BOTTLENECKS TO SURVIVAL

ROBERTSON CREEK ENHANCED STEELHEAD DIFFERENTIAL RELEASE TRIALS

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Photo credit: Danny Swainson

EXECUTIVE SUMMARY

This study evaluated the survival and behaviour of Robertson Creek hatchery steelhead through PIT-tagging over three years. A total of 14,866 steelhead were tagged and released, with 6,897 released into the ocean, 6,443 into the Stamp River, and 1,526 from the 2021 outmigration year not allocated to a specific release group due to detection difficulties during sorting. Tagging-related mortalities (0.7%) and tag rejections (0.05%) were low, likely due to the relatively large size of steelhead at tagging. Data from 2022 and 2023 release years showed a minimum residualization rate of 1.3-1.5% within the first 10 months post-release.

Preliminary adult return data indicated 37 steelhead returning to the Stamp Falls Fishway Array as of April 23, 2024, survival to age two and age three for the 2021 river release were 0.20 and 1.01%. The unknown release group fish had a survival rate of 0.07 and 0.26% for return age two and three respectively. There were no returns from the 2021 ocean release group. The 2022 river release group saw a survival rate of 0.53% to age two, while the 2022 Ocean Release group had a survival rate to age two of 0.04%.

The Stamp Falls Fishway demonstrated a 92.3% pass-through rate. Additional data on bypass rates and residualization provide valuable insights into hatchery impacts and competition. Recommendations include installing a full-stream mainstem PIT array, deriving accurate outmigration timing, supporting annual PIT tagging with provincial funding, allocating funds to monitoring programs, and developing adult escapement estimates using mark-recapture methods.

Citation:

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INTRODUCTION

Steelhead populations have been deteriorating along the Pacific Northeast. The decrease in overall survival rates has led to persistently low returns, hindering recovery efforts of both wild and hatchery cohorts in British Columbia (Ward, 2006; Moore et al., 2010; Melnychuk et al., 2009; Moore et al., 2015; Kendall et al., 2017; Wilson et al., 2022). The decline in steelhead abundance is a complex issue with multiple contributing factors. These include changes in marine and freshwater regimes (i.e. Pacific Decadal Oscillation, La Niña, El Niño), impacts to freshwater rearing habitats from logging, development, and other anthropogenic impacts, summer drought (climate change), increased predation pressure from marine predators such as pinnipeds, and negative impacts from coastal infrastructure (Ward 2006; Welch et al. 2000; Wilson et al. 2021; Moore et al. 2021; Moore and Berejikian 2022; Wilson et al. 2022).

Bottlenecks to survival are spatiotemporal mortality events that significantly decrease a population and are considered critical issues in Pacific Salmon recovery (Michel 2018). Bottlenecks can occur at any life stage and are variable between species. Early marine survival is suggested as one of the bottlenecks to survival for steelhead (Goetz et al. 2015). High mortality in the early marine period has been associated with predation, which is augmented by anthropogenic impacts and climate change (Goetz et al 2015; Kendall et al., 2017; Malick et al., 2022; Moore and Berejikian, 2022)

Steelhead enhancement is also a bottleneck to survival for wild steelhead populations if done improperly. Araki et al. (2007) highlighted the genetic effects of captive breeding, indicating that even a few generations of domestication may negatively affect natural reproduction in the wild. Kostow & Zhou (2006) showed the negative impacts of an introduced summer steelhead hatchery stock on the productivity of a wild winter steelhead population. Studies have consistently pointed to the ecological and demographic costs of hatchery releases, including the potential for adverse interactions with wild populations and the concerning rates of residualism (i.e. nonmigratory life-history) among hatchery steelhead (Hausch and Melnychuk 2012; Scheuerell et al. 2021). However, while steelhead enhancement can have negative impacts on wild fish, low marine survival rates and habitat degradation may necessitate the use of hatcheries for achieving any sports fishery, population re-establishment or conservation program in the future (MFLNRO 2016; Scheuerell et al. 2021; Wilson et al. 2021). Further understanding the fundamental impacts of an enhancement program on a wild population is critical in achieving the precautionary principle, which guides steelhead head management in British Columbia (MFLNRO 2016).

Recent studies have tried to determine where changes in the management of hatchery steelhead can be made to reduce impacts on wild populations while also increasing hatchery survival rates and lowering overall production. Berejikian and Van Doornik (2018) showed that conventional hatchery practices are likely to impact the available genetics in a population, but by making slight adjustments, these genetic effects could be reduced. Moore et al. (2012) suggested that hatchery practices can influence the early marine survival of steelhead, which can be a primary driver of overall marine survival. Balfry et al. (2011) explored several different release strategies and used acoustic tags to measure the impact on early marine survival. Various release strategies were developed (i.e. day vs night, summer vs winter run, different release timing, direct ocean release). However, none of these strategies resulted in higher early marine survival, except for the direct ocean release (Balfry et al. 2011).

Due to the complex nature of steelhead life histories and marine survival bottlenecks, innovative conservation strategies are necessary to address the challenges these fish face during their critical early marine period. Identifying the potential impacts of predation, environmental conditions, competition, and freshwater residualism are critical to increasing the post-release survival of hatchery-reared steelhead while also decreasing their impacts on wild steelhead. Therefore, the Bottlenecks to Marine Survival Program (hereafter the Bottlenecks Program) initiated a study to examine the effects of differential release locations on the survival of hatchery steelhead on the west coast of Vancouver Island, BC.

This project is designed to by-pass the in-river and early freshwater and marine mortality mechanisms (hypothesized to be predation, high water temperatures, pollution, underwater noise etc.) by circumventing the lower river, estuary and Port Alberni inlet areas and releasing steelhead in the ocean off the West Coast of Vancouver Island. This study was also conducted to determine the bypass rate of returning adult steelhead at the Stamp Falls fishway. Determining the bypass rate of adult steelhead will allow for informed expansions of the current and historical camera data collected annually by Fisheries and Oceans Canada (DFO). This project aims to provide empirical evidence on the effects of release location to guide future hatchery management and species conservation efforts.

MATERIALS AND METHODS

Study Area

The study area encompasses the Stamp and Somass rivers, the Robertson Creek Hatchery, the Alberni Inlet, and the Broken Group Islands. These areas are situated within a complex watershed system that plays a critical role in the life cycle of steelhead. The Stamp and Somass rivers are integral to the local ecosystem, serving as vital spawning and rearing habitats for steelhead and other salmonid species (Figure 1).

The Robertson Creek Hatchery (RCH) near the Stamp River is a major operational facility of the Salmon Enhancement Program (SEP). RCH leads the breeding and rearing of steelhead to support the natural populations in the watershed. Provincial biologists oversee the hatchery's practices and protocols, and steelhead releases are conducted by the Freshwater Fisheries Society of British Columbia (FFSBC). From release, steelhead migrate ~4 km to tidewater and the head of Alberni Inlet where they enter the marine environment.

The Alberni Inlet, a long and narrow fjord-like body of water, is a critical migration corridor for smolts travelling from the freshwater rivers to the open ocean. The inlet's varying depths and water conditions present unique challenges and opportunities for studying smolt adaptation and survival during their seaward journey.

The Broken Group Islands, part of the Pacific Rim National Park Reserve, are located within Barkley Sound and offer a complex marine environment characterized by many small islands, channels, and reefs. This area provides rich marine habitat crucial for steelhead smolt post-release survival and growth.

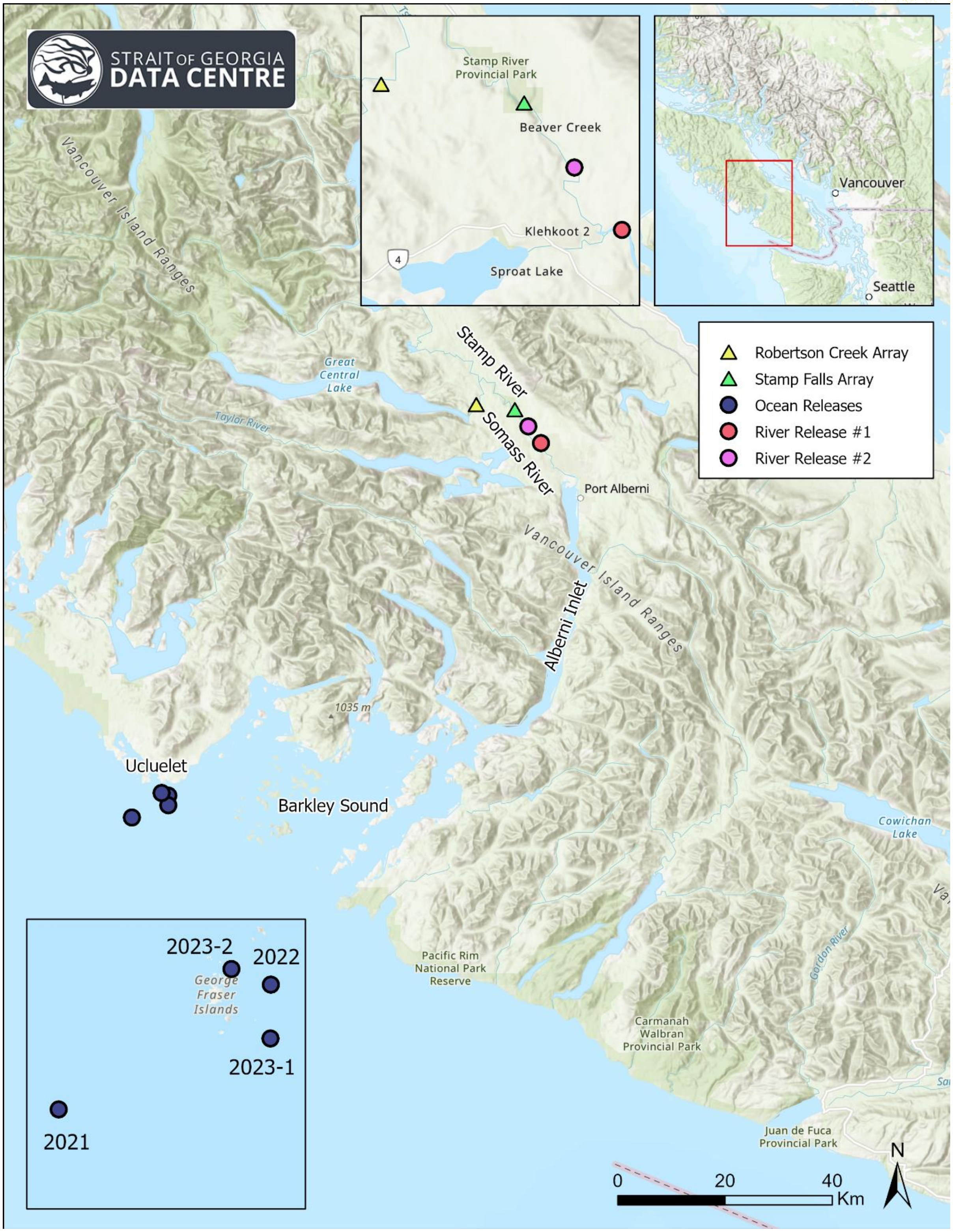

Figure 1. Map depicting release locations for the steelhead differential release study.

Fish Handling & Tagging

RCH steelhead were PIT tagged at the RCH in January of each study year (Table 1). Hatchery fish were removed from the main populations a day (or more) before tagging, and fish were kept off food for 24 hours before tagging events.

On the tagging day, fish were removed from the holding tank(s) and anesthetized with 50 mg/L of Tricaine methanesulfonate (TMS) for 4 minutes before tagging (Keith, I, DFO-SEP, Veterinarian. pers. comm. 2021). The anesthetic bath was buffered with sodium bicarbonate ($NaHCO_3$) to prevent acidification, following the Canadian Council on Animal Care's standardized methodology prepared by Ackerman, Morgan & Iwama (2005). All anesthetic baths included Vidalife (Syndel Canada, Nanaimo, BC), a water conditioner that preserves the fish's natural mucous layer and helps prevent abrasions.

Fish were handled carefully and quickly to reduce the time exposed to TMS and air. All steelhead were tagged with 12 mm FDX-B PIT tags pre-loaded into sterile, single-use needles (Biomark, Boise, ID). PIT tags were administered in steelhead with a fork length ≥ 69 mm (i.e., the tag is no more than ~17.5% of a salmonid's fork length) to minimize the risk of mortality from tagging (Vollset et al. 2020). The needle was gently inserted along the ventral midline just above the pelvic girdle to break the skin. The tag was inserted by pulling the PIT tag gun 'trigger'; inserting the tag towards the head, as the needle is gently drawn back toward the tagger. Once injected, the tag sits within the peritoneal cavity (Figure 2).

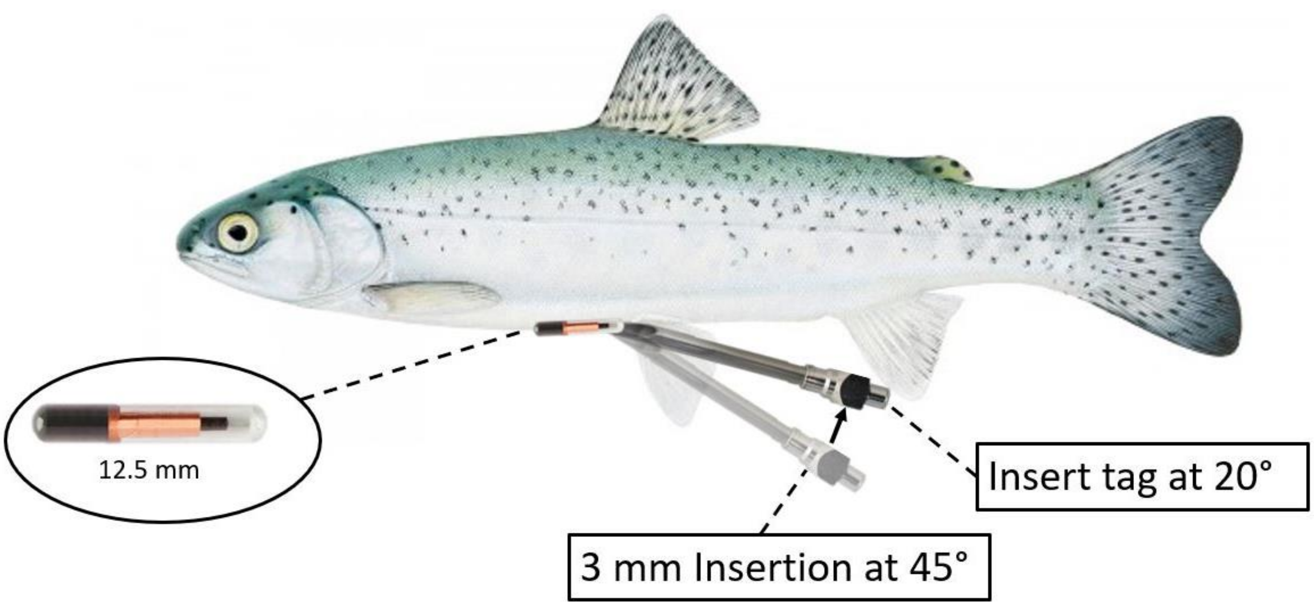

Figure 2. PIT tags are inserted into each fish's body cavity, anterior to the pelvic girdle, using a sterile, one-time-use hypodermic needle (illustration by Joseph R. Tomelleri).

Immediately post-tagging, fish were released into flow-through tagging tables and directed into a holding tank (concrete raceway in 2021 and circular tanks in 2022 and 2023). Tagged fish were monitored for PIT tag rejections and tagging-related mortality for a minimum of 14 days before release. Discarded PIT needles were scanned at the end of each tagging day to check for squibs. A squib is a tag that did not properly eject from the preloaded needle and was detected post-tagging in the discarded needle pile.

A total of 15,000 tags were deployed during the study; 5,000 each year. Although winter-run steelhead were the target population for this study, in 2021, an unknown number of summer- and winter-run steelhead were tagged due to the mixing of cohorts during rearing. In Years 2 and 3, only summer-run steelhead were tagged.

In Year 1, tagged steelhead could not be held in separate tanks (one for each release group) post-tagging due to facility capacity. Due to this, tagged steelhead were scanned during the loading prior to transportation. PIT tag scanning was done with a Biomark HPR plus handheld reader and custom-built "loop" antenna using a Biomark IS1001 reader board and 600 v, five conduit, 12-gauge copper wire. Unfortunately, many were not detected due to the high speeds of the fish being transported within tubes. This resulted in a portion of the first year's fish not being confidently assigned to a release group. In Years 2 and 3, release groups were tagged with assigned tags and held in separate tanks to ensure more accurate data collection.

Starting in Year 2, steelhead were tagged in two groups of 2,500 and kept in separate circular tanks during post-tag monitoring and up until release; this was done to ensure all fish released were properly accounted for.

Differential Releases

Following the conventional mid-May release procedures for RCH steelhead, the FFSBC arrived in the morning to pump fish from their rearing locations into a mobile livewell truck (International 4300 5-ton, 1,800-litre capacity) to be transported to the two river release locations (Figure 1). River release locations were identical across each study year and are the principal locations for the main population releases. The river release locations are ~3 km apart (Figure 1).

The day after the river releases, the ocean release cohort were moved into the live-well truck and transported to Ucluelet Harbour. Steelhead were transferred from the truck into three fish totes (993 L) on a chartered barge. The barge carried the fish as far into Barkley Sound as possible (weather dependent) before fish were released, via buckets, into the ocean. Marine water was added to the fish totes during the transport to help steelhead transition from freshwater to marine.

Ocean group release locations were variable between each study year. The variation in release locations resulted from poor weather preventing the barge from transiting into the open ocean and from pinniped abundances during the final release year, which resulted in a portion of the group being released in two marine locations to avoid congregating pinnipeds (Figure 1).

PIT Tag Detection Arrays

Multiple PIT tag antennas are required to detect PIT-tagged fish during their juvenile freshwater outmigration and/or when they return to spawn. PIT antennas (single) and arrays (multiple antennas) come in various sizes and are constructed specifically to suit the requirements of each site. The Stamp Falls Fishway, a man-made fishway which allows fish to migrate into the upper river, was chosen as the primary and downstream location for a full array (two antennas). Additionally, scanning would be required upstream to confirm detection efficiencies derived at the Stamp Falls Array, so an array was installed in the attraction channel at the RCH, located ~11 km upstream of the Stamp Falls Fishway. PIT antennas were custom-built and installed in the Stamp Falls Fishway and the attraction channel at RCH.

The Stamp Falls antennas were constructed differently, with the upstream antenna being constructed in 2020 as part of another study. This upstream fishway antenna was constructed using 12 AWG single conductor multi-strand copper wire looped 2-3 times inside of ¾" schedule 40 PVC conduit. The dimensions of the antenna were 3.15 m x 0.55 m. The antenna was anchored to the concrete using 6.35 mm x 76.2 mm stainless steel wedge anchors, nylon lock nuts, and metal conduit strapping. The antenna was positioned on the downstream side of the fishway orifice for protection against turbulence and debris. Together, the upstream and downstream antennas comprised the Stamp River Falls array.

The downstream fishway antenna was constructed using 12 AWG, five conductors, and multi-strand copper wire inside a 3.81 cm ABS schedule 80 conduit. The dimensions of the antenna were 2.52 m x 0.40 m. The downstream antenna was anchored to the concrete fishway using 6.35 mm x 76.2 mm stainless steel wedge anchors, nylon lock nuts and four custom-made HDPE brackets (Figure 3). The antenna was positioned on the downstream side of the orifice for protection. It was installed on Aug 22, 2022, and was subsequently damaged due to velocity and was not operational from Mar 15, 2023 - Aug 23, 2023. A new antenna was installed and was operational on Aug 23, 2023, one chamber downstream and on the front side of the orifice, using a larger 3" ABS pipe with the same antenna materials and mounting methods as the first.

The RCH attraction channel PIT array was installed on Aug 23, 2022 (Figure 4). Each PIT antenna within the array was constructed of 0.07 m ABS Solid Core conduit, which housed 12 AWG, 600-volt, five conduit multi-strand copper wire. Each antenna was 0.5 m x 0.5 m.

All four PIT antennas comprising the two arrays (i.e. Stamp Falls and RCH) were operated by single IS1001 boards (Biomark, Boise, Idaho) connected with a synchronization cable and set in a master, secondary master orientation (i.e. one board controls when the other board scans for tags to prevent interference). Twin-axial 16 AWG multi-strand copper wiring connected each antenna to its IS1001 board. IS1001 boards were located above the high-water mark and were stored in a waterproof HDPE enclosure for the Stamp Falls Array and a metal job box (Better Built, 106.68 cm, 2042-BB MODEL 2042-BB), which also housed the battery bank at RCH.

Both PIT arrays (Stamp Falls and Robertson Creek) were powered by four 12 v 125-amp hour AGM batteries (AGM-12125-CI, Stark Energy), with batteries connected in series-parallel to create a 24-volt power bank. Both sites utilized a Biomark battery switcher (24-volt PCB BATTSWITCHER) to allow for external power sources to charge one bank while the second bank powers the PIT arrays; this allows for reduced electrical interference from the external power source, increasing the read range and functionality of the PIT array.

The Stamp Falls external power source was a hydrometric pump (LH1000 Low Head Propeller Turbine, Entergy Systems Design) operated by DFO throughout the summer months. This also powered the fishway camera. During winter, the site was powered by an SFC Energy Methyl generator (125W EFOY ProEnergyBox 4060P Fuel Cell Hybrid System) installed and operated by DFO. The Robertson Creek array used 120-volt shore-based AC electricity, allowing full-time power at the site.

Figure 3. PIT antenna array installed at the Stamp River fishway showing the upstream antenna (left) and downstream antenna (right).

Figure 4. The PIT array was installed at the Robertson Creek Hatchery. Antennas are located between concrete blocks in the attraction channel.

Figure 5. PIT antenna IS1001 reader board housings for Stamp Falls array (left) and the Robertson Creek array (right).

PIT Array and Antenna Efficiencies

PIT arrays are not 100 % efficient, and some tags pass over without detection. Therefore, the detection efficiency (DE) of the arrays needed to be calculated and incorporated into our analyses. Calculating DE can be done in several ways depending on the number of PIT antennas and the direction of tag travel, and it is crucial for understanding the dynamics of fish migration and survival. This section outlines the calculations to determine PIT array efficiencies at the Robertson Creek and Stamp Falls arrays.

Individual Antenna Detection Efficiency

Detection efficiency for each antenna was derived using a methodology inspired by Connolly et al. (2008), which accounts for inter-transect detection overlaps.

The equation employed is as follows:

Eq. 1. $$DE_t = \frac{A_t}{A_t + U_t}$$

where:

DE_t is the detection efficiency of transect *t*, A_t is the number of unique tags detected at transect *t*, and U_t is the estimated number of unique tags undetected at transect *t* but detected at other transects.

System-wide Detection Efficiency

The Stamp Falls array efficiency (SFE) evaluates the detection capability at the Stamp Falls fishway. This efficiency is calculated by comparing the detections at the Stamp Falls array to those at the Robertson Creek array.

The equation is as follows:

Eq. 2. $$DE_{system} = \prod_{t=1}^{4}(1 - DE_t) \times 100$$

where DE_{system} is the system-wide detection efficiency, and DE_t is the detection efficiency of each transect *t*.

Smolt to Adult Survival Estimates

Smolt-to-adult survival (SAS) was defined as detecting a fish at the Stamp Falls array after at least one year post-release, and only if that individual was not detected at an antenna within the first ten months post-release; these fish are considered to be resident.

Survival (S); from release (river or ocean) to river escapement was calculated as:

Eq. 3. $$\left(\frac{SF}{RG}\right) * 100 = S$$

where SF is the number of total tags detected at the Stamp Falls PIT array, and RG is the number of total tags deployed in each release group.

Confidence intervals with 95% coverage were calculated for survival proportions using the Clopper Pearson interval (known as the *exact* method; Clopper and Pearson 1934); this is due to the normal approximation of the binomial interval being unreliable for small sample sizes and survival proportions near 0.

Data Wrangling and Analysis

All data wrangling and analyses were completed using R statistical software (R Core Team 2023; version 2023.09.01 "Desert Sunflower"). Data wrangling and cleaning were conducted using the dplyr package. Analyses and figures were conducted using Base R functions and Tidyverse (Wickham et al. 2019).

RESULTS

Tagging-Related Mortality and Tag Rejection

Steelhead tagged at the Roberson Creek Hatchery were monitored daily for tagging-related mortalities and tag rejections during the initial 14 days post-tagging. Over the three years, 134 tags were associated with mortality, rejection, or squib, resulting in an overall tagging-related mortality rate of 0.7% and a tag rejection rate of 0.05% (Table 1).

After accounting for tagging-related mortalities, rejections, squibs and unknowns (could not be directly associated with mortality or rejection), 14,866 steelhead were released during the three-year study.

Table 1. Summary of tagging related mortalities and rejections during each study year.

OUTMIGRATION YEAR	TAG STATUS	COUNT (N=)
2021	unknown	8
	mort	44
	reject	2
2022	unknown	3
	mort	62
2023	unknown	9
	reject	5
	squib	1

Differential Releases

A total of 6,897 hatchery steelhead were released in the Ocean group, while 6,443 were released in the River group across the three years of the study. 1,526 steelhead were unable to be allocated to either group for the 2021 release year and are marked as unknown (Table 2).

Table 2. Summary of hatchery steelhead releases and tagged releases, 2023.

OUTMIGRATION YEAR	DATE TAGGED	RELEASE GROUP	RELEASE DATE	TOTAL TAGS DEPLOYED	TOTAL RELEASE GROUP
2021	2021-01-20	Ocean	2021-05-14	1,933	1,933
		River	2021-05-13	1,487	57,057
		Unknown	N/A	1,526	1,526
2022	2022-01-18	Ocean	2022-05-12	2,470	2,470
		River	2022-05-11	2,465	60,667
2023	2023-01-18	Ocean	2023-05-16	2,494	2,494
		River	2023-05-15	2,491	30,320

System Detection Efficiency

Since the PIT antennas were installed in August 2022, 112 individual steelhead have been detected (Table 3).

2022/23 Detection Efficiency

A total of 5 returning steelhead were detected at the Stamp Falls array in the fall/winter of 2022 and 2023 (Table 3). Only one returning adult steelhead was detected on the RCH array. However, that individual was detected on the Stamp Falls array, resulting in a 100% detection efficiency for the array and each antenna in the Stamp Falls array (Eq. 1, Eq 2; Table 3).

2023/24 Detection Efficiency

Thirty-two steelhead were detected returning in fall/winter 2023/2024 (Table 3). Of the 31 steelhead detected on the Stamp Falls array, 12 were redetected on the RCH array, resulting in a detection efficiency at the Stamp Falls array of 96% (Eq 1, Eq 2; Table 3).

Table 3. Summary of PIT antenna detection efficiency based on methods described by Conolly et al. 2008. This table does not show system-based detection efficiencies; it only shows individual antennas. SRF = Stamp River Falls; RCH = Robertson Creek Hatchery.

RETURN YEAR	VARIABLE	SRF FISHWAY LOWER	SRF FISHWAY UPPER	RCH LOWER	RCH UPPER
2022	Unique Tags Detected at Antenna (N)	5	5	1	1
	Detection Efficiency (%)	100	100	20	N/A

2023	Unique Tags Detected at Antenna (N)	15	31	11	13
	Detection Efficiency (%)	47	96	34	N/A

Steelhead Movements

Residualized steelhead

Steelhead detected within the first ten months post-release were considered residualized. A total of 31and 37 steelhead were detected in 2022 and 2023, resulting in a minimum residualization rate of 1.3 and 1.5%, respectively. Only one fish from these detected river releases was redetected after 10 months post-release. And this fish, from the 2022 river release group was detected at the Robertson Creek array in January 2024. These residualized fish migrated ~4 to 8 km upstream post-release, into the fishway, and likely into the upper river. All detections of steelhead at the Stamp Falls array are presented in Appendix A.

Stamp Falls Bypass Rates

In 2023, 13 returning steelhead were detected on the Robertson Creek array. Of those, 12 were detected on the Stamp Falls array, specifically the upper fishway antenna (A2); this results in a Stamp Falls bypass rate of ~7.7%. Resulting in approximately 92.3% of all returning steelhead utilized the fishway to migrate into the upper river.

Adult Return Timing

Due to the mixing of stocks during the 2021 study year, steelhead were a mix of summer- and winter-run populations. However, the escapement timing of this mixed cohort covers both run timings, indicating that both runs were, in fact, tagged and released. In the 2022-2023 return year, the first adult steelhead was detected on September 5, 2022, with the last detection occurring on January 29, 2023 (Figure 6). There is no visible separation between the return timing of summer-run and winter-run cohorts.

However, the 2023-2024 return year showed a bimodal return of steelhead (Figure 6). The first adult was detected on June 29, 2023, and detections continued frequently until September 15, 2023; however, no detections of new adult steelhead returned between September 15 and November 29, 2023. Detections of returning steelhead began again on November 29, with the last detection occurring on January 29, 2024. These two distinct migration times likely indicate a split between the summer and winter-run cohorts from the 2021 release.

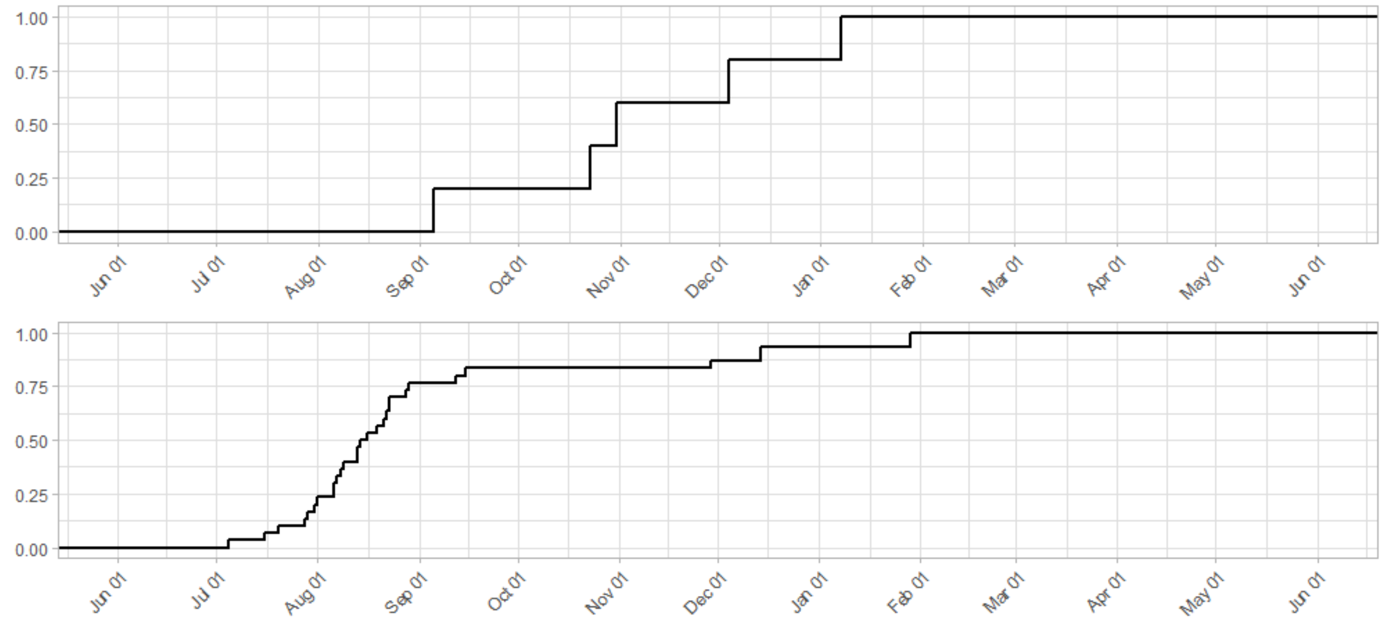

Figure 6. Adult return timing for the 2022-2023 (top) and 2023-2024 (bottom) returns. These return curves represent fish from the 2021, and 2022 release groups. Both summer and winter run steelhead cohorts are represented, from the 2021 release group, due to mixing of stock before tagging. The 2022 release group was comprised of the winter-run cohort only.

Smolt to Adult Survival

As of April 23, 2024, 37 steelhead have been detected returning on the Stamp Falls array. Survival for the 2021 river release and unknown release groups to return age 2 were 0.20 and 1.01% and 0.07 and 0.26% for return age 3, respectively. There were no returns from the 2021 ocean release group, resulting in an overall survival to age 3 of 0%. The 2022 river and ocean release groups have survival rates of 0.53% and 0.04%, to age 2 (Table 4). Additional, years are required to calculate overall survival for all study years.

Individuals detected within the first ten months post-release were removed from survival estimates as these individuals likely residualized and thus will not have gone to sea. Further, due to no returns from the 2021 ocean release group and a few returns from the unknown group (2022: n = 1, 2023: n = 4), the unknowns were included into the river release adult survival calculation.

Table 4. Summary of Smolt to Adult Survival Rates.

OUTMIGRATION YEAR	RELEASE GROUP	RETURN YEAR	SURVIVED	TAGS DEPLOYED	SURVIVAL PERCENT (95% CI)
2021	River	2022	3	1,487	0.20 (0.07 – 0.58)
2021	Ocean	2022	0	1,933	0.00
2021	Unknown	2022	1	1,526	0.07 (0.02 – 0.36)
2021	River	2023	15	1,487	1.27 (0.41 – 0.98)
2021	Ocean	2023	0	1,933	0.00
2021	Unknown	2023	4	1,526	0.26 (0.11 – 0.67)
2022	River	2023	13	2,465	0.53 (0.31 – 0.90)
2022	Ocean	2023	1	2,470	0.04 (0.01 – 0.22)

DISCUSSION

The findings from this study provide new insights into the survival rates of hatchery-reared steelhead, with a particular focus on the early marine period, residualization, and adult returns. The implementation of a marine release strategy aimed at circumventing the lower river, estuary, and Port Alberni inlet areas represents a novel approach to improving survival rates by reducing exposure to predation and environmental hazards. Despite the potential of this method, the absence of returning adults from the 2021 ocean-released cohort and the return of only one individual from the 2022 cohort after 468 days underscores the complexity and unpredictability of steelhead survival.

To date, 37 steelhead have been detected returning, with the majority observed at the Stamp Falls array. These are preliminary numbers, as there is still an additional year of monitoring before final survival estimates can be calculated for the 2021 release year. For the 2023-2024 return year, age 2 steelhead accounted for 42% of the return class, while age 3 steelheads comprised the larger percentage at 58%.

This study highlights the significant challenges in understanding and improving marine survival rates for hatchery-reared steelhead. Factors such as predation, environmental conditions, and anthropogenic impacts are known to play crucial roles during the early marine period (Goetz et al. 2015; Kendall et al. 2017; Malick et al. 2022; Moore and Berejikian 2022), making it difficult to isolate specific causes of mortality and develop targeted mitigation strategies. The dynamic nature of marine ecology further complicates the ability to draw definitive conclusions, suggesting that additional research is needed to identify effective strategies for improving marine survival rates.

Several river-released steelhead migrated upstream 4 to 8 kilometres and were detected on the Stamp Falls array (N = 68) within the first 10 months post-release. Additionally, several fish were detected on the Roberston Creek array, having migrated through Stamp Falls and into the upper river. However, only one residualized steelhead was detected after the 10-month post-release period. This residualized steelhead, released in 2022, was detected on the Robertson Creek array during the later winter spawning season (Jan 29 – Feb 13, 2024). Preliminary residualization rates of 1.3% and 1.5% observed within the first 10 months for the 2022 and 2023 study years, post-release, provide critical data on the behaviour and fate of hatchery-reared steelhead.

The overall survival and rate of residualized steelhead cannot be calculated due to the unknown nature of their behaviour and the lack of PIT infrastructure in the mainstem of the upper and lower Stamp River. The absence of multiple detections of residualized steelhead returning to the hatchery to spawn or outmigrating beyond the 10-month period could be related to in-river mortality and/or outmigration from the lower river after the initial 10 months of residency. Some fish may not have migrated into the upper river but were detected on the Stamp Falls array and then moved back into the lower river. Unfortunately, these details remain unknown.

The impact of steelhead enhancement on wild steelhead and rainbow trout populations remains contentious and unresolved. Previous research has documented the genetic and ecological costs associated with hatchery releases, including adverse interactions with wild populations due to significant rates of residualism among hatchery steelhead (Araki et al. 2007; Kostow & Zhou 2006; Hausch and Melnychuk 2012; Scheuerell et al. 2021). The current study's findings reinforce these concerns, highlighting the need for careful and adaptive management of hatchery practices to minimize negative impacts on wild populations. And with the data in hand changes to the release location of river released enhanced steelhead should be explored to reduce rates of residulatization (Hausch and Melnychuk 2012)

Based on detections at the Robertson Creek array, the Stamp Falls array was determined to have a 92.3% pass-through rate. This indicates that the Stamp Falls Fishway is the primary migratory corridor for adult steelhead migrating into the upper Stamp River. This information will facilitate informed extrapolations of camera count data collected in the fishway, enhancing the understanding of escapement estimates.

Ethical Considerations

The study complied with ethical guidelines and approved by the relevant institutional review board or ethics committee. All necessary permits and permissions were obtained for tagging and monitoring the fish. Data confidentiality and anonymity were maintained throughout the study.

Study Limitations

While experimental releases to understand how to increase the survival of hatchery fish are worthwhile, actualizing the findings if they were positive in this scenario would be difficult. However, drastic differences in survival are easier and cheaper to measure. Experiments such as this provide a better understanding of how to and how not to increase survival. Limitations in monitoring (PIT tag infrastructure) restrict the ability to accurately calculate residualization rates and returns to the lower river, preventing a more in-depth understanding of the behaviours of hatchery steelhead. As such overall residualization rates and survival to the lower river are unknown.

Conclusions

The low survival rates of the 2021 and 2022 ocean release groups, at 0% and 0.4% respectively, are significantly lower than anticipated. In contrast, the survival rate of river-released steelhead to age 3 for the 2021 release was 1.5%, which is comparable to that of the Keogh River (Trevor Davies, WLRS, Steelhead Scientist, 2024). This marks the first time that survival to adult return has been calculated for RCH steelhead.

Despite these initial findings, the ocean release method does not appear successful, given the return of only one individual. However, these results are preliminary, and further data collection over the next three years will be necessary to complete the assessment of adult returns. It is crucial to continue monitoring to obtain a comprehensive understanding of the success of these release methods.

Additionally, the data gathered on the Stamp Falls bypass rate and the residualism of river-released fish provides valuable insights into the effects of hatchery releases. The high proportion of returning steelhead utilizing the Stamp Falls Fishway will enable higher-resolution escapement estimates and facilitate a mark-recapture study. Information on residualization rates is essential for understanding potential competition between wild and hatchery fish in the freshwater environment.

Overall, while these preliminary findings highlight areas of concern, ongoing monitoring and additional data collection will be critical for making final assessments and informing future management practices.

Recommendations

- A full-stream Mainstem PIT array to
  - understand residualization of hatchery fish
  - Winter-run Smolt to Adult Survival
- Release steelhead lower in the river, near tidewater to reduce residualization rates.
- Further work to identify where the bottleneck is and alter marine release location (e.g. maybe release in the estuary is still beneficial at removing freshwater mortality mechanisms and fish will survive better if they can still rear in the estuary)
- Derive accurate outmigration timing
- Annual PIT tagging of hatchery and wild steelhead supported by Provincial Funding to provide required data into proper management of highly angled population
- Develop adult escapement of Summer-run using Mark Recapture methods
  - PIT detections
  - Camera counts

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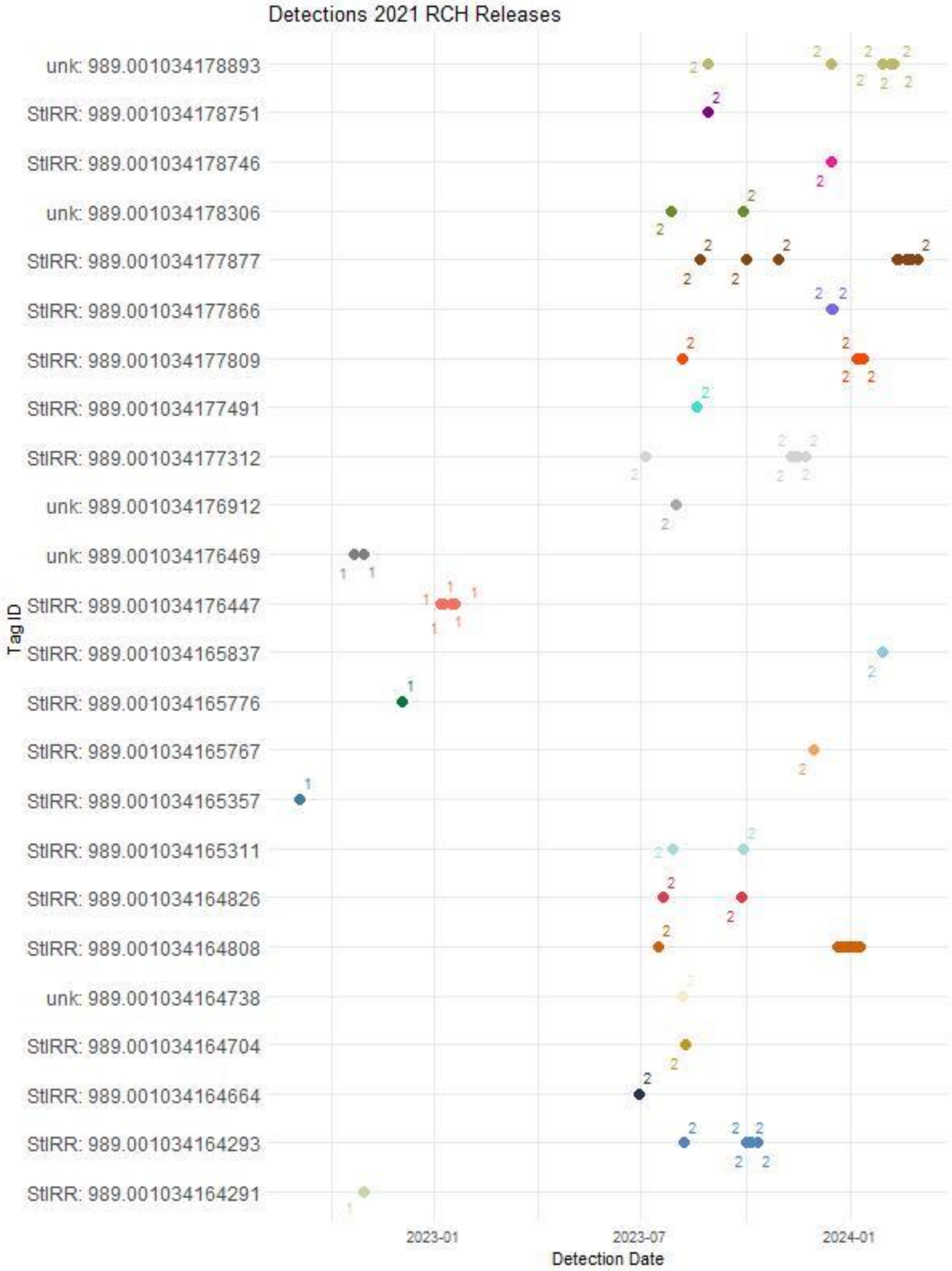
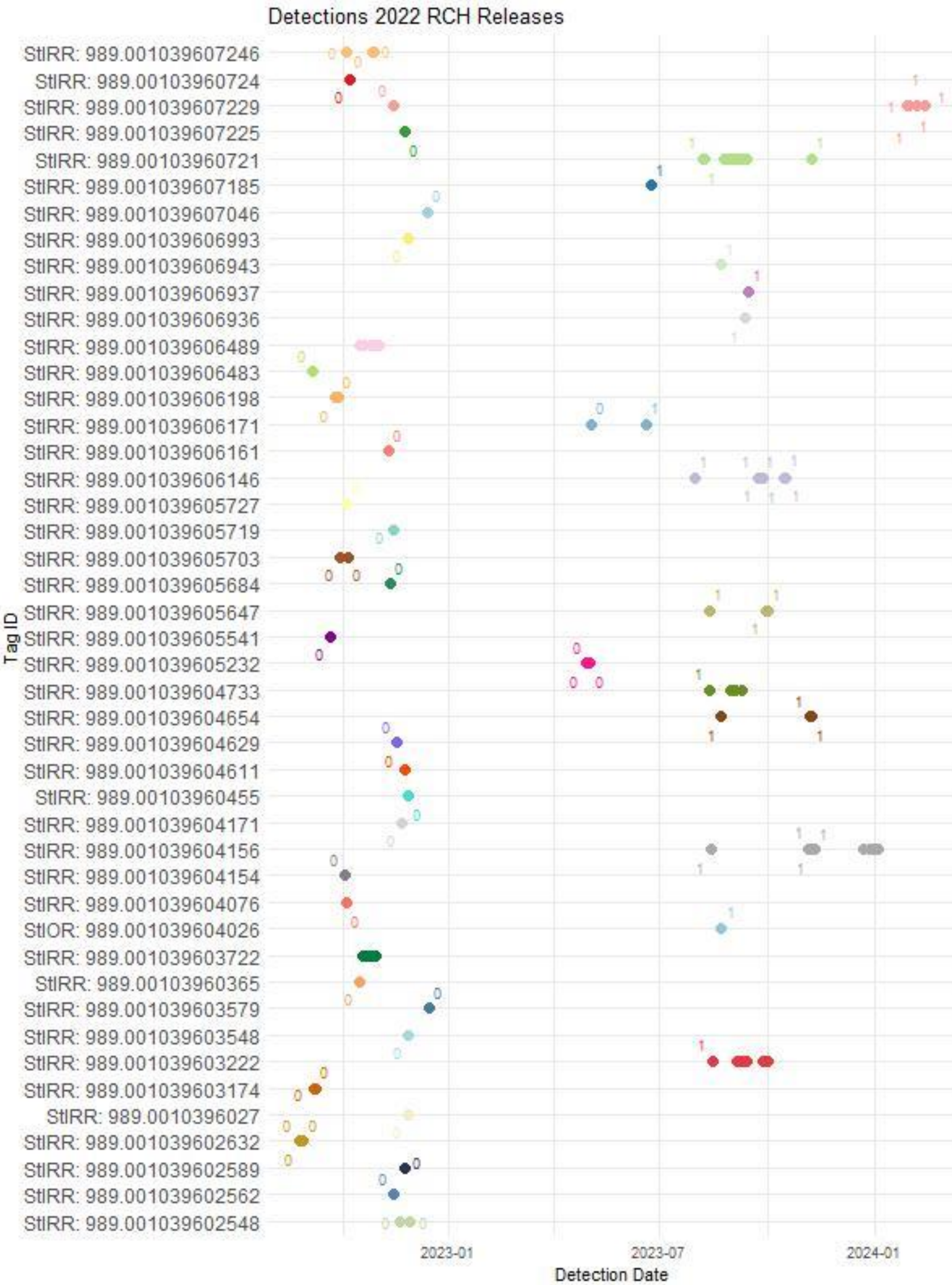
APPENDIX A: DETECTIONS OF STEELHEAD BY RELEASE YEAR AT STAMP FALLS

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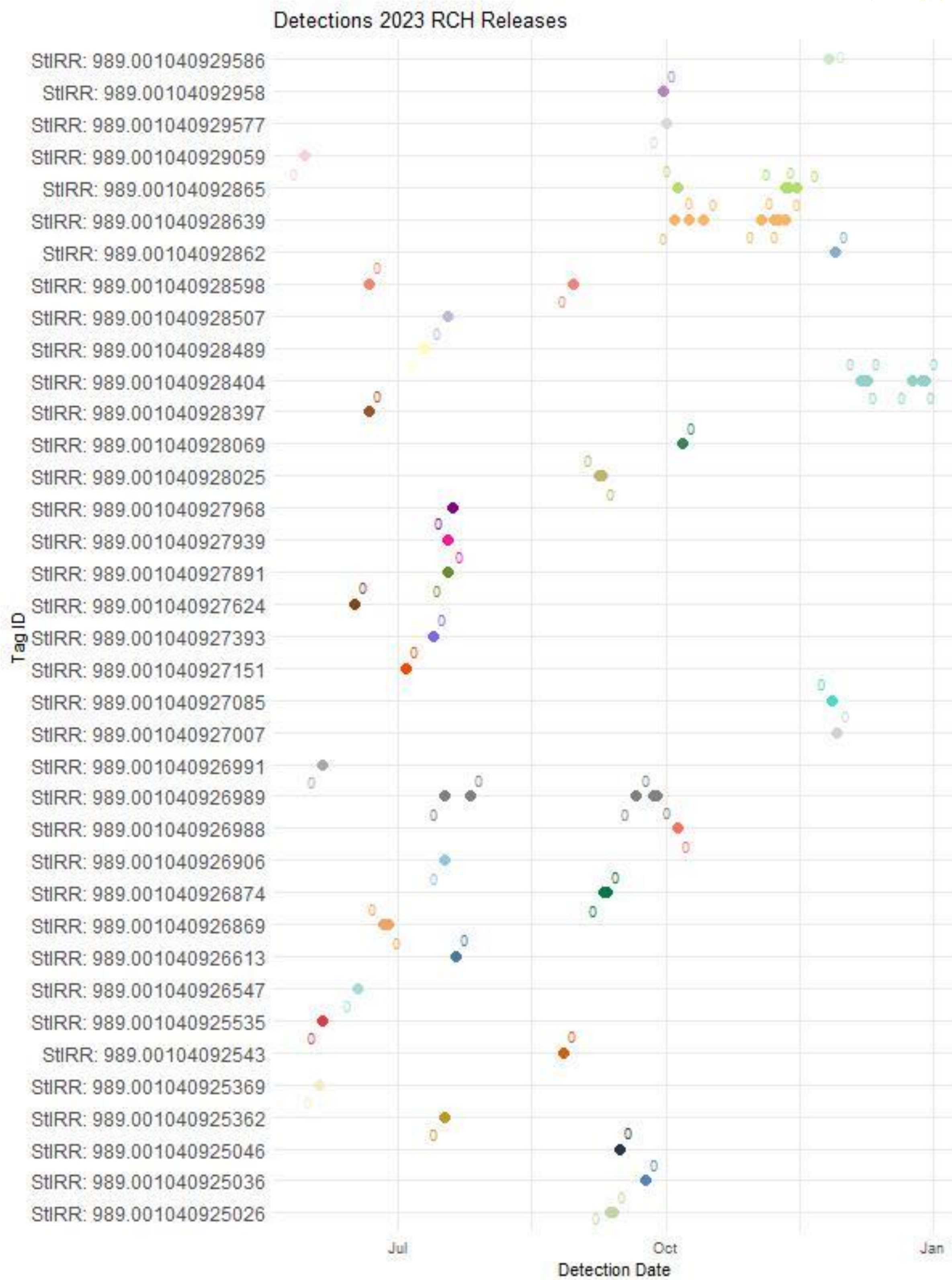
Tag ID
2023-01
2023-07
2024-01
Detection Date



Detections 2023 RCH Releases
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Tag ID
Jul
Oct
Jan
Detection Date

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