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Coquitlam River Floodgate Effectiveness and Salmon Passage: Report Year 3 of 4

Prepared for: Fish and Wildlife Compensation Program and DFO - BC Salmon Restoration and Innovation Fund

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RESILIENT WATERS

A project of MakeWay

10/July/2024

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 four-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 This research will help to quantify the potential benefits of replacing outdated flood-control infrastructure with fish-friendly alternatives, as well as to provide guidance on how these self-regulated gates may be programmed to maximize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 2 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 out-migrate 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 of the study, we once again repeated the timed release of 500 Coho at each site, plus an additional 1500 salmon upstream (away from any of the established sites). We worked with Metro Vancouver operations staff to alter the programming and operation of the floodgate to allow for an extended window of fish passage and increased water volume and flow across the floodplain. We also performed extensive minnow trapping sessions, in partnership with Pearson Ecological and Bailey Environmental 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 was pulled behind canoes and detections were 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 is 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.

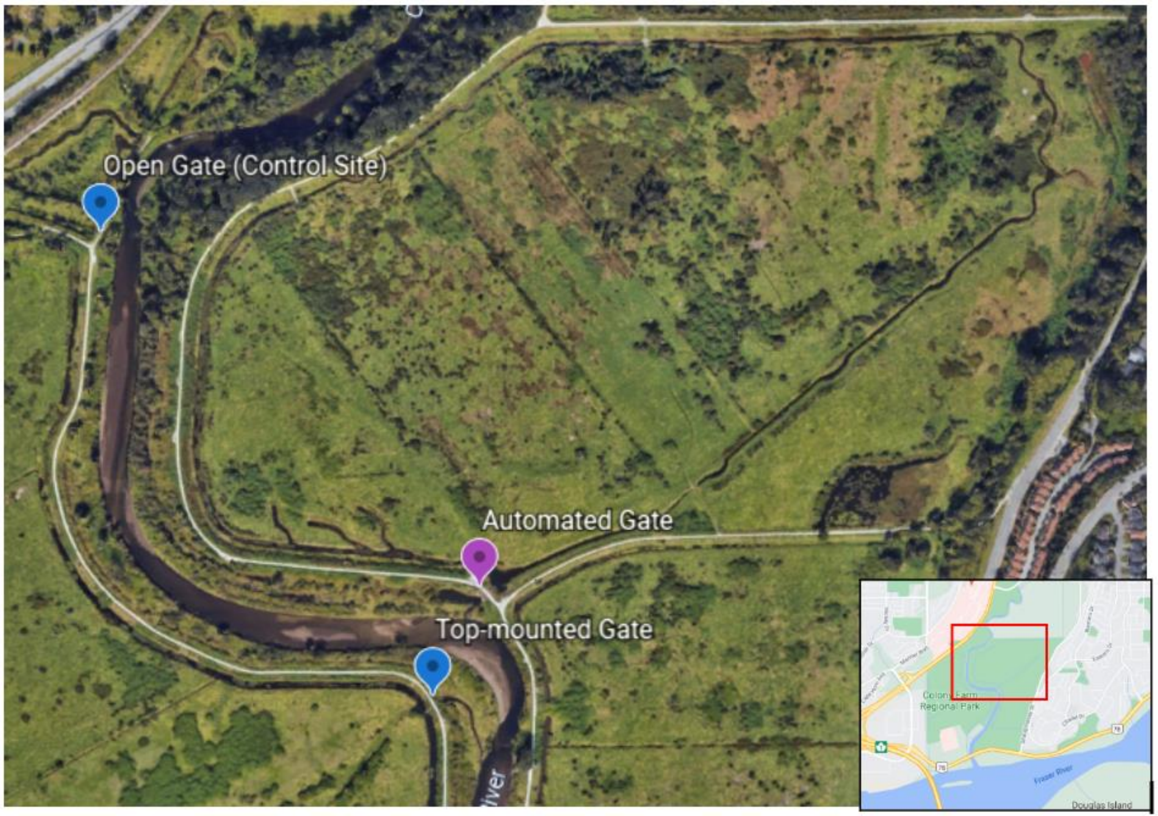

Figure 1: Three floodgate sites being studied at Colony Farm Regional Park. [Follow this link to explore the study area.]

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 Zachary Sherker


Figure 4: Top-mounted floodgate. Photo by Zachary 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. Recently, a manuscript[1] was published 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.

[1] https://www.researchgate.net/publication/381218024_Novel_application_of_two-_and_four-lobed_noise-canceling_passive_integrated_transponder_antennas_for_tracking_fish_in_areas_of_high_ambient_electromagnetic_interference

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 (2021-22) 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 totaled 160 traps for each site (20 traps x 8 sampling days).

4.3 Year 2 (2022-23) Monitoring Methods

For Year 2 monitoring, we used hatchery-reared juvenile coho salmon grown and maintained at the Grist-Goelson Memorial Hatchery. Juvenile salmon were tagged with 12-mm FDX PIT tags and released in groups of 50 fish in the forebays along the mainstem of the Coquitlam River, approximately 5 m downstream of each of the three floodgate sites. Fish were released weekly over the course of 10 weeks from November 2022 – February 2023, with a total of 1,429 PIT-tagged juvenile coho released during the study. 980 of these juvenile coho (68.6%) were detected attempting passage at one or more of our three floodgate sites. All fish were released on the downstream end of one of the floodgate treatments, with a total of 474 fish released at the top-mounted floodgate, 478 fish released at the self-regulating floodgate, and 477 fish released at the side-mounted gate. An additional 300 PIT tagged fish were released upstream of the 3 floodgates and another 600 PIT tagged fish released into Reeve Slough for a total of 1500 fish released upstream.

Wild juvenile Coho and Chinook were captured using minnow traps in the Lower Coquitlam River to be included in the fish passage trials (~500 total per year). Fish passage trials were conducted throughout juvenile migration into overwintering habitat (October-December), when passage into floodplain habitat is most critical. PIT antennas were maintained throughout overwintering (October-May) to document downstream passage during smolt outmigration. Minnow trapping was conducted upstream of floodgate sites to compare juvenile salmon survival and growth during overwintering using mark-recapture techniques. These fish sampling surveys will 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).

4.4 Year 3 (2023-24) Monitoring Methods

For Year 3 monitoring, we once again used hatchery-reared juvenile coho salmon grown and maintained at the Grist-Goelson Memorial Hatchery. Juvenile salmon were tagged with 12-mm FDX PIT tags and released in groups of 50 fish in the forebays along the mainstem of the Coquitlam River, approximately 5 m downstream of each of the three floodgate sites. Fish were released weekly over the course of 10 weeks from November 2023 – February 2024, with a total of 1500 PIT-tagged juvenile coho released downstream during the study. An additional 300 fish were released upstream of each of the 3 floodgates for a total of 900 fish and another 600 fish released into Reeves Slough.

Fish were detected using PIT antennas operating directly on the upstream and downstream ends of each of the three floodgate sites. We operated four PIT antennas at each floodgate site, with two antennas on the downstream end and two antennas on the upstream end. This antenna set up allowed us to assess juvenile salmon passage success (number of attempts or approaches before successful passage), efficiency (rate of passage), and timing (time of day, tidal conditions, time

Wild juvenile Coho and Chinook were captured using minnow traps in the Lower Coquitlam River to be included in the fish passage trials (~500 total per year). Fish passage trials were conducted throughout juvenile migration into overwintering habitat (October-December), when passage into floodplain habitat is most critical. PIT antennas were maintained throughout overwintering (October-May) to document downstream passage during smolt outmigration. Minnow trapping was 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.

4.5 Year 4 (2024-25) Monitoring Methods

For Year 4 monitoring, we will once again be using hatchery-reared juvenile coho salmon grown and maintained at the Grist-Goelson Memorial Hatchery. Juvenile salmon will be tagged with 12-mm FDX PIT tags and released in groups of 50 fish in the forebays along the mainstem of the Coquitlam River, approximately 5 m downstream of each of the three floodgate sites. Fish will be released weekly over the course of 10 weeks from November 2024 – February 2025, with a total of 1500 PIT-tagged juvenile coho released downstream during the study. An additional 300 PIT tagged fish will be released upstream of each of the 3 floodgates for a total of 900 fish and another 600 fish released into Reeves Slough.

Minnow trapping will be performed upstream of floodgates 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.

5 Results

5.1 Year 1 (2021-22) 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).

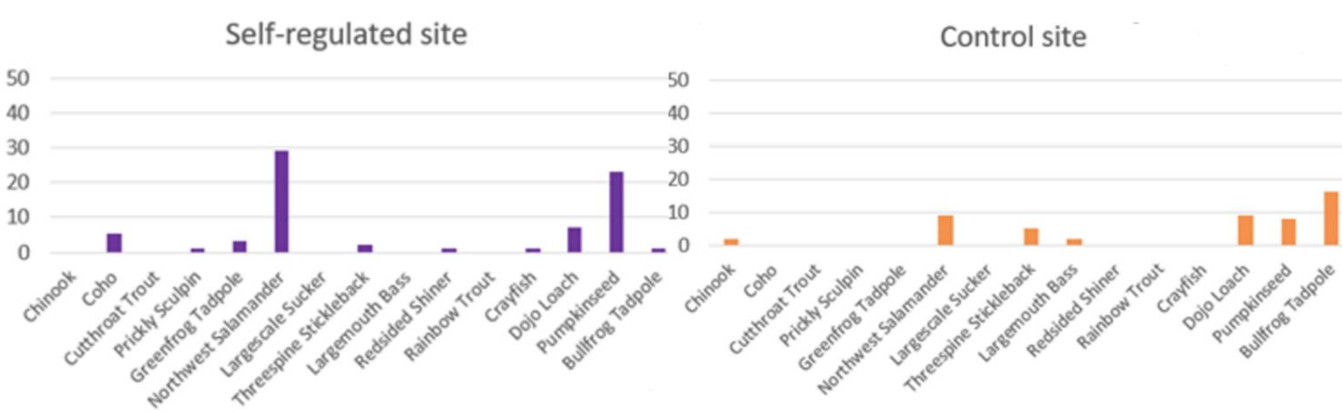

Figure 10: Fish abundance from minnow trap surveys upstream of the treatment (self-regulated gate) and control (top-mounted gate) site (October 2021 – May 2022).

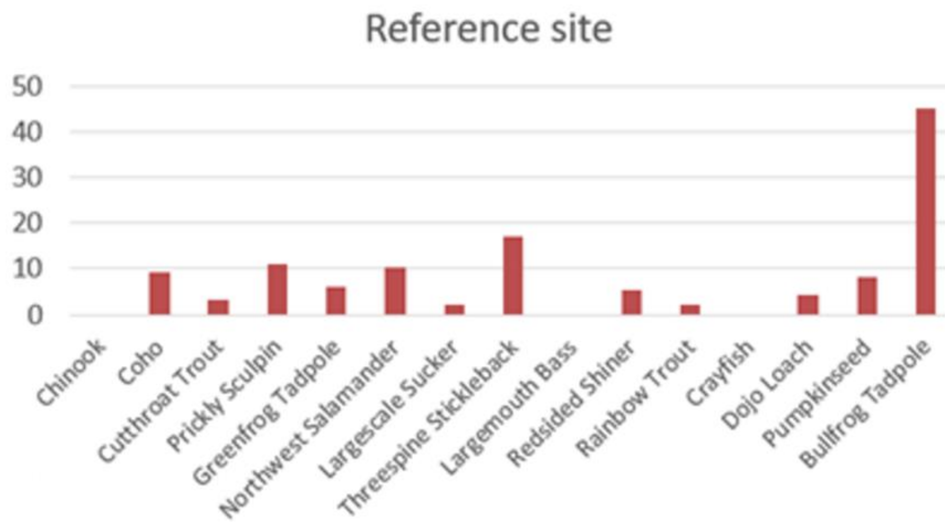

Figure 11: Fish abundance from minnow trap surveys upstream of reference (gate permanently chained open) site (October 2021 – May 2022).

5.2 Year 2 (2022-23) 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 and another 900 PIT tagged hatchery-reared coho release on the upstream end of each of the 3 floodgates. 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.

For the fish released at each floodgate treatment, the percent of fish that were detected attempting passage at the associated floodgate was 42.0% at the top-mounted gate, 47.4% at the decommissioned gate and 62.6% at the self-regulating gate. Since fish released on the downstream end of any of the floodgate treatment sites were free to swim to any of the other sites, we were able to calculate overall attraction rates for each site. Of the 980 juvenile coho detected attempting passage at one or more of the floodgates over the course of the study, 25.4% were detected attempting passage at the top-mounted gate, 40.2% were detected at the decommissioned gate, and 54.4% were detected at the self-regulating gate.

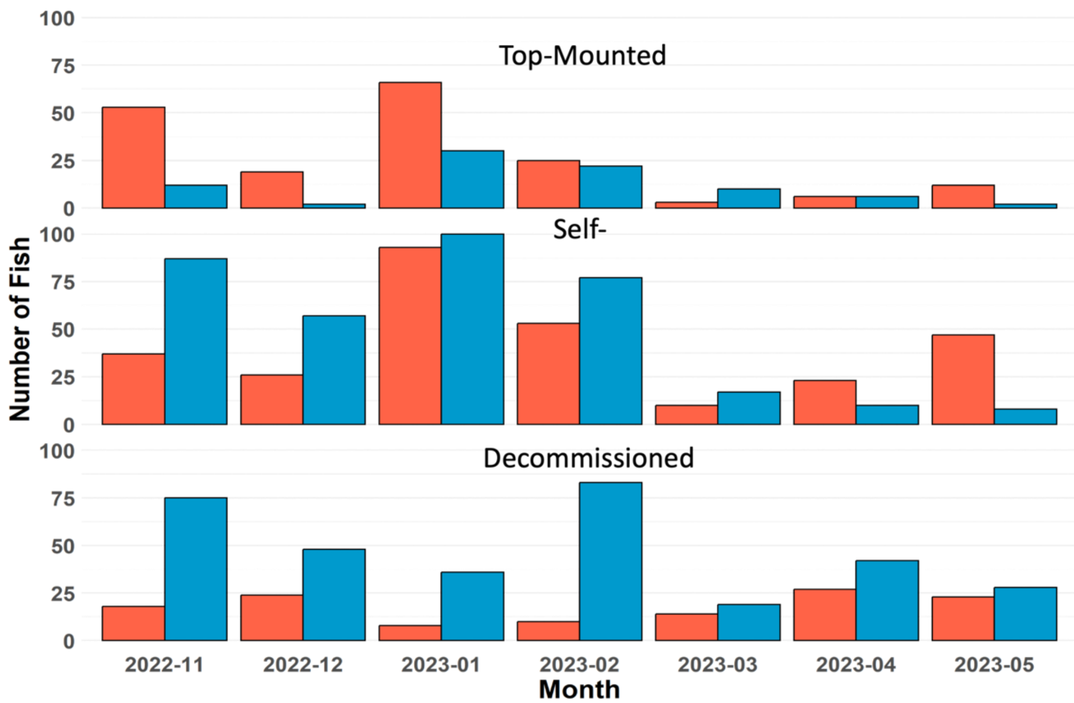

Figure 12 Number of fish detected at each of the three floodgate sites in each month, with fish that successfully passed upstream through floodgate in blue and fish that attempted passage but were unsuccessful at getting upstream in red.

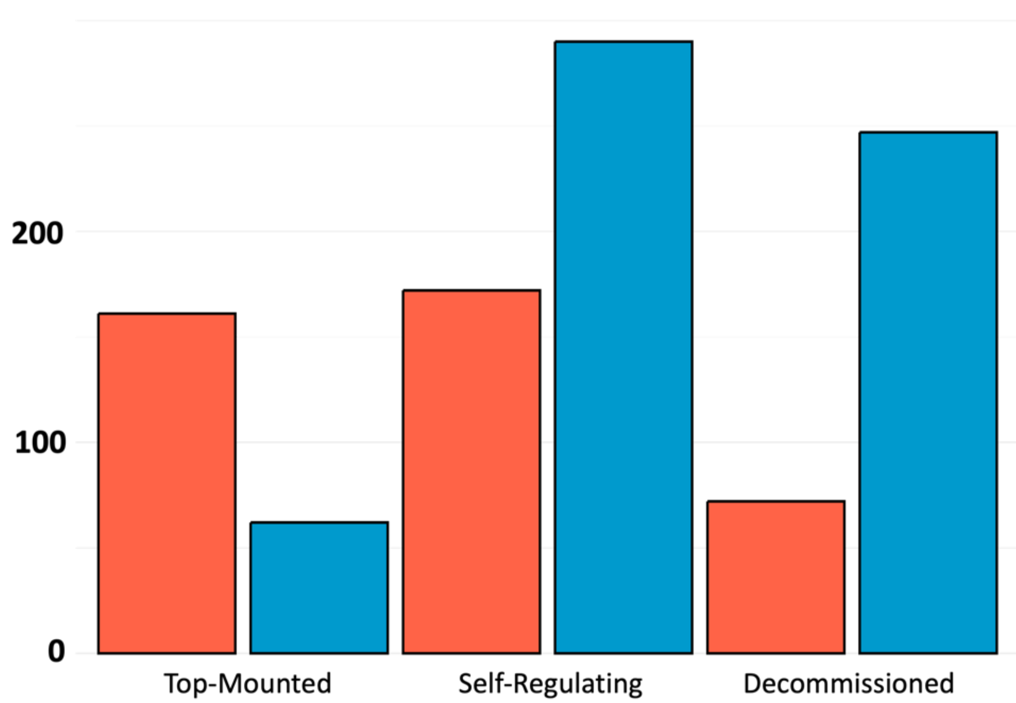

Figure 13 Total number of PIT-tagged juvenile coho salmon that were successful (blue) and unsuccessful (red) in passing upstream of the three floodgate treatments to access off-channel overwintering habitat upstream.

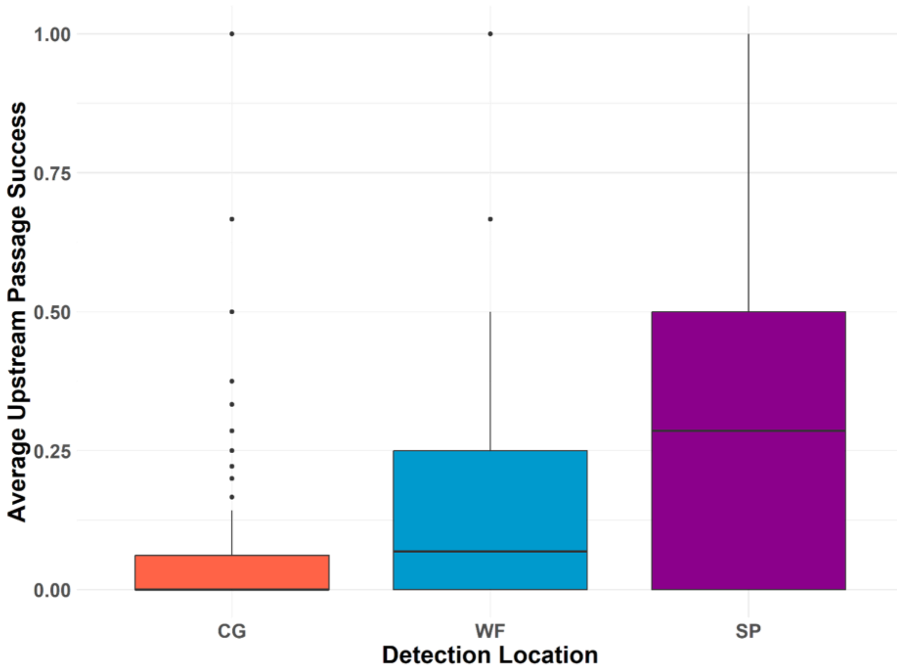

Figure 14 Average upstream passage success (number of upstream passage attempts/number of successful upstream passage attempts) at each of the three floodgate sites from November 2022 – May 2023.

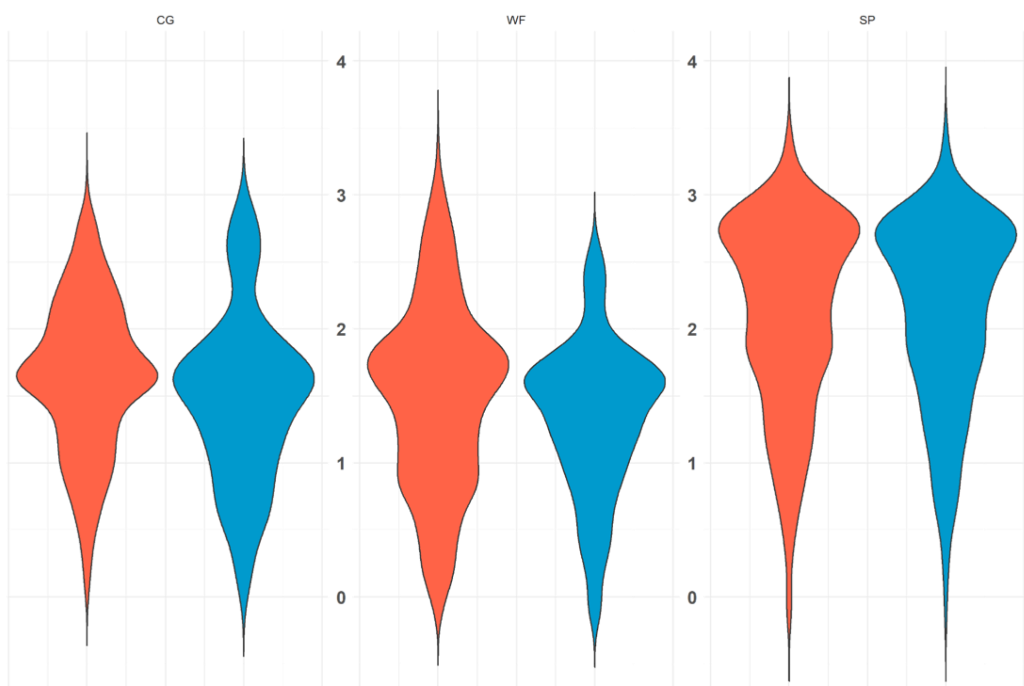

Figure 15 Violin plot showing the density of passage attempts at the three floodgate treatments relative to tidal height (m). The red plot shows all fish approaches at the floodgates, both successful and unsuccessful, and the blue plot shows the successful upstream passage attempts relative to tidal height.

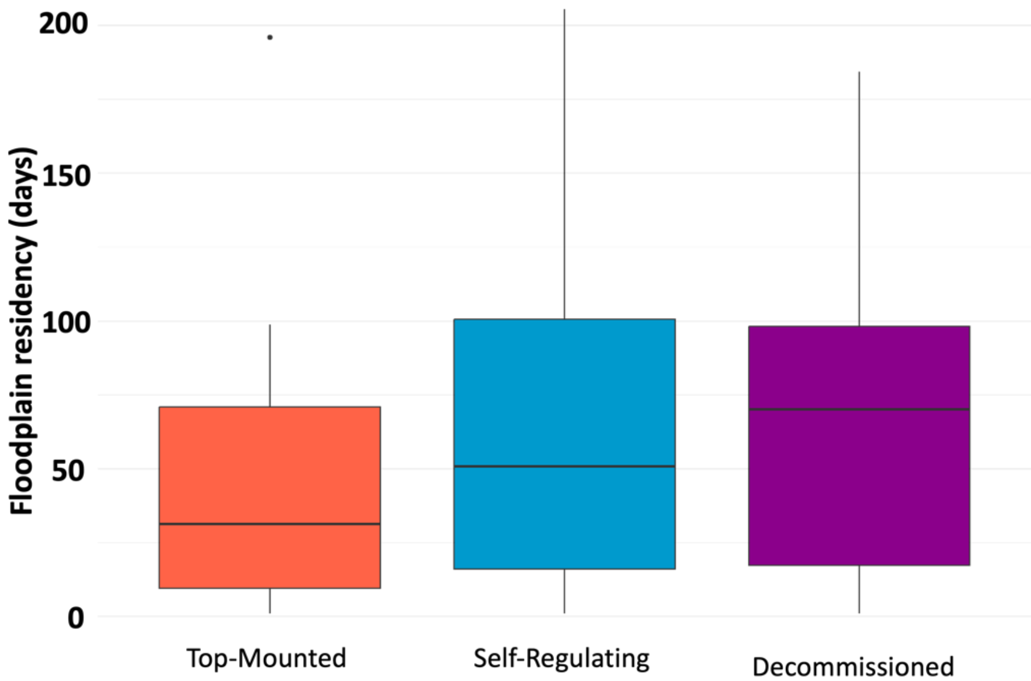

Figure 16 Boxplot of the floodplain residency for fish that successfully made it upstream of the top-mounted floodgate (n=39), fish upstream of the self-regulating floodgate (n=223) and fish upstream of the decommissioned floodgate (n=137). Only fish with a floodplain residency > 1 day were included in these plots.

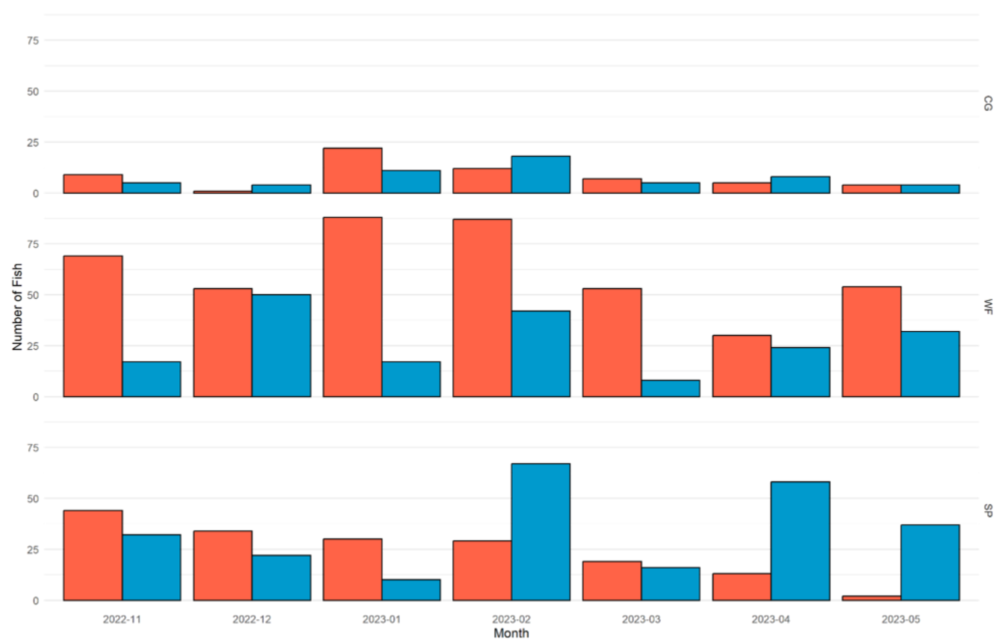

Figure 17 Number of fish detected at each of the three floodgate sites in each month, with fish that successfully passed downstream through floodgate in blue and fish that attempted passage but were unsuccessful at getting downstream in red.

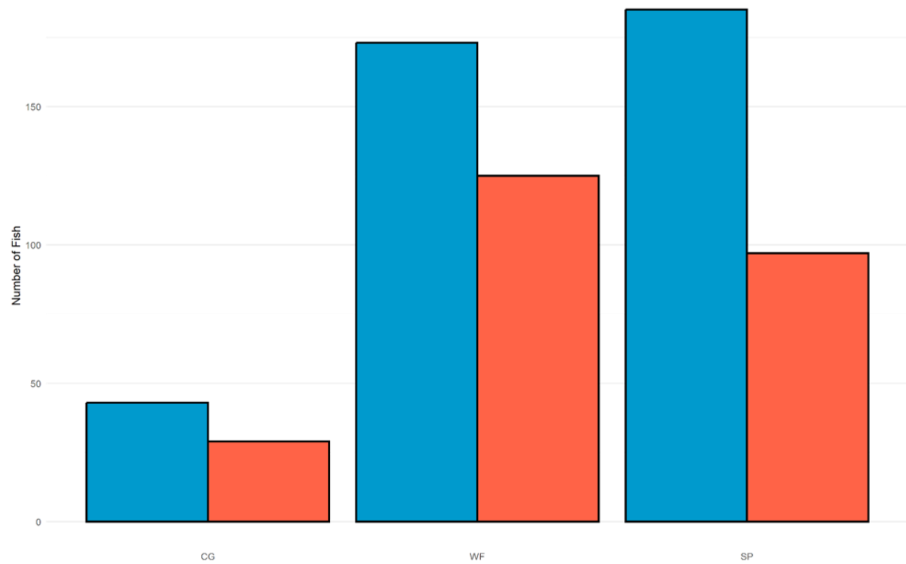

Figure 18 Total number of PIT-tagged juvenile coho salmon that were successful (blue) and unsuccessful (red) in passing downstream of the three floodgate treatments to access off-channel overwintering habitat downstream.

5.3 Year 3 (2023-24) results

The data for the 2023-2024 field season have been inputted and cleaned, and analyses will be completed by Fall 2024. Preliminary results suggest that adjustments to the self-regulating gate made in December by KWL and Metro Vancouver to allow for longer opening times and increased water volume have resulted in increased upstream fish passage into the floodplain.

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.

It took juvenile salmon approximately 130% longer to migrate upstream through the top-mounted floodgate (45.4 min (36.2-54.5 min)) upon entry into the structure than either of the self-regulating (34.2 min (30.1-38.3 min)) or decommissioned (35.13 min (32.1-38.1 min)) floodgates. In all these structures, the fish are required to swim the same distance through the floodgate (approximately 7 meters). The difference in upstream transit speed is likely due to differences in flow and hydrologic conditions in the top-mounted floodgate when it is open and accessible to juvenile salmon than either of the self-regulating or decommissioned floodgate. As in the case of the top-mounted culvert in our study, culverts that convey water and fish through the floodgate are often undersized for the streams they are servicing. Additionally, the only time that the floodgates open is when there is a considerable head difference between the upstream and downstream waterways, resulting in rapid flows through the structure to drain the upstream water channels until the gate closes again. These flow conditions have likely resulted in the observed higher transit time for juvenile salmon migrating upstream of the top-mounted floodgate. This increased time required swimming upstream through the structure likely has energetic consequences on the fish and may result in poorer survival through overwintering. Juvenile salmon that were able to access off-channel habitat upstream of the floodgate treatments remained in the system for an average of 63.2 days (58.1-68.4 days). This represents a considerable portion of the overwintering period, and shows an opportunity for fish to experience higher growth and survival through overwintering in the floodplain habitat upstream of floodgates compared with fish in the mainstem of the river during this time.

Floodplain residency was significantly shorter in the habitat upstream of the top-mounted floodgate (66% of the average residency duration) compared to the other floodgate treatments. This is likely due to poorer water quality in the upstream habitat towards the end of overwintering due to higher temperatures and lower connectivity to the river mainstem compared to habitat upstream of the self-regulating and decommissioned floodgates. The fish that exit the system upstream of the top-mounted floodgate either have to seek off-channel habitat elsewhere or remain in the mainstem of the river for the rest of overwintering, which likely has an adverse impact on juvenile salmon survival to smolt outmigration. Juvenile coho survival to outmigration from the floodplain was relatively consistent among floodgate treatments (approximately 40%), and is a similar to other published juvenile salmon overwintering survival rates in natural off-channel floodplain habitats.

This is also the first study to monitor the effectiveness of a self-regulating floodgate design in improving juvenile salmon passage and habitat access. Preliminary data analysis has shown that the floodgate improves juvenile salmon passage compared to a top-mounted floodgate. Adjustments to the programming of the self-regulating gate to remain open for a larger portion of the incoming tide have improved juvenile salmon passage and transit efficiency greatly. Further adjustments to increase the time that the gate remains open and increased water volume across the flood plain are recommended to improve upstream passage and habitat access and quality for juvenile salmon during overwintering.

7 Recommendations

In year 4, to expand on and compare overwintering survival estimates between the floodplain systems upstream of our three floodgate sites, we recommend releasing an additional 900 PIT tagged hatchery-reared juvenile coho directly into the floodplain upstream of each of our three floodgate treatments and another 600 PIT tagged fish into Reeve Slough. 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.

Adjustments to the programming of the self-regulating gate to remain open for a larger portion of the incoming tide have improved juvenile salmon passage and transit efficiency greatly. Further adjustments to the programming of the self-regulating gate to increase the time that the gate remains open and allow increased water volume across the flood plain are recommended to improve upstream passage and habitat access and quality for juvenile salmon during overwintering.

Minnow trapping surveys should be performed monthly 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.

Once final analyses of year 2 and year 3 data have been completed, additional recommendations can be made to inform further adjustments to the programming of the self-regulating gate, and inform potential upgrades to the top-mounted gate.

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