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Coquitlam River Floodgate Effectiveness and Salmon Passage: Report Year 2 of 3

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RESILIENT WATERS

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Executive Summary

Flood control infrastructure in the Lower Fraser River currently blocks access to >80% of historical juvenile rearing and overwintering floodplain habitat for Chinook, Chum and Coho salmon populations, some of which are at risk. Further, the quality of these floodplain habitats is degrading due to nutrient loading and infilling caused by a lack of flow from the mainstem river, particularly at tidally influenced sites (downstream of Mission). This also allows invasive species to take a foothold in otherwise prime salmon habitat.

This project uses relatively novel Passive Integrated Transponder (PIT) tag technology to track and compare individual juvenile salmon movements through a self-regulated floodgate (treatment) compared to a traditional top-mounted floodgate (control) and a gate that has been permanently chained open (reference). All sites are located within a kilometer of each other in Colony Farms Regional Park on the lower Coquitlam River. This three-year effectiveness monitoring study employs a Before-After Control-Impact (BACI) design to compare salmon passage under current self-regulated floodgate operations (default settings) in year one with experimental manipulation of the operational settings to better match floodgate opening/closing with salmon movements documented at the reference site in years two and three. This research will help to quantify the potential benefits of replacing outdated flood-control infrastructure with fish-friendly alternatives, as well as to provide guidance on how these self-regulated gates may be programmed to maximize their benefits for salmon populations at Colony Farm, at other tributaries adjacent to the Fraser, and beyond.

In year two of the study, we tagged and released 500 hatchery juvenile Coho at each of the three floodgate sites over 10 release sessions for a total of 1500 fish released. The 12 PIT antennas (four antennas at each floodgate site, two upstream and two downstream to document directional movement of tagged salmon), gathered data on each individual tagged salmon logging any time they moved through one of the antenna systems. Over 2.5 million detections and 15,000 passage attempts were logged which revealed major differences in fish passage between the three floodgate systems. At the open gate (reference) approximately 80% passed successfully into the upstream, ~55% at the self-regulating gate (treatment), and ~20% at the top-mounted gate (control). There was also a lot of movement between sites for juvenile salmon during the overwintering period. Fish released at the control site were detected passing at the treatment site 350m upriver, and at the reference site 1km upriver. During high water levels in May, floodgates were blocked (due to negative head differential) salmon consequently were unable to outmigrate until water levels dropped in June, which would have detrimental impacts on food availability for their natural outmigration to the estuary, a potential cause for delayed mortality from floodgate operations.

In Year 3, the program will repeat the timed release of 500 Coho at each site, plus an additional 200-500 salmon upstream (away from any of the established sites). We will also have extensive minnow trapping sessions in each of the floodplain channels upstream of the floodgate sites to compare fish community structure, assess salmonid growth, and document distribution of Coho within the floodplain system. A towable PIT antenna will be pulled behind canoes and detections will be synchronized with GPS to passively detect and locate PIT tagged coho in the floodplain system.

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1 Introduction

There are 150+ flood control structures acting as barriers to fish movement on tributaries adjacent to the Lower Fraser River (Watershed Watch 2018), effectively restricting juvenile salmon from accessing hundreds of kilometers of important tidal creek habitat (Thomson *et al.* 1999; Watershed Watch 2018). Most of these structures are floodgates composed of culverts with large doors, hinged on either the top or the sides, that are placed on tributary outlets to protect upstream agricultural land from being inundated with water during high tide or flooding events. These floodgates require sufficient head difference between the downstream and the upstream sides to manually push the doors open and allow for freshwater to flow out of the floodplain systems. Important to note that top-mounted gates are the most prevalent in the Lower Fraser watershed and require the more head difference significantly limiting fish passage, while side mounted require less head difference and for that reason are typically more fish-friendly than top-mounted gates, but not as friendly as self-regulating or manually controlled gates optimized for fish passage.

These structures, especially top-mounted gates, remain closed for large portions of the day and year, restricting access for native fish species and causing stagnation of upstream floodplain systems (Thomson *et al.* 1999; Kroon & Ansell 2006; Scott *et al.* 2016). In the Lower Fraser River, these flood-control structures can remain closed for weeks to months at a time due to flooding in the mainstem during annual snowmelt freshets and large rain events that prevent the gates from opening (Thomson *et al.* 1999). These structures form a physical barrier to fish movement when closed, and can also act indirectly as barriers even when open due to the resulting degradation of water and habitat quality upstream resulting from lack of water movement (Kroon & Ansell 2006) or accelerated flow velocities at the outflow upon opening (Haro *et al.* 1998; Russon & Kemp 2011). Reduced access and lower water quality have resulted in drastic shifts in the native fish assemblages upstream of floodgates and allowed for the proliferation of non-native species that are less impacted by poor water quality (Kroon & Ansell 2006; Scott *et al.*2016; Seifert & Moore 2018). Some efforts have been made to remediate the effects of floodgates on local fish communities and upstream habitat quality, however, few studies have investigated the effectiveness of these remediation efforts.

Traditional floodgate remediation techniques to restore habitat connectivity in floodplain systems include the installation of counterbalances to lessen the upstream head difference required to open floodgates, the construction of smaller fish passage gates in the floodgate to allow water mixing and fish access, and, less frequently, the automation of programmable floodgates that open regardless of flow and tidal conditions (Pollard & Hannan 1994; Giannico & Souder 2004), yet the efficacy of these various remediation techniques have received little attention (Seifert & Moore 2018).

One before-after control impact (BACI) study found that the installation of fish gates and the intermittent opening of floodgates via manual winching both resulted in rapid stream recolonization by economically important native species and a decrease in fish assemblage disparity between treatment sites and reference streams (Boys *et al.* 2012). Wright *et al.* (2014) found that the use of counterbalances increased the amount of time that floodgates were opened and improved the downstream passage of juvenile trout.

See the Resilient Waters website for animations that visually describe how each type of floodgate responds to water flow, head differential, and impacts to fish passage.

2 Goals and Objectives: Evaluating fish passage of traditional and novel floodgate solutions

The Lower Fraser River is highly impacted by floodgate operations (Scott *et al.* 2016; Seifert & Moore 2018), and presents a relatively unique system for effective remediation (Thomson *et al.* 1999). Strong seasonal freshets flood the mainstem of the river and prevent floodgates from opening for a substantial portion of the year (Thomson *et al.* 1999), rendering some remediation techniques ineffective in the Lower Fraser River. For example, fish passage gates and counterbalances require higher upstream heads to push open gates and allow for fish passage and water mixing. These hydraulic conditions may not occur during critical times of the year in the Fraser River, such as the spring outmigration of juvenile salmon (Thomson *et al.* 1999). Access to these floodplain habitats are critical for the survival of juvenile salmon during their seaward migration (Murray & Rosenau 1989). Furthermore, these tidally influenced creeks provide important nursery habitat for ecologically, economically, and culturally important salmon species, including Chinook and Coho during overwintering from late-Fall through winter (Levings *et al.* 1995), a time when traditional remediation techniques are less effective in reducing impacts on fish assemblages and water quality (Boys *et al.* 2012).

There have been few studies investigating the effectiveness of automated, programmable floodgates in improving upstream fish passage and water quality (PSF 2016), though it is likely that any increase to the amount of time a floodgate is open will result in higher fish access and water mixing (Seifert & Moore 2018). Further research is required to determine the optimal remediation style and operational regime to improve fish access and habitat restoration at flood-control structures in a site-specific manner (Boys *et al.* 2012; PSF 2016). Given its unique situation and the need for improved habitat access to support native fish species, the most fitting remediation strategy at a subset of sites may be the installation of self-regulating, programmable floodgates to replace aging flood-control infrastructure in the Lower Fraser River.

This research and improvements directly relate to FWCP's habitat-based action to improve rearing habitat capacity for Chinook and Coho Salmon in the Lower Coquitlam River by increasing the availability and passage to already existing off-channel habitat connected to these floodgates being studied. By modifying and testing different configurations of the self-regulating tide gate, this research will also allow us to closely understand how many salmon use the area before and after, and ultimately optimize the configuration of the gate for flood protection and fish passage.

3 Study Area

The self-regulating floodgate at Colony Farms on the Coquitlam River is one of only two such structures on the Lower Fraser River (the other located on Musqueam Creek) and presents a unique opportunity to empirically investigate the effectiveness of programmable floodgates and their various operational capacities. Colony Farm Regional Park lies on Kwikwetlem First Nation's unceded territory and is a Metro Vancouver Regional Park within the lower mainland of BC, bordered by Kwikwetlem First Nation Reserves Coquitlam 1 and Coquitlam 2, the municipalities of Coquitlam to the west and north and Port Coquitlam to the east and north.

Colony Farm served as agricultural land for over 80 years before farming operations ceased in 1983. It became a Metro Vancouver Regional Park in 1996, with the Wilson Farm area dedicated to wildlife management. As part of an environmental condition from Fisheries and Oceans Canada for the Port Mann/Highway 1 Improvement Project, Transportation Investment Corporation replaced a top-mounted floodgate at Wilson Farm with an automated, programmable, side-mounted floodgate in 2011 to restore fish access and improve upstream habitat quality. Prior to remediation, the aquatic habitat upstream of the Wilson Farm floodgate was largely inaccessible to fish, and habitat quality was diminished by low dissolved oxygen content and high-water temperatures related to stagnation and vegetation overgrowth (PSF 2016). Baseline environmental monitoring found that only one fish species, Three-spine sticklebacks, was present upstream of the Wilson Farm floodgate prior to remediation works (PSF 2016). Restoration resulted in 42,000m^2 of instream and 135,000m^2 of riparian fish habitat including construction of vernal ponds, riparian plantings, and enhancing and constructing roughly 4.5 km of tidal channels.

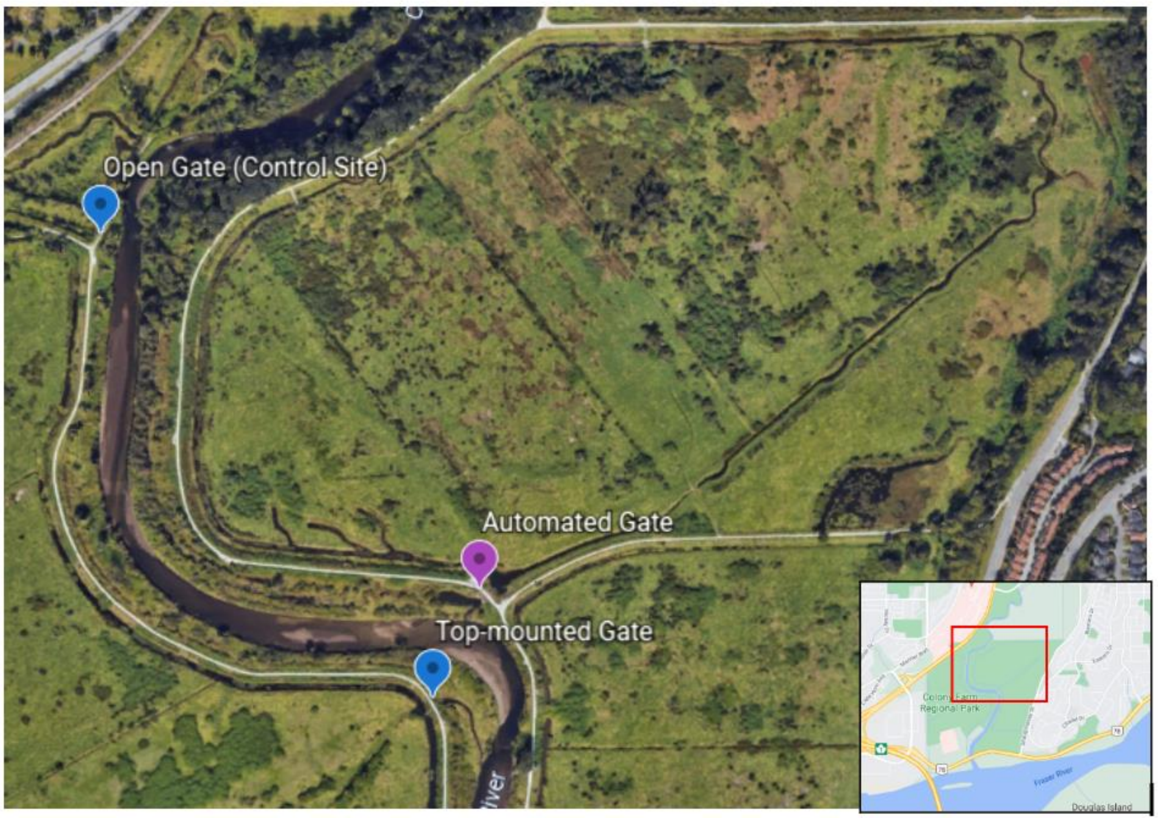

Figure 1: Three floodgate sites being studies at Colony Farm Regional Park. [Follow this link to explore the study area.]

Figure 2: Overhead photo of Self-regulating tidegate and associated ponds at Wilson Farm

Figure 3: Exit point, or upstream end, of self-regulating tidegate. Photo by Zach Sherker

Figure 4: Top-mounted floodgate. Photo by Zach Sherker

In a five-year fish monitoring study conducted after the construction of the automated floodgate, recolonization was documented for some native species, including several species of salmonids, and water quality was greatly improved during times of the year when salmon rely on floodplain habitat (PSF 2016). Aquatic habitat upstream of the automated Wilson Farm floodgate was used as overwintering habitat by juvenile Coho salmon in the fall and Chum salmon fry, and juvenile Chinook were found in the ponds outside (downstream) of the gates (PSF 2016). Annual spring sampling found significant numbers of Coho salmon in both the Wilson Farm tributaries and a nearby control site, Mundy Creek, where a floodgate was recently decommissioned (PSF 2016). This suggested that juvenile salmon were able to pass through the automated floodgate in all years to access floodplain habitat, despite its more limited openings in the spring to avoid flooding during the Coquitlam River freshet (PSF 2016). However, fall fish assemblages upstream of the Wilson Farm floodgate included Coho salmon in only 3 of the 6 years of effectiveness monitoring following remediation, while Coho salmon were found 5 of the 6 years in the control system (PSF 2016). This indicates that although the installation of an automated, programmable floodgate in the Wilson Farm system did improve fish access and upstream water quality, further improvements can be made to assist juvenile salmon during various critical life-history stages.

Based on results of the Wilson Farm effectiveness monitoring study, it was recommended that fish habitat access could be improved through operational alterations to the automated floodgate (PSF 2016). Yearling Coho salmon from the Wilson Farm site were significantly larger than conspecifics in the control system, suggesting that upstream habitat was of a high quality for overwintering (PSF 2016).

However, fewer Coho were captured in the Wilson Farm system, suggesting that access is still limited compared to the control site (PSF 2016). The automated floodgate was found to be open 30-50% of the day during times of high juvenile salmon migration (PSF 2016). Altering the operations of the programmable automated floodgate to open wider and for longer portions of the day during salmon migrations could improve habitat access for juvenile Coho during overwintering (PSF 2016). However, the effectiveness of various operational strategies has yet to be empirically investigated for automated floodgates, and more information is required to match floodgate operations with fish movements to achieve optimal benefits for native fish passage.

4 Methods

4.1 Passive Integrated Transponder Antenna Construction and Installation

This study is using a Passive Integrated Transponder (PIT) methodology. This means first installing in-stream PIT antennas that can detect fish as they pass through down to the individual fish. These antenna systems are installed at three sites described above, along with data collection and reading devices and a battery bank for each antenna setup. This fish tracking technique will allow us to take an individualistic approach that accounts for the effects of fish size, species, condition, and age on the passage success and timing of fish movements. This will be the first study to use individual fish tracking to assess the upstream and downstream passage of juvenile salmon at flood-control structures.

PIT antennas have now been set up at each site with four antennas per site, with two upstream and two downstream of the floodgates, to gather data on directional movement of individual fish, as well as data on juvenile salmon passage success (number of attempts or approaches before successful passage), efficiency (rate of passage), and timing (time of day, tidal conditions, flow conditions, floodgate operations, time of year). PIT antennas use electromagnetic fields to charge the tags implanted in juvenile salmon, triggering them to send a radio signal with a specific code assigned to the particular fish. However, these antennas often have trouble working in metal structures due to interference with the electromagnetic field. We designed a novel PIT antenna configuration to minimize interference in collaboration with InStream Consulting. We employed a figure-8 design (or infinity loop ∞) using overlayed circular coils (see Figure 5), as opposed to traditional rectangular coils, to improve detection efficiency. The symmetrical coverage of the circular coils, as well as the placement of the wire further from the floodgate walls compared to rectangular designs, reduced the resistance of the metal within the floodgate structures on the electromagnetic fields, allowing us to build antennas of the appropriate size and power for our study design. We are currently writing a manuscript for submission in a peer-reviewed journal outlining the utility of this antenna configuration in metal structures (e.g., fishways, culverts) where fish passage assessments may be required.

Figure 5: Front on perspective of innovative infinity loop PIT antenna design. Photo by: Zachary Sherker, project lead

Figure 6: Antenna installation with lumber frame in final position at self-regulating gate. Photo by: Zachary Sherker, project lead

Figure 7: Lowering antenna at self-regulating floodgate. Photo by: Zachary Sherker, project lead

Figure 8: Antenna installation at Sheep Paddocks floodgate (control) site. Photo by Zach Sherker

Figure 9: Antenna setup inside Sheep Paddocks control site. Photo by Zach Sherker

4.2 Year 1 Monitoring Methods

The challenges of constructing and installing the PIT antennas left little time to monitor in year 1. However, there was a total of 16 field days at all sites, with 8 days setting traps and 8 days retrieving and sampling catch. Sampling effort was 10 traps upstream and 10 traps downstream at each of the three sites. This totalled to 160 traps for each site (20 traps x 8 sampling days).

4.3 Year 2 Monitoring Methods

For Year 2 monitoring we have established a collaboration with DFO and the Grist Goesen Memorial Hatchery, we will be tagging and releasing ~1,500 hatchery-reared Coho annually to assess passage at our floodgate sites in fall 2022. Fish will be tagged and maintained at the Grist Goesen Hatchery (~5 km from study sites) and transported in oxygenated fish tanks to the study sites for release. Juvenile Coho will be released in groups of 20 fish biweekly in forebays just downstream of floodgate sites. Releases will be simultaneous at the three sites to compare fish passage and floodgate operations at under identical hydraulic conditions. Block nets will be used for the first 24 hours after release to prevent fish entering directly into the mainstem Coquitlam upon release. Wild juvenile Coho and Chinook will be captured using beach seines and minnow traps in the Lower Coquitlam River to be included in the fish passage trials (~500 total per year). Fish passage trials will be conducted throughout juvenile migration into overwintering habitat (October-December), when passage into floodplain habitat is most critical. PIT antennas will be maintained throughout overwintering (October-May) to document downstream passage during smolt outmigration. Minnow trapping and beach seine surveys will be conducted upstream of floodgate sites to compare juvenile salmon survival and growth during overwintering using mark-recapture techniques. These fish sampling surveys will also be used to assess fish community structure relative to floodgate operations and water quality upstream of our study sites.

We will be using an intensive before-and-after effectiveness monitoring design to investigate the influence of floodgate operations on juvenile salmon access to important floodplain habitats. Fish tracking will be conducted from 2021-2024, providing one year of 'before' data collection, in which the automated floodgate operations will be unaltered from their original programming. Fish movement data relative to floodgate openings and passage success from the first year of the study will be used to reprogram floodgate operations and better match fish movements in the following years, providing two years of 'after' data. This will be the first study to conduct a field experiment assessing this new floodgate design and its potential operations. Throughout this fish tracking study, we will be collecting data on water quality, the timing and extent of floodgate openings, native and non-native fish assemblages, and habitat quality to be compared upstream and downstream of floodgates, as well as among study sites. This research will inform future floodgate operations to minimize impacts on accessibility to critical fish habitat in the Lower Fraser River, as well as provide rationale for the implementation of further fish-friendly floodgate designs. This research is particularly timely as aging flood-control infrastructure in the Lower Fraser River will have to be restored in the coming years to combat the effects of climate change on sea-level rise and coastal flooding (Church *et al.* 2013).

5 Results

5.1 Year 1 results

Through collaboration with Bailey Environmental Consulting, minnow trap surveys were conducted from October 2021 – May 2022 upstream of the three floodgate treatments. Preliminary results suggest that passage and water quality may be influencing upstream fish communities, with few fish and mostly invasive species found upstream of the traditional top-mounted floodgate, more fish and a mix of invasive and native species (Coho salmon) upstream of the self-regulated gate, and mostly native species upstream of the reference site (Coho, Chinook, cutthroat trout, three-spine stickleback, red-sided shiner, largescale sucker).

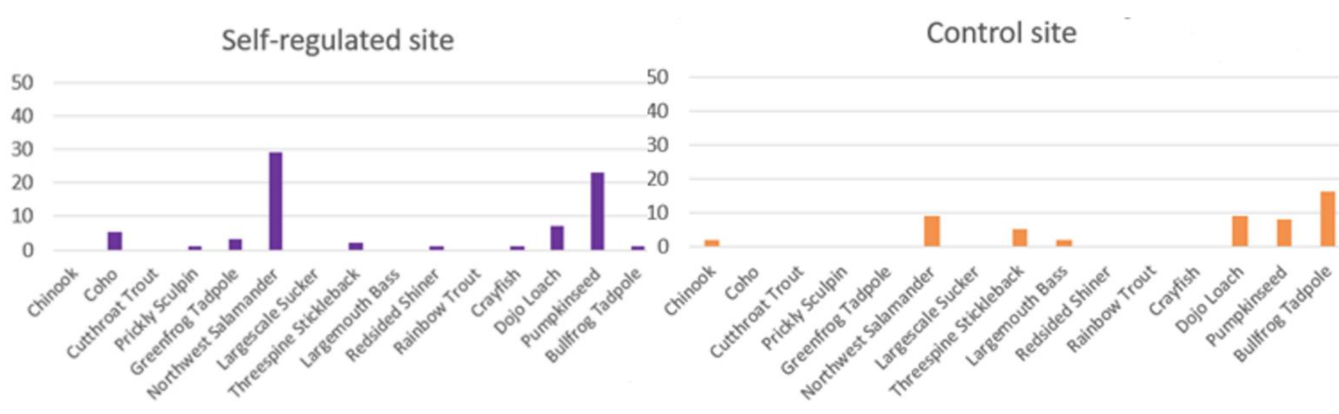

Figure 10: Fish abundance from minnow trap surveys upstream of the treatment (self-regulated gate) and control (top-mounted gate) site (October 2021 – May 2022).

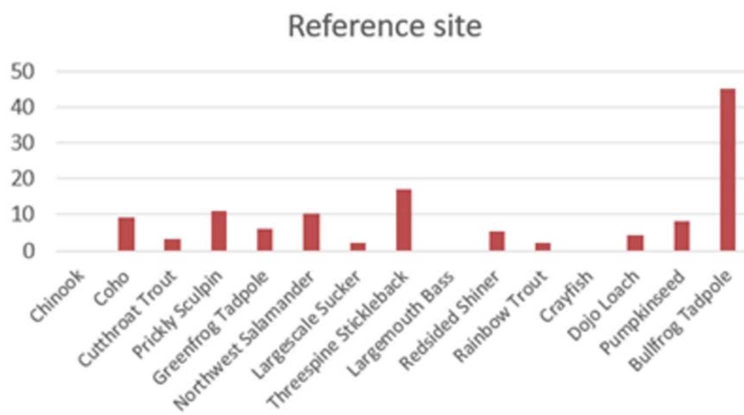

Figure 11: Fish abundance from minnow trap surveys upstream of reference (gate permanently chained open) site (October 2021 – May 2022).

5.2 Year 2 results

Analyses for year 2 salmon passage at floodgates on the Coquitlam River are ongoing, the following section outlines preliminary summaries of trends we detected in year 2. Throughout overwintering, ~500 PIT tagged hatchery-reared coho were released on the downstream end of each of the three floodgate sites. Between our 12 PIT antennas, we amassed over 2.5 million detections and approximately 15,000 passage attempts of varying success. We were able to document major differences in fish passage between the three floodgate treatments assessed in year 2.

Of the PIT-tagged juvenile coho that approached the floodgates, approximately 80% were able to successfully pass upstream of the floodgate at the reference site to access the floodplain habitat for overwintering. This compares with ~55% at the self-regulating site (treatment) and ~20% at the top-mounted site (control). At the reference site and the treatment site, approximately 70% of fish released were detected approaching the floodgate structures to attempt upstream passage. This compares with approximately 30% of fish at the top-mounted floodgate (control). These approach data suggest that salmon are having trouble detecting flow from the top-mounted floodgate, indicating that fish attraction may be a major issue for top-mounted floodgates on the Lower Fraser River. In total, of all the fish released at each site, approximately 53% of the fish released at the reference site successfully accessed the floodplain upstream, compared to 40% at the treatment site and <7% at the top-mounted gate.

6 Discussion

These results are the first to outline to what extent top-mounted floodgates are barriers to overwintering habitat access for juvenile salmon, and suggest that while the self-regulating gate is a massive improvement for fish passage compared to a top-mounted gate, there is still room for improved passage through altering the operations to better match floodgate opening with timing of upstream passage for juvenile salmon.

Additionally, we found quite a bit of movement between sites for juvenile salmon during overwintering. For example, fish released at the control site that were not able to move upstream of the top-mounted floodgate were detected attempting passage at the treatment site (350 m upstream) and the reference site (1 km upstream). This requires considerable transit through the mainstem of the Coquitlam River, exemplifying the considerable lengths these juvenile salmon go through to find off-channel habitat to survive off the mainstem of the river during overwintering.

Fish were detected at the PIT antennas throughout overwintering and a number of fish survived to be detected leaving the systems during smolt outmigration. Analyses are still in progress to determine survival to outmigration of fish between the three floodgate treatments. In early May 2023, an early spring freshet resulted in considerably high water levels in the mainstem of the Coquitlam River. This resulted in floodgates at all three sites remaining pinned closed for about 4 weeks. During that time, we detected tens of fish in the floodplain unsuccessfully attempting downstream passage through the floodgate.

When the mainstem water level lowered in June, the floodgates opened, finally allowing the fish to continue their downstream migration. Considerable delays in downstream migration can be detrimental for juvenile salmon, who time their seaward migration to match foraging opportunities in the estuary and nearshore environment prior to continuing out to sea as sub-adults. Delays in estuary arrival likely means sub-optimal foraging during estuary residence, potentially causing delayed mortality for juvenile salmon.

7 Recommendations

In year 3, to expand on and compare overwintering survival estimates between the floodplain systems upstream of our three floodgate sites, we will be releasing an additional 200-500 PIT tagged hatchery-reared juvenile coho directly into the floodplain upstream of each of our three floodgate treatments. Survival-to-outmigration for these fish will be used as a proxy for water and habitat quality between sites relative to connectivity with the Coquitlam River mainstem.

We have contracted Pearson Ecological to run extensive minnow trapping surveys in each of the floodplain systems throughout the overwintering season (November-May) to compare fish community structure (both native and non-native species), assess salmonid growth through recapture of PIT-tagged coho, and document the distribution of juvenile coho within the floodplain systems. These minnow trapping surveys will be done from canoe, and we have developed a towable PIT antenna to be outfitted on the canoes with GPS to passively detect PIT-tagged coho in the floodplain during canoe surveys. These detections will be used to document coho movements and habitat use throughout overwintering.

We will also be continuing our downstream releases throughout overwintering (500 coho per site, released weekly in groups of 50 from Nov-Feb) to compare fish passage between our floodgate sites. In year three, we will be raising the water level of the floodplain upstream of Wilson Farm (self-regulating gate) to see how it alters floodgate operations (amount of time open, angle of openings, upstream and downstream water levels) and fish passage.

In year 2 we allowed the side mounted gate to operate as normal, and in year 3 we will be chaining the gate open to simulate an ungated off-channel habitat. This will also allow us to assess the impacts of the side-mounted gate on fish passage through a before-after design, and will provide us with a true ungated reference site to assess the natural movements of juvenile salmon into off-channel habitat for year 3.

We will also be setting up fyke nets on the outflow of the three floodgates during spring juvenile salmon outmigration to compare overall overwinter growth of coho at the three sites through the recapture of PIT-tagged fish.

8 Acknowledgements

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