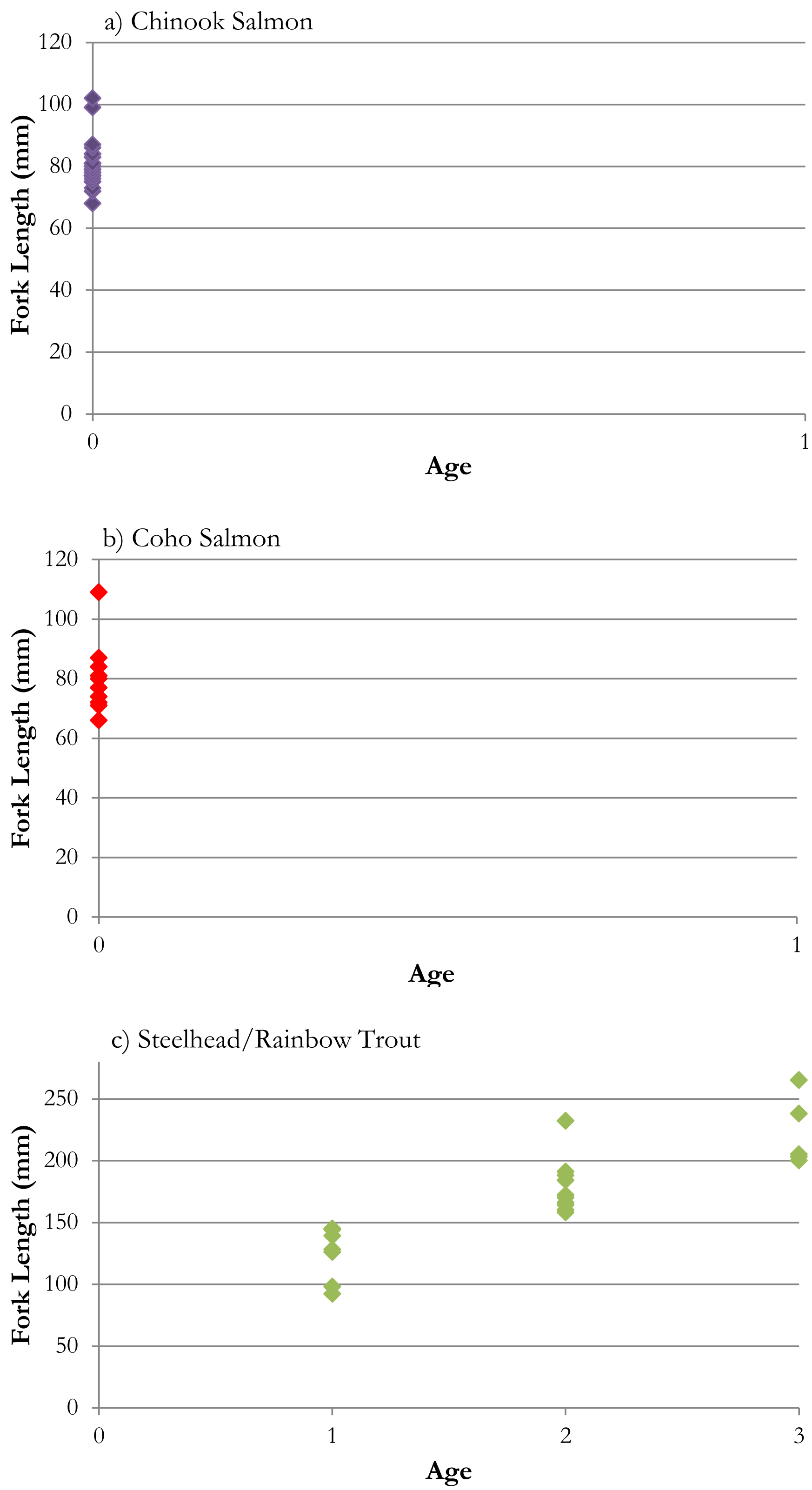


Table 7. Estimated size at age classification for juvenile Chinook Salmon, Coho Salmon, and Steelhead/Rainbow Trout.

Species	Age Class	Length bins (mm)
Chinook Salmon	0+	≤102
Coho Salmon	0+	≤109
Steelhead/Rainbow Trout	0+	≤63
	1+	79-145
	2+	158-191
	≥3+	200+

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 2,770 released fish, 246 fish (9%) were recaptured (Table 8 and Table 9). The capture efficiencies were comparable across species and life stages except for Coho Salmon fry and smolts (Table 8 and Table 9). In addition, no Pink or Sockeye Salmon fry were marked and released. Only nine of the 620 Coho Salmon fry and none of the 200 Coho Salmon smolts were recaptured, which resulted in low recapture rates. These results for Coho Salmon fry are similar to results in 2015 and 2016, which is likely because the released Coho fry choose to stay in Elk Canyon after their release. The results for Coho parr do not coincide with previous years and also indicate that Coho parr stay longer in Elk Canyon after their release. These results were further confirmed during calibration swims during which marked Coho parr were observed holding below the release site. One hypothesis for the behavior was colder water temperatures in spring 2017 compared to previous years. However, spring water temperatures appear to have been similar from 2015 to 2017 (Figure 19).

The trial capture efficiency estimates were based on recent recapture rates within the release periods (Table 8). Chinook Salmon fry trial capture efficiencies ranged from 0.106 to 0.194 (mean = 0.165), Coho Salmon fry trial capture efficiencies ranged from 0.010 to 0.020 (mean = 0.015), and Chum Salmon fry trial capture efficiencies ranged from 0.093 to 0.162 (mean = 0.133). The Chinook Salmon smolt capture efficiencies ranged from 0.082 to 0.130 (mean = 0.104), while no Coho Salmon smolts were recaptured (Table 8).

The overall capture efficiency estimates varied from 0.000 to 0.165 and were based on grouping the releases and recaptures for each species and life stage (Table 9). Excluding Coho Salmon fry and smolts, the overall capture efficiency across all species and life stages was 0.135, which is lower than the average capture efficiencies from 2015 and 2016 of 0.208 and 0.167, respectively.

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

Species[1]	Fish Lifestage	Release Date	Total Released Fish	Total Recaptured Fish	Trial Capture Efficiency
Chinook Salmon	Fry	6-Mar-17	199	21	0.106
		13-Mar-17	273	53	0.194
		20-Mar-17	200	37	0.185
				Average	**0.165**
	Smolt[2]	1-May-17	200	20	0.100
		8-May-17	200	26	0.130
		15-May-17	196	16	0.082
				Average	**0.104**
Chum Salmon	Fry	18-Apr-17	197	32	0.162
		24-Apr-17	199	24	0.121
		1-May-17	86	8	0.093
				Average	**0.133**
Coho Salmon	Fry	10-Apr-17	200	2	0.010
		17-Apr-17	218	3	0.014
		24-Apr-17	202	4	0.020
				Average	**0.015**
	Smolt[3]	22-May-17	200	0	0.000
		29-May-17	200	0	0.000
				Grand Average	**0.104**

[1] No Pink Salmon or Sockeye Salmon were marked in 2017.

[2] May 1 and May 15 releases of Chinook Salmon 0+ fry were marked with the same fin clip location and therefore it was not possible to differentiate between fish recaptured from these two dates subsequent to May 15.

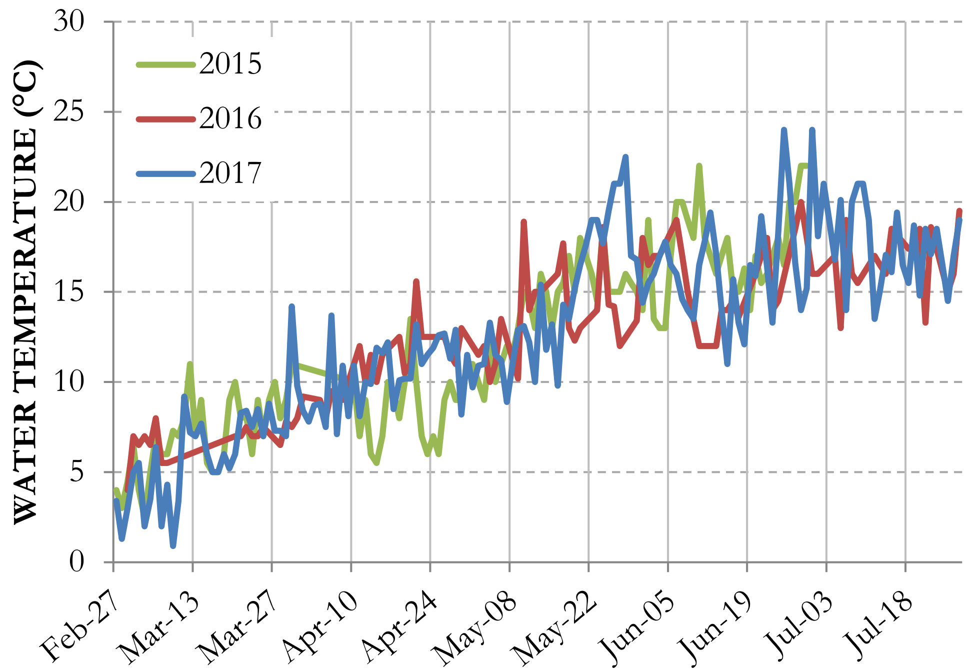
[3] Grand averages exclude Coho Salmon smolts as none were recaptured.

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

Species	Total Number of Released Fish	Total Number of Recaptured Fish	Overall Capture Efficiency
Chinook Salmon Fry	672	111	0.165
Chinook Salmon Smolt	596	62	0.104
Chum Salmon Fry	482	64	0.133
Coho Salmon Fry	620	9	0.015
Coho Salmon Smolt	400	0	0.000
Overall Capture Efficiency[1]	**1,750**	**237**	**0.135**

[1] Excludes Coho Salmon fry and smolts.

Figure 19. Water temperature measured daily at the RST during spring deployment in 2015, 2016 and 2017.



3.1.4. Otolith Analysis

Only one of the 29 sampled Chinook Salmon smolts had a hatchery thermal mark on its otolith indicating hatchery origin. Incidentally, this individual was the largest (102 mm fork length) of the smolts analyzed, with the rest ranging from 68 mm to 99 mm fork length, and captured on June 15, over one month after the last Chinook Salmon release from Quinsam hatchery. This suggests that a relatively low number of hatchery reared Chinook Salmon are travelling upstream into Elk Canyon and being captured in the RST. The ratio of hatchery to wild smolts captured in the RST was therefore assumed to be 0.034, and estimates of out-migration were corrected by this proportion below.

3.1.5. Calibration Snorkels

In total, 325 and 574 fish were observed during calibration snorkels on May 8 and 9, 2017, respectively (Table 10, Table 11). Of these, the majority were Coho Salmon fry and Steelhead/Rainbow Trout. In general, Coho Salmon fry were much more prevalent in the upper reaches, whereas Steelhead/Rainbow Trout were observed more evenly distributed among the six sites. Surprisingly, no Chinook Salmon juveniles were observed during calibration swims despite the high number captured in the RST in June. However, Coho Salmon fry that were observed during the swims were small and still largely holding within the substrate. Given the colder temperatures and longer winter in 2017, it may be that Chinook Salmon fry present within the reach that were captured in the RST later in the deployment period were still hiding in the substrate during the day and therefore were not observed during the snorkels. This is corroborated by the fact that few Chinook Salmon were captured in the RST prior to the calibration swims and peak out-migration of Chinook occurred over a month later in late June. In addition, the main spawning area for Chinook is further upstream than the six index sites, which means that the majority of juveniles may be rearing further upstream.

Minnow trapping was conducted in all six calibration sites, for a total effort of 23 hours of soak time. One Coho Salmon fry was captured via this method in the uppermost site (CBR-NSK01). Nine Coho Salmon fry were also captured through beach seining in this site. No fish observed or captured during calibration snorkels, minnow trapping, or beach seining were noted to be recaptures. All Coho observed during calibration swims were fry (40-59 mm estimated fork length) while Steelhead/Rainbow parr (80 mm to >400 mm estimated fork length).

Table 10. Effort and conditions during spring calibration snorkels.

Date	Waypoint/Site	Sub-Site	Total Effort (hr)	Water Temp °C	Air Temp °C	Estimated Visibility (m)[1]
08-May-2017	CBR-NSK01		0.64	8.0	10.0	10
	CBR-NSK02	Section 1 Riffle	0.16	8.0	10.5	10
		Section 2 Cascade	0.14	8.0	10.5	10
		Section 3 Run	0.20	8.0	10.5	10
		Section 4 Cascade	0.10	8.0	10.5	10
	CBR-NSK03		1.00	8.0	11.0	10
	CBR-NSK04		0.46	8.5	11.0	10
	CBR-NSK05		0.50	8.5	11.0	10
	CBR-NSK06		0.46	8.5	11.0	10
09-May-2017	CBR-NSK01		0.66	9.0	11.0	10
	CBR-NSK02	Section 1 Riffle	0.24	9.0	11.0	10
		Section 2 Cascade	0.16	9.0	11.0	10
		Section 3 Run	0.24	9.0	11.0	10
		Section 4 Cascade	0.16	9.0	11.0	10
	CBR-NSK03		0.44	9.0	11.0	10
	CBR-NSK04		0.44	9.5	12.0	10
	CBR-NSK05		0.50	9.5	12.0	10
	CBR-NSK06		0.54	9.5	12.0	10

Table 11. Fish observations during calibration snorkels in May 2017.

Date	Waypoint/Site	Sub-Site	Fish Observed[1]			
			CM	CO	CT	RB
08-May-2017	CBR-NSK01		1	21	3	27
	CBR-NSK02	Section 1 Riffle	0	2	3	22
		Section 2 Cascade	0	5	0	6
		Section 3 Run	0	17	1	23
		Section 4 Cascade	0	0	0	15
	CBR-NSK03		0	39	0	41
	CBR-NSK04		0	16	0	23
	CBR-NSK05		0	2	0	26
	CBR-NSK06		0	0	0	32
09-May-2017	CBR-NSK01		1	250	4	36
	CBR-NSK02	Section 1 Riffle	0	0	2	28
		Section 2 Cascade	0	5	0	6
		Section 3 Run	0	8	0	20
		Section 4 Cascade	0	0	0	10
	CBR-NSK03		0	35	0	46
	CBR-NSK04		0	10	0	35
	CBR-NSK05		0	0	0	33
	CBR-NSK06		0	0	0	45

[1] CM = Chum Salmon, CO = Coho Salmon, CT = Cutthroat Trout, RB - Rainbow Trout

3.1.6. Estimates of Salmonid Out-migration

Estimates of RST CPUE by half month (Table 12) and total out-migration of salmon smolts and fry (Table 13) were generated for Elk Canyon. Chum Salmon out-migration was the highest of all salmonid species with an estimated out-migration of 20,997 fry. Coho Salmon out-migration was estimated to be 121 fry and 446 age 0+ smolts. The out-migration of age 1+ Coho Salmon smolts is assumed to be zero as none were captured in the RST in 2017. Chinook Salmon out-migration was estimated to be 199 fry and 1,823 age 0+ smolts. Steelhead/Rainbow Trout out-migration was estimated to be 28 age 0+ fry, 72 age 1+ parr, and 74 age 2+ parr, and 54 age ≥3+ smolts. Pink Salmon and Sockeye Salmon out-migration was estimated at only 15 and 133 fry, respectively.

Out-migration estimates in 2017 were considerably lower than those in 2016. Chum, Coho, and Chinook Salmon fry out-migrations were estimated to be roughly 8%, 2%, and 1%, respectively of those in 2016. In contrast, the estimated out-migration of Coho Salmon 0+ smolts was only 51% smaller than in 2016, and that for Chinook Salmon 0+ smolts was very similar between the two years. Similarly, Steelhead/Rainbow Trout out-migration estimates were also lower in 2017 at 53%, 50%, and 9% of those in 2016 for fry 0+, 1+ parr, and 2+ parr, respectively. No ≥3+ Steelhead/Rainbow Trout were aged in 2016 meaning that their out-migration was not estimated. However, there were five fish captured in 2016 with lengths within the 2017 ≥3+ size class range. In 2017, seven individuals in this size class were captured. Estimates of Pink and Sockeye Salmon fry out-migrations were also lower in 2017 at only 2% and 15% of those in 2016, respectively. It is likely that these low out-migration estimates relative to 2016 result from the large spill event between November 4 and 24, 2016 (Figure 1), which was likely to have scoured out much of the redds within Elk Canyon.

Table 12. 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+	3+	Fry 0+	Fry 0+	Salmon Fry
Feb 26-28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Mar 1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.4	0.0	0.0
Mar 16-31	1.6	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	5.6	0.1	0.0
April 1-15	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	24.0	0.0	0.0
April 16-30	0.6	0.0	1.1	0.0	0.0	0.0	0.0	0.1	0.1	144.0	0.1	1.2
May 1-15	0.0	0.1	0.0	1.6	0.0	0.0	0.1	0.1	0.1	6.1	0.0	0.0
May 16-31	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	1.8	0.0	0.0
June 1-15	0.0	2.1	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0
June 16-30	0.0	10.5	0.0	0.4	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
July 1-15	0.0	0.4	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
July 16-30	0.0	0.0	0.0	1.3	0.0	0.3	0.3	0.0	0.1	0.0	0.0	0.0

Table 13. 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[1]	Estimated Outmigration (# of fish)[2]
Chinook Salmon	Fry 0+	34	0.165	199
	Smolt 0+	196	0.104	1,823
Coho Salmon	Fry 0+	17	0.135	121
	Smolt 0+	58	0.135	446
	Smolt 1+	0	0.135	0
Steelhead/ Rainbow Trout	Fry 0+	3	0.135	28
	Parr 1+	9	0.135	72
	Parr 2+	10	0.135	74
	Smolt 3+	7	0.135	54
Chum Salmon	Fry 0+	2,784	0.133	20,997
Pink Salmon	Fry 0+	2	0.135	15
Sockeye Salmon	Fry 0+	18	0.135	133

[1] The overall capture efficiency of the RST was used to estimate outmigration for Coho 0+ fry and smolts and Pink and Sockeye Salmon fry.

[2] Estimated out-migrations of Chinook and Coho Salmon were corrected for the proportion of hatchery reared fish based on otolith analysis (3.4 %).

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 in 2017 (Figure 20, Table 14, paired t-test: $t_5 = -2.032$, $p = 0.098$ for densities calculated based on observer efficiency, and $t_5 = -1.174$, $p = 0.293$ for densities calculated based on the Peterson estimator). These relationships were consistent when both years of monitoring were combined (Figure 21) and tested through linear mixed-effects models with site and survey year as random effects ($\chi^2(1) = 0.55$, p-value = 0.46 for densities based on observer efficiency and $\chi^2(1)=0.96$, p-value=0.33 for densities based on the Peterson estimator). In general in both years and seasons, Steelhead/Rainbow Trout had the highest densities in sites CBR-NSK02 and CBR-NSK04, and the lowest densities in the most downstream site, CBR-NSK06.

In total, 112 and 131 Steelhead/Rainbow Trout were observed and marked during the snorkel mark sampling in fall and spring, respectively (Table 14). In fall 2016, 102 Steelhead/Rainbow Trout were observed during the resight sampling, 33 of which were previously marked fish. The site-specific observer efficiency ranged from 0.18 to 0.50 with a mean of 0.30. In spring 2017, 95 Steelhead/Rainbow Trout were observed during the resight sampling, 31 of which were previously marked fish. The site-specific observer efficiency ranged from 0.11 to 0.35 with a mean of 0.24.

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 20, Figure 21). The fall 2016 site population density estimates ranged from 2.0 fish/100 m^2 to 6.3 fish/100 m^2 based on the observer efficiency and 2.2 fish/100 m^2 to 6.6 fish/100 m^2 based on the Peterson estimator. The spring site population density estimates ranged from 3.1 fish/100 m^2 to 6.4 fish/100 m^2 based on the observer efficiency and 2.6 fish/100 m^2 to 6.5 fish/100 m^2 based on the Peterson estimator.

Coho Salmon parr were observed in the fall sampling but not during the spring sampling in Elk Canyon (Table 15). In total, 48 and 24 Coho Salmon parr were observed in fall 2016 during the mark and recapture sampling, respectively. Of the 48 marked parr, only five were recaptured among three of the sites yielding observer efficiencies ranging from 0.09 to 0.40 (average 0.11). No Coho Salmon parr were observed in the early spring. The fall population density estimates of Coho Salmon parr in 2016 ranged from 1.7 fish/100 m^2 to 3.4 fish/100 m^2 (Figure 22). These observed densities of Coho Salmon parr were similar to those observed in the fall of 2015, with the exception of CBR-NSK01 and CBR-NSK04, which had densities of up 10.7 fish/100 m^2. The low numbers of Coho Salmon parr observed in the overwintering snorkel surveys match the output from the RST, which indicated that no 1+ Coho overwintered in Elk Canyon.

The habitat conditions for the six monitoring sites that were established in Elk Canyon are shown in Table 16. With the exception of water temperature, which was much lower during spring surveys, sampling conditions and sampling effort were comparable between sampling days and seasons.

Table 14. Observed Steelhead/Rainbow Trout parr during overwintering snorkel surveys.

Season	Site	Captures/Observations[1]				Observer Efficiency
		M	C	R	O	
Fall 2016	CBR-NSK01	18	12	4	0	0.22
	CBR-NSK02	34	42	13	0	0.38
	CBR-NSK03	12	11	3	0	0.25
	CBR-NSK04	17	12	3	0	0.18
	CBR-NSK05	11	12	5	1	0.50
	CBR-NSK06	20	13	5	0	0.25
					Average	0.30
					Standard Deviation	0.12
					Standard Error	0.05
Spring 2017	CBR-NSK01	20	12	7	0	0.35
	CBR-NSK02	32	32	8	0	0.25
	CBR-NSK03	24	13	5	0	0.21
	CBR-NSK04	17	13	4	0	0.24
	CBR-NSK05	19	9	2	1	0.11
	CBR-NSK06	19	16	5	0	0.26
					Average	0.24
					Standard Deviation	0.08
					Standard Error	0.03

[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 15. Observed Coho Salmon during overwintering snorkel surveys.

Season	Site	Captures/Observations[1]				Observer Efficiency
		M	C	R	O	
Fall 2016	CBR-NSK01	3	3	0	0	n/a
	CBR-NSK02	11	8	1	0	0.09
	CBR-NSK03	13	5	2	0	0.15
	CBR-NSK04	6	2	0	0	n/a
	CBR-NSK05	10	2	0	0	n/a
	CBR-NSK06	5	4	2	0	0.40
Spring 2017	CBR-NSK01	0	0	0	0	n/a
	CBR-NSK02	0	0	0	0	n/a
	CBR-NSK03	0	0	0	0	n/a
	CBR-NSK04	0	0	0	0	n/a
	CBR-NSK05	0	0	0	0	n/a
	CBR-NSK06	0	0	0	0	n/a

[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

Figure 20. Estimated population density of Steelhead/Rainbow Trout parr in fall 2016 and spring 2017. Error bars represent 95% confidence intervals.

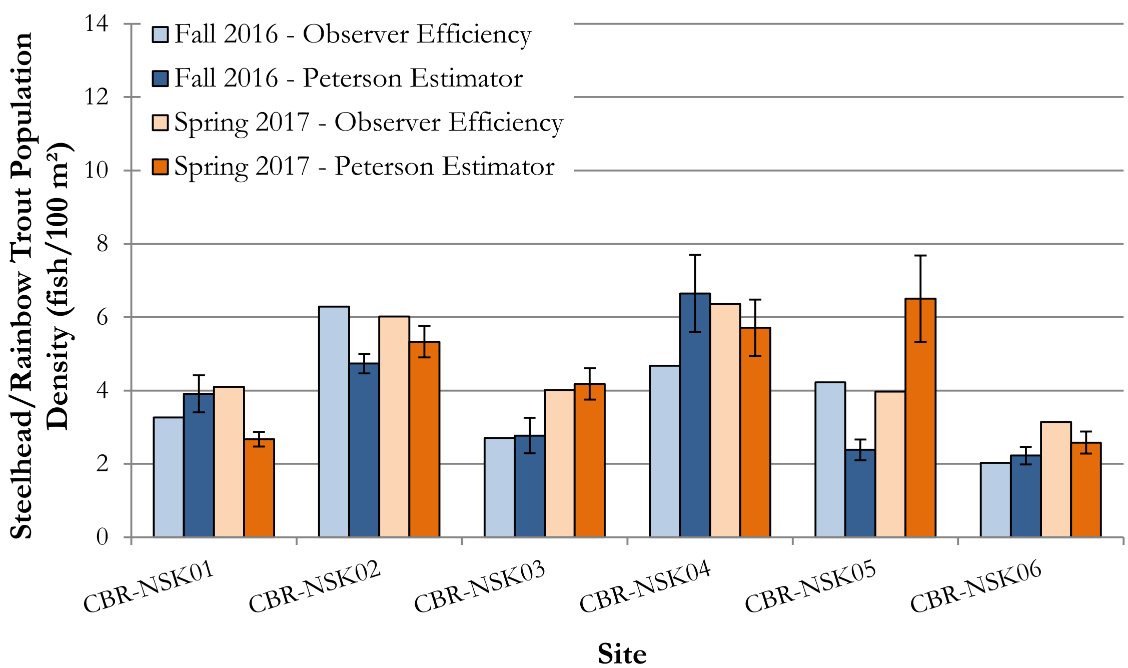
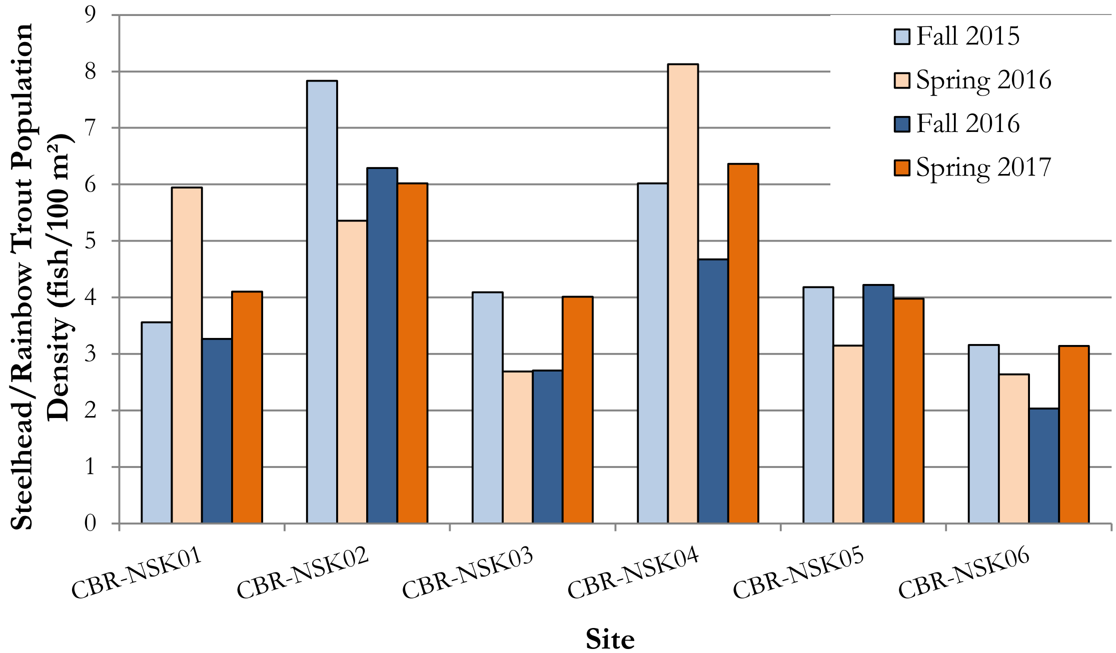


Figure 21. **Estimated population density of Steelhead/Rainbow Trout parr in Year 1 (fall 2015 and spring 2016) and Year 2 (fall 2016 and spring 2017) of monitoring based on a) observer efficiency and b) the Peterson estimator. Error bars represent 95% confidence intervals.**

a)



b)

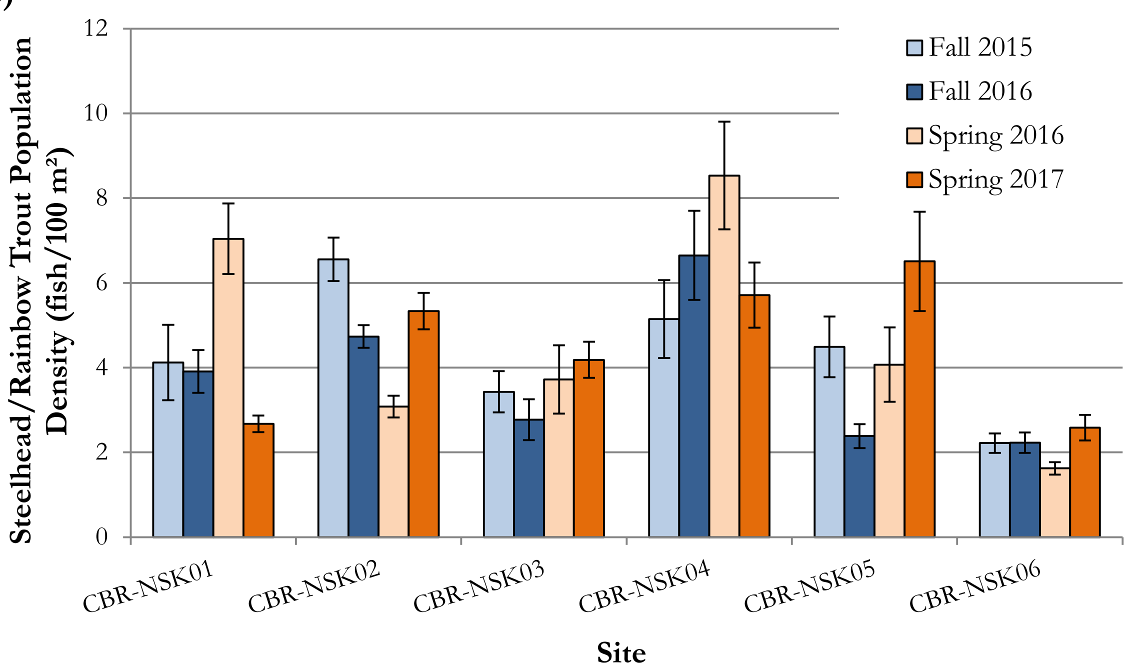


Figure 22. Estimated population density of Coho Salmon parr in Year 1 (fall 2015 and spring 2016) and Year 2 (fall 2016 and spring 2017) of monitoring based on the average observer efficiency estimated in fall 2016.

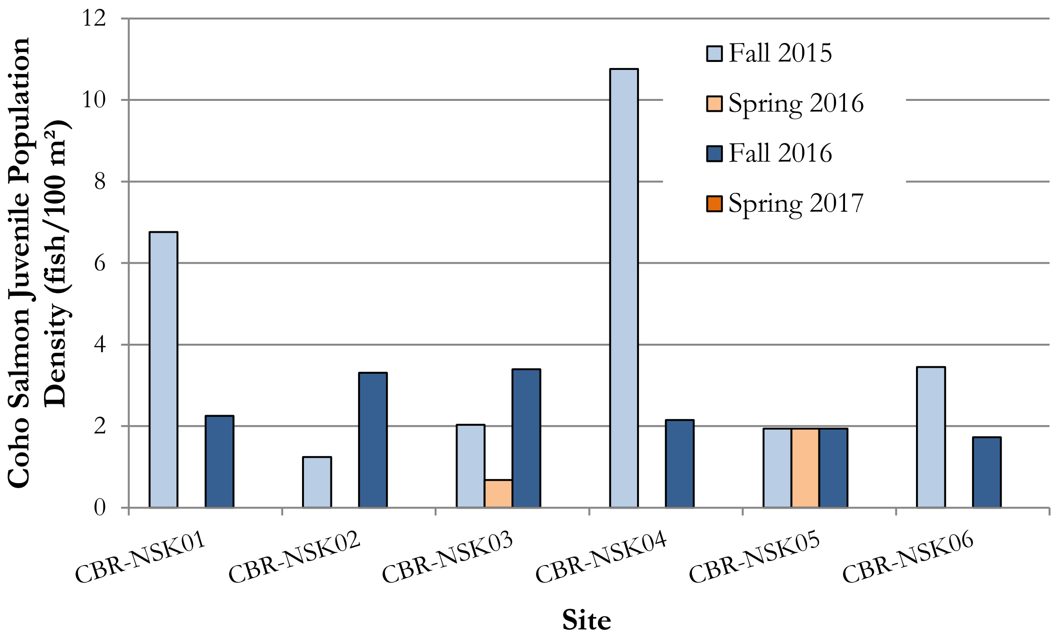


Table 16. Overwintering snorkel site conditions.

Season	Sampling Objective	Date	Waypoint/Site	Sub-Site	Total Effort (hr)	Water Temp °C	Air Temp °C[1]	Estimated Visibility (m)[1]
Fall	Mark	10-Sep-16	CBR-NSK01	CBR-NSK01	2.00	19	14.5	8
			CBR-NSK02	Section 1 Riffle	0.88	19	n/c	8
				Section 2 Cascade	1.48	19	n/c	8
				Section 3 Run	1.32	19	n/c	8
				Section 4 Cascade	1.40	19	n/c	8
			CBR-NSK03	CBR-NSK03	1.08	19	n/c	8
			CBR-NSK04	CBR-NSK04	1.80	19	n/c	8
			CBR-NSK05	CBR-NSK05	1.80	19	n/c	8
			CBR-NSK06	CBR-NSK06	1.12	19	n/c	8
	Re-Sight Index	11-Sep-16	CBR-NSK01	CBR-NSK01	0.94	18	15	8
			CBR-NSK02	Section 1 Riffle	1.16	18	15	8
				Section 2 Cascade	0.46	18	15	8
				Section 3 Run	0.64	18	15	8
				Section 4 Cascade	0.44	18	15	8
			CBR-NSK03	CBR-NSK03	1.16	18	n/c	n/c
			CBR-NSK04	CBR-NSK04	0.86	18	15	8
			CBR-NSK05	CBR-NSK05	0.84	18	15	8
			CBR-NSK06	CBR-NSK06	0.84	18	n/c	8
Spring	Mark	2-Feb-17	CBR-NSK01	CBR-NSK01	1.84	3	n/c	6
			CBR-NSK02	Section 1 Riffle	0.96	3	n/c	6
				Section 3 Run	0.50	3	n/c	6
				Section 4 Cascade	0.66	3	n/c	6
				Section 2 Cascade□	0.66	3	n/c	6
			CBR-NSK03	CBR-NSK03	0.84	3	3	6
			CBR-NSK04	CBR-NSK04	1.16	3	n/c	6
			CBR-NSK05	CBR-NSK05	0.94	3	n/c	6
			CBR-NSK06	CBR-NSK06	1.16	3	n/c	6
	Re-Sight Index	2-Feb-17	CBR-NSK02	Section 1 Riffle	0.36	3	n/c	n/c
				Section 2 Cascade	0.44	3	n/c	n/c
				Section 3 Run	0.44	3	n/c	n/c
				Section 4 Cascade	0.34	3	n/c	n/c
			CBR-NSK03	CBR-NSK03	1.20	3	n/c	6
		2017-02-03	CBR-NSK01	CBR-NSK01	1.16	3	n/c	6
			CBR-NSK04	CBR-NSK04	0.84	3	n/c	n/c
			CBR-NSK05	CBR-NSK05	1.40	3	n/c	6
			CBR-NSK06	CBR-NSK06	0.90	3	0.5	n/c

[1] n/c represents not collected.

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 to the pulse release (paired t-tests: all $t_6 < |1.69|$, all p-values > 0.14). 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 23). Therefore, based on Year 3 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 markedly between periods of pulse flows ($\Delta salmon/day_{pulse\ flow}$) and periods of base flows ($\Delta salmon/day_{base\ flow}$) for Coho Salmon, Chinook Salmon, Chum Salmon, and Steelhead (paired t-tests: all $t_5 < |1.32|$, all p-values > 0.24). The average rate of salmon in-migration per day of these species was near to zero and was similar to the average rate of salmon in-migration per day during base flows, which acts as the control (Figure 24). Therefore, based on Year 3 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 for these species. In contrast, Sockeye Salmon in migration per day did differ between periods of pulse and base flows (paired t-tests: $t_5 = |2.60|$, p-value <0.05). While in-migration was relatively close to zero during pulse flows, in-migration was higher during base flows. Therefore, based on Year 3 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 rejected for this species.

There were several salmon counts that provide some evidence that the pulse flow release was a success. Counts of Coho Salmon increased considerably post pulse release during weeks 1, 5, and 6, while those of Chinook increased during weeks 3 and 5, those of Chum increased during weeks 5, 6, and 7, and those of Steelhead increased during weeks 1, 3, 5, and 6 (Figure 23). Coho, Chinook, and Chum Salmon abundance in Elk Canyon gradually increased through the fall of 2016, with Coho and Chum peaking near the end of October and Chinook Salmon peaking in mid-October. In contrast, Steelhead abundance appeared to be more variable throughout the fall but had decreased by November. Sockeye Salmon abundance decreased through the fall with few spawners observed during surveys conducted after mid-October.

Figure 23. 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 October 27, 2016. Target species include A) Coho Salmon, B) Chinook Salmon, C) Chum Salmon, D) Steelhead and E) Sockeye Salmon.

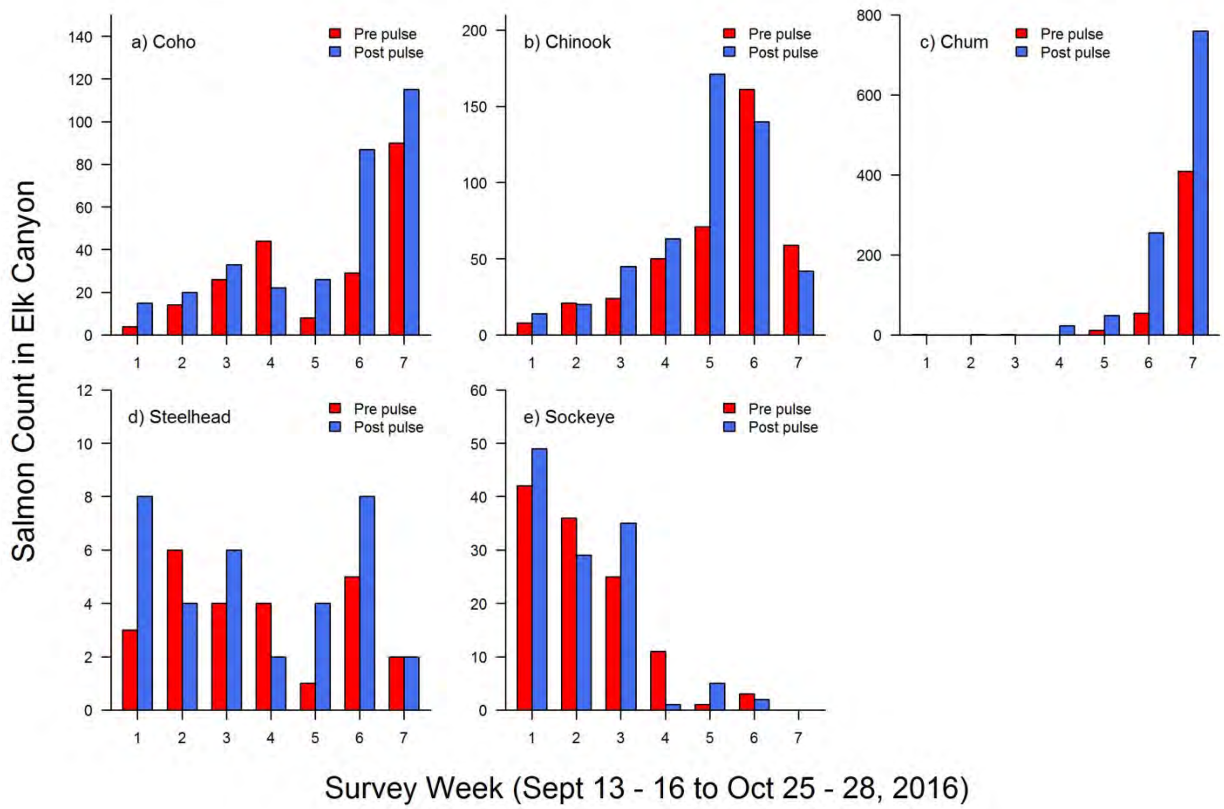
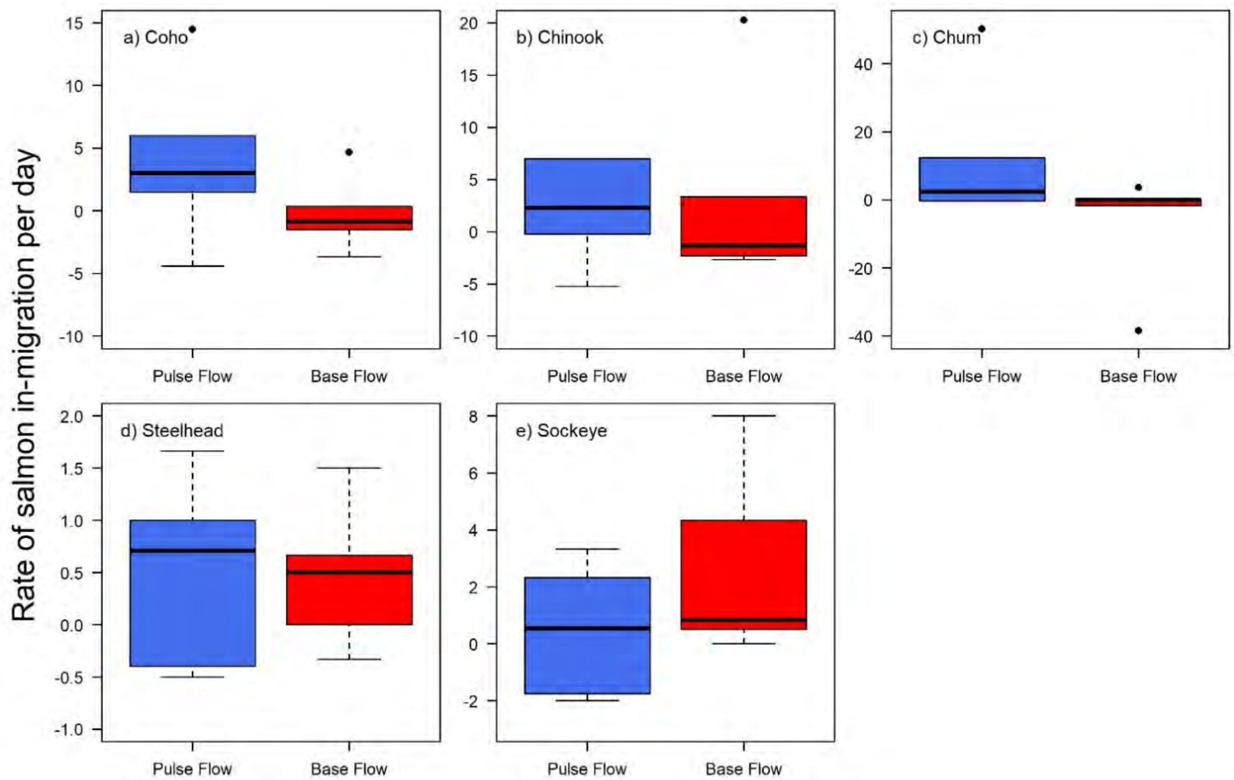


Figure 24. Rate of salmon in-migration per day during the pulse flow release and during base flows for A) Coho Salmon, B) Chinook Salmon, C) Chum Salmon, D) Steelhead and E) Sockeye Salmon. Boxplots show the median (solid line) of the nine tests, the middle 50% of the data (box), the outer quartiles (whiskers), and outliers (solid points).

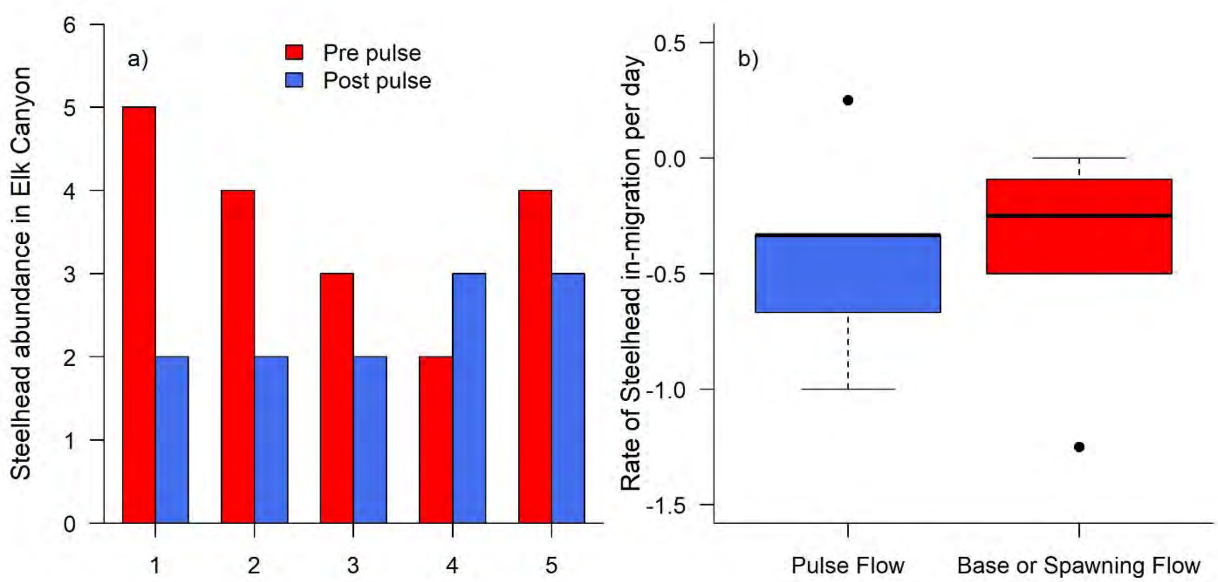


3.3.2. Spring Pulse Flow Assessment

There was little difference in the count of Steelhead in Elk Canyon the day after the 2-day 10 m^3/s spring pulse releases in 2017 compared to the day prior to the pulse releases (paired t-test: $t_4 = 1.81$, p-value = 0.14 compared to paired t-test: $t_4 = 3.66$, p-value = 0.035). Counts of Steelhead immediately after the spring pulse release were lower than the day prior to the pulse release during the first three weeks, with little difference between counts in the last two weeks, although, as in Year 2, counts of Steelhead were low (maximum = 5 individuals) (Figure 25a). Based on Year 3 data, the null hypothesis ($H_0$5) was retained of no difference in the number of Steelhead following pulse flow release compared to just prior to the release. These results were confirmed when data from Year 2 and Year 3 were combined and the difference between Steelhead counts the day prior to and the day after spring pulse releases were tested using a mixed-effects model including year as a random effect. On average, Steelhead counts were 1.4 times higher (± 0.86 SE) prior to spring pulse flows than immediately after on average, but this relationship was not significant ($\chi^2(1) = 2.61$, p-value = 0.11).

Similar to Year 2, the rate of Steelhead in-migration per day did not differ between periods of pulse flows (Δsalmon/day$_{\text{pulse flow}}$) and periods of base/spawning flows (Δsalmon/day$_{\text{base flow}}$) (paired t-test: $t_4 = 0.005$, p-value = 0.996). The average rate of Steelhead in-migration during the pulse and base/spawning flows in Year 3, was near to zero (Figure 25b). Therefore, based on Year 3 data, the null hypothesis ($H_0 3$) was retained 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. These results were also confirmed when data from Year 2 and Year 3 were combined and the difference between rates of Steelhead in-migration per day during pulse flows and base/spawning flows was tested through a linear mixed-effects model with year as a random effect. On average in-migration was 28% lower during pulse flows, but again, this relationship was not significant ($\chi^2(1) = 1.19$, p-value = 0.28). Based on results from Year 2 and Year 3 of monitoring, at present, there is no evidence to suggest that spring pulse flows attract Steelhead into Elk Canyon.

Figure 25. 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.



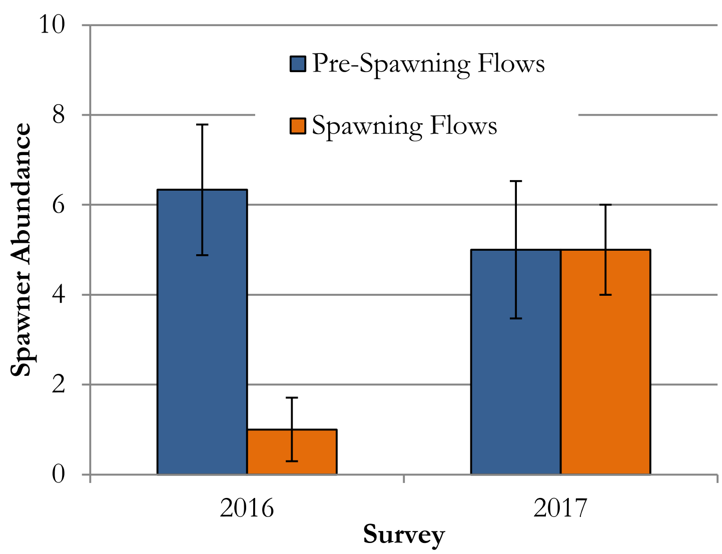
3.4. Steelhead Spawning Flow Assessment

The abundance of Steelhead in Elk Canyon averaged five individuals just prior to the spawning flow release and only two individuals during the release (Table 17). Peak count of Steelhead in the spring of 2017 was eight individuals which occurred on March 28. When the Year 2 and Year 3 data are combined (Figure 26), the abundance of Steelhead in Elk Canyon is found to be higher prior to the spawning flow releases, than during the spawning flow releases (independent t-test: t = 2.38, p-value = 0.04), which is opposite to that predicted, but largely driven by the 2016 data. A more complete synthesis analysis will be completed after a third year of spawning flow assessment.

Table 17. Counts of Adult Steelhead prior to and during the spawning flow release in 2017.

Spawning Flow Condition	Date	Count of Adult Steelhead
Pre Spawning Flow Release	21-Mar-17	4
	24-Mar-17	3
	28-Mar-17	8
	Average	*5*
During Spawning Flow Release	3-Apr-17	6
	10-Apr-17	4
	Average	*5*

Figure 26. Adult Steelhead Abundance during individual surveys prior to and during spawning flow releases in 2016 and 2017.



3.5. Spawner Enumeration

3.5.1. Fall Spawners

Chinook and Coho Salmon adult abundance were estimated to be 275 and 249 individuals respectively using the area under the curve method (Table 18). Chum Salmon had the highest estimated abundance of 1,094 individuals. A population of 763 Pink Salmon and 89 Sockeye Salmon were also estimated (Table 18). Few Steelhead were observed in fall with a peak observed abundance of only eight individuals.

As in previous years, the peak spawning time was variable across salmon species. Pink Salmon had the earliest peak, with observed spawner counts peaking in late September (Figure 27). Sockeye Salmon had the next peak in counts, which was observed in mid to late September; however the peak was not as clear as other species (Figure 28). Chinook Salmon had a peak in mid-October (Figure 28). Coho and Chum Salmon had the latest peak in spawning in late October/early November (Figure 28, Figure 29). A maximum of eight Steelhead were observed in mid-September and mid-October (Figure 30).

Pink, Sockeye, and Chinook Salmon spawner counts had peaked and subsequently decreased to low numbers by the start of November, and thus, were likely not heavily affected by the large spill event that occurred between November 4 and 24, 2016. In contrast, Chum and Coho Salmon spawner counts did not peak until mid-November in 2016 and therefore may not have reached their peak prior to the large November spill event. The high discharge levels through Elk Canyon during this time likely flushed out all of the spawners as no individuals from any species were observed during surveys conducted after discharge levels had receded in late November and early December.

Not all observed adults spawned in Elk Canyon. The number of redds was also recorded during the fall spawner surveys. The maximum number of redds observed varied considerably among species (Table 19). Chum, followed by Pink Salmon had the highest numbers of redds at 280 and 97 redds, respectively, while a maximum of 44 Chinook Salmon redds, 10 Sockeye Salmon redds, and only one Coho Salmon redd were observed during fall snorkels. Similar to spawner counts, redd counts peaked for all species in September and October, with Pink and Sockeye Salmon redd counts peaking the earliest, followed by counts of Chinook and Chum Salmon redds. The large November spill event also likely washed out many of the redds as only two redds were observed after the event (Table 19).

3.5.1.1. Productivity of Fall Salmon Spawners

Salmon fry and smolt production from Elk Canyon was estimated based on the fall 2016 redd counts. These estimates were compared to the 2017 out-migration predicted from RST catch. Based on the mean fecundity by salmon species and the maximum number of redds observed for each species, Chum Salmon had the greatest number of estimated eggs produced with 896,000, followed by Chinook, Pink, Sockeye, and Coho Salmon (Table 20). After correcting for egg-to-fry and egg-to-smolt survival, in most cases, the estimated fry and smolt production from redd counts was much greater than the out-migration estimate derived from RST catch. For example, only 15 Pink Salmon fry were estimated as out-migrated compared to 20,079 individuals predicted from the maximum number of Pink redds observed. Differences in predictions were also large for Chinook, Chum, and Sockeye Salmon fry and Chinook smolts (Table 20). The one exception to this was for Coho smolts with only 495 estimated based on egg production from redds, and 446 estimated from the RST catch. 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. However, they also suggest that there was very low egg-to-fry survival in Elk Canyon through the winter of 2016-2017. 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). Another likely explanation this year, is the influence of the 480 m^3/s spill event in November 2016.

Table 18. Fall salmon spawner counts by species and estimates of abundance.

Date	Count of Adult Fish Species[1]					
	ST	CH	CM	CO	PK	SK
7-Sep-16	7	13	1	1	4	32
13-Sep-16	3	8	1	4	24	42
16-Sep-16	8	14	0	15	82	49
19-Sep-16	6	21	0	14	92	36
23-Sep-16	4	20	1	20	246	29
27-Sep-16	4	24	1	26	763	25
30-Sep-16	6	45	0	33	463	35
3-Oct-16	4	50	0	44	264	11
8-Oct-16	2	63	23	22	33	1
11-Oct-16	1	71	12	8	12	1
14-Oct-16	4	171	49	26	1	5
17-Oct-16	5	161	54	29	0	3
21-Oct-16	8	140	255	87	0	2
25-Oct-16	2	59	409	90	0	0
28-Oct-16	2	42	759	115	0	0
31-Oct-16	6	28	1,094	135	0	1
29-Nov-16	1	0	1	2	0	0
2-Dec-16	1	0	0	2	0	0
6-Dec-16	1	0	0	1	0	0

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

Figure 27. Adult Pink Salmon counts in Elk Canyon by date.

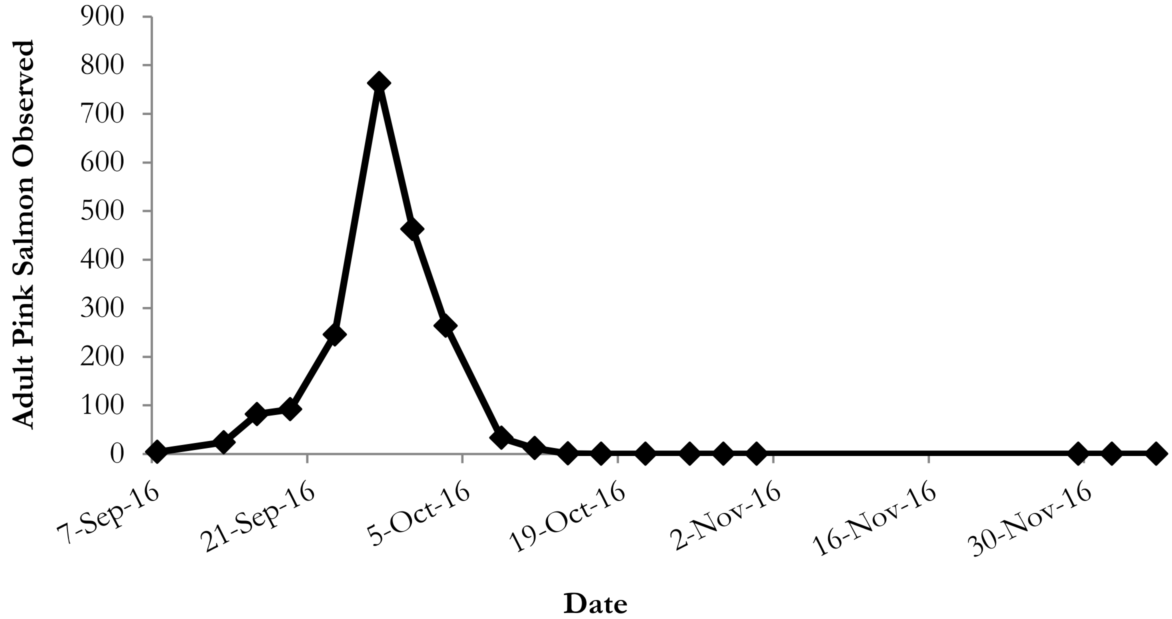


Figure 28. Adult Coho, Chinook, and Sockeye Salmon counts in Elk Canyon by date.

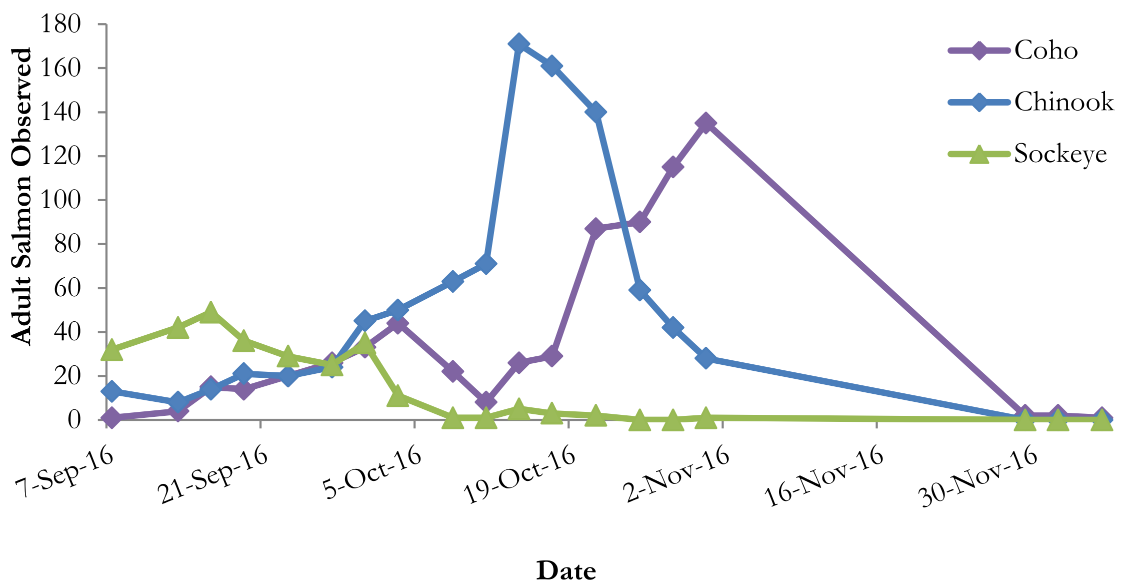


Figure 29. Adult Chum Salmon counts in Elk Canyon by date.

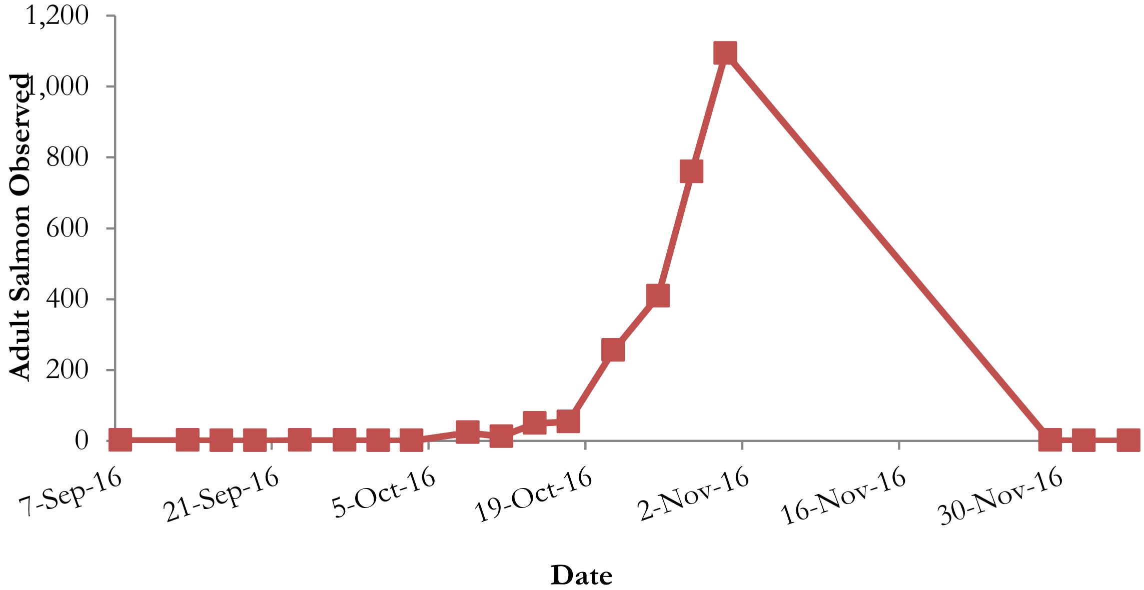


Figure 30. Adult Steelhead counts in Elk Canyon by date.

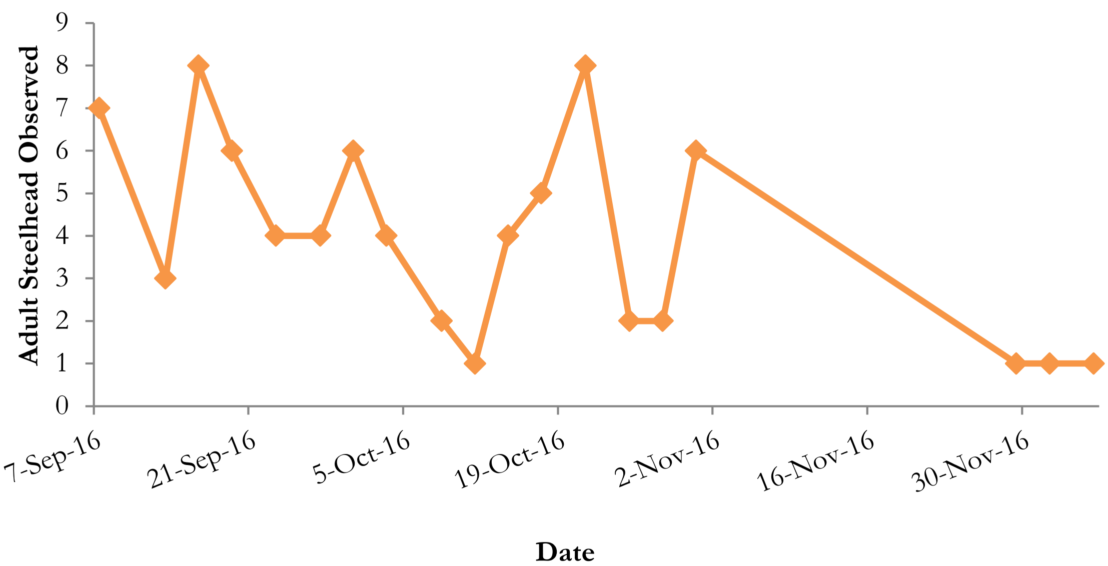


Table 19. Fall counts of salmon redds by species.

Date	Count of Fish Redds[1]					
	ST	CH	CM	CO	PK	SK
7-Sep-16	0	0	0	0	0	0
13-Sep-16	0	0	0	0	0	0
16-Sep-16	0	0	0	0	0	0
19-Sep-16	0	0	0	0	7	4
23-Sep-16	0	0	0	0	15	10
27-Sep-16	0	1	0	0	81	7
30-Sep-16	0	0	0	0	86	8
3-Oct-16	0	2	0	0	97	2
8-Oct-16	0	4	0	0	16	0
11-Oct-16	0	12	1	0	4	0
14-Oct-16	0	19	3	0	0	0
17-Oct-16	0	33	1	0	0	0
21-Oct-16	0	44	57	0	0	0
25-Oct-16	0	37	169	0	0	0
28-Oct-16	0	16	280	0	0	0
31-Oct-16	0	6	224	1	0	0
29-Nov-16	0	0	1	1	0	0
2-Dec-16	0	0	0	1	0	0
6-Dec-16	0	0	0	0	0	0
Max Observed	**0**	**44**	**280**	**1**	**97**	**10**

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

Table 20. 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	97	174,600	0.12		20,079		15	
Chum	3,200	280	896,000	0.13		115,584		20,997	
Sockeye	3,500	10	35,000	0.13		4,445		133	
Coho	3,000	1	3,000	0.25	0.17	759	495	121	446
Chinook	4,300	44	189,200	0.38	0.10	71,896	19,109	199	1,823

[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.

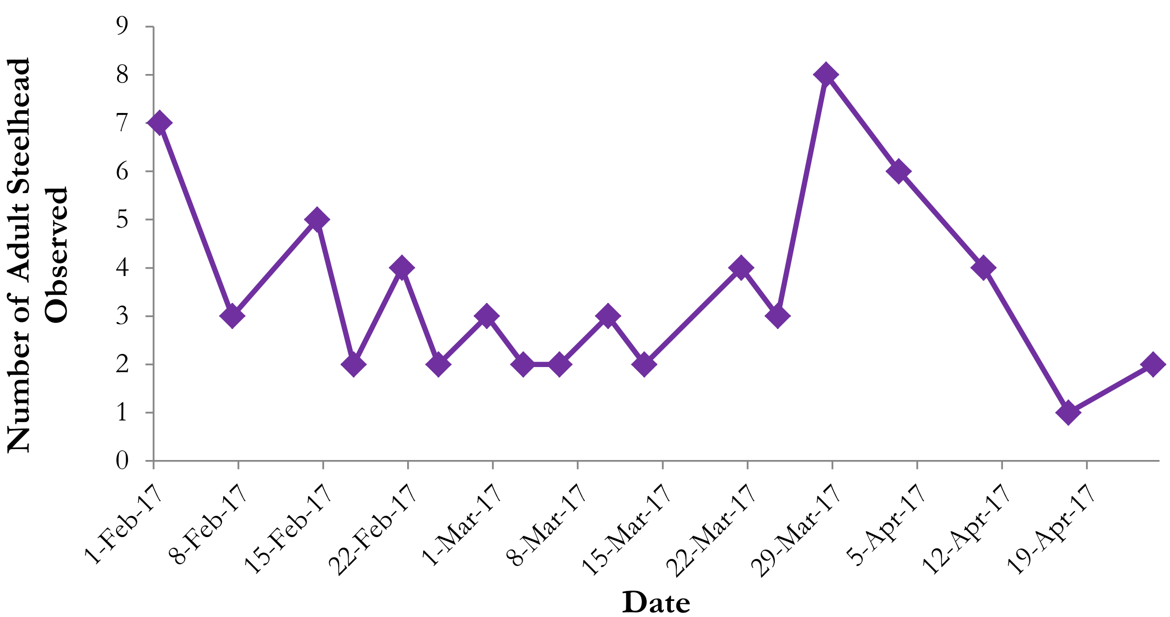
[5] Sockeye RST outmigration estimates did not differentiate between fry and smolt; therefor Sockeye escapment estimates are assumed to be fry.

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

3.5.2. Spring Spawners

Steelhead abundance in Elk Canyon peaked at a maximum count of eight individuals in late March (Figure 31). Steelhead counts declined in April to only one to two individuals. No Steelhead redds were observed during this period.

Figure 31. Steelhead counts during the spring spawner survey 2017.



4. CONCLUSIONS

4.1. Overview

All BC coast salmonid species were observed using Elk Canyon for spawning and/or rearing during the Year 3 of sampling 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 following sections highlight the main conclusions for each component of the study conducted in Year 3.

4.2. Smolt Enumeration

The RST worked well during its third year and remains a viable technique for enumerating juvenile fish that are out-migrating from Elk Canyon. As in previous years, Chum Salmon out-migration was the highest of all salmonid species with a 2017 estimated out-migration of 20,997 fry. Coho Salmon out-migration was estimated to be 121 fry, 446 age 0+ smolts, while no age 1+ smolts were captured in 2017. Chinook Salmon out-migration was estimated to be 199 fry and 1,823 age 0+ smolts. Steelhead/Rainbow Trout out-migration was estimated to be 28 age 0+ fry, 72 age 1+ parr, 74 age 2+ parr, and 54 ≥3+ smolts. Sockeye and Pink Salmon out-migration was estimated at only 15 and 152 fry, respectively. These estimates are much lower than in Year 2, particularly for fry, with estimates of Chum, Coho, Chinook, Pink, and Sockeye Salmon and Steelhead/Rainbow Trout fry out-migration roughly 8%, 2%, 1%, 2%, 15%, and 53%, respectively of those observed in 2016. Smolt/parr estimates of out-migration in 2017 were also generally lower than in 2016, but the difference was less pronounced; estimates for Coho Salmon smolts were roughly 51% than in 2016, those of Chinook smolts were similar between the two years, and those of 1+ and 2+ Steelhead/Rainbow trout parr were 50% and 9% of those in 2016, respectively.

The markedly lower estimates of out-migration compared to the previous year as well as estimated juvenile production derived from fall spawner enumeration may be related to the exceptionally high discharge spill event that occurred in November 2016, which was likely to have flushed out spawners of some species such as Chum and Coho Salmon prior to peak spawning and scoured a proportion of the redds of all species. This was corroborated by the lack of redds observed during snorkels following the large November spill event and the observed displacement of gravels from Elk Canyon.

Mark/recapture trials had an average recapture efficiency of 13.5% across all salmon species and life stages (excluding Coho Salmon fry and smolts), which is similar but slightly lower than the average recapture efficiency from Years 1 and 2 of 20.8% and 16.7%, respectively. These average capture efficiencies exclude Coho Salmon fry and smolts, which seem to not immediately emigrate from Elk Canyon after release. This was corroborated by calibration swims in May that found numerous Coho fry still holding upstream of the RST.

Out-migration timing information by life stage is evident within and across species from the RST data. For example, several life history stages of Coho Salmon, Chinook Salmon and Rainbow Trout/Steelhead were captured in the RST. In line with results from 2016, all of the Chinook Salmon that were caught in the RST are likely to be 0+ fish based on otolith age analysis. This indicates that they are exclusively 'ocean type', meaning that they rear for only a few months in freshwater and then migrate to the estuary to continue rearing. Two peaks in Chinook out-migration were observed, an early peak in March of Chinook fry that may rear downstream in the Campbell River system, and a later peak in June of larger individuals that have reared for a few months in Elk Canyon. A small number of these larger fish may have originated from the Quinsam Hatchery, as confirmed by one thermally marked fish out of 29 sampled from the RST.

Two Coho Salmon life stages were evident including an early migration of Coho fry in March and April, and a later migration of larger 0+ Coho smolts from May through July. No 1+ Coho Salmon smolts were observed in Year 3.

Four age classes of Steelhead/Rainbow Trout were identified in the RST catch, including 0+, 1+, 2+ and ≥3+ fish. Steelhead/Rainbow Trout did not have a clear peak in out-migration timing suggesting that catches represent more localized movements rather than out-migration. Only three 0+ individuals (e.g., < 79 mm fork length) were captured in the RST, all in June. The majority of Steelhead/Rainbow Trout were 1+ (28%), 2+ (31%), and ≥3+ fish (24%), which were captured between March and July throughout the full period of RST deployment.

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 out-migration peaks are captured. In Year 3, as in Year 2, a clear second peak in out-migration was observed for Chinook in June as was a low but steady out-migration of Coho throughout 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 second year in Year 3 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 abundance was similar between fall (September) and early spring (February) 2017 sampling seasons in Elk Canyon. This conclusion was supported by an analysis across both years of study, which showed that average Steelhead/Rainbow Trout parr abundance is similar both between years and seasons and is relatively consistent at each of the sampling sites. This 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. This conclusion is preliminary and further analyses will be completed after each year of overwintering assessment data collection.

Coho Salmon parr were observed during the fall of 2016 but none were observed during spring mark/resight swims in 2017. These low numbers of observed Coho Salmon parr match the observations from the RST catch, in which no 1+ Coho Salmon smolts were captured in spring 2017. This suggests that no 1+ Coho overwintered in Elk Canyon in 2017. In contrast, a small cohort of 1+ Coho were observed in the RST catch in 2016.

4.4. Pulse Flow Assessment

Year 3 included the second year of fall and spring pulse flow assessments. The snorkel survey methods for these components 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. 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.

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 fall pulse flow releases were a success. Counts of Coho Salmon increased considerably post pulse release during weeks 1, 5, and 6, while those of Chinook increased during weeks 3 and 5, those of Chum increased during weeks 5, 6, and 7, and those of Steelhead increased during weeks 1, 3, 5, and 6. Sockeye Salmon showed an opposite trend where in-migration was higher during base flows compared to pulse flows.

There was little difference overall in the count of Steelhead in Elk Canyon the day after the 2-day 10 m^3/s spring pulse releases compared to the day prior to the pulse releases in 2017. The rate of Steelhead in-migration per day also did not differ between periods of pulse flows and periods of base/spawning flows in Year 3. These results were confirmed when data from Year 2 and Year 3 were combined and analysed. At present there is no evidence to suggest that spring pulse flows attract Steelhead into Elk Canyon.

These conclusions for both fall and spring pulse flows should be considered preliminary until one more year of pulse flow assessments is completed, including a final synthesis analysis across all years.

4.5. Steelhead Spawning Flow Assessment

The abundance of Steelhead in Elk Canyon in spring 2017 prior to the two-week spawning flow release was not significantly different to Steelhead abundance during the release. However, when both years of data were analysed together, Steelhead abundance was found to be significantly higher prior to the spawning flow release compared to during the spawning flow release. This is the opposite of predictions at the time when the flow prescription was set. In particular considering the small numbers of Steelhead individuals observed, this conclusion should be considered preliminary until one more year of spawning flow assessments are completed, including a final synthesis analysis across all years.

4.6. Spawner Enumeration

Snorkel surveys are an appropriate method to enumerate adult fish in Elk Canyon. Adult Chinook Salmon, Chum Salmon, Coho Salmon, Pink Salmon, Sockeye Salmon and Steelhead were all observed in Elk Canyon; Chinook Salmon, Chum Salmon, Coho Salmon, Pink Salmon and Sockeye redds were also counted.

Chum Salmon followed by Pink Salmon had the highest estimated abundances at 1,094 and 763 individuals, respectively, followed by Chinook Salmon, Coho Salmon, and Sockeye Salmon at 275, 249, 89 individuals, respectively. A maximum of only eight Steelhead were observed during both the fall and a spring surveys.

The peak spawning time was variable across salmon species. Pink Salmon spawned the earliest, followed by Sockeye Salmon and Chinook Salmon. Chum Salmon and Coho Salmon spawned the latest and it is possible that the at the large spill event within Elk Canyon throughout November may have flushed out spawners and prevented upstream migration before their peak spawning was reached. No spawners of any species were observed during surveys in late November and early December following the spill event.

The estimated production of salmon fry and smolts from counts of redds was compared to estimates of salmon out-migration determined from RST catch. In all cases, but particularly for Chinook, Chum, Pink and Sockeye Salmon fry, production estimates were considerably lower than out-migration estimates. Superimposition by later spawning Chum Salmon may account for some reduction in egg-to-fry survival of earlier spawning species in the limited gravel available. However, a more likely explanation this year is the large 480 m^3/s spill event during November 2016 that mobilized significant gravel and disturbed the redds of all species.

5. CONSIDERATIONS FOR YEAR 4

The following represents a summary of considerations for Year 4.

Smolt enumeration component:

1. The RST is an effective method to inventory juvenile salmonids (fry and smolts) that are migrating out of Elk Canyon and obtain valuable life history information. In Year 3, the mark-recapture experiments included wild Chum fry in addition to Quinsam hatchery Chinook and Coho fry and smolts. These experiments with wild fry will continue if sufficient catches are observed in Year 4.
2. In the mark-recapture experiment, fry releases were marked with Bismarck Brown. These marks fade after several days causing some potential confusion between wild versus hatchery rearing Coho and Chinook fry caught in the period after that release if they choose to remain in the canyon for an extended period of time. We recommend that for the remainder of the

program that no Coho or Chinook fry be included in mark-recapture experiments. Mark recapture experiments should continue with hatchery Coho and Chinook smolts that are clearly marked with a fin clip or with wild Chum, Pink and Sockeye fry where the expectation is for the fry to move downstream immediately upon release.

3. There is still some uncertainty as to the origin of Chinook and Coho Salmon fry and smolts that are being caught in the RST in May, June and July. Smolts released from Quinsam Hatchery may swim up the Campbell River after their release and end up in the RST. Wild Chinook and Coho juveniles may also swim upstream and get caught in the RST. One of 29 Chinook Salmon smolts sampled for otolith analysis had a thermal mark, indicating that a small proportion of RST catch are hatchery-origin fish. These analyses should be conducted again in Year 4 to confirm the proportion of hatchery releases being captured in the RST.

4. Calibration snorkel swims were conducted in early May in Year 3 in the six index sites from the overwintering assessment to provide further calibration to the RST out-migration data. A large number of Coho fry were observed, which matches the later catch of Coho 0+ smolts in June and July. However, in contrast to the results for Coho Salmon, no Chinook Salmon juveniles were observed during the calibration swims. These calibration swims were conducted during the day when Coho and Chinook Salmon fry were just beginning to become active during the day. The lack of Chinook Salmon fry observations during these swims may thus have been due to these fish still hiding within the substrate during the swims. To better quantify the numbers of juvenile salmon holding upstream of the RST, and to support comparisons between seasons, we recommend that the two calibration swims be conducted later in the growing season in Year 4 during early to mid-June. We also recommend that the calibration swims use the night snorkel mark/resight methodology so that the data can be compared between the fall, winter and late spring periods.

Overwintering assessment component:

5. The night snorkeling mark/resight methods worked well again in Year 3 and were used to test $H_0 2$ of the TOR for Steelhead/Rainbow Trout and Coho Salmon. As in Year 2, similar numbers of Steelhead/Rainbow Trout were observed in Elk Canyon in the fall and the early spring, providing little evidence for net immigration or net emigration to or from Elk Canyon during this period. Coho Salmon were observed during the fall in Elk Canyon, although none were observed during the spring mark/resight swims. These low numbers of observed Coho Salmon parr match the observations from the RST, in which no 1+ Coho Salmon smolts were captured from Elk Canyon in spring 2017. The mark/resight methods will continue in Year 4, and attempts will be made to mark and resight Coho Salmon parr in early spring if sufficient densities are observed.

Pulse flow assessment component:

6. Year 3 was the second year that pulse flow assessments were conducted. Snorkel surveys were successful in testing $H_0$3 and $H_0$5 of the TOR, and results were similar to those in Year 2. A third year of pulse flow assessment will be completed in Year 5 of the program, after which, a synthesis analysis across years will be conducted that will provide a three-year assessment of the effectiveness of the current pulse flow prescription for Elk Canyon.

Steelhead spawning flow component:

7. Year 3 was the second 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 5 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 3 was the second year that estimates of production derived from RST catches were compared to estimates of production predicted from redd counts by species. This was a useful component of the analysis, which showed that the large spill event in November 2016 likely reduced egg-to-fry survival of all species.

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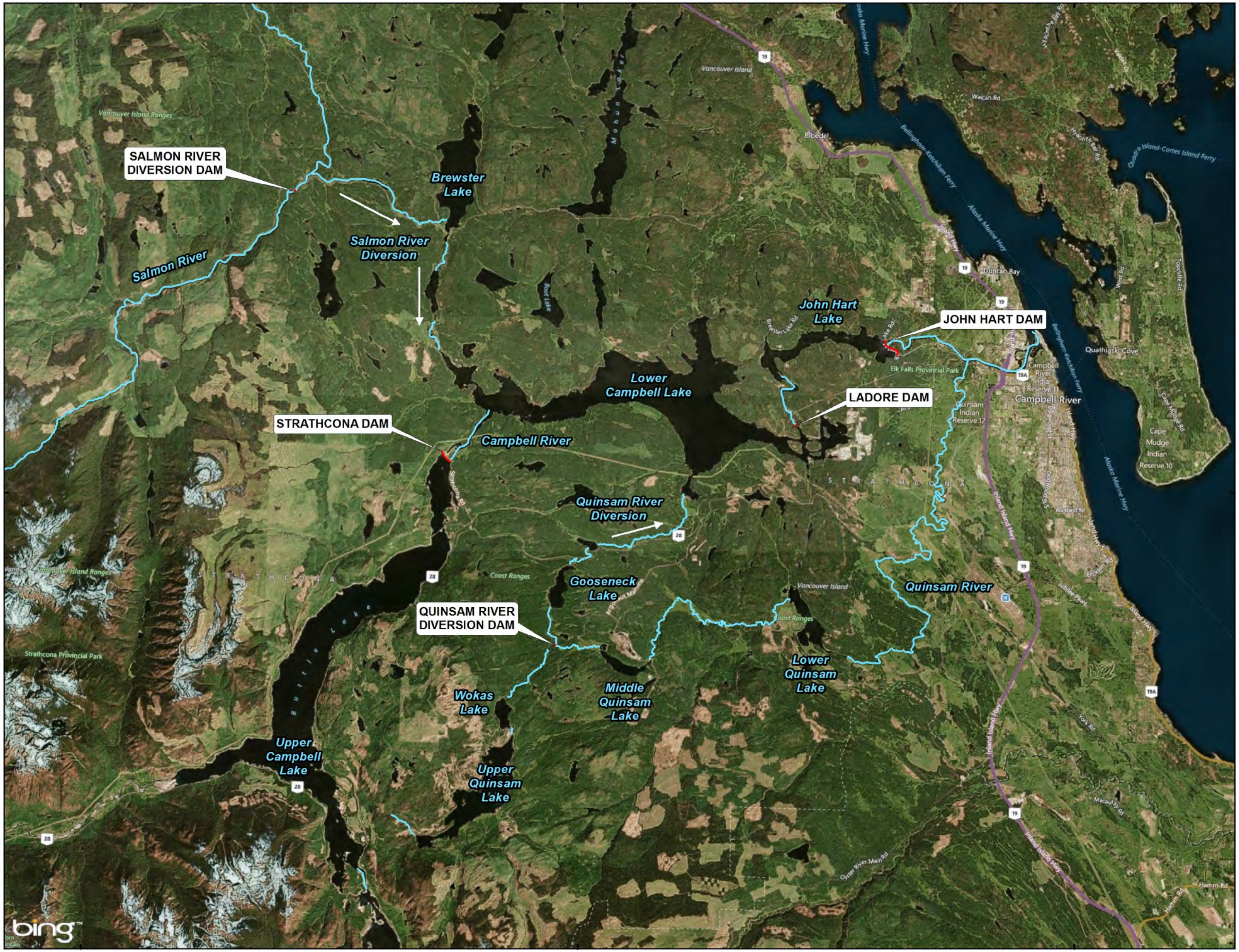
PROJECT MAPS



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			
4			
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Date Saved: 2/24/2015
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 1

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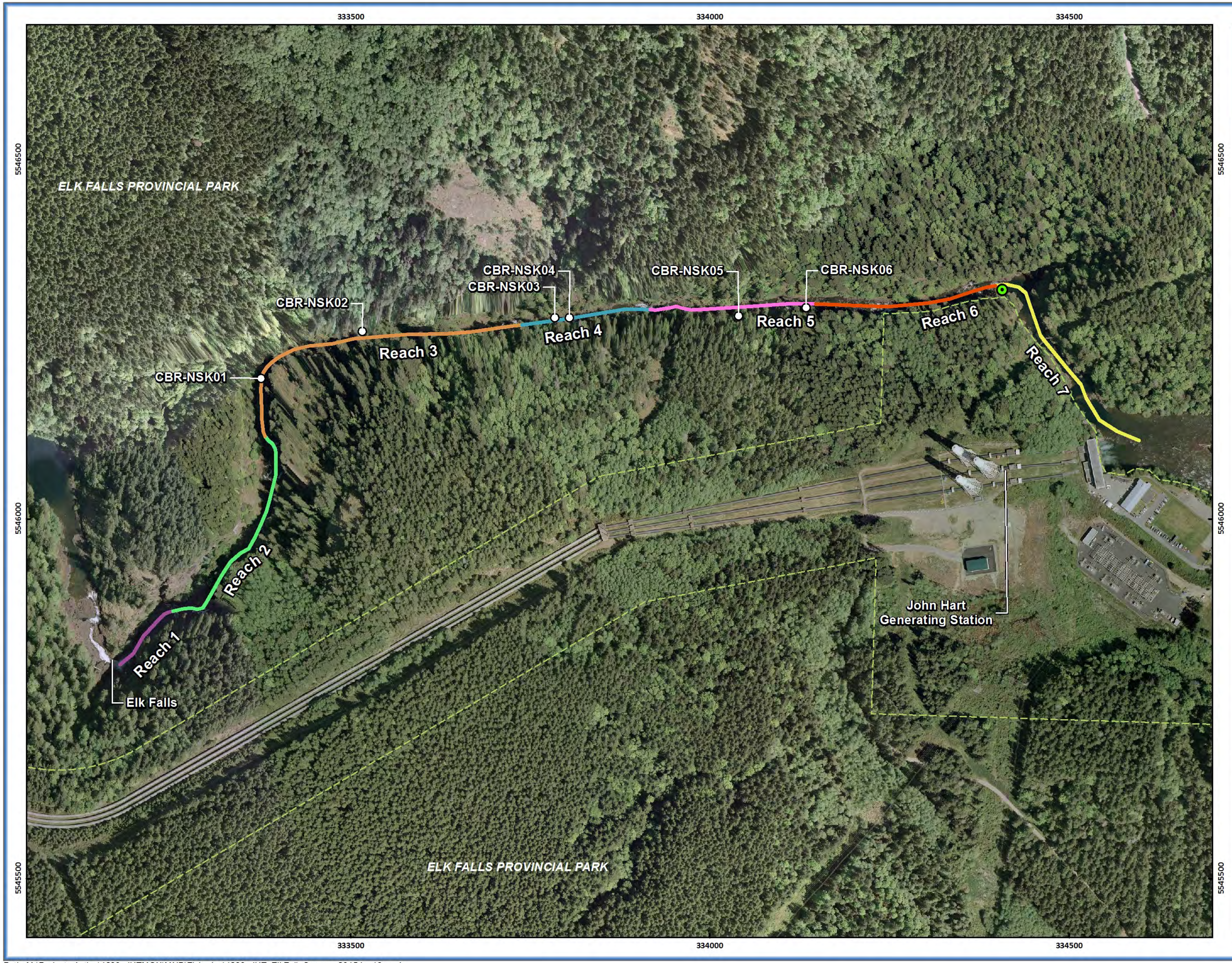
JHTMON Campbell River Water Use Plan

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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Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 2

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