Campbell River Project Water Use Plan

Elk Canyon Smolt and Spawner Abundance Assessment

Implementation Year 1

Reference: JHTMON-15

JHTMON-15: Elk Canyon Smolt and Spawner Abundance Assessment

Study Period: 2015

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

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JHTMON15

Year 1 Annual Monitoring Report

Prepared for:

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EXECUTIVE SUMMARY

The Elk Canyon on the lower Campbell River is used by all 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 use 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, with smolt enumeration and spawner counts being completed annually. The two main sampling techniques employed in Year 1 of the monitor were snorkel swim counts of adults and juveniles and rotary screw trap (RST) enumeration of outmigrating fry and smolts. A mark-recapture study was also completed to determine RST trap efficiency. The Year 1 data collection was considered to be a baseline study to verify the proposed methods and to develop a more detailed work plan for subsequent years rather than to immediately answer the management questions.

A broad diversity of fish species, including all BC coast salmonids, were observed using Elk Canyon for spawning and/or rearing during the pilot year 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 RST was in operation from the end of February to the end of June. In total, 2,315 fish were captured using the RST. The catches were primarily composed of sculpin (70%) and followed by Coho Salmon (11%), Chum Salmon (6%) and Steelhead/Rainbow Trout (5%). The combined catch of target species comprising Steelhead/Rainbow Trout, Coho Salmon, and Chinook Salmon accounted for 19% of the total catch (448 fish).

Mark-recapture trials for Chinook Salmon fry and smolts and Coho Salmon smolts had approximately a 20% recapture efficiency, while trials with Coho Salmon fry had approximately a 2.5% recapture efficiency. With these recapture efficiencies, it was possible to estimate juvenile salmon outmigration from Elk Canyon using the RST data. Coho Salmon outmigration was the highest of all salmon species with a mean abundance of 1,360 fry and 984 to 1,342 smolts. These Coho fry leaving Elk Canyon may be dispersing in search of suitable rearing habitat elsewhere in the watershed. Chinook Salmon fry outmigration was estimated to be 50 to 53 individuals, while Chinook Salmon smolt outmigration was estimated to be 326 to 341 individuals. The mean abundance of Chum Salmon and Pink Salmon fry was estimated to be 623 to 696 and 149 to 166 individuals respectively. Steelhead/Rainbow Trout outmigration was estimated to be 604 to 674 individuals.

There were clear periods of peak outmigration for each species and for different age classes based on the RST data. Chum and Pink Salmon outmigration peaked in early March, which was the earliest outmigration compared to the other salmonid species. Steelhead/Rainbow Trout catch steadily increased from mid-March until mid-May 1-15. During this time, the majority of catch were larger individuals (most between 160 and 220 mm). After May 15, catches of Steelhead/Rainbow Trout steadily declined; however, Steelhead/Rainbow Trout fry and parr (most between 55 and 135 mm) composed most of the catches in June.

Coho Salmon fry were observed outmigrating from Elk Canyon in March and April. In April, a combination of Coho fry and larger Coho smolts (perhaps 2+ year old) were caught in the RST. Peak Coho Salmon outmigration of 1+ smolts occurred in late May, and remained high through to the end of June.

Chinook Salmon outmigration was relatively low until the peak in June. The average fork length of Chinook Salmon caught in the RST in May and June was roughly 100 mm. It is unclear whether these fish are 0+ (ocean type) or 1+ (stream type) or some combination of both life histories.

The overwintering assessment conducted in September and February using snorkel survey methods tested if salmonids use Elk Canyon during their entire rearing period or if a significant proportion of the population consists of immigrant juveniles. In September, Steelhead/Rainbow Trout observations ranged from 973 to 1,443 (mean = 1,134) juveniles and Coho Salmon ranged from 2,409 to 2,863 (mean = 2,687) juveniles. No Chinook Salmon juveniles were recorded. No fish were observed during daytime snorkel swims in early February. Night snorkeling was conducted on February 23, 2015 to evaluate the effectiveness of the daytime snorkel survey. Reaches 4 through 7 were sampled and 250 Steelhead/Rainbow Trout juveniles and zero Coho Salmon were observed. Two Chinook Salmon parr were observed during this survey.

Snorkel surveys and area under the curve methods were used to estimate the abundance of fall spawners using Elk Canyon, including Chinook, Coho, Pink, Chum, and Sockeye Salmon. Chinook Salmon and Coho Salmon adult abundance was estimated to be 127 and 1,403 individuals, respectively, at a similar peak of abundance in mid-October. Pink Salmon peaked in early September and had the highest estimated abundance of all species at 63,120 individuals, although >90% of these consisted of Pink Salmon holding in the furthest downstream sampling reach. A population of 50 Chum Salmon that peaked in mid-November and 132 Sockeye Salmon that peaked in late September was also observed. Pink, Coho, and Chum Salmon redds were observed. Sockeye adults were observed above the RST up to Elk Falls; however, no Sockeye redds were counted and no Sockeye juveniles were caught in the RST. If spawning and incubation were successful we would expect to have captured Sockeye juveniles in the RST.

Steelhead were observed during the spring spawner surveys. A maximum count of nine adult Steelhead were observed in Elk Canyon on February 22nd 2015. Several weeks later a maximum of three Steelhead redds were observed on April 10th 2015.

The following represents a summary of recommendations based on Year 1 sampling of the JHTMON-15 program.

Overview of study design:

1. The first management question of JHTMON-15 centers on the base flow of 4 m^3/s in Elk Canyon and whether it is sufficient to provide juvenile rearing habitat to near maximum values. At present, the base flows of 4 m^3/s are fixed by the WUP as a single treatment for 10 years, with no experimental comparisons to other base flows. This limits the ability of the study to test the efficacy of different flow prescriptions. We therefore recommend that the JHTMON-15 program consider assessing juvenile production via a combination of the current productivity methods and an instream flow study (IFS) that can be used to develop habitat-flow relationships for each species and life stage of interest.

Smolt enumeration component:

2. The RST is an effective method to inventory juvenile salmonids (fry and smolts) that are migrating out of Elk Canyon. The RST data can be used to estimate Elk Canyon productivity for migratory Steelhead/Rainbow Trout and Chinook, Chum, Coho, and Pink Salmon. We therefore recommend that the RST work be continued.
3. The mark recapture experiment with Coho fry and smolts and Chinook fry and smolts was effective and generated recapture efficiency estimates of roughly 20% (exception is Coho Salmon fry at less than 5%). This was completed using hatchery fish since capture rates of wild fish were too low for a valid sample size. We recommend that this experiment be repeated at least one more time.
4. The mark recapture experiment with Coho fry and smolts and Chinook fry and smolts used the same mark for each of the three trials. Although most marked fish will migrate out of the canyon soon after their release, some may remain for a longer period. This means that some marked fish can be mixed up between trials. To maximize data quality, we recommend that either a unique mark be used across the three release trials or that the trials be staggered further apart to reduce the likelihood that fish recaptured from a trial period may belong to an earlier trial period.
5. The RST was effective at demonstrating run timing of outmigrating fry and smolts, including multiple age classes of Chinook Salmon, Coho Salmon and Steelhead/Rainbow Trout. It is possible that some 'stream type' Chinook Salmon are present in Elk Canyon. Therefore, we recommend that age analyses using collected scales be conducted on Chinook Salmon, Coho Salmon and Steelhead/Rainbow Trout individuals caught in the RST in future years of the program.
6. The RST may have missed a part of the Chinook and Coho Salmon smolt summer outmigration. We recommend that the period of operation of the RST be extended until the end of July. This will be reevaluated following the 2015 sampling season.
7. The RST will not be effective for estimating population size of resident fish such as resident Rainbow Trout and Cutthroat Trout. However, we also note that the resident fish are not

the target of the smolt enumeration program. For resident fish using Elk Canyon, we recommend that snorkel surveys and mark re-sight methods be considered for estimating their standing stock.

8. Several challenges to the operation of the RST in Year 1 include the cost of operation, the required removal of the RST from operation during larger spills, and public disturbance to the RST. We recommend that the JHTMON-15 program consider reducing RST operation in terms of the number of years sampled (5-6 years rather than 10 years) and number of days per week (only operate on weekdays and close trap on weekends).

Overwintering assessment component:

9. There were several challenges to the overwintering assessment methods in Year 1 of the JHTMON-15 program. In particular, day time snorkel surveys in winter resulted in no fish being observed, likely because of inactivity due to cold water temperatures. Night snorkeling in winter showed similar abundance to day time snorkels in the fall for Rainbow Trout but measured zero Coho Salmon despite large counts in the fall and catch of Coho smolts in the RST from March to June. This likely indicates Coho Salmon inactivity in cold water in both day and night. We thus recommend that the overwintering assessment methods be modified to include night time snorkel surveys in both fall and winter at index snorkel sites rather than the entire canyon. Mark resight methods could also be employed. This recommendation recognizes that these methods will be appropriate for Rainbow Trout and Cutthroat Trout, but may not be useful for Chinook Salmon and Coho Salmon.

Pulse flow assessment component:

10. The options analysis (Hatfield and Johnson 2015) yielded no single best method for inventorying adult fish migrating into and out of the canyon during pulse flows or spawning flows. In contrast, the Year 1 program of JHTMON-15 showed that snorkel surveys of the entire canyon reach are a feasible method for inventorying adult salmon and can be accomplished safely at flows up to 7 m^3/s. We therefore recommend that snorkel surveys using a before – after experimental design be considered in future years of the program for testing hypotheses $H_0 3$ to $H_0 6$.

Spawner enumeration component:

11. Snorkel surveys and area under the curve calculations are appropriate methods to estimate spawner abundance in Elk Canyon. We recommend that these methods continue but that in future years' counts of holding fish be separated from counts of spawning fish. Further all counts in reach 7 below the RST should be removed from estimates of spawner abundance. This is because not all adult fish that were counted in Year 1 spawned in Elk Canyon.

MON-15 STATUS of OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES after Year 1 (2015)

Study Objectives	Management Questions	Management Hypotheses	Year 1 (fiscal year 2014-2015) Status
The Elk Canyon on the lower Campbell River is used by all salmonid species for at least part of their life history. The WUP prescribed a flow regime with the intent of maximizing fish use in the canyon. However, there remains considerable uncertainty over the extent to which fish use of Elk 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	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?	$H_0$1: Carrying capacity of the Elk Canyon reach, as measured by annual smolt outmigrant 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 outmigration. $H_0$9: Annual abundance of 'resident' smolts is not correlated with an index of Steelhead spawner abundance.	Juvenile salmonid surveys were conducted in the canyon using snorkel surveys and a rotary screw trap (RST) to assess if base flows are sufficient to maximize juvenile rearing habitat and juvenile production. Adult spawner counts were conducted using snorkel surveys, and area under the curve calculations of spawner abundance that complements juvenile data. A TOR review was conducted with BCH and it was recommended that in future years of the program we would: a) Conduct an instream flow study (IFS) in Elk Canyon b) Continue overwintering snorkel surveys to confirm overwintering use of the canyon. Modify the snorkel methods based on first year results. Conduct night time index snorkel surveys with potential for mark-resight snorkel calibrations. Conduct overwintering assessment for five more years. c) Continue operation of the RST, although perhaps with reduced number of years sampled

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how this relates to BC Hydro operations.			and total days sampled per year. d) Continue spawner surveys (total of 10 years) Conclusion: Some aspects of these recommendations would require revisions to the TOR, and would need to be approved before implementation. Management question 1 and associated hypotheses are not answered yet, but we are on track to answer these by the end of the program.
	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?	$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.	No fieldwork was conducted for this management question and associated hypotheses in Year 1 of the MON-15 program. This work will be initiated in spring 2016 in the Year 2 program. Snorkel surveys will be conducted using a before-after design in three separate years. DFO will be consulted about trialing a DIDSON. Conclusion: Management question 2 and associated hypotheses are not answered yet, but we are on track to answer these by the end of the program.
	3. Is the two-week long 7	$H_0$6: The estimated number of spawning steelhead during the	No fieldwork was conducted for this

	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?	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 and associated hypothesis in Year 1 of the MON-15 program. This work will be initiated in spring 2016 in the Year 2 program. Snorkel surveys will be conducted using a before-during-after design in three separate years. An IFS has been recommended to support answering of this management question. Conducting an IFS would require revisions to the TOR, and would need to be approved before implementation. <u>Conclusion</u>: Management question 3 and hypothesis 6 are not answered yet but we are on track to answer these by the end of the program.
	4. Does the resumption of base flows following the spawning release keeps redds adequately wetted throughout the egg incubation period as expected? If not, what should the spawning release be to ensure all redds are wetted at the base flow?	$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	No fieldwork was conducted for this management question and associated hypotheses in Year 1 of the MON-15 program. This work will be initiated in spring 2016 in the Year 2 program. Snorkel surveys will be conducted using a before-during-after design in three separate years. An IFS has been recommended to support answering of this management question. Conducting an IFS would require revisions to the TOR, and would need to be approved before implementation. <u>Conclusion</u>: Management question 4 and hypothesis 6 are not answered yet, but we are on

		mortality from stranding, is not considered significant compared to the total number of redds in the reach.	track to answer these by the end of the program.
	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?	$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.	No fieldwork was conducted for this management question and associated hypotheses in Year 1 of the MON-15 program. This work has been initiated in fall 2015 at the start of the Year 2 program. Snorkel surveys will be conducted using a before-after design over three separate years. <u>Conclusion</u>: Management question 5 and associated hypotheses are not answered yet, but we are on track to answer these by the end of the program.
	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,	All hypotheses	In Year 1 we conducted the first year of a 10-year monitoring of juvenile and adult abundance in Elk Canyon. This will allow for an understanding of Elk Canyon productivity and how this may change over time. An IFS has been recommended to support answering of this management question. This

	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?		would allow for predictions of how flow variation affects habitat availability for salmonids using Elk Canyon. Conducting an IFS would require revisions to the TOR, and would need to be approved before implementation. Conclusion: Management question 6 and associated hypotheses are not answered yet, but we are on track to answer these by the end of the program.

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 all of BC Hydro's hydroelectric facilities through a consultative process involving local stakeholders, government agencies and First Nations. The framework for water use planning requires that a WUP be reviewed on a periodic basis and there is expected to be monitoring to address outstanding management questions in the years following the implementation of a WUP.

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

The Elk Canyon on the lower Campbell River is used by all salmonid species for at least part of their life history. The WUP prescribed a flow regime with the intent of maximizing fish use in the canyon. However, there remains considerable uncertainty over the extent to which fish use of the canyon by juveniles and spawners is affected by the implemented flow regime. The *Elk Canyon Smolt and Spawner Abundance Assessment* (JHTMON-15) is part of wider monitoring of the Campbell River WUP. JTHMON-15 is designed to assess the extent to which fish production is driven by flow in Elk Canyon and how this relates to BC Hydro operations. This report presents results from Year 1 of the JHTMON-15 study.

1.2. BC Hydro Infrastructure, Operations and the Monitoring Context

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

1.2.1. Elk Canyon

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

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

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

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

1.3. Management Questions and Hypotheses

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

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

2) Does the 2-day 10 m^3/s pulse release every two weeks trigger the upstream migration of spring spawners as expected? If not, is this the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulse attraction release unnecessary?

3) Is the two-week long 7 m^3/s spawning flow effective at increasing available spawning habitat for spring spawners? If not, by how much should the spawning release increase (or decrease) and what would be the expected gain in habitat area?

4) Does the resumption of base flows following the spawning release keeps redds adequately wetted throughout the egg incubation period as expected? If not, what should the spawning release be to ensure all redds are wetted at the base flow?

5) Does the 2-day 7 m^3/s pulse release every week trigger the upstream migration of fall spawners as expected? If not, is this the result of inadequate pulse magnitude, duration or some combination of both attributes? Or conversely, is the pulsed attraction release unnecessary?

6) Following implementation of the WUP flow prescription to the Elk Canyon reach, has the general fish productivity of the reach increased as expected? If a change is apparent, whether positive or negative, can it be attributed to WUP operations? Conversely, if no change is apparent, are some or all elements of the flow prescription still necessary?

The following hypotheses were developed to answer these management questions:

$H_0$1: Carrying capacity of the Elk Canyon reach, as measured by annual smolt outmigrant 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 outmigration.

$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 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. JHTMON-15 is scheduled for 10 years, with smolt enumeration and spawner counts being completed annually. 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 outmigrating smolts.

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 is to be measured by the smolt production of Steelhead Trout, Chinook Salmon and Coho Salmon from Elk Canyon over the duration of the monitor. The use of a rotary screw trap is one way to enumerate outmigrating smolts from February to June each year.

1.4.3. Overwintering Assessment

The carrying capacity of Elk Canyon can be viewed as containing two components; the first consisting of fish that complete their life cycle from egg to smolt within the reach (here referred to as residents) and the other consisting of immigrant juveniles that enter the reach (immigrants). For Steelhead and Coho Salmon, there is potential for estimates of carrying capacity to differ during late summer and late winter based on abundance of overwintering immigrants to Elk Canyon ($H_0$2). Therefore, snorkel swim counts of resident juveniles were conducted late in the growing season (September) and prior to smolt outmigration (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 2-5 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 outmigrant 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 10 m^3/s every two weeks in spring (February 15 to March 15) as an attraction flow primarily for spawning Steelhead. Hypotheses $H_0$3, $H_0$4 and $H_0$5 were developed to test the effectiveness of these pulse flows in 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 pulse flow assessment is to be conducted in Years 2-5 of JHTMON-15 and thus, no data were collected to address hypotheses $H_0$3, $H_0$4 and $H_0$5 for the Year 1 report. However, there was uncertainty as to the best method for counting adult fish that migrate into and out of the canyon to address these hypotheses. An initial review of methodology options during the development of the program indicated that there was not a single method that could be deployed without significant safety or technological challenges. Therefore a more detailed options analysis was conducted to evaluate the available methods to enumerate fish moving into and out of the canyon. This work is briefly summarized in this report and presented in full in a separate document (Hatfield and Johnson 2015).

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 is proposed to be completed using snorkel surveys and redd surveys prior to, during and after the spawning flows in Years 2-5 of the JHTMON-15 program. No data were collected in Year 1 to address these hypotheses. Therefore, this work will not be discussed further at this time.

1.4.6. Spawner Enumeration

Spawner counts in both fall and spring are to be conducted annually for the full JHTMON-15 program. Area under the curve estimates of abundance are calculated and used to test if the annual abundance of 'resident' smolts is correlated with spawner abundance ($H_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

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

2.1. Smolt Enumeration

2.1.1. RST Setup and Operation

Smolt enumeration was carried out using a single 1.2 m rotary screw trap (RST) located near the base of the canyon, in the first run type mesohabitat (Figure 1), just around the corner and upstream from the powerhouse at JHT-DVRST (Map 2).

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 22, 2015 and fished continuously until June 30, 2015. Crews serviced the trap daily each morning. The trap was also serviced as required in the afternoon during 10 m^3/s pulse flow events. Daily trap servicing consisted of a crew of two accessing the trap to record trap orientation and rotation, water velocity at the trap and the debris present in the trap. The trap was cleaned, serviced, and all fish were removed for sampling.

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

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

Figure 1. Rotary Screw Trap (TSP) during operation at base of canyon.

2.1.2. Mark Recapture Experiment

Mark-recapture experiments using Quinsam hatchery Coho Salmon and Chinook Salmon fry and smolts were completed to measure RST trap catch efficiency and ultimately to estimate total outmigration from Elk Canyon. A total of 12 mark recapture trials were completed from March 2 to May 7, 2015, with a release of roughly 200 fish per trial. The trials included: three trials of Coho smolts (average fork length = 135 mm, weight = 25.0g), three trials of Coho fry (average fork length = 43 mm, weight = 0.8g), three trials of Chinook fry (average fork length = 59 mm, weight = 2.5g), and three trials of Chinook smolts (average fork length = 75 mm, weight = 5.0g). All fished were marked by immersion in Bismarck Brown (0.8g of in 38 L of water) for 1.25 hrs, except for the Coho smolts which were marked using a unique ventral fin clip for each individual trial. The number of fish released per trial (200 fish) was determined by an efficiency analysis with the goal of recapturing a sufficient number of fish that the trap efficiency estimate would not be altered by more than 5% if an additional fish was captured during a given test.

The marked fry and smolts were driven to the powerhouse and then transported into the canyon in buckets with battery-powered bubblers. 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, 600 Coho Salmon fry, 594 Coho Salmon smolts, and 549 Chinook Salmon fry were released over the course of three release days for each species and each life stage (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:

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

where CE_t is the trial capture efficiency, RR_i is the number of recent recaptured fish at day i 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 three trials for each species and life stage:

$$CE_o = \frac{\sum_{i=o}^{t} R_i}{\sum r_i} \quad \text{Equation 2}$$

where CE_o is the overall capture efficiency, R_i is the number of recaptured fish at day i, and r_i is the number of released fish at day i.

Using estimates of capture efficiency, trap catches of unmarked fish can then be scaled to estimate total abundance by fish species and life stage in Elk Canyon:

$$Total\ Abundance = \frac{\sum C_{zy}}{CE_x} \quad \text{Equation 3}$$

where C_{zy} is the total catch of a given species and life stage z on day y and CE_x is the capture efficiency (either trial (CE_t) or overall (CE_o)). In cases with Coho and Chinook Salmon fry and parr, the capture efficiencies for these specific life stages and species were used to calculate the total abundance estimate. For other species (i.e., Steelhead/Rainbow Trout, Pink and Chum Salmon), the mean capture efficiency across Coho smolts, Chinook fry and Chinook smolts was used. Coho fry were excluded from this estimate of capture efficiency across species because they are much more likely to stay in the canyon after their release and not move downstream past the RST. This was confirmed by the observed data that showed similar capture efficiencies between the Coho smolts, Chinook fry and Chinook smolts, and a much lower capture efficiency for Coho fry.

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

Release Date	Release Species	Number of Fish Marked	Number of Fish Released[1]
2-Mar-15	Chinook Salmon fry	194	151
6-Mar-15	Chinook Salmon fry	200	200
10-Mar-15	Chinook Salmon fry	198	198
14-Mar-15	Coho Salmon fry	200	200
20-Mar-15	Coho Salmon fry	200	200
24-Mar-15	Coho Salmon fry	200	200
12-Apr-15	Chinook Salmon smolt	198	198
16-Apr-15	Chinook Salmon smolt	198	198
20-Apr-15	Chinook Salmon smolt	200	200
24-Apr-15	Coho Salmon smolt	199	199
30-Apr-15	Coho Salmon smolt	199	195
4-May-15	Coho Salmon smolt	200	200

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

2.2. Overwintering Assessment

2.2.1. Snorkel Surveys

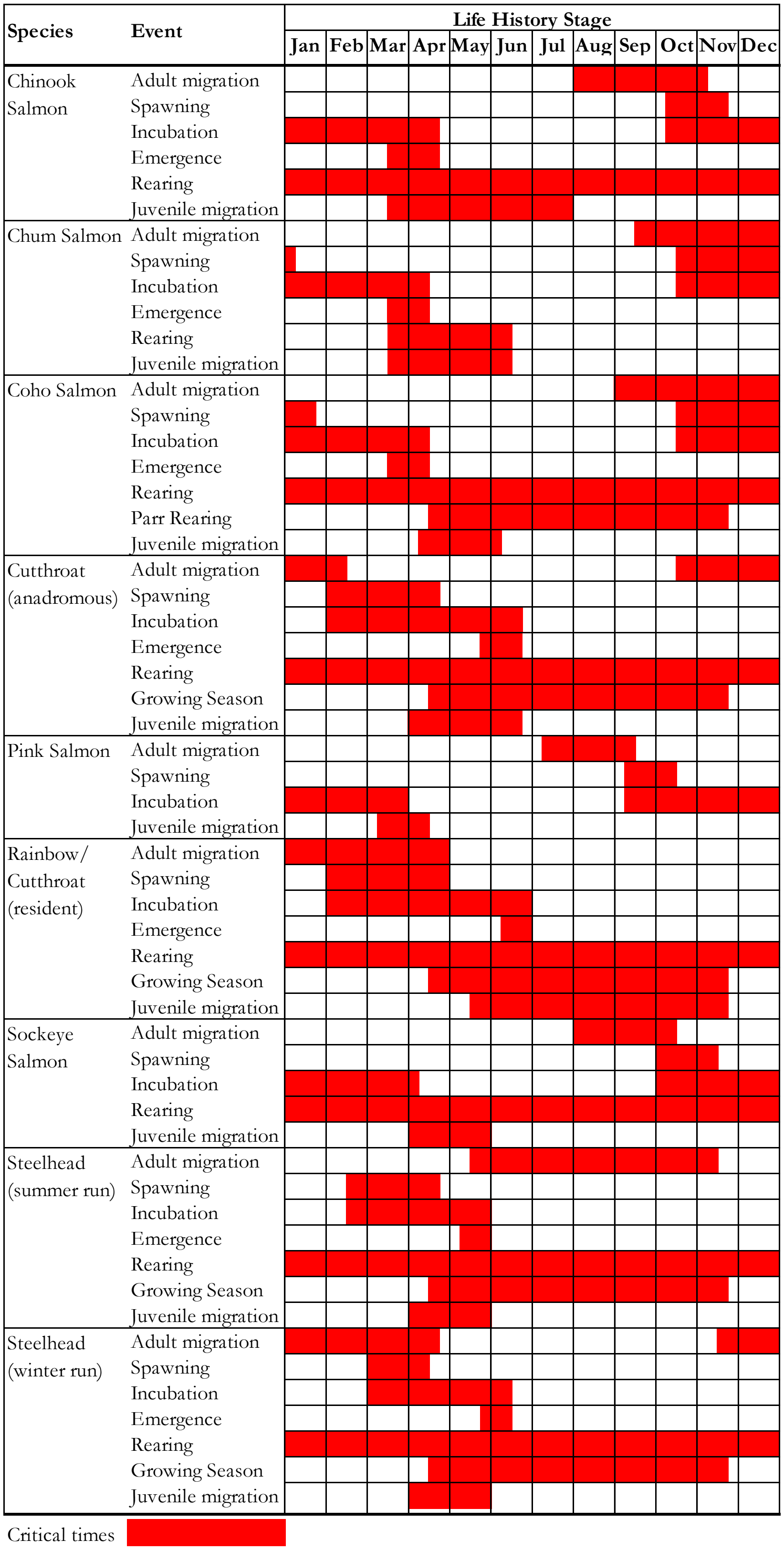
The overwintering assessment was designed to test if juvenile salmonids used Elk Canyon during their entire rearing period or if a significant proportion of the population consisted of immigrant juveniles from below the canyon. This was done by contrasting late summer parr abundance in the canyon with winter counts of parr just before onset of out-migration. For example, Coho Salmon are hypothesized to rear in Elk Canyon for over a full year after hatching and begin juvenile outmigration as 1+ smolts in mid-March (Table 2). Snorkel survey sampling occurred before this outmigration period. The periodicity chart shown in Table 2 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.

Snorkel swim counts of Steelhead/Rainbow Trout, Coho Salmon and Chinook Salmon parr were completed over three days in late summer from September 25-27, 2014 and over three days in winter from February 2-4, 2015. The snorkel counts were carried out by a crew of two swimmers swimming in tandem with a third crew member acting as a recorder of all observations. The counts took place on successive days and were carried out by the same crew on each day.

Overwintering snorkel surveys were completed across seven reaches that were established in September 2014 (Map 2). Each overwintering snorkel survey began at the top of Reach 1 and continued downstream to the end of Reach 7. It is important to note that these reach numbers do not start at tidewater, they begin at the base of Elk Falls, and are used for identifying different stream sections within Elk Canyon. Total counts of all species and age classes observed in each reach were recorded.

A night snorkel was completed on February 23, 2015 to compare the effectiveness of the winter daytime snorkels. A crew of two swimmers and one recorder conducted a night snorkel survey in the lower part of the Elk Falls canyon (reaches 4 to 7). This snorkel survey was conducted the same way as a day snorkel, but was limited to a section of the lower canyon with the easiest and safest access for crews. The field crew accessed the canyon before dark and started surveys one hour after sunset.

Table 2. Draft periodicity chart for salmonid species using Elk Canyon (Source = BC Hydro John Hart Water Use Plan)



2.3. Pulse Flow Assessment

2.3.1. Options Analysis

An options analysis was conducted to determine the best methods to evaluate adult migration into Elk Canyon (Hatfield and Johnson 2015). Potential fish counting methods were developed based on a literature review and summarized in an options matrix to support selection. Feasible methods were carried through a scoring process using 12 criteria in four general categories: technical feasibility, data quality, cost, and safety. A team of experienced Ecofish Research Ltd. (Ecofish) field biologists used the scoring definitions to provide a score for each criterion for each method. Each method was ranked according to summary scores.

2.4. Spawner Enumeration

2.4.1. Spawner Surveys

2.4.1.1. Fall surveys

Seven snorkel surveys were conducted to inventory fall spawners in Elk Canyon including Coho Salmon, Chinook Salmon, Chum Salmon, Pink Salmon, and Sockeye Salmon. The fall spawner snorkel surveys followed the same general method as the overwintering assessment and were completed on September 10th, 27th, October 9th, November 14th, 20th, and December 4th, 2014. 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. These fall surveys of spawners were not set up as a before-after study to test for the benefits of pulse flows. This work will be completed in subsequent years of the program.

2.4.1.2. Spring surveys

Seven snorkel surveys were conducted to inventory Steelhead spring spawners in Elk Canyon. The spring spawner snorkel surveys followed the same general method as the overwintering assessment and fall spawner snorkel surveys. Spring spawner surveys were completed on February 4th, 22nd, March 3rd, 17th, April 10th, 19th and 28th 2015. In each reach total counts of Steelhead, their spawning condition and the presence of redds were recorded. These spring surveys of spawners were not set up as a before-after study to test for the benefits of pulse or spawning flows. This work will be completed in subsequent years of the program.

2.4.2. 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 trout species. For salmon species, 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 3). 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 3. 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

3. RESULTS

3.1. Smolt Enumeration

3.1.1. RST Capture Data

The rotary screw trap (RST) was operational for 114 days from February 22, 2015 to June 30, 2015. RST operation was halted from March 30 to April 10, 2015 due to an increase in operational spill over 10 m^3/s, and the RST was removed from the river. Once operational spill levels decreased, the RST was reset and operations continued until June 30, 2015.

In total, 2,315 fish were captured using the RST (Figure 2 and Figure 3). The catches were primarily composed of sculpin (70%), Coho Salmon (11%), Chum Salmon (6%) and Steelhead/Rainbow Trout (5%). Chinook Salmon catch was about 3%. The combined catch of target species - Steelhead/Rainbow Trout, Coho Salmon, and Chinook Salmon accounted for 19% of the total catch (448 fish).

There were clear periods of peak outmigration for Coho Salmon, Steelhead/Rainbow Trout, Chum Salmon, and Chinook Salmon based on RST catch (Figure 4). Similar results for these species are observed when catch per-unit-effort (CPUE) is used, which accounts for the lack of RST operation between March 30 and April 10 (Figure 5). Chum Salmon outmigration peaked from March 1-15, which was the earliest outmigration compared to the other salmonid species. Steelhead/Rainbow Trout had the next peak in outmigration. Steelhead/Rainbow Trout catch steadily increased starting from March 16-31 until May 1-15. After this period, catches of Steelhead/Rainbow Trout steadily declined. Coho Salmon catches were low but variable from February to mid-May, peaked from May 16-31 and remained moderately high until the end of June. Chinook Salmon catches were relatively low (<10 fish) until their peak in June.

The fork lengths of Coho Salmon, Steelhead/Rainbow Trout, and Chinook Salmon were compared over time to determine if outmigration timing varied by the size and/or age cohort of fish (Figure 6). The average fork length of Coho Salmon was relatively low (<40 mm) until late April when the average fork length increased to 98 mm and remained relatively high for the rest of the sampling period. This corresponds to a small outmigration of fry that occurred in March and a larger outmigration of mainly one year old smolts in May and June (Figure 7). In April, a combination of Coho fry and larger Coho smolts (perhaps 2+ year old) were caught in the RST. Steelhead/Rainbow Trout displayed the opposite trend with larger individuals (most between 160 and 220 mm) outmigrating in March through May. In June, Steelhead/Rainbow Trout fry and parr were caught in the RST (most between 55 and 135 mm) (Figure 8). Chinook Salmon exhibited a trend similar to that of Coho Salmon. The average fork length of Chinook Salmon was relatively low from March until early May and increased in late May and June to near 100 mm. This corresponded to a small outmigration of Chinook fry in March and April followed by a larger outmigration of smolts in May and June (Figure 9).

Figure 2. Total RST catch by species from February 27 to June 29, 2015. ST/RB = Steelhead/Rainbow Trout, CO = Coho Salmon, CH = Chinook Salmon, CM = Chum Salmon, PK = Pink Salmon, CT = Cutthroat Trout, DV = Dolly Varden, TR = unknown trout spp., CC = sculpin (*Cottus* spp.), PL = Pacific Lamprey, SB = stickleback, UNK = unknown spp.

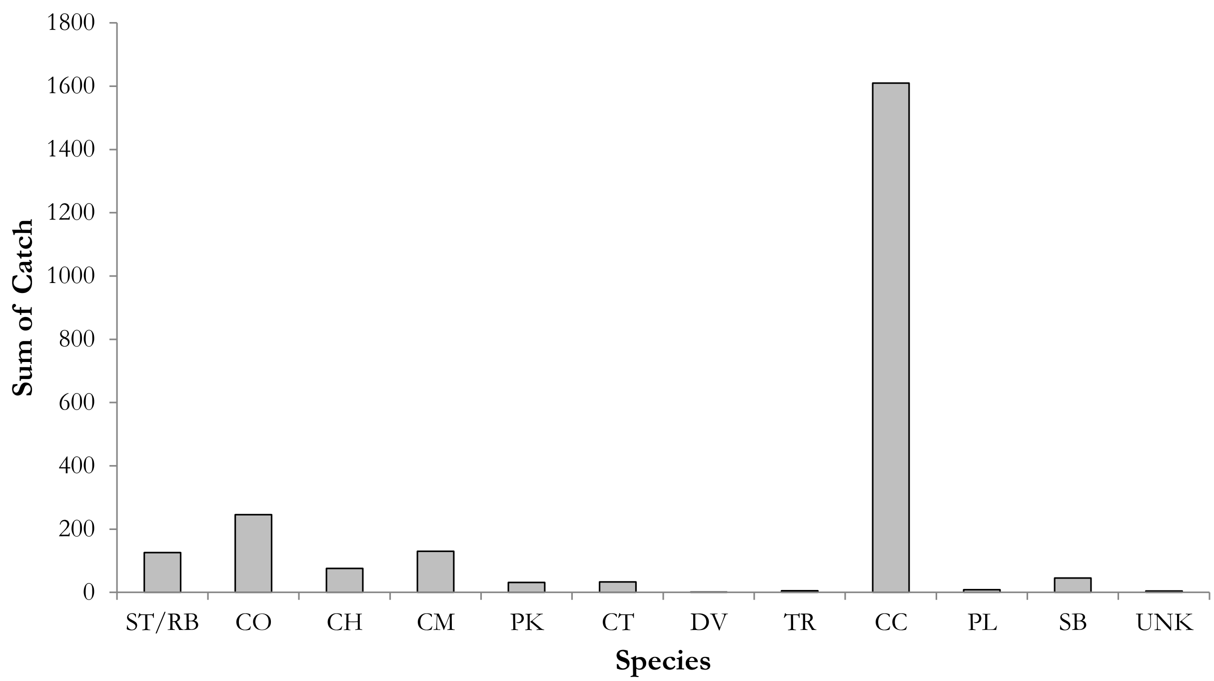


Figure 3. **Total RST catch by species from February 27 to June 29, 2015 excluding sculpin species. ST/RB = Steelhead/Rainbow Trout, CO = Coho Salmon, CH = Chinook Salmon, CM = Chum Salmon, PK = Pink Salmon, CT = Cutthroat Trout, DV = Dolly Varden, TR = unknown trout spp., PL = Pacific Lamprey, SB = stickleback, UNK = unknown spp.**

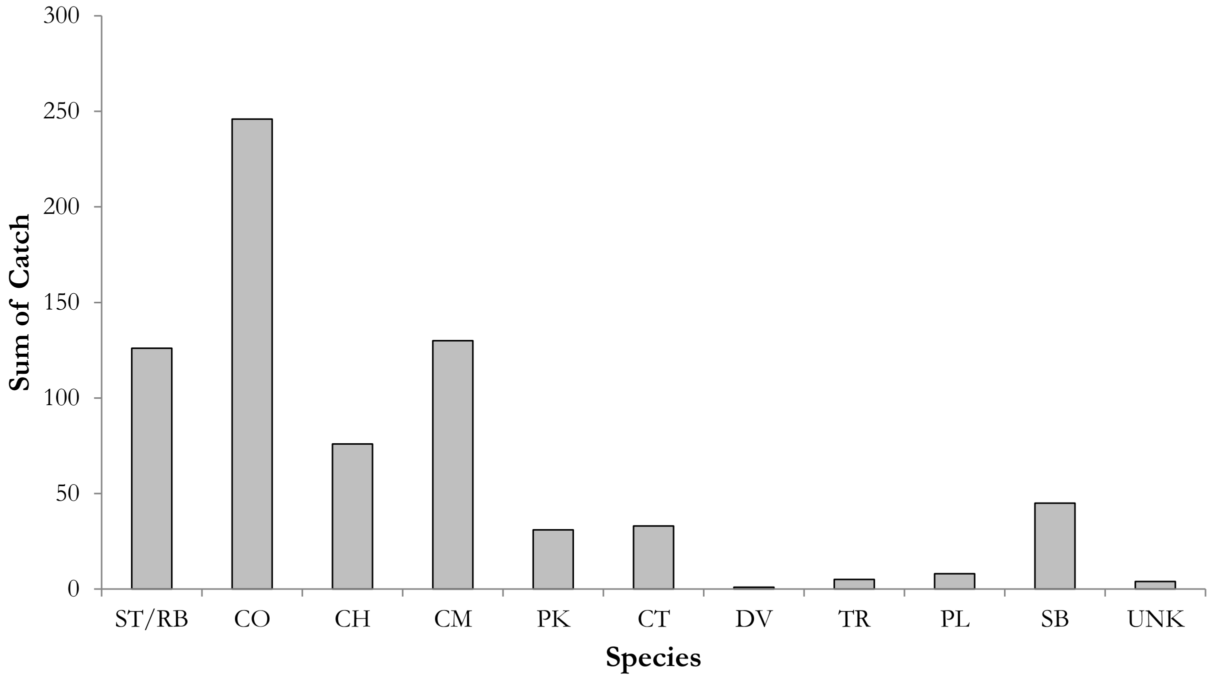


Figure 4. RST catches of key salmonid species across the sampling period.

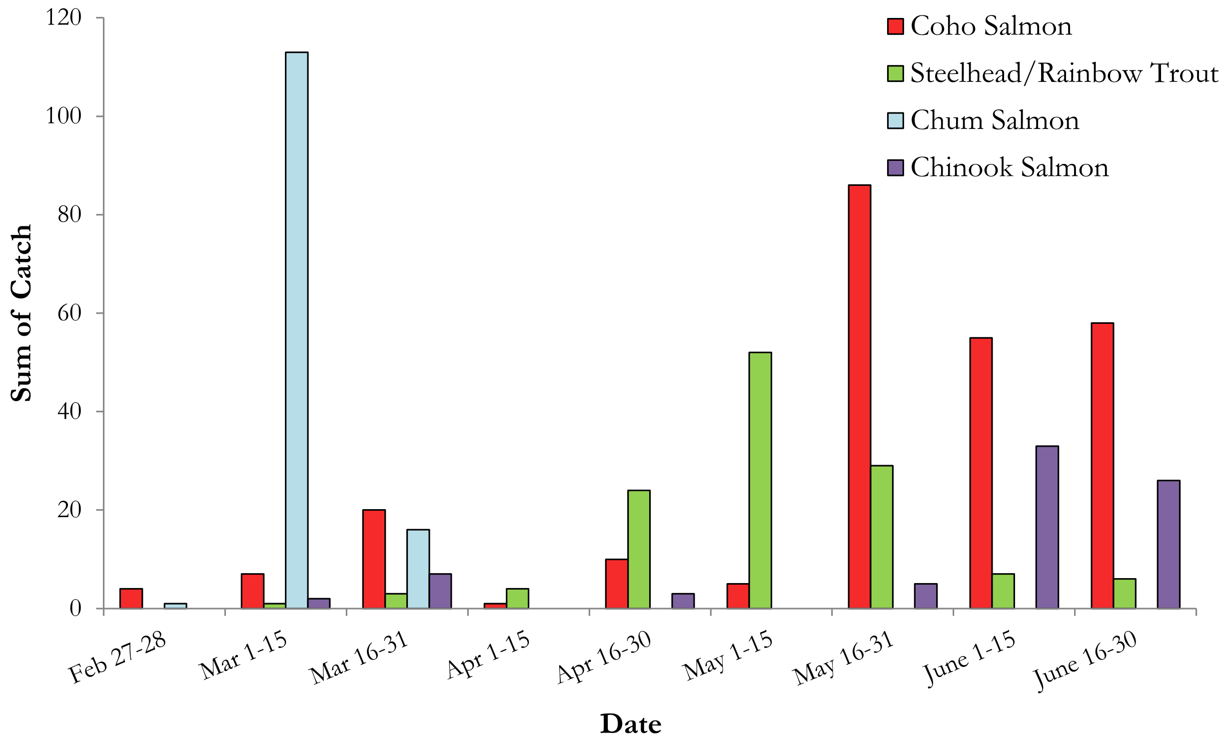


Figure 5. RST catch per-unit-effort of key salmonid species across the sampling period.

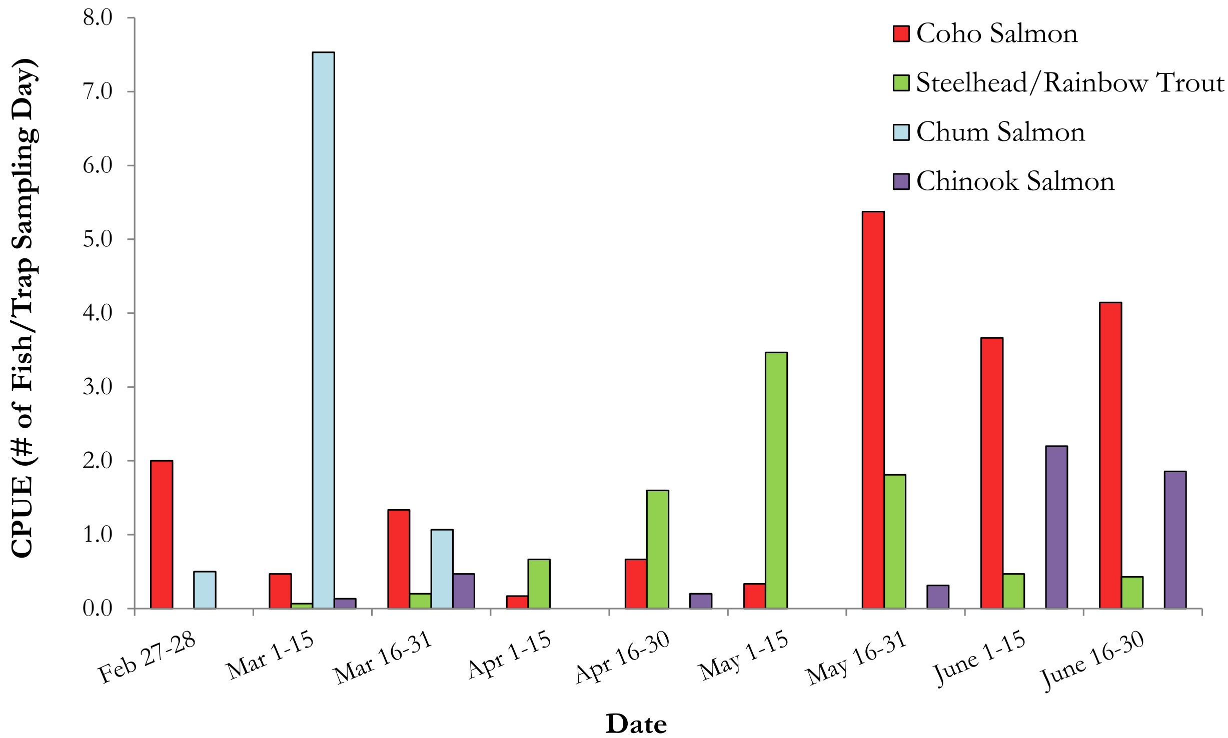


Figure 6. Average fork length of Coho Salmon, Rainbow Trout, and Chinook Salmon during RST sampling period.

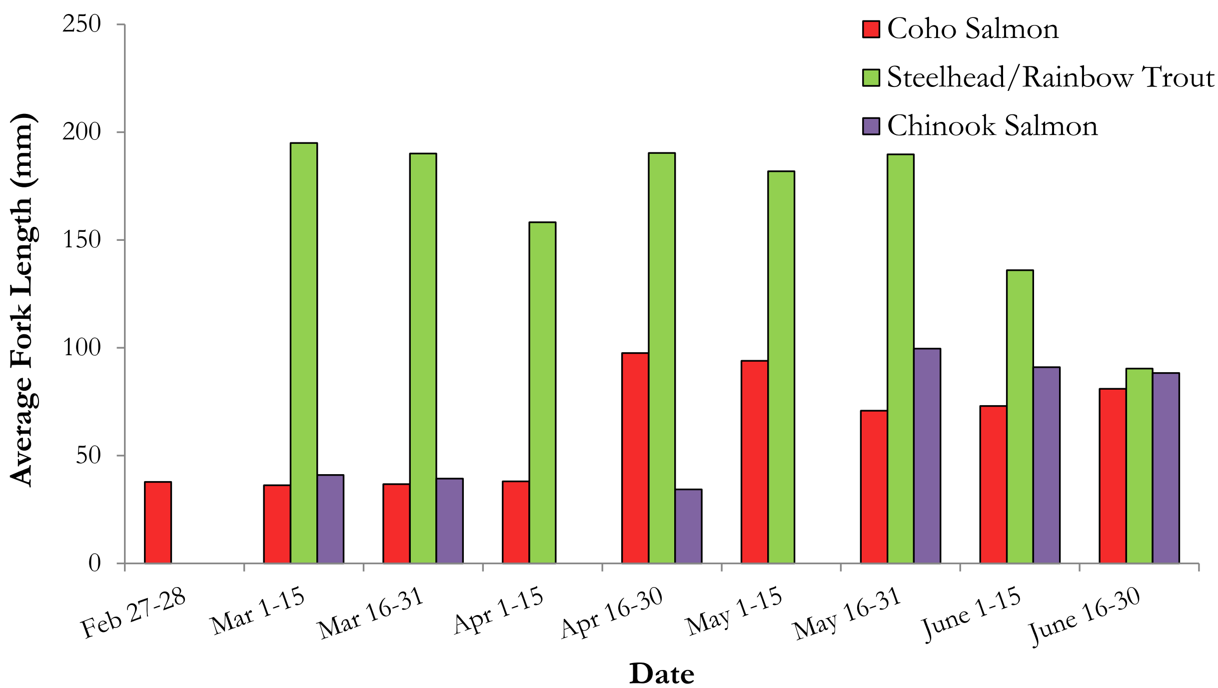


Figure 7. Length frequency histogram of Coho Salmon captured in the RST by month.

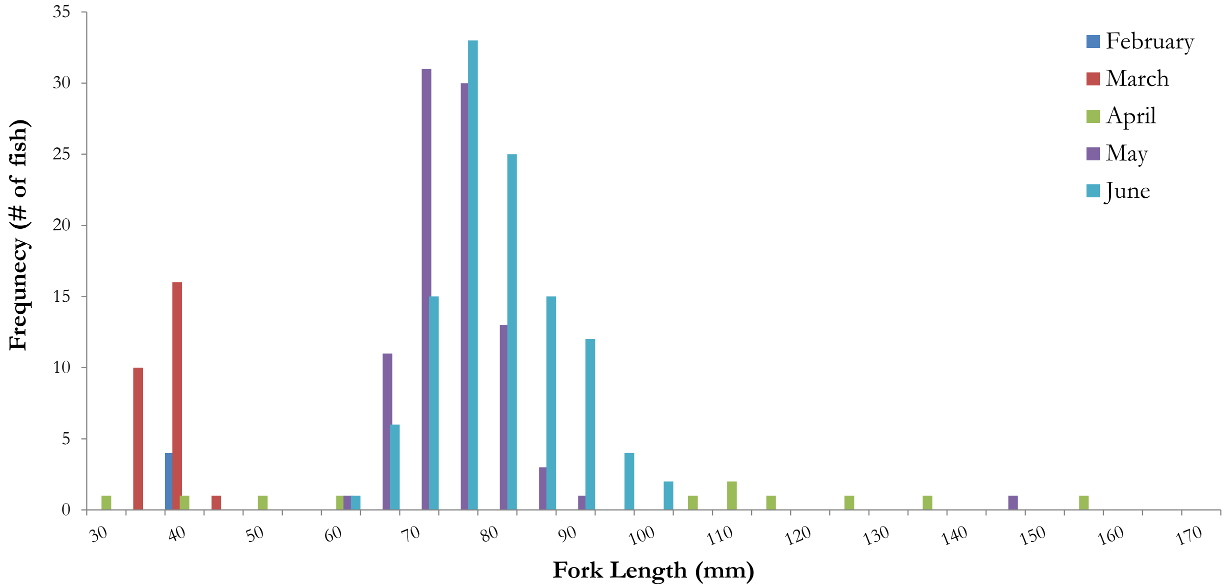


Figure 8. Length frequency histogram of Steelhead/Rainbow Trout captured in the RST by month.

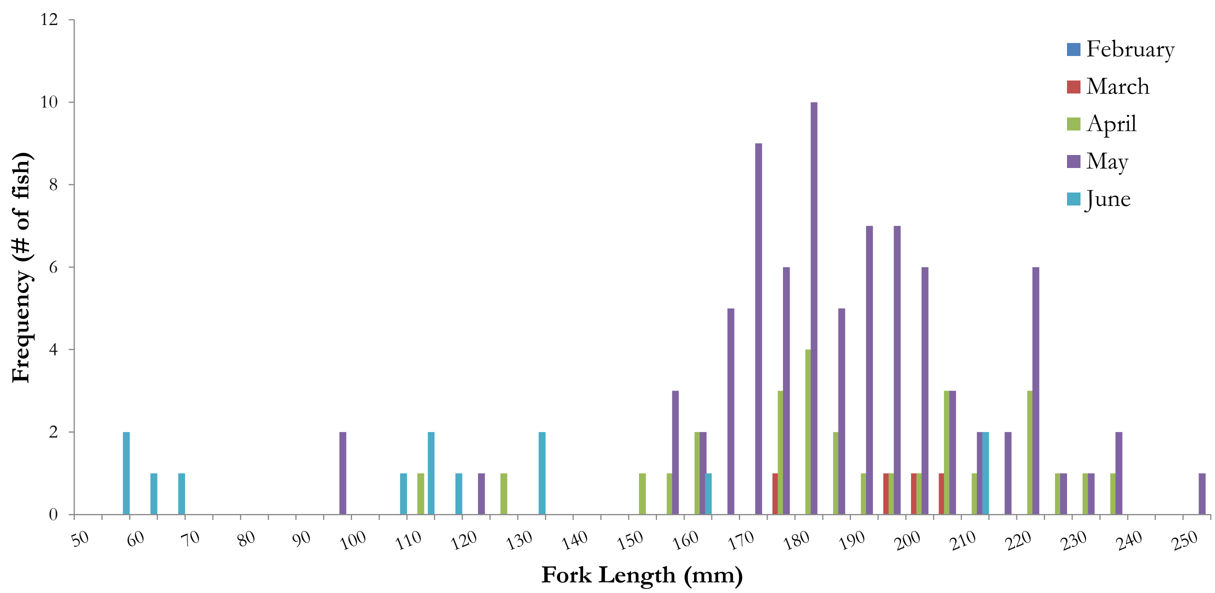
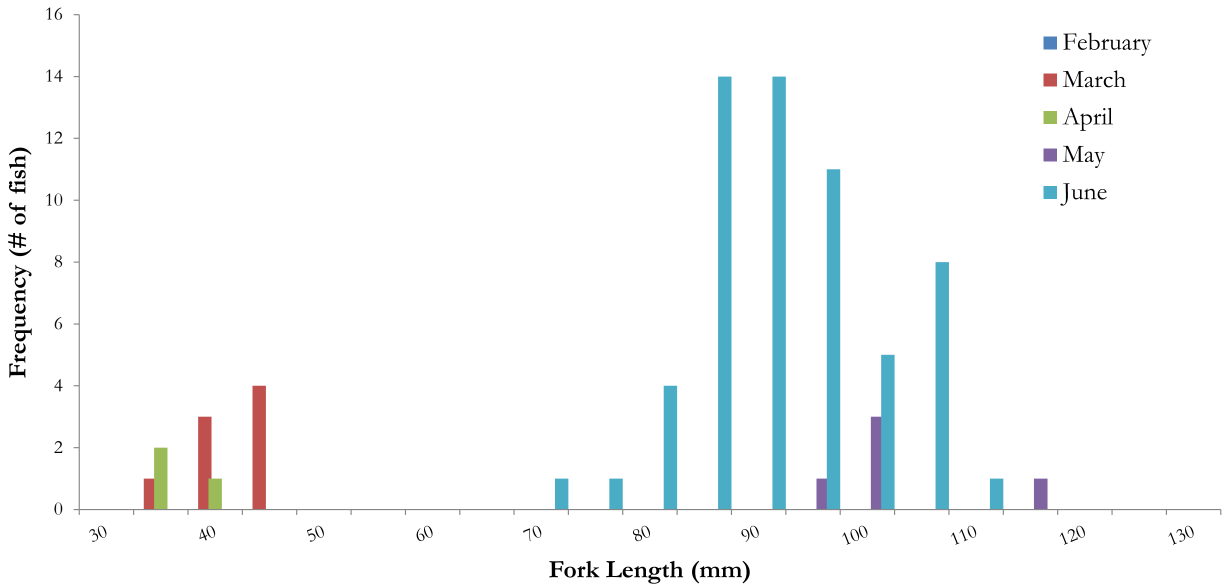


Figure 9. Length frequency histogram of Chinook Salmon captured in the RST by month.



3.1.2. RST Mark-Recapture Data

The mark-recapture trials for Chinook and Coho Salmon fry and smolts were used to estimate the capture efficiency of the RST and to ultimately generate outmigration abundance estimates from Elk Canyon.

Of the 2,339 released fish, 377 fish (16%) were recaptured (Table 4). The numbers of recaptured fish were comparable across species and life stages except for Coho Salmon fry where only 15 fish were recaptured. Of these 377 recaptured fish, 341 fish (90%) were recaptured during their corresponding recapture periods (recent recaptures).

The trial capture efficiency estimates were based on recent recapture rates within the release periods (Table 5). Chinook Salmon fry trial capture efficiencies ranged from 0.172 to 0.250 (mean = 0.206), and the Coho Salmon fry trial capture efficiencies ranged from 0.015 to 0.05 (mean = 0.025). The Chinook Salmon smolt capture efficiencies ranged from 0.131 to 0.263 (mean = 0.196), and the Coho Salmon smolt capture efficiencies ranged from 0.123 to 0.186 (mean = 0.158).

The overall capture efficiency estimates varied from 0.025 to 0.222 and were based on a grouping the releases and recaptures for a single species and life stage (Table 6). Overall capture efficiency estimates were similar to the average of the trial capture efficiency estimates.

Table 4. Release and capture results for the Mark-recapture study.

First Release Date	Last Release Date	Release Species	Total Number of Released Fish	Total Number of Recaptured Fish
2-Mar-15	10-Mar-15	Chinook Salmon fry	549	122
14-Mar-15	24-Mar-15	Coho Salmon fry	600	15
12-Apr-15	20-Apr-15	Chinook Salmon smolt	596	112
24-Apr-15	4-May-15	Coho Salmon smolt	594	128

Table 5. Trial capture efficiency estimates for each corresponding release date during the mark-recapture study.

Release Date	Release Species	Trial Capture Efficiency
02-Mar-15	Chinook Salmon fry	0.172
06-Mar-15	Chinook Salmon fry	0.250
10-Mar-15	Chinook Salmon fry	0.197
14-Mar-15	Coho Salmon fry	0.050
20-Mar-15	Coho Salmon fry	0.010
24-Mar-15	Coho Salmon fry	0.015
12-Apr-15	Chinook Salmon smolt	0.263
16-Apr-15	Chinook Salmon smolt	0.131
20-Apr-15	Chinook Salmon smolt	0.195
24-Apr-15	Coho Salmon Smolt	0.186
30-Apr-15	Coho Salmon Smolt	0.123
04-May-15	Coho Salmon Smolt	0.165

Table 6. Overall capture efficiency estimates for the mark-recapture study.

Release Species	Total Number of Released Fish	Total Number of Recaptured Fish	Overall Capture Efficiency
Chinook Salmon fry	549	122	0.222
Coho Salmon fry	600	15	0.025
Chinook Salmon smolt	596	112	0.188
Coho Salmon smolt	594	128	0.215

3.1.3. Estimates of salmonid outmigration

Estimates of total outmigration of salmon smolts and fry from Elk Canyon differed by species but were relatively similar by method to determine capture efficiency (Figure 10).

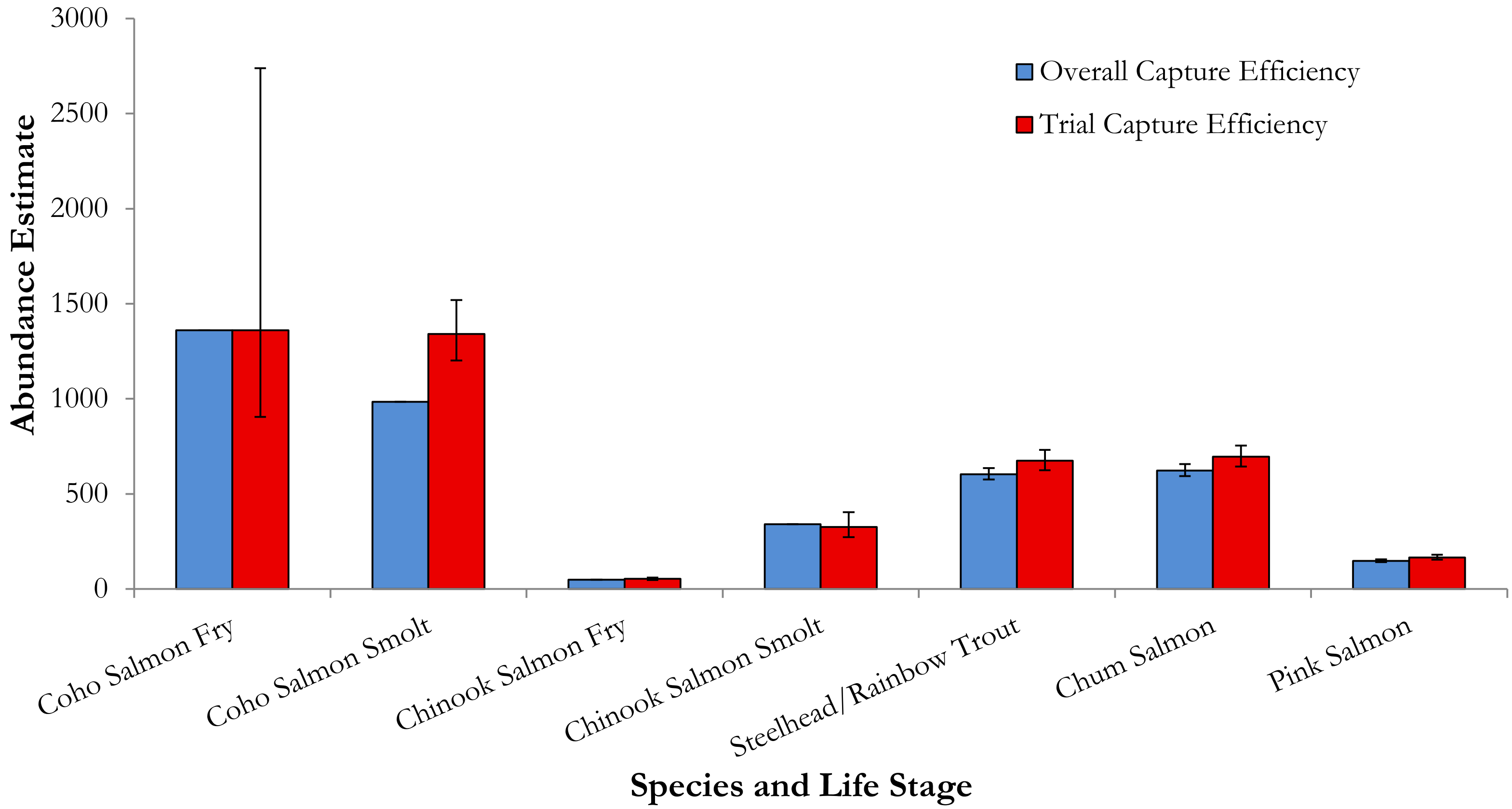
Coho Salmon outmigration was the highest of all salmon species with a mean abundance estimated to be 1,360 fry and 984 to 1,342 smolts depending on the method to determine capture efficiency. Coho Salmon fry leaving Elk Canyon may rear in lower parts of the watershed rather than heading directly to the ocean.

Chinook Salmon fry outmigration was estimated at 50 to 53 individuals, while mean abundance of Chinook Salmon smolts was from 326 to 341 individuals. Whether, these Chinook smolts are all 0+ juveniles (ocean type Chinook) or include 1+ individuals (stream type Chinook) remains unclear.

The mean abundance of Chum Salmon and Pink Salmon fry outmigrating from Elk Canyon was estimated to be 623 to 696 and 149 to 166 individuals respectively. These fish migrate downstream to the estuary.

Steelhead/Rainbow Trout outmigration was estimated to average from 604 to 674 individuals. It remains unclear whether these fish are simply moving downstream to rear or are leaving the watershed entirely.

Figure 10. Estimates of salmonid outmigration abundance from Elk Canyon by species and life stage caught in the RST. Estimates are based on trial capture efficiencies and overall capture efficiencies.



3.2. Overwintering Assessment

3.2.1. Snorkel Survey Data

The overwintering assessment tested if salmonids use Elk Canyon during their entire rearing period or if a significant proportion of the population consists of immigrant juveniles. The life history information for each salmonid species is shown in Table 2. Apart from water temperature, sampling conditions and total effort were comparable among sampling days as well as between seasons (Table 7).

Snorkel counts in September were fairly comparable among sampling days. Steelhead/Rainbow Trout observations ranged from 973 to 1,443 (mean = 1,134) juveniles and Coho Salmon ranged from 2,409 to 2,863 (mean = 2,687) juveniles (Table 8). No Chinook Salmon juveniles were recorded.

In three daytime snorkel swims in early February, no fish individuals of any species were observed (Table 8).

Based on the poor observations during the February daytime snorkel surveys, night snorkeling was conducted on February 23, 2015 to evaluate the effectiveness of the daytime snorkel survey. Reaches 4 through 7 were sampled and 250 Steelhead/Rainbow Trout juveniles and zero Coho Salmon were observed (Table 8). Two Chinook Salmon parr were observed during this survey.

The February night snorkel parr counts were comparable to the fall snorkel parr counts for Steelhead/Rainbow Trout (Figure 11), but differed for Coho Salmon (Figure 12). Fall Steelhead/Rainbow Trout estimates ranged from 73 to 207 juveniles in reach 4, 44 to 137 juveniles in reach 5, and 67 to 94 juveniles in reach 6. The single night snorkel count of Steelhead/Rainbow Trout in February counts of Steelhead/Rainbow Trout were within these ranges at each reach. In contrast, no Coho Salmon were observed during the night snorkeling in February.

Table 7. Sampling conditions of overwintering snorkel surveys.

Date	Survey Reaches	Total Effort (hr)	Water Temp (°C)	Air Temp (°C)	Estimated Visibility (m)	Estimated Flow (m³/s)
25-Sep-14	Sections 2-6	7.0	17.0	-	7.0	4.5
26-Sep-14	Sections 2-6	7.0	17.0	-	6.0	4.5
27-Sep-14	Sections 2-6	7.0	17.0	-	7.0	4.5
2-Feb-15	Sections 2-6	6.0	7.0	7.0	5.5	4.0
3-Feb-15	Sections 2-6	6.0	7.0	7.5	5.5	4.0
4-Feb-15	Sections 2-6	6.0	7.0	7.0	5.5	4.0
23-Feb-15	Sections 4-7*	6.0	7.0	5.0	6.0	4.0

* conducted overnight
"-" represents data not collected

Table 8. Observed Steelhead/Rainbow Trout (ST/RB) and Coho Salmon (CO) during overwintering snorkel surveys.

Reach	25-Sep-14		26-Sep-14		27-Sep-14		2-Feb-15		3-Feb-15		4-Feb-15		23-Feb-15	
	ST/RB	CO	ST/RB	CO	ST/RB	CO	ST/RB	CO	ST/RB	CO	ST/RB	CO	ST/RB	CO
2	370	377	482	440	427	576	0	0	0	0	0	0	-	-
3	433	850	538	1,054	266	1,227	0	0	0	0	0	0	-	-
4	73	312	207	368	89	0	0	0	0	0	0	0	117	0
5	44	541	137	534	97	526	0	0	0	0	0	0	66	0
6	67	329	79	467	94	459	0	0	0	0	0	0	67	0
7	-	-	-	-	-	-	-	-	-	-	-	-	0	0

Figure 11. **Observed Steelhead/Rainbow Trout parr during overwintering snorkel surveys. Note: counts from reaches 2, 3 and 7 and dates February 2, 3 and 4 2015 are excluded to allow for a clear visual comparison between fall and spring surveys. The February 23 survey occurred at night while September surveys occurred during the day.**

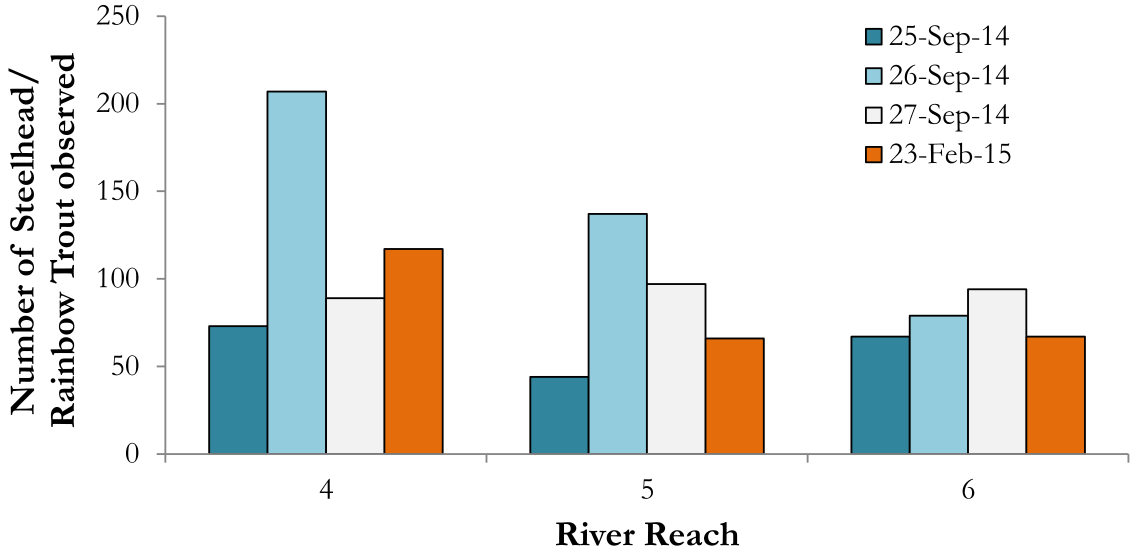
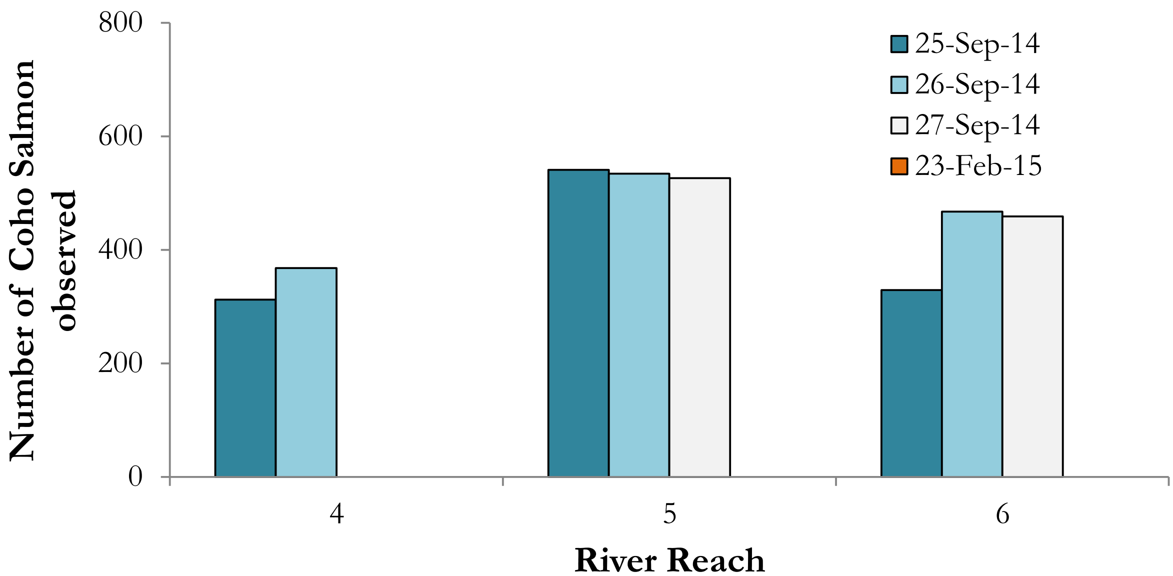


Figure 12. **Observed Coho Salmon parr during overwintering snorkel surveys. Note: counts from reaches 2, 3 and 7 and dates February 2, 3 and 4 2015 are excluded to allow for a clear visual comparison between fall and spring surveys. The February 23 survey occurred at night while September surveys occurred during the day. Zero Coho were observed on February 23 2015.**



3.3. Pulse Flow Assessment

3.3.1. Options Analysis

Video, snorkelling, hydroacoustics, DIDSON and fish weir were the best ranked methods for counting adult fish migrating into Elk Canyon. The difference in scores between these methods was not substantive. These methods should be given further consideration. Resistivity counters and PIT tagging were considered to have substantial drawbacks. The options analysis is presented separately in Hatfield and Johnson (2015).

3.4. Spawner Enumeration

Sampling conditions for both fall and spring spawner surveys were completed and are summarized in Table 9. Overall, total effort ranged from 4.0 to 6.0 hrs for the entire survey reach. Estimated visibility was comparable between sampling surveys, but generally improved in the later surveys. The estimated flows were fairly comparable between sampling surveys except for April 10, 2015 where flows were estimated at 7.0 m^3/s.

3.4.1. Fall Spawners

Chinook Salmon and Coho Salmon adult abundance were estimated to be 127 and 1,403 individuals respectively using the area under the curve method (Table 10). Pink Salmon had the highest estimated abundance of 63,120 individuals. It is important to note that Reach 7 of the canyon accounted for 95% and 92% of the observed Pink Salmon on September 10 and 27, 2014, respectively. These fish were holding in the pool and therefore, not actively spawning. We did not separate between holding and spawning adults in the current analysis, and therefore, all observed Pink Salmon were included. A population of 50 Chum Salmon and 132 Sockeye Salmon were also estimated, the majority of which were observed above the RST location (Table 10).

The peak spawning time was variable across salmon species. Pink Salmon had the earliest peak and appeared to have hit peak spawning when surveys began (Figure 13). Sockeye Salmon had the next peak in counts, which was observed in late September (Figure 14). Coho and Chinook Salmon had a similar peak in early October (Figure 14, Figure 15). Finally, Chum Salmon had the latest peak in spawning in mid-November (Figure 14).

Not all observed adults spawned in Elk Canyon. The number of redds was also recorded during the fall spawner surveys. In total, 141 redds were observed; 72 of which were Pink Salmon redds, 62 were Coho Salmon redds, and the remaining were Chum Salmon redds (Table 11).

3.4.2.Spring Spawners

Steelhead were observed during the spring spawner surveys. A maximum count of nine adult Steelhead were observed in Elk Canyon on February 22nd 2015 (Figure 16). Several weeks later a maximum of three Steelhead redds were observed on April 10th 2015.

Figure 13. Adult Pink Salmon counts in Elk Canyon by date.

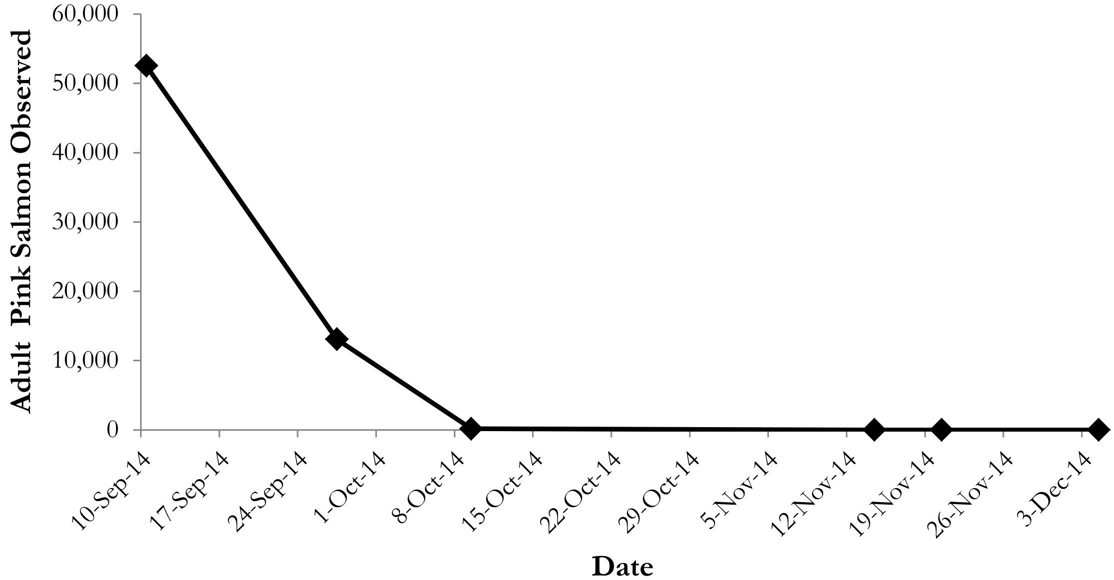


Figure 14. Adult Chinook, Chum and Sockeye Salmon counts in Elk Canyon by date.

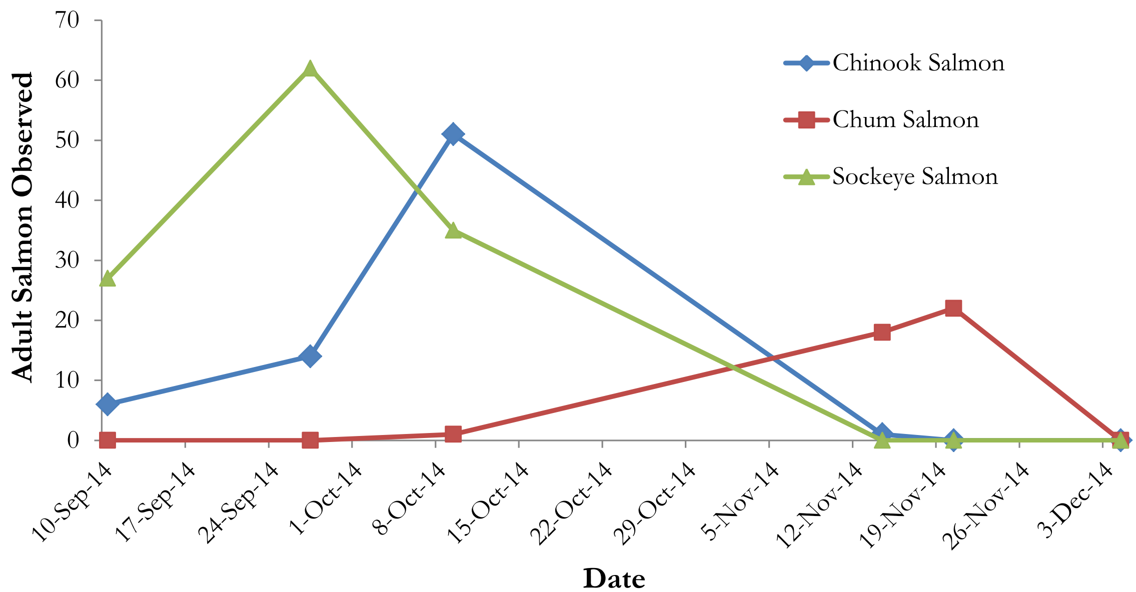


Figure 15. Adult Coho Salmon counts in Elk Canyon by date.

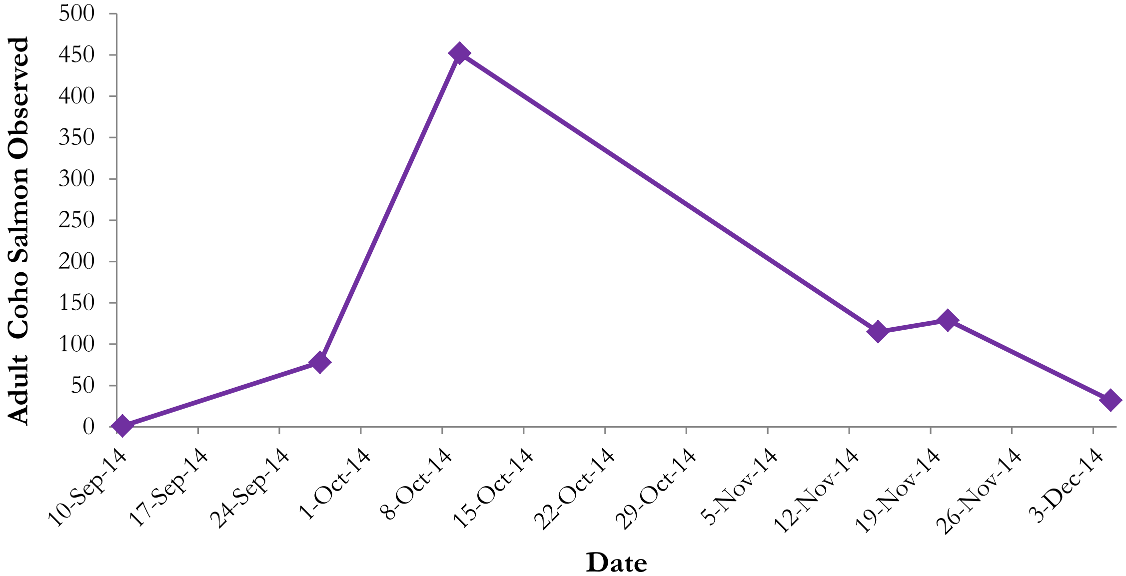


Table 9. Sampling conditions during spawner surveys.

Date	Survey Reaches	Total Effort (hr)	Water Temp (°C)	Air Temp (°C)	Estimated Visibility (m)	Estimated Flow (m^3/s)
10-Sep-14	Sections 1-7	-	17.0	16.0	6.0	4.5
27-Sep-14	Sections 1-7	4.0	17.0	-	7.0	4.5
9-Oct-14	Sections 1-7	6.0	16.0	15.0	5.0	4.0
14-Nov-14	Sections 1-7	-	8.8	3.5	8.0	-
20-Nov-14	Sections 1-7	-	7.0	4.0	7.0	4.0
4-Dec-14	Sections 1-7	4.0	6.5	4.0	7.0	4.0
22-Feb-15	Sections 1-7	5.0	7.0	5.0	6.0	4.0
3-Mar-15	Sections 1-7	5.8	6.0	4.0	6.0	4.0
17-Mar-15	Sections 1-7	5.0	7.0	5.0	7.0	4.0
10-Apr-15	Sections 1-7	4.0	8.0	10.0	8.0	7.0
19-Apr-15	Sections 1-7	4.5	9.0	13.0	9.0	4.0
28-Apr-15	Sections 1-7	5.0	10.0	13.0	9.0	4.0

"-" represents data not collected

Table 10. Fall salmon spawner counts by species and estimates of abundance based on area under the curve.

Survey	Count of Salmon Species[1]				
	CN	CM	CO	PK[2]	SK
10-Sep-14	6	0	1	52,552	27
27-Sep-14	14	0	78	13,086	62
9-Oct-14	51	1	452	159	35
14-Nov-14	1	18	115	0	0
20-Nov-14	0	22	129	0	0
4-Dec-14	0	0	32	0	0
Abundance Estimate	**127**	**50**	**1,403**	**63,120**	**132**

[1] CN = Chinook Salmon, CM = Chum Salmon, CO = Coho Salmon, PK = Pink Salmon, SK = Sockeye Salmon

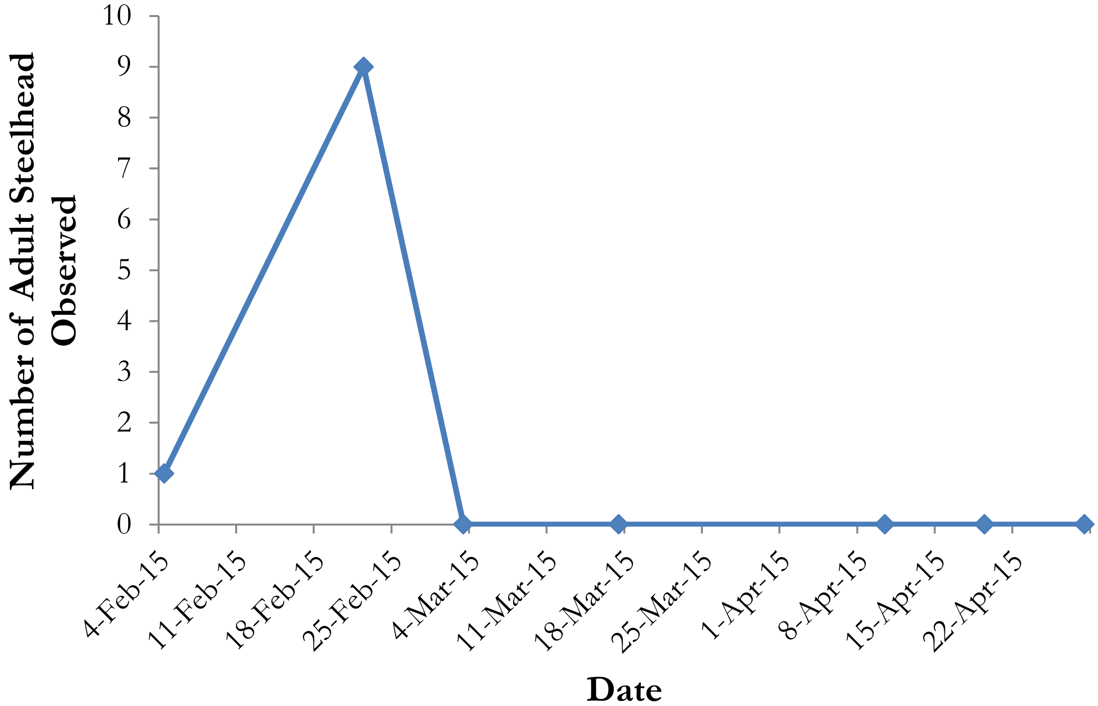
[2] The majority of observed Pink Salmon on September 10 and 27, 2014 were holding in Reach 7 and were not actively spawning.

Table 11. Fall counts of salmon redds by species.

Date	Count of Fish Redds[1]				
	CN	CM	CO	PK	SK
10-Sep-14	0	0	0	34	0
27-Sep-14	0	7	9	0	0
9-Oct-14	0	0	28	0	0
14-Nov-14	0	0	25	0	0
20-Nov-14	0	0	0	0	0
4-Dec-14	14	124	0	0	0
Total	**14**	**131**	**62**	**34**	**0**

[1] CN = Chinook Salmon, CM = Chum Salmon, CO = Coho Salmon, PK = Pink Salmon, SK = Sockeye Salmon

Figure 16. Steelhead counts during the spring spawner survey.



4. CONCLUSIONS

4.1. Overview

All BC coast salmonid species were observed using Elk Canyon for spawning and/or rearing during the first year 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 first year of sampling was mainly directed at collecting initial data and confirming methods to enumerate fish in Elk Canyon, and to provide recommendations for subsequent years of the program. The following sections highlight the main conclusions for each component of the study.

4.2. Smolt Enumeration

The RST fished well during its first year and overall is a viable technique for enumerating juvenile fish that are migrating out of Elk Canyon. All salmonid species except Sockeye Salmon recruited from Elk Canyon in Year 1 of the program. Coho Salmon were the most abundant salmonid produced from Elk Canyon in 2015, followed by Steelhead/Rainbow Trout, Chum Salmon and Chinook Salmon. Smaller numbers of Pink Salmon and Cutthroat Trout are also produced from Elk Canyon.

Mark/recapture trials conducted had a roughly 20% recapture efficiency, except for Coho Salmon fry that were closer to 5% recapture efficiency. With these capture efficiencies it was possible to estimate juvenile salmon outmigration population size from Elk Canyon using the RST data. This means that Elk Canyon productivity can be measured using the RST and linked to adult spawning abundance through time. The fact that the Coho Salmon fry capture efficiencies were very low may indicate that Coho Salmon fry released in Elk Canyon are not migrating immediately out of the canyon and instead are behaving as their life history predicts: rearing for at least another year in the canyon. For fish species other than Chinook and Coho Salmon, we assumed that a recapture efficiency of roughly 20% was representative of their respective recapture efficiencies in the RST.

Outmigration timing information is evident within and across species from the RST data. For example, several age classes of Coho Salmon, Chinook Salmon and Rainbow Trout/Steelhead were captured in the RST. For Chinook Salmon it is somewhat unclear if the fish that were caught in the RST are several months old (0+ fish) or have reared in Elk Canyon for over a year (are 1+ fish). Chinook Salmon in the Campbell River system are thought to be exclusively 'ocean type', meaning that they rear for a few months in freshwater and then migrate to the estuary to continue rearing, while 'stream type' Chinook Salmon spend one full year in freshwater before migrating to the ocean. Without age analysis, we cannot confirm if the captured Chinook or 'ocean type' or 'stream type'. In comparison, Coho Salmon fry (0+), 1+ smolts, and perhaps 2+ smolts were caught in the RST as they migrated out of Elk Canyon. The Coho Salmon 2+ smolts appear to be migrating out of Elk Canyon in April and May. Overall, we recommend that age analyses using scales be conducted on a subset of juvenile Chinook Salmon, Coho Salmon and Rainbow Trout in subsequent years of the RST program.

Based on the catch results of the target fish species, it may be appropriate to extend the RST sampling period beyond the end of June to ensure that the Coho and Chinook Salmon outmigration peaks are captured. Relatively high captures of Coho and Chinook Salmon were observed in the last sampling period (June 16-30, 2015) with no obvious decline compared to earlier periods. Therefore, if the outmigration period for these species extends into July, our Coho and Chinook Salmon smolt abundance estimates are likely to be underestimates of the true smolt outmigration abundance.

The RST appears to be working well to estimate abundance of Rainbow Trout/Steelhead smolts that are leaving Elk Canyon. However, the RST is not likely to provide reliable estimates of population size for resident Rainbow Trout and Cutthroat Trout in the way that snorkel surveys can. Therefore, we recommend that snorkel surveys and mark re-sight methods be used to enumerate standing stock of resident fish in Elk Canyon, in particular for Rainbow Trout.

There were three main challenges to RST operation in Year 1. First, the duration of the daily trap servicing was long and the cost was high. Second, it was difficult to effectively fish the RST during prescribed 10 m^3/s pulse flow events without damaging the RST or fish it captured. The RST also had to be pulled during spills higher than 10 m^3/s, which resulted in gaps in the RST data. Finally, during warmer periods beginning in June the RST was subject to some human disturbance from local swimmers, particularly on weekends, with a higher risk of RST vandalism.

Ways to address these limitations are to: 1) reduce the number of days or years of operation of the RST program; 2) adjust the time that pulse flows are initiated to better coincide with when crews are servicing the RST, allowing for readjustment of the RST fishing location specific to the flow; 3) adjust the RST catch to catch per-unit-effort as shown in Figure 5 to adjust RST catch by the days lost; and 4) operate the RST only on weekdays to minimize interactions between trap operation and public presence.

4.3. Overwintering Assessment

The overwintering assessment component of JHTMON-15 is intended to test if juvenile fish rear for their entire life history in the canyon or if a significant proportion of the population consists of immigrant juveniles. Snorkel surveys of the entire length of Elk Canyon were conducted in fall and in winter to test this hypothesis. However, there were several challenges that indicate that the overwintering assessment methods need to be reworked.

No Rainbow Trout, Coho Salmon or Chinook Salmon juveniles were observed during the daytime overwintering assessment snorkel swims in February. Only a few large-bodied adult fish were observed at this time. Based on our experience in other rivers, we hypothesized that the absence of juvenile observations was related to cold water temperatures and that fish were hiding during the day. Salmonids are known to be more active during nocturnal periods when water temperatures are below 9°C (water temperatures in February in Elk Canyon were 7°C). It is also possible that very large spills through Elk Canyon in early December 2014 displaced juvenile fish into downstream refuge areas.

A night time snorkel survey was conducted and confirmed the presence of Steelhead/Rainbow Trout in numbers similar to the fall day time surveys. However, no Coho Salmon were observed during the February night snorkel. This means that either: 1) Coho Salmon were displaced from the canyon by the high spills and then immigrated back into the canyon in spring prior to being caught in the RST; or, more likely, 2) Coho Salmon hide in the winter in cold water conditions and cannot be observed at this time through snorkel survey methods regardless of the time of day of the surveys.

Two Chinook Salmon parr were counted in Elk Canyon in February during the night time snorkel survey. Observing these Chinook Salmon in February suggests that these fish are 'stream type' and may be rearing in the canyon for a whole year. Although no Chinook Salmon parr were counted in the fall snorkel swims, this may be because it is challenging to differentiate and count the very few Chinook parr present when they are mixed in with abundant Coho parr.

We therefore recommend that the overwintering assessment methods be modified. One option is to adopt methods similar to the Puntledge River Water Use Plan monitoring where individual ~500 m^2 index snorkel sites are established and snorkelled at night in both the fall and the winter. One caveat to this method is that it may not work for Coho Salmon if they hide during both the day and night when water temperatures are below 9°C.

4.4. Pulse Flow Assessment

The detailed options analysis (Hatfield and Johnson 2015) was useful for excluding PIT tagging and resistivity counters from consideration. However, the options analysis was less useful for distinguishing between the remaining methods for assessing adult migration during pulse flows. The small differences in scores for the remaining methods essentially indicate a tie for these methods, and indicate that there is no single best method that also has no weakness.

On the other hand our experience based on the Year 1 work shows us that snorkel surveys can be a viable method for counting adult salmon in Elk Canyon. Even during the winter when water temperatures are low, Steelhead adults can be enumerated using snorkel methods. This work can be done safely and reliably. Therefore, it is possible in future years of the JHTMON-15 program to use snorkel surveys and a before – after design to test if pulse flows are effective at attracting fish to Elk Canyon. Snorkel surveys are likely to be less expensive than methods that depend on technologies like DIDSON or underwater video.

4.5. 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; Coho Salmon, Pink Salmon and Steelhead redds were also noted. There are clear trends in run timing by species, and the area under the curve method works well for calculating total escapement by species.

However, there are several current limitations to these data. First, it is clear that not all adults enumerated during fall snorkel surveys actually spawn in Elk Canyon. For example, the number of redds observed was much lower than the number of adult fish estimated using area under the curve. DFO typically records the number of spawning fish and the number of holding fish and use these to more accurately estimate salmon escapement. Future surveys should adopt this methodology because adult counts will be used to relate to juvenile production from Elk Canyon. Second, future estimates of escapement should also exclude reach 7 from the analysis. This is because these fish occur below the RST, and are also mainly holding rather than spawning fish that may move to another location other than the Elk Canyon to spawn. For example, 50,000 holding Pink Salmon were estimated in reach 7 in early September. Separating out reach 7 from the analysis is still possible with this year's data as adult counts were split by reach during surveys.

5. SUMMARY OF RECOMMENDATIONS

Overview of study design:

1. The first management question of JHTMON-15 centers on the base flow of 4 m^3/s in Elk Canyon and whether it is sufficient to provide juvenile rearing habitat to near maximum values. At present, the base flows of 4 m^3/s are fixed by the WUP as a single treatment for 10 years, with no experimental comparisons to other base flows. This limits the ability of the study to test the efficacy of different flow prescriptions. We therefore recommend that the JHTMON-15 program consider assessing juvenile production via a combination of the current productivity methods and an instream flow study (IFS) that can be used to develop habitat-flow relationships for each species and life stage of interest.

Smolt enumeration component:

2. The RST is an effective method to inventory juvenile salmonids (fry and smolts) that are migrating out of Elk Canyon. The RST data can be used to estimate Elk Canyon productivity for migratory Steelhead/Rainbow Trout and Chinook, Chum, Coho, and Pink Salmon. We therefore recommend that the RST work be continued.
3. The mark recapture experiment with Coho fry and smolts and Chinook fry and smolts was effective and generated recapture efficiency estimates of roughly 20% (exception is Coho Salmon fry at less than 5%). This was completed using hatchery fish since capture rates of wild fish were too low for a valid sample size. We recommend that this experiment be repeated at least one more time.
4. The mark recapture experiment with Coho fry and smolts and Chinook fry and smolts used the same mark for each of the three trials. Although most marked fish will migrate out of the canyon soon after their release, some may remain for a longer period. This means that some marked fish can be mixed up between trials. To maximize data quality, we recommend that either a unique mark be used across the three release trials or that the trials be staggered further apart to reduce the likelihood that fish recaptured from a trial period may belong to an earlier trial period.
5. The RST was effective at demonstrating run timing of outmigrating fry and smolts, including multiple age classes of Chinook Salmon, Coho Salmon and Steelhead/Rainbow Trout. It is possible that some 'stream type' Chinook Salmon are present in Elk Canyon. Therefore, we recommend that age analyses using collected scales be conducted on Chinook Salmon, Coho Salmon and Steelhead/Rainbow Trout individuals caught in the RST in future years of the program.
6. The RST may have missed a part of the Chinook and Coho Salmon smolt summer outmigration. We recommend that the period of operation of the RST be extended until the end of July. This will be reevaluated following the 2015 sampling season.

7. The RST will not be effective for estimating population size of resident fish such as resident Rainbow Trout and Cutthroat Trout. However, we also note that the resident fish are not the target of the smolt enumeration program. For resident fish using Elk Canyon, we recommend that snorkel surveys and mark re-sight methods be considered for estimating their standing stock.
8. Several challenges to the operation of the RST in Year 1 include the cost of operation, the required removal of the RST from operation during larger spills, and public disturbance to the RST. We recommend that the JHTMON-15 program consider reducing RST operation in terms of the number of years sampled (5-6 years rather than 10 years) and number of days per week (only operate on weekdays and close trap on weekends).

Overwintering assessment component:

9. There were several challenges to the overwintering assessment methods in Year 1 of the JHTMON-15 program. In particular, day time snorkel surveys in winter resulted in no fish being observed, likely because of inactivity due to cold water temperatures. Night snorkeling in winter showed similar abundance to day time snorkels in the fall for Rainbow Trout but measured zero Coho Salmon despite large counts in the fall and catch of Coho smolts in the RST from March to June. This likely indicates Coho Salmon inactivity in cold water in both day and night. We thus recommend that the overwintering assessment methods be modified to include night time snorkel surveys in both fall and winter at index snorkel sites rather than the entire canyon. Mark resight methods could also be employed. This recommendation recognizes that these methods will be appropriate for Rainbow Trout and Cutthroat Trout, but may not be useful for Chinook Salmon and Coho Salmon.

Pulse flow assessment component:

10. The options analysis (Hatfield and Johnson 2015) yielded no single best method for inventorying adult fish migrating into and out of the canyon during pulse flows or spawning flows. In contrast, the Year 1 program of JHTMON-15 showed that snorkel surveys of the entire canyon reach are a feasible method for inventorying adult salmon and can be accomplished safely at flows up to 7 m^3/s. We therefore recommend that snorkel surveys using a before – after experimental design be considered in future years of the program for testing hypotheses $H_0 3$ to $H_0 6$.

Spawner enumeration component:

11. Snorkel surveys and area under the curve calculations are appropriate methods to estimate spawner abundance in Elk Canyon. We recommend that these methods continue but that in future years' counts of holding fish be separated from counts of spawning fish. Further all counts in reach 7 below the RST should be removed from estimates of spawner abundance. This is because not all adult fish that were counted in Year 1 spawned in Elk Canyon.

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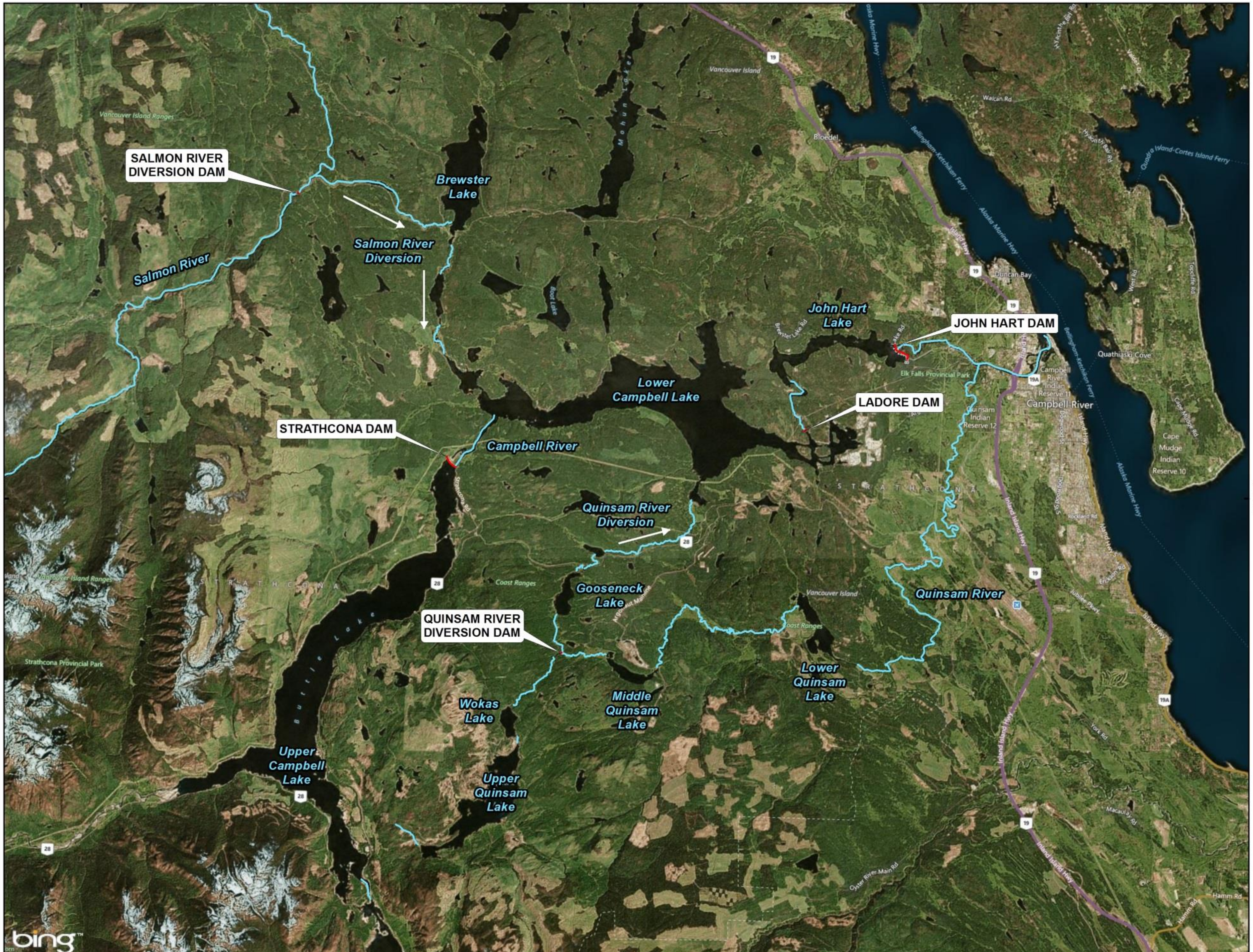
PROJECT MAPS



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
1	2/24/2015	1230_BCH_CRFacilities_2014Dec18	CGA
2			
3			
4			
5			

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

ECOFISH RESEARCH

Map 1

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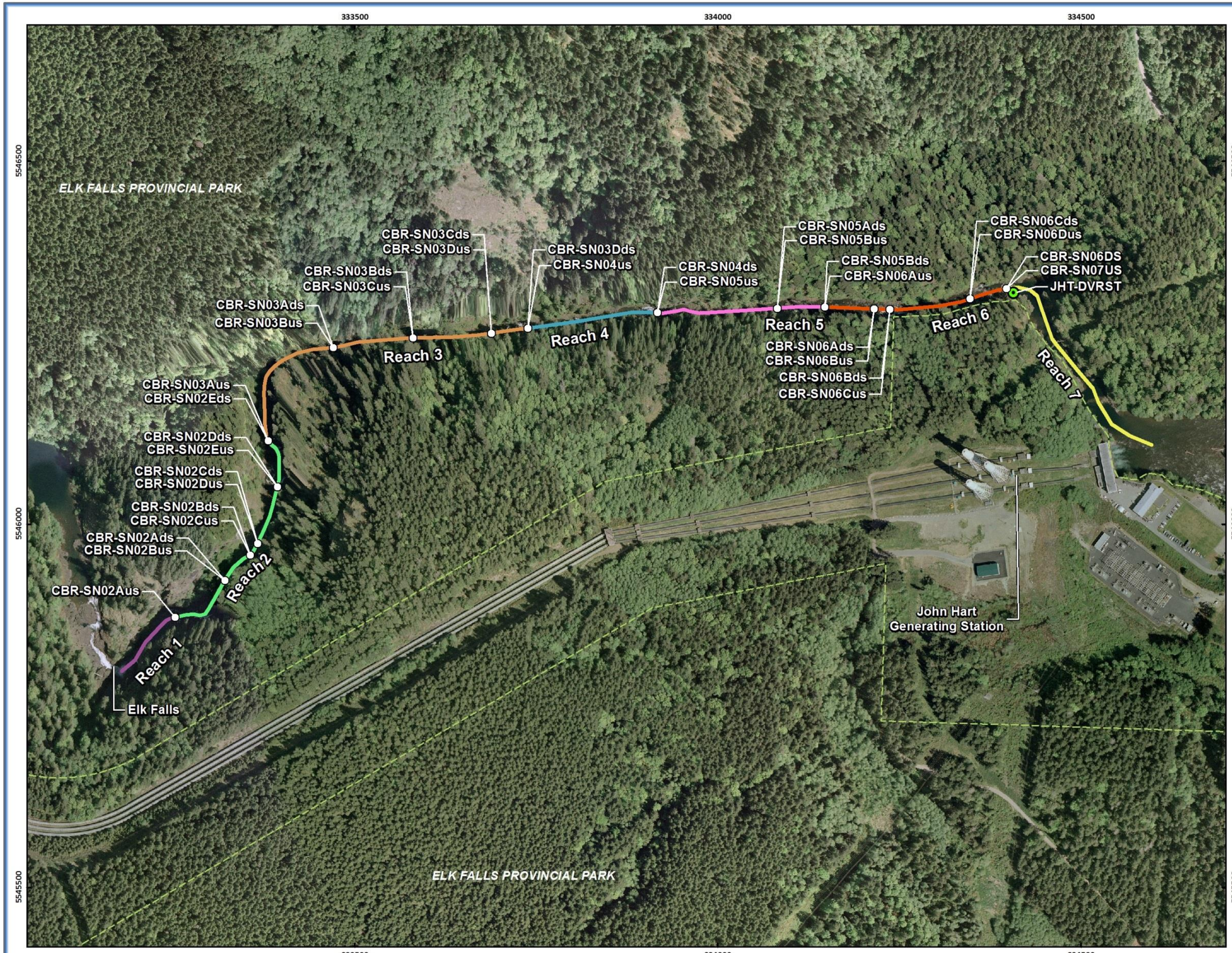

JHTMON Campbell River Water Use Plan

Elk Falls Canyon

Legend

- 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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2			
3			
4			
5			

Date Saved: 14/08/2015
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 2