Capilano Seymour Joint Water Use Plan

Effectiveness Assessment of the Fish Trap & Truck Program at Cleveland Dam




Prepared for:

Greater Vancouver Water District
Watersheds and Environment
4515 Central Boulevard
Burnaby, BC, V5H 0C6

January 19, 2022

Prepared by:

Ecofish Research Ltd.

Published by Ecofish Research Ltd., 600 Comox Rd., Courtenay, B.C., V9N 3P6

For inquiries contact: Technical Lead documentcontrol@ecofishresearch.com 250-334-3042

Citation:

Swain, N., H. Wright, C. Hojnowski, I. Girard, T. Hicks, and A. Lewis. 2021. Capilano Seymour Joint Water Use Plan - Effectiveness Assessment of the Trap & Truck Program at Cleveland Dam. Consultant's report prepared for the Greater Vancouver Water District by Ecofish Research Ltd, January 19, 2022.

Certification: *stamped version on file*

Senior Reviewer:

Adam Lewis, M.Sc., R.P.Bio. No. 494

Fisheries Scientist/Principal

Technical Leads:

Noel Swain, M.Sc., R.P.Bio. No. 3007

Fisheries Biologist/Task Manager

Harlan Wright, Dip. Tech.,

Senior Environmental Technician/Task Manager

Disclaimer:

EXECUTIVE SUMMARY

Ecofish Research Ltd. (Ecofish) was retained by the Greater Vancouver Water District to conduct the third-party independent effectiveness assessment of the Capilano Trap and Truck Program at the Cleveland Dam (CLD) between February and December 2021. This report presents the assessment results, which are based on Ecofish's fish passage experience combined with a literature review of the Capilano Trap and Truck Program and similar initiatives at other dam facilities, interviews with staff and consultants involved in the program, and field visits to observe the program in action.

The Capilano Trap and Truck Program has been assessed regularly since its formal inception in 2008. This report highlights several continuous improvement initiatives and changes that could increase fish capture and transport numbers, including the use of new low-level outlets (LLOs) as a dam operations strategy to improve smolt capture efficiency.

Overall, we find that the program has effectively implemented most past assessment recommendations, with consistent improvements to maximize the efficiency of smolt captures within both the upper Capilano River and Reservoir with existing dam infrastructure and in consideration of industry standards and practices. However, smolt captures in the upper Capilano River may be further increased through strategic re-establishment of rotary screw traps (RSTs) during low flow years, and by continued operation of RSTs for seven days a week during the peak smolt out-migration period. In the Capilano Reservoir, several adjustments may increase smolt captures during low water level years, including deployment of additional trap nets, trap net design modifications, and use of active fish capture via purse seining or pelagic trawling. These adjustments may be worth implementing, but contingent on further evaluation.

New LLOs at the CLD offer the potential to further improve fish capture efficiency in trap nets within the Capilano Reservoir, as well as to reduce fish attraction and mortality over the CLD spillway. When dam safety considerations and operations allow, therefore, we recommend maximal use of new LLOs during peak smolt out-migration, particularly in the spring prior to strong temperature stratification within the reservoir, when attraction flows are likely to be greater and potential temperature related effects to downstream fish populations is likely to be minimal.

Following capture, handling of smolts should continue to be minimized in accordance with practices in place since 2018, with continued implementation of measures to reduce handling stress, including reducing air exposure, monitoring water temperatures, cooling with ice or cold river water when necessary, using rubber meshed dip nets, transporting fish in dark holding containers with lids, and holding fish for at least 10 hours prior to release at sites located within or near the estuary.

The ultimate success of the Capilano Trap and Truck Program will be measured not just by fish capture and transport numbers but also by increased returns and successful spawning of anadromous fish. However, these populations are determined by survival during marine life phases, as well as by freshwater phases prior to smolt out-migration. Therefore, this effectiveness assessment concludes with identification of several additional beneficial actions, including measures to reduce estuary

predation following smolt release, design of a permanent fish holding and release facility, and consideration for the development of a metric-based system to evaluate overall program success.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MAPS

LIST OF APPENDICES

1. INTRODUCTION

The Cleveland Dam (CLD) in North Vancouver, British Columbia (BC) was completed in 1954 to create the Capilano Reservoir, which supplies water to the Metro Vancouver Regional District (Map 1). The CLD presents a complete barrier to upstream fish movement, and partial barrier to downstream fish movement between the lower Capilano River (downstream of the Cleveland Dam) and the Reservoir and upper Capilano River (upstream of the Reservoir). These barriers and permanent alterations to aquatic habitat have resulted in significant declines in Coho Salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) runs following the dam's construction and operation.

To offset these negative effects, the Greater Vancouver Water District (GVWD), and Fisheries and Oceans Canada (DFO), with assistance from the Province of BC (the Province), Squamish Nation, and the District of West Vancouver (DWV) work collaboratively to transport fish above and below the CLD via a Trap and Truck program, allowing adults to spawn in the abundant habitat available within the upper Capilano River and their offspring to migrate downstream to the ocean. Over the years, the effectiveness of the Capilano Trap and Truck Program has been assessed repeatedly as part of an adaptive management approach to maximize efficiency and implement enhancements and corrective measures as needed (e.g., Lill 2015, Chung *et al.* 2019, Plate 2019).

The GVWD developed a *Joint Water Use Plan for the Capilano and Seymour Watersheds* (JWUP) over an approximately eight-year period (2010-2018) to ensure the sustainable management of the water in the Capilano Reservoir for drinking water, fisheries habitat, recreation, culture, heritage, safety, and potential hydropower generation (GVWD 2021a). In 2018, the Province issued an Order under Section 93 of the *Water Sustainability Act* to implement the JWUP (Province of BC, 2018) among other requirements related to dam operations and fisheries monitoring. As part of the Order, the Province required that the GVWD elicit a third-party independent effectiveness assessment of the Trap and Truck program at the CLD to continually improve its success.

In 2021, Ecofish Research Ltd. (Ecofish) was retained by the GVWD to conduct the third-party independent effectiveness assessment of the Capilano Trap and Truck Program between February and December 2021. This report provides the assessment results, which were based on Ecofish's fish passage experience combined with a literature review of the Capilano Trap and Truck program and similar programs at other dam facilities, interviews with staff involved in the program, and field visits to observe the program in action.

The following sections provide the objectives of the effectiveness assessment, a general background of the Capilano Trap and Truck Program, the methods used to complete the effectiveness assessment, the assessment results, and recommendations to enhance smolt capture, transport, and release, to improve survival of out-migrating smolts, and to maximize overall program success.

Capilano River Trap and Truck Program Overview

Legend

- Reservoir Fish Processing and Boat Launch
- Adult Release Locations
- Smolt Release Locations
- Rotary Screw Traps/Fish Processing Locations
- Trap Net Locations
- Streams
- Lakes

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 1 2 km

Scale: 1:77,500

NO.	DATE	REVISION	BY
1	2021-12-21	1416_CAP_ProgramOverview_4414_20211221	CGA
2			
3			
4			
5			

Date Saved: 2021-12-21
Coordinate System: NAD 1983 UTM Zone 10N

ECOFISH RESEARCH

Map 1

Path: M:\Projects-Active\1416\MXD\Overview\1416_CAP_ProgramOverview_4414_20211221.mxd

1.1. Objectives

The objective of this effectiveness assessment is to identify continuous improvement opportunities, or more major changes as applicable, to ensure the appropriate tools and level of effort are committed to maximize smolt capture and minimize dam spillway mortality. This assessment is specific to the safe downstream passage of smolts past the CLD and does not include upstream adult transport. A comprehensive list of past recommendations developed from previous studies (Blair, 2019) was reviewed to assess any further implementation viability.

The effectiveness assessment addresses the following program management questions as laid out in the assessment terms of reference (TOR; GVWD 2020):

1) Has the current program maximized efficiency in smolt capture with existing dam infrastructure and in consideration of industry standards and practices?
2) What continuous improvement initiatives or changes could be implemented or further explored to improve fish capture and transport numbers?
3) Are there dam operations strategies that can be further explored to improve smolt capture efficiency?

2. BACKGROUND

The Capilano River originates in the Pacific Ranges of the Coast Mountains of BC and flows approximately 32 km south through Vancouver's North Shore before entering Burrard Inlet (Map 1; Plate 2019, Diewert *et al.* 2004). The CLD was constructed on the Capilano River by the GVWD in 1954; it is located approximately five kilometres upstream of the river's confluence with Burrard Inlet, creating the Capilano Reservoir, which supplies one third of the Metro Vancouver's water supply (GVWD 2021b, GVWD 2021c). The construction of the CLD restricted fish access to 95% of spawning habitat and 75% of rearing habitat on the Capilano River (Diewert *et al.* 2004).

Since the construction of the CLD, fish passage objectives for the Capilano Water Supply Area have generally remained the same: (1) ensuring the Capilano River's salmonid populations have access to approximately 100 km of fish habitat above the CLD, and (2) ensuring their progeny can move downstream with high survival rates. Passage of salmonids into and out of the Capilano Water Supply Area is integral to population persistence and genetic diversity, particularly because of limited habitat downstream of the CLD due to flow regulation and urbanization.

As an initial mitigation, in 1954 the GVWD constructed a weir, fish ladder, and holding pond below the CLD to collect and hold adult Coho Salmon and steelhead for transport upstream of the dam for spawning. However, due to high mortality rates of juvenile salmonids that now had to pass over the dam's 92-metre high spillway during their out-migration, Coho Salmon and steelhead populations declined in the 1960s and 1970s. To address this, DFO built the Capilano River Hatchery in 1971 to rear and release juvenile salmonids below the dam. In addition, returning wild Coho Salmon and steelhead adults in excess of hatchery requirements for brood stock were transported upstream of the

CLD to allow them to spawn within the abundant habitat in the upper Capilano River. The populations for these two species appeared to rebound in response (Diewert *et al.* 2004).

In 2001 and 2002, the GVWD conducted significant seepage control works at the east abutment of the CLD. To facilitate the works, the district lowered the water level in the reservoir below the level of the spillway, effectively halting downstream migration of fish (Diewert *et al.* 2004). As a mitigation measure, GVWD financed a Trap and Truck Program with DFO and the Province to trap Coho Salmon and steelhead smolts upstream of the reservoir and transport them to release sites below the dam (Map 1).

Following a formal request for steelhead mortality mitigation from the Province of BC, the Trap and Truck Program was again initiated in 2008. Annually between early April and late June, rotary screw traps (RSTs) within the upper Capilano River and trap nets within the Capilano Reservoir are used to capture out-migrating Coho Salmon and steelhead (Map 1). Captured fish are then transported below the CLD by GVWD staff to prevent the high mortality incurred when fish pass over the spillway.

To date, the estimated capture efficiency of the migratory smolt population varies between approximately 10% and 50% annually, with success rates directly and strongly correlated with seasonal dam spillway discharge (i.e., attraction flow; GVWD 2020) and snow water equivalent within the Watersheds on April 1st of each year. New low-level outlets (LLOs) at the CLD, which became operational in early 2021, offer the potential to further improve fish capture efficiency in trap nets within the Capilano Reservoir, as well as to reduce fish attraction to the spillway.

3. METHODS

The effectiveness assessment included a comprehensive review of Capilano Fish Trap and Truck Program-related publications and reports, literature associated with other trap and haul programs, and other pertinent research. In addition, Ecofish led interviews with personnel from the Capilano Trap and Truck Program and several other associated groups (i.e., DFO Hatchery staff and InStream Fisheries Research Inc.), and we conducted site visits to assess current operations, understand program challenges, and discuss potential recommendations for improvement.

3.1. Review of Program-Specific and External Literature

We reviewed past program assessments and associated reports and documents provided by GVWD in order to understand current operations and application of past initiatives, identify areas for further investigation, and prepare for interviews and site visits. Key documents that helped direct this review included a compilation of all past recommendations by Blair (2019), recent assessment reports (e.g., Lill 2015 and Plate 2019), and a draft assessment report of past recommendations by GVWD program biologists (all Registered Professional Biologists; GVWD 2021e). We tabulated past recommendations and GVWD assessments in Appendix A, along with an external assessment of their status, feasibility, and relevance to the three program management questions (Section 1.1; TOR, GVWD 2020).

We also conducted an external literature review based on suggestions from GVWD biologists, references from project associated documents, literature familiar to Ecofish, and searches via Google Scholar. Relevant findings from the external literature review aided in assessing past recommendations, current program status, and potential areas for improvement; these findings are summarized in Appendix B.

3.2. Interviews and Site Visits

Interviews and site visits with GVWD staff and associated personnel were conducted to document historical experiences, improvements that have been implemented over time, sources of uncertainty in the current program, operations, and conditions during the 2021 program, and potential future improvements. Interviewees were selected in collaboration with GVWD and included both staff that are currently working on the program (including DFO staff at the Capilano River Hatchery) as well as staff and consultants that have previously worked on or assessed the program (e.g., Instream). In total, three interviews and three site visits with nine professionals were conducted between March 25, 2021, and October 26, 2021 (Table 1). Photographs taken during site visits are provided in Appendix C.

Table 1. Summary of Capilano Trap and Truck Program Interviews and Site Visits.

Date	Activity	Location	Attendees[1]	Objectives
March 25, 2021	Pre-interview meeting with GVWD and Ecofish	Teleconference	Adam Lewis, Tom Hicks, Noel Swain - ERL, Jesse Montgomery, Jeremy Appleton, Scott Stuart, Thomas Jackman - GVWD	Familiarize Ecofish with the Capilano Trap and Truck Program and discuss questions regarding past past assessment reports.
April 21, 2021	Site visit #1 prior to peak smolt outmigration and staff interview	Cleveland Dam, Capilano Reservoir, Upper Capilano River, Second Narrows and Ambleside Park estuary release sites	Noel Swain, Harlan Wright - ERL Jesse Montgomery, Jeremy Appleton, Georgia Dixon, Cara Blair - GVWD	Visit all project areas; trap locations, fish sampling stations, Cleveland Dam, smolt and adult release locations, fish habitat upstream of the dam. Discuss Capilano Trap and Truck Program operations (history of the program, improvements, effective practices, peak migration periods).
May 11, 2021	Interview with GVWD and Capilano Hatchery Manager	Teleconference	Noel Swain, Harlan Wright - ERL, Jeremy Appleton, Scott Stuart - GVWD, Hamid Seshadri - DFO	Discuss Ecofish questions pertaining to hatchery operations: adult releases upstream of CLD, juvenile releases in lower river, discuss collaboration for joint release location with Capilano Hatchery and GVWD.
May 12, 2021	Site visit #2 near peak smolt outmigration and staff interview	Capilano Reservoir fish processing and trap nets, current and past RST sites and adult spawner release site in Upper Capilano, release to estuary near Ambleside Park	Noel Swain, Harlan Wright - ERL, Jeremy Appleton, Jesse Montgomery, Thomas Jackman, Scott Stuart, Georgia Dixon, Cara Blair, Lucas Lachambre - GVWD	Observe daily fish captures and transport from the RST and reservoir trap nets and fish processing methods. Observe fish release procedures at the Ambleside estuary release site. Compare operations against past program effectiveness assessment recommendations.
June 1, 2021	Site visit #3 - potential release site locations and and staff interview	Lions Gate Wastewater Treatment Plant, DFO West Vancouver Laboratory	Noel Swain - ERL, Jeremy Appleton, Scott Stuart - GVWD	Visit release locations at Lion's Gate Wastewater Treatment Plant site and DFO West Vancouver laboratory. Discuss benefits and challenges associated with each site and potential for permanent holding/release facilities.
October 26, 2021	Interview with InStream	Teleconference	Noel Swain - ERL, Jesse Montgomery, Jeremy Appleton - GVWD, Dani Ramos-Espinoza - IFR	Discuss Ecofish questions pertaining to capture efficiency of reservoir trap nets, upper river RSTs, past initiatives, and InStream's assessment of program effectiveness and areas for further improvement.

[1]ERL - Ecofish Research Ltd., GVWD - Greater Vancouver Water District, DFO - DFO Capilano Hatchery, IFR - InStream Fisheries Research Inc.

4. RESULTS

The following sections summarize current program practices and relevant past recommendations for smolt capture, handling, transport, and release, and provide recommendations for continued improvements.

4.1. Smolt Capture

4.1.1. Current Practice

Following recommendations by Chung *et al.* (2019), GVWD currently operates one RST within the upper Capilano River and up to 10 trap nets within the Capilano Reservoir to capture out-migrating Coho Salmon and steelhead smolts for transport downstream during peak migration between roughly April 1st and June 15th (GVWD 2021e).

4.1.1.1. Upper Capilano River

RSTs have been used by DFO and the GVWD since 2002 (e.g., GVWD 2021d). Between 2012 and 2018, RSTs were deployed within the upper Capilano River at the Mid-Valley, Dean Creek, and Lake-Head sites (Map 1). However, deployment of the RSTs aside from that at Dean Creek was seriously constrained by flows and logistics, limiting their effective fishing days and associated capture efficiencies. All sites except Dean Creek have been discontinued since 2019 (GVWD 2021e). Following recommendations by Ladell *et al.* (2012), RSTs were largely refurbished in 2013, and the Dean Creek RST is currently in good working order.

The Dean Creek RST is located in the mainstem of the Upper Capilano River, roughly three km upstream of the reservoir (Map 1; Appendix C, Figure 10), in an ideal location as described by Plate (2019). The RST is deployed from a continuous cableway spanning the river, allowing its position to be adjusted to fish within the main flow of the river, thus maximizing capture efficiency while also allowing the trap to be pulled into calmer water during high flows. During trap servicing and fish removals, the trap is positioned to river right adjacent to an abandoned bridge pillar whereby personnel can safely access the RST to extract captured fish from the holding tank (Appendix C, Figure 11).

The Dean Creek site has a pronounced, narrow thalweg entering the front of the trap and safe access for staff, with a deep slow pool downstream for egress if a person was to fall into the river (Plate 2019). The cable anchors are designed so that the trap can be pulled from the fishing position towards shore to allow for safe access. The site also has a breakaway system that allows the trap to swing towards shore into a large back eddy if a main cable breaks due to high flows and debris load.

Considering discussions with GVWD staff and observations by Ecofish staff during site visits, it appears that much of the available steelhead rearing habitat within the upper Capilano River exists above the Dean Creek RST, but that at least one km of highly suitable rearing habitat with larger substrate and higher gradient is downstream and is thus not effectively fished.

In 2021, a single 8' diameter RST was operated at the Dean Creek site for 30 days between April 28th and June 11th. Installation was conducted after flows declined below approximately 20 m^3/s, and the

RST was removed after smolt capture rates declined over multiple consecutive days (GVWD 2021f). The trap was operated through the weekends from May 3rd to 28th, except for three days when the trap was pulled out of the main flow due to high river discharge. Outside of this peak migration period, the trap was set on Monday morning and fished for four evenings and checked daily, before being pulled to shore prior to the weekend (GVWD 2021f). A total of 141 steelhead smolts and 4,543 Coho smolts were captured by the RST in 2021. A more detailed description of 2021 RST operations is provided in GVWD (2021f).

4.1.1.2. Capilano Reservoir

Custom-built trap nets are the predominant method of smolt capture within the Capilano Reservoir and were first trialed in 2001 (Perrin 2003), though their consistent deployment did not begin until the initiation of the current program in 2008 (e.g., Ladell and McCubbing 2008). The trap nets consist of an anchored floating trap box connected to shore by a central lead net, which, along with two floating wing nets, funnel fish that are migrating along the shoreline through a narrow opening into a box (Perrin 2003, Chung *et al.* 2019; GVWD 2021f; Appendix C, Figure 5 – 7). GVWD has made continual modifications to trap nets in response to program assessment recommendations, fine tuning the length of lead and wing nets to maximize capture and operational efficiency while maintaining structural integrity and minimizing debris accumulation (e.g., Lill 2015; Chung *et al.* 2019; GVWD 2021e). In accordance with recommendations for increased capture effort within the reservoir, additional traps were added to the program as new locations and placements were trialed and subsequent capture efficiencies were assessed, with six traps deployed in 2008, eight traps in 2009, and up to 10 traps beginning in 2012 (Chung *et al.* 2019; GVWD 2021e).

Trap nets are set in the most effective habitat available (i.e., the habitat that yields the highest captures of smolts while balancing appropriate shoreline conditions for effective deployment and maintenance and considering available staff resources and logistical constraints). The number of traps deployed within the reservoir and the length of deployment vary annually based on river and reservoir conditions such as higher- or lower-than-typical water levels within the reservoir due to annual snowpack or dam maintenance, high inflows and outflows, and wind. Trap number, location, and configuration appear to have been optimized based on trials of different locations and assessment of fish capture rates over the course of the program to date, reservoir bathymetry studies, results from smolt radio-telemetry and acoustic tagging initiatives, numerous past assessment recommendations, and a formal optimization study by InStream (Ladell and McCubbing 2011; Chung *et al.* 2019; GVWD 2021e). Because they are less constrained by flows, trap nets are usually installed earlier and removed later than RSTs each year, with their deployment typically being between April 1 and June 15 (i.e., coinciding with peak smolt out-migration).

To support maintenance of trap nets, GVWD collects and stores debris for removal. GVWD has had success in installing short debris catches adjacent to some trap nets where debris accumulation has hindered their effectiveness. As per recommendations by Lill (2015), replacement of an existing debris boom deployed at Mid-Lake is scheduled for 2022 and will improve smolt collection below the boom by limiting debris accumulation on trap nets.

To increase steelhead smolt captures within the reservoir, a commercial purse seining vessel was trialed in 2015, completing a total of 101 sets over six days during exceptionally low water levels and high thermal stratification conditions (Ladell 2015). This method was effective, capturing 139 steelhead smolts, accounting for approximately 25% of the total steelhead captures in that year. However, due to concerns around potential public perception, high relative costs, equipment requirements, and a lack of similar reservoir conditions in subsequent years, this method of capture has not been used again (GVWD 2021e).

In 2021, only six of the 10 reservoir trap nets were operated due to lower than typical reservoir water elevation (due to dam maintenance operations) that limited the number of appropriate deployment sites (GVWD 2021f). For instance, the most effective trap location in previous years has been located along a gradual sloping shoreline at the northwest end of the lake approximately 500 m from the mouth of the upper Capilano River (TN2; Map 1; Montgomery pers. comm. 2021). However, this site was omitted in 2021 because this area of shoreline was too shallow or dewatered. New Low-level outlets (LLOs) also came online in spring 2021 and were operated for much of the peak of the smolt-outmigration period. LLOs were expected to increase trap net capture rates. LLO operations resulted in reduced spill during the peak outmigration, similar to a period of reduced spill in 2015 due to extremely low inflows.

Trap nets were operated for 64 days between April 12 and June 14, 2021, capturing a total of 38,754 Coho smolts and 320 steelhead smolts. These numbers represent the second highest captures to date, following captures in 2015. A more detailed description of 2021 operations is provided in GVWD (2021f).

4.1.2. Past recommendations

4.1.2.1. Upper Capilano River

Earlier program assessments recommended establishing additional RSTs in the upper Capilano River watershed to increase steelhead smolt catches prior to their entry to the reservoir where the likelihood of their capture decreases (e.g., Ladell *et al.* 2011). Other assessments recommended modifying and upgrading existing RSTs to improve safety standards and allow for partial trap fishing during low flows with the drum in a partially lowered position (e.g., Ladell *et al.* 2012); this recommendation was applied in 2013 by GVWD (GVWD 2021e). Additional prior recommendations for use of RSTs included application of mark-recapture programs aimed at determining estimating smolt yield, trap net capture efficiency, and spillway survival; these components are outside of the management questions associated with this assessment and are not described further.

Given the limited effectiveness of the RSTs and high operational effort observed over the course of the program, past assessments have also recommended phasing out RSTs in favour of more effective capture systems such as an adjustable diversion weir and smolt screening collection facility (e.g., NHC 2013; Lill 2014, 2015). However, a three-year planning study identified significant limitations to such a facility due to the physical structure of the Capilano River and its variable and extreme flow rates, which were expected to result in low effectiveness and limited use (Lill 2015). The facility was not deemed feasible given its high cost, limited effectiveness, and the critically low steelhead abundance to which the facility was directed (GVWD 2021e). While such systems for collection of out-migrating smolts have been successfully implemented as part of other trap and transport programs (e.g., McCubbing and Ward 1997; Börk *et al.* 2012), we agree with the decision by GVWD to not move forward on the facility, given the inhibitive cost and variable and comparatively high flows and associated large sediment and woody debris movement experienced within the Upper Capilano River watershed.

4.1.2.2. Capilano Reservoir

Consecutive annual reports by InStream recommended using additional trap nets within the reservoir to increase capture of smolts, and for deployment of traps in specific locations within the reservoir where capture rates were expected to be highest based on results from reservoir bathymetry, smolt radio-telemetry, and acoustic tagging studies (e.g., Ladell and McCubbing 2008, 2009, 2012; Lill 2015). In response, traps were added to the program between 2008 and 2012, with up to 10 traps currently deployed in the most effective locations throughout the reservoir, including site TN2 where smolt captures have typically been highest (Ladell and McCubbing 2011). Considering past optimization studies and GVWD staff experience, we deem that the current number and placement of traps is likely optimal and appears to have resulted in a general increase in smolt captures, particularly of Coho Salmon, over the course of the program (GVWD 2021e).

Multiple past assessments and annual reports have also recommended adjusting trap design to increase capture efficiency, for example by extending the length of wing nets, replacing the bottom of traps with conical, rubberized mesh panels and a central collection bucket, or installation of adjacent floating barrier nets or debris booms (e.g., Lill 2015; Plate 2019). Our site visits, discussions, and literature review highlighted the importance of trap positioning and straightness of the lead and wing nets over length. Retrofits to the trap panels themselves do not seem plausible, and GVWD personnel appear to have a highly efficient technique of netting fish out of traps with minimal air exposure. Overall, trap design appears to be generally optimized in terms of trap stability, operability, and capture efficiency; trials of most retrofits as per these and other recommendations were found to impede performance and operation of traps with GVWD reporting issues with traps and nets maintaining their shape during low reservoir levels or periods of high flows and wind and becoming impeded by algal and woody debris accumulation, all reducing their effectiveness. In support of improved trap effectiveness, Lill (2015) recommended installation of an effective debris boom within the upper reservoir to reduce effects of debris accumulation on southern trap nets; this installation is scheduled for 2022.

Alternative trap types such as Merwin traps or a full reservoir-spanning net pen close to the reservoir's upper narrows have been suggested in past assessments (e.g., Lill 2014, 2015). However, following discussion with Tacoma Power personnel (Underwood pers. comm. 2014) and further research, GVWD biologists deemed that both alternative trap designs would be less effective than the updated trap nets currently in use, given the complexity of Merwin trap design and the challenges with debris accumulation, damage, predation, trap avoidance, and smolt residualization associated with a large-scale net pen (Lill 2015; GVWD 2021e).

In line with the broader literature (e.g., Lusardi and Moyle 2017, Kock *et al.* 2020), multiple past assessments have recommended reviewing current dam operations to determine how to reduce the magnitude and frequency of spill over the spillway, including through use of the LLOs to reduce attraction flows and increase smolt captures within the reservoir trap nets (e.g., Ladell *et al.* 2014; Lill 2014, 2015). While there has been limited capacity to minimize flows over the spillway due to the nature of the LLOs and CLD infrastructure in previous years, construction of the new LLOs was completed in spring 2021, and they were in use for much of the latter portion of the smolt out-migration period. The fact that smolt captures were the second highest to date, following captures in 2015, despite significantly decreased collection efforts (only six of 10 trap nets, and no purse seining; GVWD 2021e, 2021f) suggests that reduction in spill via use of the new LLOs was successful at increasing capture rates of traps.

The use of active smolt capture methods has also been recommended in the past, including continuation of the purse seining trial conducted in 2015 (Ladell 2015) or pelagic trawling (Plate 2019) in conjunction with hydroacoustic surveys to track the location and depth of steelhead smolts within the reservoir. Following the purse seine trial in 2015, Jackman (2015) made several recommendations to improve the method, including reducing net mesh size to increase Coho smolt captures (only two Coho smolts were captured through purse seining in 2015), increasing the overall net area (e.g., to 70 × 700 ft), conducting seining in conjunction with the deployment of a mid-lake curtain net to limit downstream migration of smolts and constrain seining efforts to a smaller area of the reservoir, and having GVWD personnel onboard to streamline fish handling, enumeration, and data collection. While this method has not been trialed since, further consideration of seine fishing is warranted, particularly under low spillway flows caused either by low snowpack accumulation or effective use of the new LLOs.

Past assessments have also recommended considering construction and operation of permanent smolt bypass or collection facilities within the reservoir, at or above the CLD, possibly in conjunction with the potential hydropower installation currently under review. Such facilities would include installation of a siphon or helical screw pump and diversion channel at the west end of the CLD (e.g., Ward and Associates 2004) or a reservoir spanning barrier net and floating surface collector at or above the CLD (Lill 2014 but see Lill 2015). Lill (2014) provided a detailed summary and assessment of existing smolt capture facilities and associated pilot projects in the North Pacific United States, but noted that many experienced variable successes, and that in many cases, implementation is ongoing. We agree that permanent facilities may greatly increase smolt capture rates and subsequent transport downstream given more recent reported successes associated with such facilities in numerous US trap and transport programs (e.g., as reviewed by Lusardi and Moyle 2017; Kock *et al.* 2019, 2020, and references therein).

4.1.3. Recommendations

Past recommendations have generally been successfully implemented by the Capilano Trap and Truck Program, with continual improvements to maximize the efficiency of smolt captures within both the upper Capilano River and Reservoir with existing dam infrastructure. Where recommendations have not been adopted, there is clear rationale. Here we highlight and add to several past recommendations for consideration.

4.1.3.1. Upper Capilano River

GVWD should consider re-establishing the historical Mid-Valley RST (as recommended by Ladell and McCubbing 2011) to increase capture of out-migrating steelhead smolts prior to their entry into the reservoir, where their capture rates appear to diminish. Specifically, this location should be tested in an adaptive framework in years or periods of out-migration when flows are predicted to be moderate based on snowpack within the watershed. Further, the deployed RST should continue to have an adjustable drum that can be raised and lowered in relation to flows, as implemented at the Dean Creek site. While catch per unit effort is higher at the Dean Creek RST location, this previous RST location within the upper watershed was successful in capturing a significant proportion of out-migrating steelhead (and to a lesser extent Coho Salmon) smolts in some years of operation (e.g., Chung *et al.* 2019, Dixon 2020). Given current river conditions and experience by the GVWD and InStream, it is likely that deployment of RSTs at the Lake-Head site will not be effective, given the small area of river channel covered and lack of effective refuge for the trap during high and low flow events. We recommend that historic RST capture data, operation logs, and associated flows be reviewed in further detail to construct a decision matrix that could be applied to snowpack and flow conditions to determine when capture efficiency and operation was optimized at each RST location in order to inform deployment based on pre-season forecasts and in-season hydrometric data.

GVWD should continue to prioritize operating RSTs within the upper Capilano River seven days a week throughout the peak out-migration period (typically early May to early June) based on observed capture rates over the period. This recommendation, first suggested by Chung *et al.* (2019) and reiterated by an internal review by GVWD (Dixon 2020), was trialed in 2021, and is likely to have contributed to the near record numbers of smolts captured within RSTs this year (i.e., the second and third highest annual captures of steelhead and Coho smolts to date, respectively, at the Dean Creek site despite the fourth lowest number of fish days since 2013; GVWD 2021f).

4.1.3.2. Capilano Reservoir

Foremost, we recommend that whenever operationally feasible, the GVWD reduce flows over the spillway by maximizing use of the new LLOs during peak spring smolt out-migration, prior to strong temperature stratification in the reservoir (when potential downstream impacts, such as steelhead redd degree days are reduced, e.g., Lewis and Hicks 2021). Use of the LLOs will decrease attraction flows and potentially increase capture efficiency of trap nets while minimizing mortality over the spillway (e.g., Ward and Associates 2004; Lill 2014). This strongly suggests that use of the LLOs during spring smolt migration will improve the survival of Coho Salmon and steelhead smolts. Use of the LLOs in 2021 may have contributed to the second highest captures within trap nets to date, despite lower effort than in the most effective year when reservoir conditions were similar (GVWD 2021e), though further investigation of this is warranted to rule out the effect of other environmental variables (e.g., water temperature and flows) or the possibility that 2021 also coincided with higher than typical smolt out-migration. The options for future operation of the LLOs at CLD as it pertains to fisheries management were provided in a memo from Ecofish to GVWD on May 25, 2021 (Lewis and Hicks 2021).

We also recommend evaluating the use of past trap net locations during lower water level years within the reservoir (e.g., 2015) to determine whether there are alternative sites that can be used to maximize the number of traps deployed under such conditions, particularly with increased use of the LLO Ongoing fine-tuning and trap modifications will likely need to continue as climate change exacerbates annual variability in precipitation, snowpack, and associated flows and reservoir levels (e.g., Pike *et al.* 2010; Yasarur and Sturm 2016). For example, a shallower, considerably extended lead net and shortened wing nets, along with modified placement to allow for safe access by boat might allow for deployment of a modified trap at site TN1 under low water level conditions such as those experienced in 2021.

The GVWD should consider reintroducing active fish capture in the reservoir through purse seining or pelagic trawling, particularly during years with reduced snowpack and in conjunction with LLO operations. To reduce cost and lessen concerns around public perception, the GVWD could explore options to reduce the scale of the operation and conduct focused sets with a smaller fishing vessel. The use of sonar or hydroacoustic equipment can be utilized to maximize the effectiveness of active fish capture by elucidating diurnal movements of fish, locating smolts and identifying typical holding areas where effort should be focused. While this is an unconventional capture method for trap and transport programs with no known examples found in the wider literature, it has been found to be an effective method for capture of smolts for mark-recapture studies associated with such programs (e.g., Giorgi 1984). Hydroacoustic surveys trialed in 2009 to examine interactions between trout and juvenile Coho Salmon populations within the Reservoir provided limited results due to the apparent association of fish to nearshore habitats and limitations of equipment to effectively survey these habitats (Stables 2009). However, the use of sonar was used successfully during seining trials in 2015, and advancements in hydroacoustic survey techniques in recent years (e.g., Doire 2021, Mrnak *et al.* 2021) would likely allow for more effective surveys of nearshore shallow habitats and census of Reservoir fish populations in future years of the program. Considering this, we recommend that prior to future trials of active capture methods, the GVWD should consider conducting more comprehensive hydroacoustic surveys of the Reservoir to determine fish distributions and habitat use to focus active capture methods and potentially refine placement of trap nets to capture the target species more effectively.

4.2. Smolt Handling, Transport, and Release

4.2.1. Current Practice

Fish handling, transport, and release covers all aspects of the program outside of the passive capture of smolts and other fish within RSTs and reservoir trap nets, including extraction of fish from the two traps, species and age class identification and enumeration, sorting Coho Salmon and steelhead smolts to be transported and released downstream of the CLD from bycatch to be released back into the Upper Capilano River or reservoir (exceptions described below), transportation between traps, fish processing facilities, and transport tanks, and ultimately release downstream of the CLD. These components are detailed in Appleton and Jackman (2020) and generally follow past assessment recommendations (e.g., Plate 2019) following best practices to minimize stress or harm to fish and increase program efficiency by minimally handling fish in all stages. Similar methods for smolt handling, transport, and release are applied for fish captured in both RSTs and trap nets; when relevant, noteworthy differences are highlighted below.

4.2.1.1. Handling and Transport

During RST fishing, fish are removed from the holding tank by dip-net and transferred into five-gallon pails to be transferred to a processing location on the riverbank. Smolts captured at the Dean Creek RST are typically processed at a station on the abandoned bridge pillar on river right adjacent to the RST site, and in previous years when additional RSTs were deployed, smolts were similarly processed on the riverbank adjacent to RSTs, before being moved in pails to a truck-mounted holding tank (or if non-targeted species or age classes, released downstream of the RST). Smolts are then transported and held at downstream fish processing facilities while fish are extracted from reservoir trap nets and processed, after which all fish are transported downstream of the CLD to be released.

When mark-recapture, radio-telemetry, and acoustic tagging initiatives were conducted in previous years, a portion of the smolts captured in RSTs were released back into the upper Capilano River for potential recapture in downstream RSTs or trap nets, or to be tracked throughout the reservoir or downstream if they passed over the spillway (e.g., Chung *et al.* 2019).

Trap nets are accessed via one of two small outboard rigid inflatable boats moored in the Capilano Reservoir. The boat is positioned adjacent to the trap nets, and portions of the netting of the bottom panel are pulled up to corral fish into the wetted corners of the net so that fish remain wetted while personnel run dip nets along the trap net to effectively extract fish. Netted fish are quickly transferred to separate perforated, dark-coloured buckets within a larger holding tank with circulating reservoir water on the boat. Fish are then transferred via the dark buckets to a larger holding tank with circulating reservoir water onshore to be processed, enumerated, and sorted. Non-target species and life stages are released back into the reservoir while Coho Salmon and steelhead smolts are transferred to either large, secured holding buckets or a truck- or trailer-mounted insulated holding tank to be transported and released downstream of the CLD.

In line with past recommendations (e.g., Plate 2019), throughout both handling and transport, air exposure is limited as much as possible, water temperatures are monitored, and fresh river/reservoir water or ice are used to reduce temperatures on exceptionally hot days or when reservoir surface temperatures are approaching 19 ºC. In the past, the program has included considerable fish handling, including mark-recapture, PIT, radio-telemetry, or acoustic tagging, length and weight measurements, and age structure and genetic sampling (Chung *et al.* 2019). However, 10 years of intensive monitoring suggested that handling be decreased in order to maximize capture, transport, and release of fish while minimizing fish injury and stress. Handling was therefore reduced in 2019 to netting from traps, separating species and life-stages between holding buckets, and counting individuals prior to transport downstream of the CLD (for target species and sizes) or release into the upper river downstream of the RST or within the reservoir (for non-target species and life stages).

When species identification is necessary, fish are placed in water within a clear fish viewer. Past genetic analyses of trout and steelhead have been used to calibrate identification accuracy by program personnel, and overall positive identification of steelhead smolts was estimated at approximately 90% (Jackman 2019). However, in cases where species identification is uncertain, a precautionary approach is applied and possible steelhead smolts are transported downstream rather than being released back into the upper river or reservoir (Montgomery pers. comm. 2021). In addition, larger adult trout have been transported and released downstream of the CLD in some years to reduce predation pressure on smolts within the reservoir and to improve recreational fisheries diversity downstream of the dam (Montgomery pers. comm. 2021).

In typical years, fish processing occurs at a permanent facility at the northeastern drawdown zone near the mouth of the upper Capilano River, where a covered work area and automatic digital VAKI fish counter have been installed for bulk counting of smolts. This facility is not accessible at lower reservoir water levels such as those experienced in 2021, so a smaller, temporary facility was established at the more southerly dock site. Ecofish visited both facilities during site visits in 2021, and although the permanent facility would allow for more efficient processing with slightly less handling of fish, personnel appeared highly competent and were able to efficiently minimize handling and air exposure at the temporary facility.

In 2021, in contrast to most previous program years, all Coho Salmon juveniles (i.e., both smolts and younger juveniles) caught in trap nets were kept and transported downstream. This decision was made in consideration of the low probability of their being recaptured again as smolts (as per results in Chung *et al.* 2019) and the low probability of their survival over the spillway (Ward and Associates 2004; Ladell and McCubbing 2014) likely leading to their mortality if released back into the reservoir (Montgomery pers. comm. 2021). As in previous years, fish were transported downstream of the CLD in 2021 via either 20-gallon buckets with lids secured within a larger tank filled with water in the bed of a pickup truck if <300 fish were being transported or within a larger trailer mounted insulated aluminum tank if >300 fish were being transported (GVWD 2021f). In line with past seasons, and in accordance with Appleton and Jackman (2020) and previous assessment recommendations (e.g., Plate 2019), both systems included aeration or oxygen stones to maintain oxygen levels > 70% saturation.

4.2.1.2. Release

Numerous release locations downstream of the CLD have been trialed over the years, based on both accessibility and past recommendations. In past years, smolts were released downstream of the hatchery plunge pool and from Fullerton Bridge (Montgomery pers. comm 2021), considering that some research has found increased adult homing success for river-released fish due to increased olfactory imprinting to their natal system (e.g., Keefer *et al.* 2008). However, given the logistical difficulties of releasing to these upper locations and evidence of increased early mortality of river-released fish due to extended predation and other in-river hazards (e.g., Balfry *et al.* 2011), such releases were discontinued (Montgomery pers. comm 2021). Four other main locations have been used in the past as well as in 2021, all of which were assessed by Ecofish during site visits: 1) the Ambleside Park estuary release site, 2) the Taylor Way Bridge release site (located 80 m upstream of the Taylor Way Bridge), 3) Lions Gate Wastewater Treatment Plant (LGWTP), and 4) the First Narrows watermain tunnel crossing (Appendix C, Figures 13 – 16). The Ambleside Park estuary location is used most, as it offers easy road access along the parkway with the fish transport truck and trailer. All four locations are within the estuary, though the Taylor Way Bridge and Ambleside Park locations are within the Capilano river mouth, while LGWTP and First Narrows sites are located east of the river mouth (Map 1).

In 2015 and 2016 the GVWD trialed direct release of some fish adjacent to a marine net pen at the DFO West Vancouver Laboratory facility, however this was discontinued in subsequent years due to concerns over the possible effects of releasing juvenile steelhead directly to the marine environment. This site was also visited in 2021 by Ecofish and GVWD staff to assess the possibility of using the net pens to hold fish for an extended period prior to release, releasing fish at night, and reducing predation risk (Appendix C, Figure 17). However, given considerable increase in effort to transport fish to the facility and concerns about potential increases in straying and predator aggregation associated with a release site so far from the Capilano River mouth regularly used by DFO for release of large numbers of Chinook Salmon, this location was not used in 2019-2021.

Smolts are released directly into the water either from 20-gallon buckets that are carried down to the shoreline by hand (GVWD 2021f) or using a long, gravity fed, 7.6-cm diameter semi-rigid plastic hose attached to the bottom valve on a trailer-mounted transport tank. This hose outlet is vertically inverted so that fish rise about 40 cm and fall back to the estuary with minimal shock (Appendix C, Figure 14).

The total number of release events conducted at each of the locations during the day and evening/night in 2021 are as follows, with further details described by GVWD (2021f):

- Taylor Way Bridge: 11 days;
- Estuary: 8 days, 6 evenings;
- LGWTP: 8 days, 2 evenings; and
- First Narrows: 1 day, 3 evenings.

Notably, 11 of the 39 releases were conducted in the evening in 2021, in accordance with past recommendations (e.g., Lill 2015, Plate 2019). Anecdotal observations by GVWD personnel noted that predator presence (seals and birds) and density, as well as boat activity were lower during the evening releases than during the daytime (GVWD 2021f), while GVWD personnel reported heavy predation by seals, gulls, and blue herons during day releases. Ecofish also observed these predators hunting at the mouth of the river following an afternoon smolt release on May 12, 2021. Together, these observations suggest that evening releases may improve early marine survival of smolts as per past assessment conclusions.

The Park Royal Beach release location used in previous years was shifted approximately 300 m further upstream in 2021, approximately 80 m upstream of the Taylor Way bridge crossing. This location offered safe and convenient parking for hand releases from 20-gallon buckets but is near the uppermost extent of the estuary and may reduce smolt survival, particularly given the shallow riffle habitat downstream of the bridge that may impede smolts' successful out-migration and increase their exposure to avian predators.

4.2.2. Past Recommendations

4.2.2.1. Handling and Transport

In general, past recommendations related to smolt handling and transport have been implemented by GVWD (GVWD 2021e), with clear handling and transport procedures described in Appleton and Jackman (2020) appearing to be effectively followed.

Past assessments and associated annual reports have made numerous recommendations to initiate or continue mark-recapture and tagging studies to support estimates of RST and trap net capture efficiencies, estimate out-migrating smolt abundance, determine smolt movements within the reservoir, spillway passage and survival, and assess marine survival rates (e.g., Ward and Associates 2004; Stables 2009; Lill 2015; Plate 2019; Chung *et al.* 2019). DNA sampling has also been recommended to verify species identification (e.g., Chung *et al.* 2017; Jackman 2019). After more than ten years of data collection, these components were discontinued after 2018 as program focus shifted to maximizing smolt capture, transport, and release (GVWD 2021e). As these past recommendations are outside of the management questions associated with this assessment, we do not cover them further here.

Many past recommendations called for reducing air exposure and overall handling of smolts and monitoring and maintaining water temperature and aeration within buckets and transport tanks through circulation of reservoir or river water and aerators, and if necessary, ice. It was observed that all these measures were being well applied by GVWD during operations in 2021, though cool surface temperatures negated the need for addition of ice or replenishment of cool water.

Plate (2019) made several new recommendations, including use of dark containers and lids for all fish transport holding containers and tanks to reduce fish stress, and replacement of dip nets with rubberized nets to reduce injury to fish. It was observed that these recommendations were largely implemented in 2021, though some white or opaque transport buckets were still in use and the holding tank at the lower fish processing facility was translucent white.

To reduce handling, Plate (2019) also suggested using fish size ratios to identify species. However, this method was not deemed feasible given the considerable overlap in lengths of captured juvenile salmonids, the need to observe key identifying features to differentiate between steelhead smolts to be released downstream and resident trout and hybrids to be re-released upstream, and the need for some handling to sort out fish to be re-released upstream of the CLD from those to be transported downstream (e.g., GVWD 2021e).

4.2.2.2. Release

Past assessments have made a variety of recommendations about fish release location, often reflecting conflicting conclusions from the wider literature (e.g., increased early survival of estuary- or ocean-released fish relative to increased successful adult return rates). As a result, and due to field logistics, fish releases have occurred in numerous locations over of the course of the Capilano Trap and Truck program.

Multiple past recommendations (e.g., Ward and Associates 2004; Lill 2015; Plate 2019) have focused on daytime versus nighttime release of smolts. Juveniles are crepuscular to nocturnal and tend to migrate at night, and other studies of wild and hatchery salmon have found increased survival of smolts during night release (e.g., Keefer *et al.* 2008). Nighttime release could also reduce predation due to lack of visual cues for primary predators such as seals, herons, cormorants, and gulls. Periodic nighttime releases were initiated in 2021 season, with approximately 30% of releases conducted at night. Additional nighttime releases were prevented by the logistics of extracting fish earlier in the day and monitoring and effectively holding them until nighttime release as well as logistics around staff shift hours.

4.2.3. Recommendations

4.2.3.1. Handling and Transport

As per Plate (2019) and current Trap and Truck Program objectives, we recommend that GVWD continue to minimize handling by not implementing any further mark-recapture, tagging, aging, or DNA sampling unless specific initiatives are necessary to inform clear program objectives or to test new operations where there is a high degree of uncertainty. In addition to reducing fish stress, reduction in handling will allow more resources to be directed towards maximizing capture, transport, and release of fish. Exceptions would be to periodically conduct genetic analyses of steelhead, resident trout, and hybrids to calibrate and verify the accuracy of field identification, as this is likely to contribute to the program efficiency by reducing the amount of time spent assessing species identification (and likelihood of misidentification) during fish processing.

We further recommend that GVWD continue to apply the fish loading guidelines laid out in Appleton and Jackman (2020) as they are in line with best industry practices (e.g., Plate 2019); these guidelines include:

- Monitoring water temperature and utilizing ice or cooler water from the upper Capilano River to maintain transport tank temperatures below 19°C;
- Utilizing the large, insulated fish transport trailer-tank for catches of >300 fish, and the smaller bucket transport tank for <300 fish;
- Maintaining oxygen levels at >70% saturation, with utilization of supplemental oxygen as needed, and
- Keeping loading densities within the maximum limits:
  - Large transport tank: 7,500 smolts with oxygen supplementation; 1,625 smolts without oxygen supplementation.
  - Bucket transport tank: 1,350 smolts with oxygen supplementation; 300 smolts without oxygen supplementation.

The stress-reducing fish handling techniques recommended by Plate (2019) should also continue to be applied, i.e., minimizing air exposure, using rubber dip-nets when transferring fish from traps or between holding containers, and transporting and holding fish in dark buckets and tanks with similarly dark lids to reduce stress.

The GVWD should consider construction of a more permanent shore-adjacent floating fish processing location on the reservoir that can be accessed directly by boat under both high and low reservoir level conditions, given the probability of future low-level years due to dam operations and climate-change induced variability in snowpack and drought (e.g., Pike *et al.* 2010; Yasarur and Sturm 2016). This would likely allow for increased efficiency of fish processing, including use of the VAKI digital fish counter and possibly a trolley system to aid in transport of fish from the processing station to truck-based transport tanks.

4.2.3.2. Release

Fish should continue to be released from easily accessible areas in the estuary, including Ambleside Park, LGWTP, and First Narrows Line 1 (Map 1).

5. SUMMARY

Based on our review of current and past practices of the Capilano Fish Trap and Truck Program, recommendations made by previous program assessments and associated reports, the wider literature relevant to the program, and interviews and site visits with program staff and associates, we address below the three main management questions in the TOR (GVWD 2020). We also suggest three additional recommendations that, although outside of the immediate scope of the TOR, we believe may be of interest to GVWD due to their potential to contribute to the overall effectiveness of the Trap and Truck Program.

5.1. Management Questions

1) Has the current program maximized efficiency in smolt capture with existing dam infrastructure and in consideration of industry standards and practices?

The Capilano Trap and Truck Program has effectively implemented most past assessment recommendations relevant to maximizing efficiency in smolt capture using existing dam infrastructure and in consideration of industry standards and practices. The program has continued to minimize fish handling and processing to gain efficiencies, while at the same time applying fish handling best practices to minimize fish stress and injury during operations. Where the program has deviated from past assessment recommendations, there has been clear rationale, including that recommendations are not feasible given current infrastructure or would in fact reduce efficiency of smolt capture by directing resources toward other activities (e.g., continuation of mark-recapture and other tagging programs).

2) What continuous improvement initiatives or changes could be implemented or further explored to improve fish capture and transport numbers?

This report highlights multiple continuous improvement initiatives or changes that could be implemented or further explored to improve fish capture and transport numbers. Key recommendations include:

Fish Capture in the Upper Capilano River and Reservoir

- Consider re-establishing historical Mid-Valley RST to increase capture of out-migrating steelhead in years or periods when flows are forecasted to be moderate in order to augment captures at the Dean Creek RST.
- Prioritize operating RSTs within the upper Capilano River seven days a week throughout the peak smolt out-migration period.
- Review past trap net locations and orientation during low water level years to determine if there are appropriate locations for additional traps to be deployed under such conditions.
- Consider additional trap net modifications, such as extending lead nets and shortening wing nets, to allow for trap net deployment during low water level periods, particularly at high capture locations such as TN1 and TN2.
- Consider reintroducing active fish capture through purse seining or pelagic trawling, particularly during years of reduced snowpack and in conjunction with increased LLO operations.

- Consider revisiting hydroacoustic surveys of the Reservoir to determine fish distributions to focus active fish capture and potentially trap net placement to capture Coho and steelhead smolts more effectively in future years of the program.

Fish Handling, Transport, and Release

- Continue to reduce handling and maximize capture efficiency by not implementing any mark-recapture or tagging programs or conducting fish processing beyond that required to determine species and age class (which is necessary to sort fish to be released back upstream and those to be transported and released downstream of the CLD). Exceptions include initiatives with clear outcomes that are likely to contribute to continued gains in program efficiency (e.g., periodic genetic analysis to calibrate species identification in the field) or that are necessary to assess the effectiveness of new program objectives where outcomes are highly uncertain (e.g., installation of expensive permanent capture facilities in conjunction with hydropower facilities).
- Continue to minimize the stress of handling and transport on smolts by reducing air exposure, monitoring water temperatures, cooling with ice or cold river water when necessary, using rubber meshed dip nets, and using dark holding containers with lids (Plate 2019).
- Follow fish loading guidelines prepared by GVWD (Appleton and Jackman 2020) when transporting fish.
- Hold fish for at least 12 hours prior to release where possible to allow for a reduction in stress levels and increase early marine survival rates.
- Continue to utilize existing release sites within the river estuary to reduce stress and increased mortality of out-migrating smolts associated with downstream movement within the river, while still allowing for some olfactory imprinting to Capilano River water to improve return rates of adult spawners.

3) Are there dam operations strategies that can be further explored to improve smolt capture efficiency?

We recommend maximal use of new LLOs during peak smolt out-migration whenever operationally feasible, particularly in the spring prior to strong temperature stratification within the reservoir, to reduce attraction flows over the spillway when potential downstream effects are minimized. This is likely to markedly increase capture efficiency of trap nets within the Capilano Reservoir while at the same time reducing fish mortality over the spillway.

Past recommendations have long noted that reduced attraction flows over the spillway would reduce smolt passage over it and improve the capture efficiency of smolts within the reservoir (e.g., Ward and Associates 2004; Lill 2015). Due to dam infrastructure, reduced attraction flows over the spillway were not achievable until completion of new LLOs, which became operational during the smolt out-migration period in 2021. Preliminary results suggest that capture efficiency of reservoir trap nets significantly increased when the new LLOs were operating in 2021. An effects assessment of the new LLO operations predicted only minor effects on egg incubation, fry emergence, and juvenile growth downstream from increased operation of the LLOs (Lewis and Hicks 2021), justifying their use to support the Trap and Truck Program effectiveness.

5.2. Additional Recommendations

This report and associated recommendations have focused directly on the three management questions laid out in GVWD's TOR for the CLD Trap and Truck effectiveness assessment (i.e., Section 1.1; GVWD 2020). However, the ultimate objective, increased habitat productivity and that of resultant populations of anadromous fish, also depends on Coho Salmon and steelhead survival during marine, spawning migration, spawning, incubation, and juvenile rearing life history phases, for which this assessment identified potential beneficial actions as follows: 1) estuary predation reduction, 2) permanent holding and release facility, and 3) the development of a metric-based system to evaluate program success.

Estuary Predation Reduction

Reductions in predation following smolt release could be achieved by: 1) staggering releases during the day and night among the different release sites, which would prevent predator habituation, or 2) holding fish for multiple days and releasing them at once, which will increase schooling. In conjunction with such adjustments to release operations, predator activity should continue to be monitored, particularly during evening versus daytime releases, and at high versus low tide levels, to assess best practices to minimize predation. Data could be collected on the number of predators observed, time of day, and tide levels during releases to guide operational decisions regarding future release sites and timing. A predator monitoring program could also help to inform the effectiveness and best operating procedure for a permanent holding facility.

Permanent Holding and Release Facility

GVWD has been investigating opportunities to establish a permanent release site with shore-based holding tanks. This is the best long-term solution to improve smolt survival during release because it allows for an increased holding period prior to release into the estuary and synchronization of release timing with high-tide and night conditions without impeding capture and transport operations. Such a facility would improve early marine survival by allowing for fish to be held for a longer period (e.g., 12-24 hours) prior to release, which will reduce stress levels (e.g., Schreck *et al.* 1989; NMFS 2011), and by facilitating easier release of fish at night and during high tide at staggered periods (as per recommendations in , to avoid high predator concentrations at the river mouth.Ecofish visited several potential locations for this facility, including the LGWTP and First Narrows release locations, and the DFO West Vancouver Laboratory, where a marine net pen holding facility is currently used for pre-release chinook salmon juveniles from Capilano Hatchery. Of these, the LGWTP is the best location for a permanent holding and release facility as it is easily accessed by GVWD staff and is fully within the estuary but closer to the river mouth than First Narrows.

Smolts should be released to the estuary but in an area where they will pass the river mouth on their out-migration to sea, improving olfactory imprinting to the river, and potentially reducing straying rates of adult fish (Keefer *et al.* 2008).

An effective facility would include:

- Sufficient holding capacity to allow for the holding of fish caught over consecutive days during peak capture periods.
- Automated release devices such as that described by Miller *et al.* 2000, which could offer an efficient means to synchronize releases with night-time and high-tide conditions, reducing the current logistical constraints of long workdays for GVWD.
- Water aeration and cooling mechanisms to ensure water conditions are maintained within holding tanks to reduce fish stress.

To further improve olfactory imprinting of released smolts, GVWD should also consider using lower Capilano River water (i.e., from near the hatchery) rather than reservoir water within the transport and/or holding tanks.

Measuring overall program success

Recent, comprehensive reviews of trap and haul programs throughout the North Pacific (e.g., Lusardi and Moyle 2017; Kock *et al.* 2020) highlight the need for improved programs to define 1) clear objectives relating to the overall program success (e.g., spawning escapement and success targets) and 2) effective metrics to measure success.

An emerging primary success metric used in other programs is Cohort Recruitment Rate (CRR), which uses genetic sampling of returning adults to conduct genetic parentage analysis and determine successful returns of spawners (e.g., Evans *et al.* 2016; Sard *et al.* 2016). The ratio of hatchery-to-wild returning adults provides a proximate metric of overall program success already reported by the Capilano Hatchery. CCR could validate this ratio as an accurate indicator of program success, using less invasive techniques, as no PIT tagging, or other marking would be required.

6. CLOSURE

This report satisfies the requirements for the 2021 effectiveness assessment of the Fish Trap and Truck Program at the Cleveland Dam under the *Capilano Seymour Joint Water Use Plan*. The effectiveness assessment included a comprehensive review of Capilano Fish Trap and Truck Program-related publications and reports and literature associated with other trap and haul programs. In addition, Ecofish led interviews with personnel from the Capilano Trap and Truck Program and several other associated groups, and we conducted site visits to assess current program operations. This report addresses the three management questions in the TOR (GVWD 2020), highlights key improvement initiatives to increase fish capture and transport numbers, including use of new LLOs to enhance capture efficiency, and offers several supplementary recommendations to maximize overall program success.

REFERENCES

Appleton, J. and T. Jackman. March 2020. Metro Vancouver Capilano Trap and Truck Program Smolt Loading Rates. March 2020. 7 p.

Balfry S., Welch D., Atkinson J., Lill A., Vincent S. (2011) The Effect of Hatchery Release Strategy on Marine Migratory Behaviour and Apparent Survival of Seymour River Steelhead Smolts (Oncorhynchus mykiss). PLoS ONE 6(3): e14779. doi:10.1371/journal.pone.0014779

Blair, C. 2019. Metro Vancouver Trap and Truck Program -2020 JWUP Program Review. Cumulative Recommendations 2008-2020. Excel file.

Börk, K., J. Krovoza, J. Katz, and P. B. Moyle. 2012. The rebirth of California Fish & Game Code 5937: water for fish. University of California Davis Law Review 45:809–913.

Braun, D., Chung, M., Lefevre, M., and Burnett, N. 2016. Coho Smolt Abundance Estimates and Steelhead Smolt Migration in the Capilano Watershed. Report prepared for Metro Vancouver - Burnaby by InStream Fisheries Research Inc. 53 p. + 3 Apps.

Chung, M., Braun, D., Ramos-Espinoza, D., Burnett, N., and Lefevre, M. 2017. Coho Smolt Abundance Estimates and Steelhead Smolt Migration in the Capilano Watershed. Report prepared for Metro Vancouver – Burnaby by InStream Fisheries Research Inc. 53 p. + 3 Apps.

Chung, M., Ramos-Espinoza, D, White, C, and Melville, C. 2019. Capilano Watershed Juvenile Salmonid Population Assessment and Smolt Transport Program, 2008-2018 Synthesis. Report prepared for Metro Vancouver - Burnaby. 91 p. + 3 Apps.

Diewert, R., Evers, S., Dickson, R., Tadey, J., & Galbraith, R. (2004). Capture and transport of juvenile coho (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) salmon past the Cleveland Dam on the Capilano River in 2001 and 2002 with an assessment of upper Capilano River production. North Vancouver: Canadian Manuscript Report of Fisheries and Aquatic Sciences, 2667. Available online at: https://publications.gc.ca/collections/collection_2007/dfo-mpo/Fs97-4-2667E.pdf Accessed on October 20, 2021.

Doire, J. 2021. Skeena/Nass Sockeye Lakes Hydroacoustic Surveys 2020. Technical Report prepared for the Pacific Salmon Commission by the Skeena Fisheries Commission. 44 p.

Dixon, G. 2020. Capilano Trap and Truck RST Performance Review. Metro Vancouver Watershed and Environmental Management. October 8, 2020. 6 p.

Evans, M. L., M. A. Johnson, D. Jacobsen, J. Wang, M. Hogansen, and K. G. O'Malley. 2016. Evaluating a multi-generational reintroduction program for threatened salmon using genetic parentage analysis. Canadian Journal of Fisheries and Aquatic Sciences. 73:844–852.

Giorgi, A. 1984. Smolt Passage Behavior and Flow-Net Relationships in the Forebay of John Day Dam, 1983 Annual Report of Research.. United States: N. p., 1984. Web. doi:10.2172/5447631.

GVWD (Greater Vancouver Watershed District). 2020. Terms of Reference: Assess Effectiveness of the Fish Trap and Truck Program at the Cleveland Dam. October 29, 2020. 6 p.

GVWD (Greater Vancouver Water District). 2021a. Joint Water Use Plan for Capilano and Seymour Watersheds - receives provincial approval/ Available online at: http://www.metrovancouver.org/services/water/plans-reports/jwup/JWUP/Pages/default.aspx. Accessed on October 20, 2021.

GVWD (Greater Vancouver Water District). 2021b. Fact Sheet Cleveland Dam. Available online at: http://www.metrovancouver.org/services/water/WaterPublications/ClevelandDam_FactSheet.pdf. Accessed on October 20, 2021.

GVWD (Greater Vancouver Water District). 2021c. Watersheds and Reservoirs. Available online at: http://www.metrovancouver.org/services/water/sources-supply/watersheds-reservoirs/Pages/default.aspx. Accessed on October 20, 2021.

GVWD (Greater Vancouver Watershed District). 2021d. Fish Passage in the Capilano Water Supply Area – An Ongoing History of Practice and Research. Metro Vancouver Watershed and Environmental Management. January 2021. 35 p.

GVWD (Greater Vancouver Watershed District). 2021e. DRAFT – Cleveland Dam Trap and Truck Program. GVWD Staff Assessment. March 9, 2021. 19 p.

GVWD (Greater Vancouver Watershed District). 2021f. DRAFT – 2021 Juvenile Salmonid Trap and Truck Program – Capilano Watershed. Metro Vancouver Water Services – Watershed and Environmental Management. November 2021. 36 p.

Jackman, T. 2015. 2015 Active Collection Pilot Project – Watershed/Environmental Management and Quality Control. Report prepared by Metro Vancouver Watershed and Environmental Management. December 2015. 14 p.

Jackman, T. 2019. Genotypic Calibration of Visual Field Identification of Juvenile Steelhead, Coastal Cutthroat Trout, and Their Hybrids in the Upper Capilano Watershed. Report prepared by Metro Vancouver Watershed and Environmental Management. March 2019. 18 p.

Keefer, M., Caudill, C., Peery, C. and S. Lee. 2008. Transporting Juvenile Salmonids around Dams Impairs Adult Migration. Available online at: https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/07-0710.1. Accessed on October 22, 2021.

Kock T., N. Verretto, N. Ackerman, R. Perry, J. Beeman, M. Garello, S. Fielding. (2019) Assessment of operational and structural factors influencing performance of fish collectors in forebays of high-head dams. Trans Am Fish Soc 148:464–479.

Kock, T., J. Ferguson, M. Keefer, C. Schreck. 2020. Review of trap-and-haul for managing Pacific salmonids (*Oncorhynchus* spp.) in impounded river systems. Rev Fish Biol Fisheries 31, 53–94. https://doi.org/10.1007/s11160-020-09627-7

Ladell, J. and D. McCubbing. (2008). Capilano Watershed Annual Juvenile Salmonid Population Assessment and Smolt Transport Program, Spring 2008. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. Spring 2008.

Ladell, J. and D. McCubbing. (2009). Capilano Watershed Annual Juvenile Salmonid Population Assessment and Smolt Transport Program, Spring 2009. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. Spring 2009.

Ladell, J. and D. McCubbing. (2010). Capilano Watershed Annual Juvenile Salmonid Population Assessment and Smolt Transport Program, Spring 2010. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. Spring 2010.

Ladell, J. and D. McCubbing. (2011). Capilano Watershed Annual Juvenile Salmonid Population Assessment and Smolt Transport Program, Spring 2011. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. Spring 2011.

Ladell, J., D. McCubbing, D. Ramos-Espinoza. (2012). Capilano Watershed Annual Juvenile Salmonid Population Assessment and Smolt Transport Program, Spring 2012. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. Spring 2012.

Ladell, J., D. McCubbing, D. Ramos-Espinoza. (2013). Capilano Watershed Annual Juvenile Salmonid Population Assessment and Smolt Transport Program, Spring 2013. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. Spring 2013.

Ladell, J. and D. McCubbing. 2014. Capilano Watershed Annual Juvenile Salmonid Population Assessment and Smolt Transport Program, Spring 2014. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. 67 p.

Ladell, J. 2015. Capilano Watershed Smolt Yield Estimate and Migration Study 2015. Report prepared for Metro Vancouver – Policy and Planning Department Utility Analysis & Environmental Management Division by InStream Fisheries Research Inc. 81 p.

Lewis, A., and T. Hicks. 2021. Low-Level Outlet (LLO) Valve replacement - options for future operations and summary of fisheries monitoring information. Memorandum prepared by Ecofish Research Ltd. for Jesse Montgomery, Greater Vancouver Water District. May 25, 2021. 6 p.

Lill, A. (2014). Capilano Smolt Program Review. RFP 13-108 Phase One: Prepared by BC Conservation Foundation, InStream Fisheries Research, and Northwest Hydraulic Consultants.

Lill, A. (2015). Capilano Smolt Program Review. RFP 13-108 Phase Two: Proposed Upper Capilano River Diversion and Collection Facility. Phase 2 of 3. Prepared by BC Conservation Foundation, InStream Fisheries Research, and Northwest Hydraulic Consultants.

Lusardi, R. and P. Moyle. 2017. Two-Way Trap and Haul as a Conservation Strategy for Anadromous Salmonids, Fisheries, 42:9, 478-487. Available online at: https://watershed.ucdavis.edu/files/biblio/LusardiandMoyle2017.pdf. Accessed on October 22, 2014.

McCubbing, D. and B. Ward. 1997. The Keogh and Waukwaas rivers paired watershed study for B.C.'s Watershed Restoration Program: juvenile salmonid enumeration and growth 1997. Province of British Columbia, Ministry of Environment, Lands and Parks, and Ministry of Forests. Watershed Restoration Project Report No. 6: 33p.

Miller, B., J. Rodgers, and M. Solazzi (2000) An Automated Device to Release Marked Juvenile Fish for Measuring Trap Efficiency, North American Journal of Fisheries Management, 20:1, 284-287, DOI: 10.1577/1548-8675(2000)020<0284:AADTRM>2.0.CO;2

Mosser, C., Thompson, L., and J. Strange. 2012. Survival of captured and relocated adult spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in a Sacramento River tributary after cessation of migration. Available online at: https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626182.pdf. Accessed on October 22, 2021.

Mrnak, J.T., Sikora, L.W., Jake Vander Zanden, M., Hrabik, T.R. and Sass, G.G. (2021), Hydroacoustic Surveys Underestimate Yellow Perch Population Abundance: The Importance of Considering Habitat Use. North Am J Fish Manage, 41: 1079-1087. https://doi.org/10.1002/nafm.10605

NHC (Northwest Hydraulic Consultants Ltd.). 2013. Capilano River Steelhead Smolt Screen: Engineering Feasibility Assessment. Prepared for BC. Conservation Foundation, December 20, 2013.

NMFS (National Marine Fisheries Service) 2011. Anadromous salmonid passage facility design. NMFS, Northwest Region, Portland, Oregon. https://www.westcoast. fisheries.noaa.gov/publications/hydropower/fish_passage_design_criteria.pdf. Accessed on November 10, 2021

NPCC (Northwest Power and Conservation Council). 2016. Staff Paper: Review of Fish-Passage Technologies at High Head Dams. Available online at: https://www.nwcouncil.org/sites/default/files/2016-14.pdf. Accessed on October 22, 2021.

Perrin, C.J. 2003. Comparison of smolt capture by net pens and rotary screw traps in the upper Capilano River drainage, 2001. Report submitted to the B.C. Ministry of Water, Land and Air Protection, Vancouver, BC. 33 p.

Pike, R., K. Bennett, T. Redding, A. Werner, D. Spittlehouse, R.D. Moore, T. Murdock, J. Beckers, B. Smerdon, K. Bladon, V. Foord, D. Campbell, and P. Tschaplinski 2010. Climate Change Effects on Watershed Processes in British Columbia. Ch. 19 in *Land Management Handbook – Compendium of Forest Hydrology and Geomorphology in British Columbia.* Vol. 1. 50 p. Available online at: https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/Lmh66/. Accessed on November 10, 2021.

Plate, E. (2019). Trap and Truck Review, May 2019. Prepared by LGL Limited for Metro Vancouver WEM.

Sard, N. M., M. A. Johnson, D. P. Jacobsen, M. J. Hogansen, K. G. O'Malley, and M. A. Banks. 2016. Genetic monitoring guides adaptive management of a migratory fish reintroduction program. Animal Conservation. 19:570–577.

Schreck, C., Solazzi, M., Johnson, S., and T. Nickelson. 1989. Transportation stress affects performance of Coho Salmon, *Oncorhynchus kisutch*. Aquaculture, 82: 15-20.

Stables, B. 2009. Acoustic Observations of Fish in Capilano Reservoir on May 28, 2009. Shuksan Fisheries Consulting, Everson, WA.

Ward and Associates and P. Slaney 2004. Cleveland Dam Temperature Augmentation and Smolt Transport Feasibility Study – Final Report. Report prepared for Greater Vancouver Water District. May 2004. 160 p.

Yasarur, L. and B. Sturm (2016) Potential impacts of climate change on reservoir services and management approaches, Lake and Reservoir Management, 32:1, 13-26, DOI: 10.1080/10402381.2015.1107665

Personal Communications

Appleton, J. 2021. Senior Biologist, Water Services, GVWD. Discussion with Noel Swain and Harlan Wright during field visit. May 12, 2021.

Mongomery, J. 2021. Division Manager, Water Services, GVWD. Discussion with Noel Swain and Harlan Wright during field visit. April 21, 2021.

Underwood, K. 2014. Natural Resource Manager, Tacoma Power. Email correspondence with Mike Mayers, Superintendent Environmental Management & LSCR, Metro Vancouver, re: Merwin Trap/Smolt Trapping information. February 02, 2014.

APPENDICES

Appendix A. GVWD summary of status and feasibility of past recommendations and independent assessment by Ecofish.

**Provided as a separate excel file*

Appendix B. External Literature Review Summary.

TABLE OF CONTENTS

1. COMPARABLE DAM PROJECTS

Over a dozen reports/publications were reviewed to identify innovative methods used at other dams in North America and elsewhere. Trap and haul methods vary based on the geomorphology, width, and depth of the stream or reservoir, as well as the target fish species and their use of the habitat. Downstream passage technologies can be grouped into six basic categories based on the means by which they provide fish protection or passage (NPCC 2016), including:

- **Fish diversion systems** such as angled screens, louver screens, Eicher screens, modular inclined screens, angled rotary drum screens, inclined plane screens and submerged traveling screens. For example, a selective water withdrawal tower is in use at Round Butte Dam since 2009 (NPCC 2016).
- **Physical barriers** such as barrier nets, wedge wire screens and rotary screw traps. For example, the use of weirs that span most of the river are used on the Lower San Joaquin River in California, USA (Lusardi and Moyle 2017). Screw traps are used on Swift Dam but their efficiency is low (1 to 15%; PacifiCorp 2020). In addition, net systems are used on some forebay collectors to funnel fish to the collector entrance ("guide nets"), decrease the likelihood of fish turning around inside the collector ("lead nets"), and prevent fish from passing the dam via alternate routes ("exclusion nets"; Kock et al. 2019).
- **Fish collection systems** such as surface collectors, spill, fish pumps and other bypasses. For example, a common form of juvenile fish passage used at dams is allowing fish to pass with water that is allowed to spill through the dam's spillway.
- **Behavioural guidance devices** such as the use of light, sounds, electric fields, air bubble curtains to direct fish away from hazards or towards fish collection systems (Kock et al. 2020). The efficiency of these methods on their own is questionable (e.g., due to a noisy near-dam environment, difficulty of fish to distinguish the sound stimulus and habituation to noise; Schilt et al. 2007; Kock et al. 2019) but show potential when combined with other methods (e.g., nets, bubble screens; Welton *et al.* 2002).
- **Passage through turbines** – fish pass through turbines; juvenile fish survival through Kaplan-type turbine units, horizontal-shaft bulb turbines, and Alden turbines is higher than more conventional turbines (Pelton).
- **Project operational changes** - Water velocity is one of the key factors affecting fish guidance. Fish can react to changes in velocity of less than 0.1 feet per second. Furthermore, downstream water currents are typically limited by the large size of the reservoir and small outflow at the dam which results in a poor cue to guide fish to passage routes. As a result, juvenile salmon and steelhead (O. mykiss) often struggle to move downstream through the reservoir and pass the dam, so many fish spend months in reservoirs where they are susceptible to residualization, predation, disease, and parasitism (Keefer et al. 2012;

Keefer et al. 2013; Beeman et al. 2016a; Monzyk et al. 2015). Project operators may therefore be able to provide spill or even lower reservoir elevations to increase water velocity for fish passage during the time periods when fish are migrating past the project. For example, the Fall Creek Reservoir in Oregon, USA is drawn down to near run-of-river level each year for several weeks during November to February period to allow juvenile Chinook salmon to volitionally pass downstream through the dam's diversion tunnel. In addition, juvenile passage (steelhead, coho salmon and Chinook salmon) is facilitated at Wynoochee Dam by not operating the turbines for 77 consecutive days each year during the primary outmigration period, which allows fish to pass through downstream passage outlets rather than through the turbines (Kock et al. 2020).

1.1. Surface oriented passage routes

Over the last 15 years engineers and biologists have implemented new technologies to provide more surface-oriented, and less stressful, passage routes for juvenile fish (NPCC 2016). Within the literature reviewed, the most common method to capture out-migrant smolts with large storage reservoirs are floating surface collectors (FSC; previously known as gulpers), which take advantage of near-surface orientation of smolts and their tendency to follow the bulk flow to guide outmigrants into a narrow channel, through a series of narrowing gates (Johnson and Dauble 2006; Sweeney et al. 2007). Much effort has been expended to develop effective FSCs throughout the Pacific Northwest of the United States (Lusardi and Moyle 2017).

Typically, surface collection systems use angled or inclined bar screens to collect juvenile fish, usually after considerable dewatering, into a holding area, where they have access to a bypass channel or are transported by truck to a safe release point downstream of the project (NPCC 2016). Dams that use this methodology include Upper Baker Dam, Swift dam, Merwin dam and Cushman dams in Washington state, USA (Lusardi and Moyle 2017), as well as Pelton Round Butte Dam in Oregon, USA. In particular, the state-of-the-art FSCs at Upper and Lower Baker Dam showed that the collectors were able to capture~ 85% of juvenile sockeye salmon and ~ 91% of coho salmon O. kisutch (Kock et al. 2019). Some FSCs use inflows as high as 170 m^3/s (Kock et al. 2019). Several of these high-volume devices collect a high percentage of tagged outmigrants (> 90%; Kock et al. 2019a), while others have been far less effective (< 40%; Kock et al. 2020). Some of the collector characteristics that affected efficiency and that were presented in a meta-analysis included (Kock et al, 2019): inflow volume, fish guidance net presence, size of the collector entrance.

Of note, a series of physical and operational modifications are typically required following commencement of a given project to optimize FSCs performance, which can be used for other collection methods as well. This optimization process may include modifying inflow levels, altering ballast height, and changing locations within the forebay. Additional elements such as net systems may also need to be added to help guide fish towards the collector entrance, or to prevent fish from passing the dam via alternate routes. These optimization processes can take time, so collection success may improve incrementally during the initial operating years (Kock et al. 2019).

1.2. Fish Handling, Transport, and Release

Stress from handling and transportation is cumulative and may reduce disease resistance, swimming ability, and osmoregulatory ability (Lusardi and Moyle 2017). Transport and handling stress may also reduce ability for conditioning to an odorant and cause failure to complete smoltification (i.e., residualization; Schreck 1980). However, some studies found higher survival of transported juveniles compared to wild ones (e.g., Balfry et al. 2011). Findings of key papers include:

- Schreck and Li (1985) showed that juvenile Chinook salmon trapped during the day under darkened conditions appeared less stressed than those exposed to the sun, and exposure to high densities of other fish species was stressful during collection.
- Schreck and Li (1985) found that loading juvenile fish into a transport vehicle appeared to be the most stressful aspect of the actual transport process and reported it took fish several days to recover.
- Schreck *et al.* (1989) assessed the transportation of yearling coho salmon (*Oncorhynchus kisutch*) from their hatchery by trucking and observed a marked physiological stress response (i.e., elevations in concentrations of circulating cortisol). Survivorship (i.e., recoveries of adults at sea and at the hatchery) was reduced in fish not given adequate time to recover from transportation stress before they were released into their migratory stream.
- Clemens et al. (2009) showed that timing of transport may also be important, with late-season low flows contributing to poor water quality during transport and reduction of survival of certain species.
- Keefer *et al.* (2008) indicated that juvenile transport can impair orientation or homing abilities of salmonids, perhaps by disrupting sequential imprinting processes during juvenile out-migration.

Results from these studies illustrate the need to carefully consider how fish are collected, held, and transported to minimize stress and its associated effects on fish health and performance. Thus, for all transport methods, protocols have been developed to protect fish during transit. A main goal of these protocols is to minimize fish stress.

Kock et al. 2020 provides the following list of recommendations to minimize stress on fish during handling and transport, which is based on personal experience with trap-and-haul operations and supported by other studies (e.g., Benda et al. 2015; Cogliati et al. 2019):

- Fish collection, transfer, holding and transport structures should not produce turbulent water conditions and should be free of sharp angles and edges that can cause injuries.
- Providing shade or creating darkened conditions, particularly in shallow water, can be beneficial.

- Water-to-water transfers are highly recommended because netting and direct handling induce high stress responses, especially if fish are dewatered.
- If netting is necessary, soft mesh should be used and nets with knotted twine should be avoided because the knots can cause skin injuries. Further, mesh should be appropriately sized for the fish being handled.
- If mesh size is too large for a particular size class of fish eye injuries and blindness can occur during netting because a fish's snout can pass through the mesh.
- Overloading nets should be avoided because fish in the bottom of a full net can be crushed or injured. This is particularly problematic for small juveniles and sexually mature female adults.
- The severity of stressors in trap-and-haul can be reduced by minimizing the risk of infection with pathogenic organisms to optimize post release performance of fish. Minimizing cross infection can be accomplished by lowering fish density, elevating flow, and for many pathogens, maintaining cool water temperature.
- Treating fish with antibiotics to increase their survival after release is an option for consideration.
- Juvenile releases that occur during dark evening hours when fish are prone to migration and less vulnerable to predators could be used to reduce stress and increase survival.
- Adding salt to transport water to approximate the physiological level of saline can help fish overcome osmoregulatory difficulties associated with stress and be beneficial in reducing the severity of the transport experience. Commercially available additives for transport water also help with disruption of the integrity of the skin caused by crowding and handling.
- Fish could be tagged as part of the loading process, rather than separately before loading occurs.
- The effects of stress experienced during trap-and haul is less severe if fish are released in locations where they can regain orientation without exposure to high-velocity currents that are energetically demanding.
- The release site should not contain substantial predator concentrations to allow sufficient time for fish to recover without facing the challenges of predation avoidance.

REFERENCES

Balfry S., Welch D., Atkinson J., Lill A., Vincent S. (2011) The Effect of Hatchery Release Strategy on Marine Migratory Behaviour and Apparent Survival of Seymour River Steelhead Smolts (Oncorhynchus mykiss). PLoS ONE 6(3): e14779. doi:10.1371/journal.pone.0014779

Beeman JW, Evans SD, Haner PV, Hansel HC, Hansen AC, Hansen GS, Hatton TW, Sprando JM, Smith CD, Adams NS (2016) Evaluation of the biological and hydraulic performance of the portable floating fish collector at Cougar Reservoir and Dam, Oregon, 2014: U.S. Geological Survey Open-File Report 2016–1003. https://doi.org/10. 3133/ofr20161003.

Benda SE, Naughton GP, Caudill DD, Kent ML, Schreck CB (2015) Cool, pathogen-free refuge lowers pathogen-associated prespawn mortality of Willamette River Chinook salmon. Trans Am Fish Soc 144:1159–1172. https://doi. org/10.1080/00028487.2015.1073621

Clemens, B. J., S. P. Clements, M. D. Karnowski, and D. B. Jepsen. 2009. Effects of transportation and other factors on the survival estimates of juvenile salmonids in the unimpounded lower Columbia River. Transactions of the American Fisheries Society 138:169–188.

Cogliati KM, Heron CL, Noakes DLG, Schreck CP (2019) Reduced stress response in juvenile Chinook salmon reared with structure. Aquaculture 504:96–101

Johnson GE, Dauble DD (2006) Surface flow outlets to protect juvenile salmonids passing through hydropower dams. Rev Fish Sci 143(3):213–244. https://doi.org/10.1080/ 10641260600864023

Keefer, M. L., C. C. Caudill, C. A. Peery, and S. R. Lee. 2008. Transporting juvenile salmonids around dams impairs adult migration. Ecological Applications 18:1888–1900

Keefer ML, Taylor GA, Garletts DF, Helms CK, Gauthier GA, Pierce TM, Caudill CC (2012) Reservoir entrapment and dam passage mortality of juvenile Chinook salmon in the Middle Fork Willamette River. Ecol Freshw Fish 21:222–234. https://doi.org/10.1111/j.1600-0633.2011. 00540.x

Keefer ML, Taylor GA, Garletts DF, Helms CK, Gauthier GA, Pierce TM, Caudill CC (2013) High-head dams affect downstream fish passage timing and survival in the Middle Fork Willamette River. River Res Appl 29:483–492. https://doi.org/10.1002/rra.1613

Kock T., N. Verretto, N. Ackerman, R. Perry, J. Beeman, M. Garello, S. Fielding. (2019) Assessment of operational and structural factors influencing performance of fish collectors in forebays of high-head dams. Trans Am Fish Soc 148:464–479.

Kock, T., J. Ferguson, M. Keefer, C. Schreck. 2020. Review of trap-and-haul for managing Pacific salmonids (*Oncorhynchus* spp.) in impounded river systems. Rev Fish Biol Fisheries 31, 53–94. https://doi.org/10.1007/s11160-020-09627-7

Lusardi, R. and P. Moyle. 2017. Two-Way Trap and Haul as a Conservation Strategy for Anadromous Salmonids, Fisheries, 42:9, 478-487. Available online at: https://watershed.ucdavis.edu/files/biblio/LusardiandMoyle2017.pdf. Accessed on October 22, 2014.

Monzyk FR, Emig R, Romer JD, Friesen TA (2015) Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoir. Report by the Oregon Department of Fish and Wildlife to the U.S. Army Corps of Engineers, Portland, Oregon. https://odfw. forestry.oregonstate.edu/willamettesalmonidrme/sites/ default/files/outmigration_monitoring_annual_2016_final. pdf.

NPCC (Northwest Power and Conservation Council). 2016. Staff Paper: Review of Fish-Passage Technologies at High Head Dams. Available online at: https://www.nwcouncil.org/sites/default/files/2016-14.pdf. Accessed on October 22, 2021.

PacificCorp 2020. Swift No. 1 Hydroelectric Project (FERC No. P-2111). Application for License Amendment Volume I of V Initial Statement and Exhibits A, C, D and G. Review Draft – January 2020

Schilt CR (2007) Developing fish passage and protection at hydropower dams. Appl Anim Behav Sci 104:295–325. https://doi.org/10.1016/j.applanim.2006.09.004

Schreck CB (1980) Effects of transportation on fitness for marine survival of Columbia River salmon. National Marine Fisheries Service Completion Report. https://ir. library.oregonstate.edu/concern/technical_reports/ ks65hk619

Schreck CB, Li HW (1985) Columbia River salmonid outmigration: McNary Dam passage and enhanced smolt quality: U.S. Army Corps of Engineers. https://ir.library. oregonstate.edu/concern/technical_reports/br86b955p

Schreck, C., Solazzi, M., Johnson, S., and T. Nickelson. 1989. Transportation stress affects performance of Coho Salmon, *Oncorhynchus kisutch*. Aquaculture, 82: 15-20.

Sweeney CE, Hall R, Giorgi AE, Miller M, Johnson GE (2007) Surface bypass program comprehensive review report. ENSR, document number 09000-399-0409, Redmond, Washington. https://usace.contentdm.oclc.org/digital/ collection/p16021coll3/id/508/

Welton, J. Beaumont, W., and Clarke, R. (2002). The efficacy of air, sound, and acoustic bubble screens in deflecting Atlantic salmon, (Salmo salar L.), smolts in the River Frome, UK. Fisheries Management and Ecology. 9. 11 - 18. 10.1046/j.1365-2400.2002.00252.x.

Appendix C. Cleveland Dam Trap and Truck site visit photographs.

LIST OF FIGURES

Figure 1. Cleveland Dam spillway, April 21, 2021.

Figure 2. Location of lower fish processing site and boat launch utilized in 2021 due to low reservoir elevation, April 21, 2021.

Figure 3. Lower fish processing site and boat launch utilized in 2021 due to low reservoir elevation, April 21, 2021.

Figure 4. Upper fish processing site typically accessible by boat under normal reservoir elevation, April 12, 2021.

Figure 5. Trap net design sketch posted at the upper fish processing site, April 21, 2021.

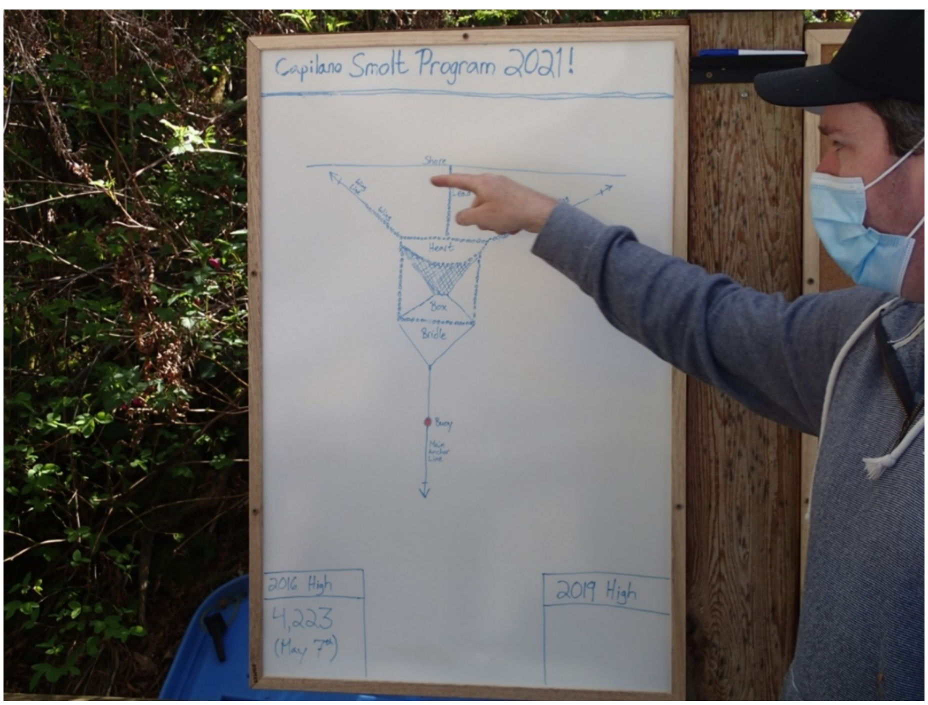

Figure 6. Trap net deployed in Capilano Reservoir, April 21, 2021.

Figure 7. Elevated bottom mesh in the trap net box to corral fish prior to removal with rubber mesh dip net, May 12, 2021.

Figure 8. Boat utilized to check trap nets, equipped with dark containers and water circulation, April 21, 2021.

Figure 9. Steelhead rearing habitat present downstream of the Dean Creek RST.

Figure 10. Dean Creek 8' RST in fishing position, May 12, 2021.

Figure 11. GVWD staff servicing the Dean Creek RST, after pulling towards the right bank bridge abutment, May 12, 2021.

Figure 12. Large fish trailer tank, April 21, 2021.

Figure 13. Estuary release site near Ambleside Center, May 12, 2021.

ECOFISH RESEARCH

Figure 14. Estuary fish release through 3" rigid pipe gravity fed from lower valve on transport tank, May 12, 2021.

Figure 15. Release location at First Narrows North Shaft watermain tunnel crossing, April 21, 2021.

Figure 16. Release location near Lions Gate Wastewater Treatment Facility, June 1, 2021.

Figure 17. Potential release location at the DFO West Vancouver Laboratory, June 1, 2021.