2023 McCloud River Winter Run Chinook Reintroduction Pilot Project

Summary Report

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Lower McCloud River near McCloud Bridge fall, 2023

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Executive Summary

In 2022 California experienced a third consecutive year of extreme drought. Consequently, the ability to maintain suitable water temperatures in the Sacramento River for the winter-run Chinook Salmon (*Oncorhynchus tshawytscha*) (winter-run) summer and early fall egg incubation period was a subject of great concern. In response, Fishery Managers, representing the

California Department of Fish and Wildlife (CDFW), the National Marine Fisheries Service (NMFS), and the United States Fish and Wildlife Service (USFWS) established a suite of emergency drought actions, which included reintroducing winter-run to a portion of their historic range in the McCloud River (Figure 1). This action was taken to utilize the known cold-water resources of the McCloud River, which provide suitable water temperatures for winter-run egg incubation even during drought conditions. In the first year of the reintroduction pilot project (Pilot Project), 40,000 winter-run eggs were reared in remote site incubators (RSI's) at Ah-Di-Na campground, with 35,298 juvenile winter-run surviving to be released in the McCloud River. Of those released, 1,600 winter-run juveniles were trapped, transported, and successfully released to the mainstem Sacramento River in Redding California, translating to a 4% conversion rate of eggs received to juveniles released. In the second year of the Pilot Project (2023), 66,041 eyed winter-run eggs were delivered to Ah-Di-Na campground and raised in two different RSI systems. A novel modified inclined plane trap used in conjunction with a fish weir improved capture efficiency of released juveniles, leading to 7,775 winter-run juveniles being transported and released to the Sacramento River, an overall 11.8% conversion rate of eggs received to fish released. The 2023 season improved upon many aspects of the 2022 season, and the contents of this report may be used to support future reintroduction efforts.

1. Introduction

The McCloud River once hosted all four runs of central valley Chinook Salmon (*Oncorhynchus tshawytscha*) and central valley Steelhead (*Oncorhynchus mykiss*). After the completion of Shasta Dam (1945) and Keswick Dam (1950), all anadromous fish populations in the McCloud were extirpated. In addition to anadromous fishes, the McCloud was once home to the Bull Trout (*Salvelinus confluentus*), which was also extirpated after the construction of the dams and is now extinct in California. Winter-run historically spawned in the McCloud and Pit Rivers and now spawn primarily in the Sacramento River below Keswick Dam (efforts to reintroduce winter-run to North Fork Battle Creek are underway). This spawning and rearing habitat must be carefully maintained by cold water releases from Shasta Reservoir. While the Sacramento River winter-run population was initially stable following dam construction, winter-run declined beginning in the 1970s and were listed as endangered under California's Endangered Species Act and threatened under the federal Endangered Species Act in 1989. In 1994, the population was relisted as endangered under the federal Endangered Species Act.

Reintroducing winter-run to their historic habitat in the McCloud River is identified in recent Biological Opinions on operation of State and Federal Water Projects and NMFS Recovery Plans (NMFS 2009, NMFS 2014, CNRA 2017). NMFS 2009 included a "Shasta Dam Fish Passage Evaluation" (SDFPE) which required the Bureau of Reclamation to coordinate with NMFS on developing a "Fish Passage Pilot Implementation Plan". Work on this plan began in 2011 but ended in 2017. A new Biological Opinion on operation of State and Federal Water Projects was finalized in 2019 but did not include an SDFPE element (NMFS 2019), and work on McCloud River winter-run reintroduction remained idle.

The spawn timing of winter-run, from late April through early August, is unique amongst all runs of North American Chinook Salmon. This timing represents a significant challenge for a species restricted below dams on the warmer valley floor, especially in the face of a changing climate. Winter-run eggs experience mortality when river temperatures exceed 56 degrees Fahrenheit (EPA 2003). The state of California's Water Control Board is tasked with maintaining Sacramento River water temperatures below 56 degrees from Keswick Dam to the Red Bluff diversion dam (Order 90-5).

In spring of 2022, California was facing its third consecutive year of drought, with January through March being the driest three months on record for Northern California. Shasta Reservoir's storage stood at only 1.74-million-acre feet on April 1st, 2022. These conditions left reservoir operators and fishery managers with great uncertainty regarding the ability to maintain suitable water temperatures for winter-run.

Portions of the McCloud River upstream of Shasta Reservoir maintain suitable water temperatures necessary to support winter-run egg incubation during the summer months. CDFW, USFWS, and NMFS, along with the Winnemem Wintu Tribe (WWT), worked together to initiate the Pilot Project within historic winter-run habitat on the McCloud River downstream of McCloud Dam at Ah-Di-Na Campground (Figure 1). Concurrence with the WWT and their spiritual and cultural leader, Chief Caleen Sisk, was a key aspect of the Pilot Project. Following a series of meetings between Chief Caleen Sisk, CDFW, and NMFS, the collaborative group reached an agreement on the implementation of the Pilot Project, including egg sourcing, incubation methods, trapping methods, and important cultural locations for conducting each step of the Pilot Project. The first year of the Pilot Project was successful and laid a solid foundation that could be built upon in future years. The Pilot Project continued in 2023, and the lessons learned in the previous year were used to improve methodology and design.

2. 2023 Pilot Project Summary

2.1 Winter-Run Egg Incubation Systems

In late spring of 2023 CDFW staff and WWT partners selected the gravel swimming beach at Ah-Di-Na Campground for RSI installation. This site supplied sufficient water (head) to the RSI's and provided a larger and more comfortable workstation to accommodate an expanded egg production effort (Figure 3).

For their 2023 egg incubation efforts CDFW staff utilized methods and information from the previous year to improve performance and accommodate increased egg production. CDFW staff elected to again install hatchery Heath Trays plumbed with river water due to their resilience to high turbidity events and ease of maintenance. Several modifications were made to the Heath Tray system to improve upon 2022 efforts. For 2023, two half Heath Tray stacks were used. A large aluminum frame was made with level adjustments in all four corners to level the Heath Tray stacks on the beach, ensuring equal flow dispersal through all trays to provide sufficient oxygen to eggs and developing fry. Both Heath Tray stacks were fixed to the frame adding rigidity to the system.

A second RSI system was also used in the 2023 season- the Nur Nature Base (NNB). An experimental design developed by WWT and UC Davis, the NNB system was designed to create a more natural, hands-off incubation method. The NNB system utilized three egg boxes connected to a large circular tank that functioned as rearing habitat and allowed for volitional passage of fry into the McCloud River. The NNB was installed at the same location as the Heath Tray system, although operated solely by WWT and UC Davis. To perpetuate the hands-off philosophy, thorough mortality checks were not conducted routinely, so no data is available on egg to fry survival in the NNB.

To improve water flow to the Heath Tray system, changes were made to the water intake and plumbing systems. Rather than the homemade fish screen box used in 2022, two Pump-Right pump-screens were deployed to limit debris accumulation. The screens were anchored around large bounders in the river with a 1/4 -inch stainless steel cable. The pump screens were each connected to a section of poly-pipe, which allowed sufficient flow down the vertical gradient. The poly-pipe diameter increased from 1.5 inches to 2 inches in 2023 to improve water volume. The extra water supplied by the larger pipes allowed for the addition of a safety valve so one pipe could service both Heath Tray stacks in case of an emergency (see Daily Operations section 2.3 for more details). The NNB system used a perforated rectangular PVC intake with three fittings at the downstream end, each attached to a section of 2-inch poly-pipe that delivered water to the three egg boxes. A homemade fish screen box and 1.5-inch poly-pipe delivered water to the large circular tank.

2.2 Egg Source and Delivery

As in 2022, all eggs used in year two of the Pilot Project were winter-run eggs sourced from Livingstone-Stone National Fish Hatchery (LSNFH). In 2023, all eggs were delivered from LSNFH to Ah-Di-Na campground by helicopter in three separate groups. The first egg group, delivered on July 12th, 2023, consisted of 25,528 eggs, which were divided by family group into the Heath Tray and NNB incubation systems. The egg group delivered to the NNB system were from six females; the eggs from each female were divided into four equal groups of 588 eggs. Each of these groups were then fertilized by a different male resulting in a total of 14,112 eggs from 24 different genetic pairs. The delivery to the Heath Trays consisted of eggs from five females, which were split into groups and fertilized by 4 males to generate 20 different genetic pairs.

The second egg group, delivered on July 26th, 2023, were once again split into two groups for the NNB and Heath Trays. The eggs were evenly divided into two groups of 14,112. Both egg groups consisted of eggs from six females separated into four groups and fertilized by four different males each, creating 24 genetic pairs for each system.

Shortly after the second delivery on July 26th, the allotment of eggs to the Heath Trays suffered a complete loss. The eggs allotted to the Heath Trays were given a 15-minute bath in Ovadine, an aquaculture grade iodine, to neutralize pathogens that may be present on the eggs before they are introduced to the McCloud River. Eggs delivered to the NNB were not treated with iodine on request of the WWT. An investigation quickly discovered that an erroneously high concentration of Ovadine was used, resulting in the death of all exposed eggs.

The third and final egg delivery took place on August 9th, 2023. Once again, the eggs were split between the NNB and Heath Tray systems. The NNB received 12,001 eggs from five females, each fertilized by four different males, thus resulting in 20 genetic pairs. The Heath Trays received 14,400 eggs from six females, each fertilized by four different males, resulting in 24 genetic pairs.

In total, 80,153 eyed winter-run Chinook Salmon eggs derived from 136 genetic pairings were delivered to Ah-Di-Na Campground: 39,228 to Heath Trays and 40,225 to NNB systems (Tables 3-4). Excluding the eggs that suffered from the catastrophic mortality event, 66,041 viable eggs from 112 genetic pairs were raised in the remote incubator systems, with 25,816 in Heath Trays (Table 3).

2.3 Remote Site Incubation Daily Operations

During the egg incubation season, CDFW staff were continuously present at Ah-Di-Na campground for daily maintenance, emergency response, and educational purposes. Each morning and evening (twice daily), field staff recorded and measured ambient air temperature, water temperature, water level on a nearby staff gauge, and weather conditions. Additionally, the team calculated the flow rate to each Heath Tray stack, in gallons per minute (GPM), by using a stopwatch to record the time to fill a five-gallon bucket. The intake diversions were also checked and cleaned twice daily. Every other day, field staff removed, counted, and recorded the number of dead eggs and fry. Dead eggs were easily identified by their white opaque color rather than the normal bright orange. For a brief period during hatching, cleaning efforts were doubled to remove discarded egg membranes and prevent the growth of harmful bacteria. All information was recorded on a data sheet along with any additional comments, when applicable.

Keeping Ah-Di-Na campground staffed continuously ensured the opportunity to act in the event of flow failure to the incubator systems or other emergencies. In the case of loss of water to the poly-pipe lines, a split, controlled by two PVC ball valves built into the incubator system, could be engaged to divert flow from one line to service both systems with a 5 GPM flow rate. If both lines were to experience loss of water, staff members were instructed to manually add buckets of water to the top of the Heath Trays at approximately 5 GPM until the issue could be fixed by another staff member. In the event of a physical break in the poly pipe, staff were prepared to cut away the broken section and splice in a spare piece of pipe with a double barbed PVC connector and two hose clamps. Once the splice was completed, staff were instructed to drill small holes along the length of poly-pipe to release trapped air. After flow is restored, these holes could be plugged with wood screws. In the case of a dislodged intake, a spare cable was kept onsite to re-anchor the intake, then the above hole drilling procedure would be repeated to release trapped air from the piping. Though none of these possibilities arose, it was essential for staff to be aware of potential failures and have an emergency preparedness plan so that losses could be minimized in the case of such circumstances.

2.4 Remote Site Incubation Survival

Egg to fry survival was calculated by subtracting the number of dead eggs and embryos from the number of eggs delivered. Discounting the catastrophic egg loss event, 25,816 viable eggs were delivered to the Heath Tray system: 11,416 in the first group and 14,400 in the third group. Mortalities in Group 1 totaled 863 (with an additional 15 sacrificed for a separate study), or a 7.57% mortality rate, bringing the estimated release number from this group to 10,538. Mortalities in group 3 totaled just 298 (with an additional 5 sacrificed for a separate study), a 2.07% mortality rate, bringing the estimated release number from this group to 14,097. In total, an estimated 24,635 fry were released into the McCloud River following incubation in the Heath Trays with an overall mortality rate of 4.50% (Table 3, Figure 3).

Overall, the total Heath Tray mortality rate was relatively low compared to the mortality rate observed in 2022. However, Group 1 had a significantly higher mortality rate when compared to Group 3 (Figure 4). Eggs from the first group were distributed among three trays, with the first two trays having approximately 4,700 eggs each, and the third tray having just over 2,000 eggs. CDFW hatchery personnel suspected that the low density of eggs in the third tray was allowing eggs to shift frequently within the tray, leading to a higher mortality rate due to micro abrasions or other factors linked to egg movement. As a result, eggs from the third tray were combined with eggs in the second tray by July 21st. However, higher mortalities continued in the second tray, so it is unknown whether the elevated mortality resulted from undercrowding or if other factors were responsible.

Water temperature within the Heath Trays was tracked with a Hoboware temperature logger beginning on July 16th (Figure 5). Daily temperature varied by as much as 8 °F and reached a maximum of nearly 60 °F on July 18th at 4:00 PM. Daily temperature maxima and means declined as the season progressed, and the eggs from Group 3 were delivered 29 days after the eggs from Group 1, so eggs from Group 3 experienced lower daily water temperatures, potentially contributing to the reduced mortality rate observed in Group 3. However, maximum daily water temperatures in both egg groups still frequently surpassed the ideal water temperature for winter-run egg development (Martin et al. 2017).

Fry/alevin escapement from the Heath Trays was another source of mortality. On several occasions, between a few and hundreds of alevins escaped from their respective trays through gaps or tears in the mesh liner of the incubator trays. This allowed alevins to flow underneath trays and onto the ground. Many “rescue missions” were conducted to save these escapees, and indeed, hundreds of alevins were saved; however, a few succumbed to mortality.

2.5 Winter-Run Fry Release

By early September, eggs from Group 1 had absorbed their yolk sacks and fully developed into salmon fry (Figure 6). Originally, they were intended to be released directly into the river at this stage. However, the traps designed to capture the juvenile winter-run before reaching Shasta Lake were not yet in place. CDFW developed a solution by plumbing a 5-foot circular tank into the existing system as a temporary holding pond that more adequately suited the spatial needs of developing salmon fry, allowed for feeding, and promoted acclimation to multi-directional flow velocities (Figure 7). The fry from the first egg group were introduced to the circular tank on September 2nd and fed hatchery fish feed regularly until release. Once the traps were installed, field staff were cleared to begin releasing the first batch of fry. The fish were released at night on September 13th and 14th, with approximately half released each night. On September 27th, the third egg group was also transferred into the circular tank to allow for additional acclimation to river currents and feeding before release. Similarly, this group was fed several times daily until being released in two separate events on the nights of October 1st and 2nd.

2.6 2023 Trapping Design

In 2023 CDFW implemented construction and operation of an experimental fish weir and trap system to improve capture efficiency of winter run fry released into the McCloud River. CDFW modified two rotary screw traps (RST) into floating inclined plane traps, dubbed "fry scoopers", and integrated them with a channel-spanning perforated screen fish weir to intercept higher numbers of winter run fry. The inclined plane traps were installed in-river just below McCloud Bridge and placed at the point of the V-shaped fish weir to funnel out-migrating fish into the traps (Figure 1,8). The weir was constructed out of large wooden tripods that interlock together with aluminum stringers and steel bars. These connections made a ridged base to support perforated screen panels constructed out of 3/16-inch aluminum sheeting with 1/8-inch holes and reinforced by a steel frame. The weir panels were placed end to end to maximize capture efficiency. To account for the gaps created at the base of the weir by uneven river substrate, large cobble and sandbags were lined in front of the screen panels. The inclined plane traps were designed to function from 18 inches to 4.5 feet of depth and an adjustable trap opening to accommodate changing water levels. The inclined plane traps utilized the live boxes from the RSTs to hold the trapped fish overnight until CDFW staff arrived each morning. Angle iron and stainless-steel punch plate were used to construct the floor and walls of the traps. Both fry scoopers followed the same dimensions and construction methods. Due to the remote nature of the McCloud River, it was necessary to carry all equipment in by hand labor. This required the traps to be made in four pieces, with the final assembly taking place on the riverbank. CDFW's experimental in-river collection system worked in conjunction with DWR's Juvenile Salmon Collection System (JSCS). The JSCS is a "head of reservoir" collection system deployed in 2022 and 2023 which operated in the McCloud River arm Shasta Reservoir, downstream of CDFW's weir and trap and downstream of the riverine/reservoir interface.

Inclined plane traps have several notable limitations. Foremost, they require a smooth river bottom with medium to small gravel. Large cobble and boulders create gaps with the ramp that could allow fish to escape, decreasing capture efficiency. Secondly, they are prone to overtopping when clogged with leaf litter or algae, thus requiring constant monitoring and cleaning. Finally, as flow velocity increases into the trap, the live box fails to create a slow holding refugia for captured fish; an additional screen or cutoff panel may be required.

Installing the weir system and traps required significant effort by staff working in arduous conditions. Higher than normal water levels at the trap location and low visibility in the McCloud River during the construction made it difficult to assemble the weir and traps. After installation, guidance wings between the weir and the inclined plane traps were constructed using seine netting and heavy gauge wire field fencing (Figure 8). Installation of the inclined plane traps began on September 12th and was completed by September 14th. Initially, one trap was installed and fished for 15 days before the second trap was added adjacent to the first. The traps operated successfully but required constant cleaning to keep them operating correctly.

The inclined plane traps, in conjunction with the weir, fished with high capture efficiency in the early season. However, near the beginning of October, the traps began to perform inconsistently; on days with a high leaf load, the live boxes would overflow, allowing fish to escape. Several modifications were made to address the issues, including removing the second inclined plane trap. Ultimately, on October 8th, the remaining inclined plane trap was converted to a single RST for the remainder of the season. The inclined plane trap components were replaced with RST components while retaining the capture efficiency benefits provided by the weir.

2.7 Trap Maintenance and Crew Duties

Field staff arrived daily at the McCloud Bridge trap site between 8:00 and 9:00am. Working in pairs, staff first waded into the McCloud River to brush accumulated debris off the weir screen panels. Regular debris removal on the screen panels was required to reduce velocities going into the live boxes and help guide downstream swimming fish toward the traps. Weir cleaning was repeated at approximately 1pm and again at 5-6pm by an additional weir cleaning crew (WWT staff). This weir cleaning frequency was required to maintain trap performance going into the month of October, when the density of deciduous leaves in the river steadily increased, especially in association with rain and wind events.

Next, field staff cleaned accumulated debris from inside the trap before beginning the process of clearing the live box of fish. The field crew then carefully sorted remaining debris and fish in the live box using dip-nets. All fish were identified and enumerated. Non-target fish species were released onsite below the fish weir, while captured winter-run juveniles were held in buckets. A maximum of 30 captured winter-run were measured (fork length, mm) each day, and any additional captured winter-run juveniles were counted but not measured to limit handling. Images were taken of the first five measured winter-run for a separate morphometric study. All winter-run juveniles were then transferred to a perforated bucket and securely placed in the river to maintain a constant supply of cold, oxygen-rich water until transportation. All data were recorded on a daily paper data sheet. The daily live box cleaning and fish processing duties were identical for both trap types (inclined plane and RST).

2.8 Juvenile Winter Run Transport

At the end of each daily trapping shift, juvenile winter-run were placed in an insulated bucket or cooler for transportation. They were then driven to the Turtle Bay boat launch (river mile 298) on the Sacramento River below Keswick Dam for release. Water temperatures in the fish transport container were taken at the start and end of transportation. The fish were acclaimed for a minimum of 15 minutes at the release site, during which staff gradually introduced river water

(Sacramento River) by bucket until the holding water temperature reached equilibrium with the river water temperature. This process reduced the possibility of thermal shock upon release.

2.9 Trapping Results

Between August 14th and December 18th, a total of 8,017 juvenile winter-run were captured in the modified inclined plane traps and RST. Of those captured, 7,775 were transported to the Sacramento River below Keswick Dam and successfully released, resulting in a survival rate of approximately 97%. This translates to a 12.1% conversion rate of eggs received to fry trapped and an 11.8% conversion rate of eggs incubated in Heath Trays at AhDiNa to fry transported and released in the Sacramento River. Daily catch peaked drastically between one and three nights after fry releases at Ah-Di-Na, then quickly fell and continued at a lower rate (Figure 9). The most fry trapped on a single day was 1,576 on August 15th, two nights after the first release on August 13th and one night after the second release on August 14th. Juvenile winter-run trapped between one and four nights after a release (9/14, 9/15, 9/16, 9/17, 9/18, 10/2, 10/3, 10/4, 10/5, 10/6) totaled 5,622, or 70% of the total catch (Figure 10). Generally, peaks in catch lagged by 1-3 nights after a fish release.

To evaluate juvenile winter-run residency in the McCloud river post release we evaluated the proximity to a fish release and flow rate as predictors of daily catch. We used the number of nights after the closest fish release as a proxy for proximity to a fish release. To linearize the relationship between variables, we applied a logarithmic transformation. A standard constant of 1 was added to daily catch totals so that all values were non-zero before the transformation. Days with missing data were removed. We used Pearson's product-moment correlation to examine the strength of the relationship between daily catch and proximity to a fish release. Perhaps unsurprisingly, the number of nights after a fish release has a very strong negative correlation with the daily total number of Chinook Salmon fry trapped (Figure 11). McCloud River flows were expected to influence the daily catch total, with periods of elevated flows serving as a biological migration signal and leading to increased catches. We used a Pearson's product-moment correlation to examine the strength of the relationship between flow rate and the daily total number of Chinook Salmon fry trapped and found a weak negative relationship, due to multicollinearity between nights after release and flow rate (Figure 12). McCloud River flows are managed downstream of McCloud Reservoir, and seasonal flow increases occur as rain becomes more common in the fall and early winter months towards the end of the trapping season. However, the proximity to the nearest fish release declines with time, hiding potential effects of flow rate. To explore the relevance of flow rate as a driver of catch while accounting for the relationship between total catch and nights after release, we employed a multiple linear regression model specified as $Y = \beta_0 + \beta_1 logDays + \beta_2 logFlow$. The overall model was significant ($P < 2.2e^{-16}$, ${}_{adj}R^2$=0.685, AIC = 276.92), although flow was not a significant contributor to predictive power (P=0.895) and the model had less overall predictive power than a simple linear regression without flow ($Y = \beta_0 + \beta_1 logDays$, $P < 2.2e^{-16}$, ${}_{adj}R^2$=0.688, *AIC = 274.94*) when tested with Akaike information criterion. The linear model is greatly improved when using the next day's catch to account for lag time as fish migrate downstream after release (${}_{adj}R^2$=0.745, *AIC = 254.94*). We tested a linear regression with an interaction effect ($Y = \beta_0 + \beta_1 logDays + \beta_2 logFlow + \beta_3 logDays*logFlow$) to see if an interaction between nights after release and flow rate affected catch and found no evidence of interaction between variables (AIC=278.13). Overall, the linear model between nights after release and the next day's catch performed best and is visualized in Figure 13 with original scale dimensions.

The strong relationship between catch and proximity to a fish release could potentially hide the impact of flow rate. To solve this issue, we examined a subset of data after catches decreased later in the trapping season (10/23/2023-12/18/2023). With this subset of data, we used Pearson's product-moment correlation to examine the relationship between flow rate and catch, finding no significant correlation (P=0.514, R = 0.094). We then tested the above linear models again, finding that the linear regression with an interaction effect now performed best ($Y = \beta_0 + \beta_1 logDays + \beta_2 logFlow + \beta_3 logDays*logFlow$, P=0.0037, ${}_{adj}R^2$=0.203, AIC=125.33; $Y = \beta_0 + \beta_1 logDays$, P=0.027, ${}_{adj}R^2$=0.079, AIC=130.69), and there was a significant interaction between flow rate and nights after release (P=.0073), meaning that the effect of nights after release on daily catch is influenced by daily flow rate. Flow rate can influence catch totals, but this effect is only relevant after the influence of proximity to a fish release has weakened. There was only one occurrence of higher catch during a period of higher flow (11/6/23), which was followed by another day of relatively high catch yet lower flow rate (11/7/23), indicating that increased catches following pulse flow events can continue for at least one day. The relationship between catch and flow is complicated by flow-catch lag and conflicting trap operations, such as low trap efficiency during increased flows or trapping hiatus due to weather conditions, making positive results difficult to identify. Nonetheless, proximity to a fish release remains the largest factor in determining catch, overshadowing any effect of flow rate over the duration of the trapping season.

Since no marking method was used to differentiate winter-run juveniles originating from the Heath Tray and NNB systems, the exact number trapped from each system is unknown. Similarly, outmigration from the NNB system is unknown. The NNB system was designed so that winter-run fry would out-migrate at any time upon their own volition. In theory, this would allow for a steady stream of fry to be out-migrating into the river system, and ultimately into the trap. In contrast, fry reared in Heath Trays were explicitly released in large batches on specific dates. The timing of release events was arbitrary rather than based on biological reference points, so there is no reason to believe all NNB system fry out-migrated at the same time the Heath Tray fry were released. The pattern of daily catch coincides strongly with dates fish were released from the Heath Tray system (Figures 9–10). This pattern is consistent with what would be expected if the majority of winter-run fry trapped originated from the Heath Tray system. Furthermore, the NNB system started with over 14,400 more viable eggs, so, assuming similar mortality rates, many more fry should have been present from the NNB system, which should have further dampened the pattern seen here. This interpretation is supported by the correlation and linear regression results (Figures 11,13), which demonstrate that daily catch is strongly related with the proximity to a Heath Tray system fry release.

2.10 Juvenile Winter-Run Growth

To evaluate juvenile winter-run growth in the McCloud River, we employed a simple linear regression between fork length and date of capture (Figure 14). Fork length had a strong positive relationship with date and was fit by the equation $y = -5.69x10^{3} + 0.292x$, where x is date or the number of days in the river, and y is fork-length in millimeters. Although the majority of fry begin their downstream migration soon after entering the river, some individuals did hold within the river and continued to grow before migrating downriver (Figure 13). This number, however, is relatively few when compared to the overall catch numbers. The origin and release date of each fish was unknown, so the growth model should not be interpreted directly as an equation to predict growth. Rather, it should be seen as a rough guide for expected growth or serve as a timeseries component for evaluation of in-river growth conditions for juvenile winter-run in the McCloud River.

2.11 Trap Efficiency and Mortality

Several different trap configurations were used during the trapping period, each with potentially different capture efficiencies. Efficiency trials were conducted periodically to test capture efficiency, or the number of fish that were captured in comparison to the number that arrived at the trap. Five efficiency trials were conducted. For each trial, juvenile winter-run were sourced from LSNFH, dyed with Bismarck Brown dye, and given a caudal fin clip to make them easily identifiable. The marked fish were then released 300 yards upstream from the trap location. The number of trial fish captured was used to calculate the overall efficiency of the trap. The results of each trial are displayed in Table 5. Capture efficiency was highest when using a single inclined plane trap with an improved weir entrance, and lowest when using an RST.

On several occasions, fish were injured when removed from the trap and later died in transport; we therefore used total mortality (the sum of trap mortality and transport mortality) on a given day to calculate mortality rates for each trap. Mortality rate was calculated as the total mortality on a given day divided by the total number caught on that same day. Results are displayed in Table 6 and Figure 15. The overall total mortality rate was 3.02%. The inclined plane trap mortality rate was slightly lower than that for the RST, although not significantly different. Complications with debris load and concerns over mortality led to a transition from the inclined plane to an RST. The RST was expected to handle debris load better while also minimizing mortality. Anecdotally, the RST was able to continue operations despite high debris flow; however, there was no improvement in mortality rate (Table 6, Figure 14). Given the significantly lower efficiency and lack of improved mortality rate for an RST, an inclined plane style trap should be used in future endeavors with modifications, such as adding a debris boom, to improve capture efficiency and reduce trap-related mortalities.

2.12 Bycatch

Nine different bycatch species or species groups were caught during the trapping season. Results are presented in Table 7 and Figure 16. Spotted Bass (*Micropterus punctulatus*) were the most common bycatch species overall, although the vast majority were trapped within the first 10 days. *Cypriniform* fry were abundant early in the trapping season, then declined in catch frequency as the season progressed. Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*) were rarely or never caught early in the season with the inclined plane trap, then became very common once the trap was switched to an RST. Riffle Sculpin (*Cottus gulosus*), Sacramento Sucker (*Catostomus occidentalis*), Crappie (*Pomoxis* spp.), Kokanee (*Oncorhynchus nerka*), and a variety of Sunfish (*Lepomis* spp.) were all caught in relative low abundance with catches dispersed throughout the trapping season.

Both seasonality and trap type affected bycatch. The inclined plane trap selected for smaller individuals and species, generally excluding larger and stronger fishes that were able to fight the current and escape the trap. The RST prevented these larger fishes from escaping upon entering the trap. This difference in size selectivity could potentially explain why Rainbow Trout and Brown Trout were more frequently trapped later in the season, although seasonality is still likely a contributing factor. Spotted Bass counts were already declining in abundance before the trap was switched to an RST. This could be the result of a seasonal shift, or because trapping and releasing Spotted Bass downstream behind the trap essentially depleted individuals residing near the trap site. With Spotted Bass being the main observed predatory species on juvenile winter-run near the trapping location, a viable predation mitigation method could be to simply install the trap early in the season, monitor bycatch, and release fry after Spotted Bass numbers have subsided.

3. Conclusion

For the past 77 years, until the start of the pilot project in 2022, the McCloud River had been devoid of Chinook Salmon following the construction of Shasta and Keswick Dams. In 2022, 40,000 winter-run eggs were delivered to Ah-Di-Na campground, 35,298 winter-run juveniles were released into the McCloud River, and 1,600 juveniles were successfully trapped and released to the mainstem Sacramento River. In 2023, beginning on July 12th, 80,153 winter-run eggs were delivered to Ah-Di-Na campground in three groups and incubated using two different methods (Heath Tray and NNB systems). Egg mortality and outmigration from the NNB system were not recorded, therefore its contribution to the experimental population is unknown. The mortality in the Heath Tray system was closely monitored: 39,228 eggs were delivered, of which 25,816 were considered viable due to the catastrophic loss of the second egg delivery. Of the remaining 25,816 eggs, 24,635 winter-run juveniles were successfully reared and released into the river. Remote site incubation on the McCloud River was highly successful in 2023. Lessons learned will refine the approach of future efforts to incubate Chinook Salmon eggs on the McCloud River until self-sustaining adult populations are established.

Approximately 20 miles downstream of the egg incubation and fry release site, a trapping site was constructed consisting of a fish guidance weir and fish trapping gear to capture juvenile winter-run released at Ah-Di-Na. This location was just upstream of the river interface with Shasta Reservoir. A novel trap design, based on converting an RST into a modified inclined plane trap was operated in 2023 and had remarkable capture success compared to the standard RST used later in the season. The pattern of daily catch suggests that fish released from the Heath Tray system were highly successful at reaching the trap downstream. The success of fry originating from the Nur Nature Base is much less certain. Furthermore, these results indicate that a majority of winter-run fry begin their downstream outmigration shortly after emergence, which is consistent with observations of juvenile winter-run life history expression within the Sacramento River population (Poytress et al. 2014). Overall, the 2023 season's trapping efforts were a large improvement over 2022 and resulted in the successful transport and release of 7,775 endangered winter-run from the McCloud River to the Sacramento River. Further methodological adaptations based on the results of this report should promote improvements in future reintroduction efforts.

4. References

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5. Tables and Figures

Table 1: The number of eggs received, mortalities, and number released in each egg group in 2022.

Group	Eggs Received	Mortalities	Est. Number Released	Mortality Rate
Group 1	20000	3991	16009	19.96%
Group 2*	20000	719	19281	3.60%
2022 Total	40000	4710	35290	11.78%

Table 2: The estimated trap efficiency for each trial and trap configuration in 2022.

Capture Date	Trap Configuration	Trap Efficiency
9/13/2022	Two RSTs and two fyke nets	38%
10/14/2022	Two RSTs and two fyke nets	12%
11/10/2022	Two RSTs and guide nets	5%
11/30/2022	Two RSTs	13%

Table 3: The number of eggs received, mortalities, and number released in each egg group for the Heath Tray system in 2023. Eggs from Group 2 suffered catastrophic mortality and were not included in the 2023 totals (as denoted by the *).

Group	Eggs Received	Mortalities	Sacrificed for Study	Est. Number Released	Mortality Rate
Group 1	11416	863	15	10538	7.57%
Group 2*	14112	14112	0	0	100%
Group 3	14400	298	5	14097	2.07%
Total	25816	1161	20	24635	4.50%

Table 4: The number of eggs received, mortalities, and number released in each egg group for the Nur Nature Base in 2023.

Group	Eggs Received	Mortalities	Sacrificed for Study	Est. Number Released	Mortality Rate
Group 1	14112	Unk	0	Unk	Unk
Group 2	14112	Unk	0	Unk	Unk
Group 3	12001	Unk	0	Unk	Unk
Total	40225	Unk	0	Unk	Unk

Table 5: The estimated capture efficiency for each trial and trap configuration in 2023.

Capture Date	Trap Configuration	Capture Efficiency
9/20/2023	Single Inclined Plane Trap	38%
9/28/2023	Single Inclined Plane Trap with fish-tight weir entrance	53%
10/5/2023	Dual Inclined Plane Trap	39%
10/11/2023	Single Rotary Screw Trap with weir	13%
11/02/2023	Single Rotary Screw Trap with weir	12%

Table 6: The mortality rates for each trap type and total combined mortality rate in 2023.

Trap Type	Mortality Rate
Inclined Plane	2.90%
Rotary Screw Trap	3.82%
Total	3.02%

Table 7: The total count of all bycatch by species or species group in 2023.

Species	Count
Spotted Bass (*Micropterus punctulatus*)	238
***Cypriniform* Fry**	211
Brown Trout (*Salmo trutta*)	101
Rainbow Trout (*Oncorhynchus mykiss*)	65
Sunfish (*Lepomis* spp.)	10
Crappie (*Pomoxis* spp.)	8
Sacramento Sucker (*Catostomus occidentalis*)	7
Riffle Sculpin (*Cottus gulosus*)	6
Kokanee (*Oncorhynchus nerka*)	3

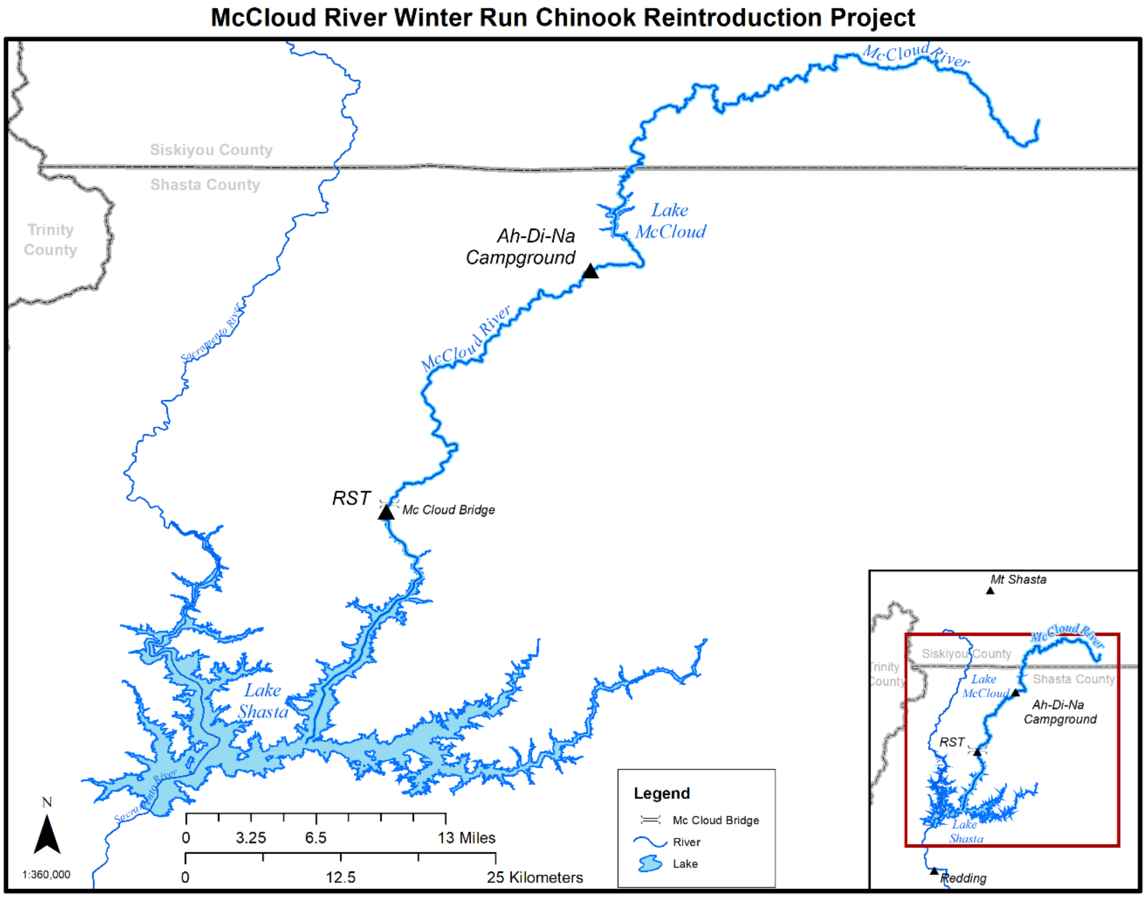

Figure 1: Map of the McCloud River incubation site and trapping location.

Figure 2: Staff from Livingston Stone National Fish Hatchery placing eyed winter-run Chinook Salmon in a cooler for transport to Ah-Di-Na Campground.

Figure 3: Heath Tray system including aluminum framework at Ah-Di-Na campground in 2023.

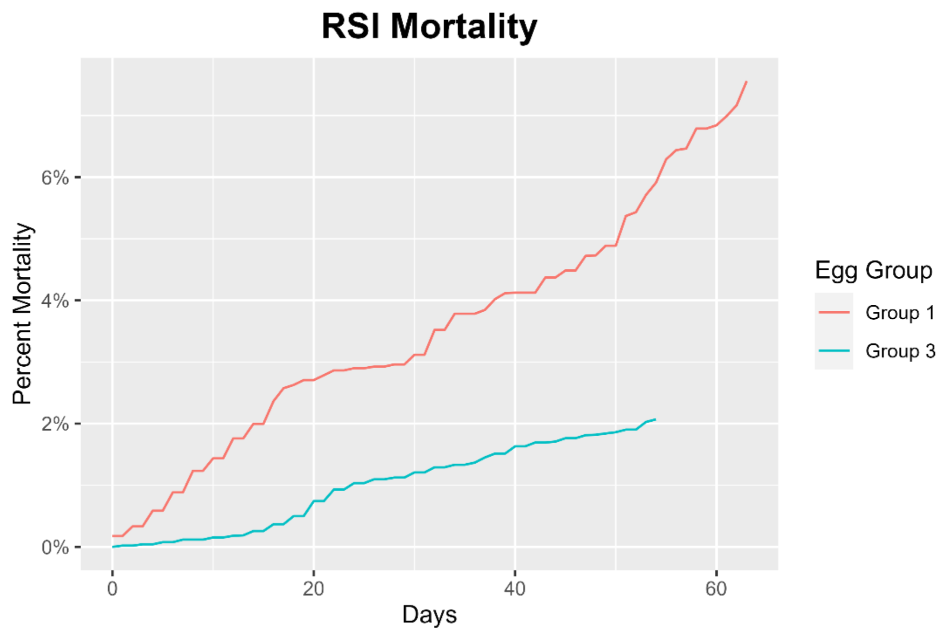

Figure 4: The cumulative mortality rate tracked for each Heath Tray system egg group in 2023.

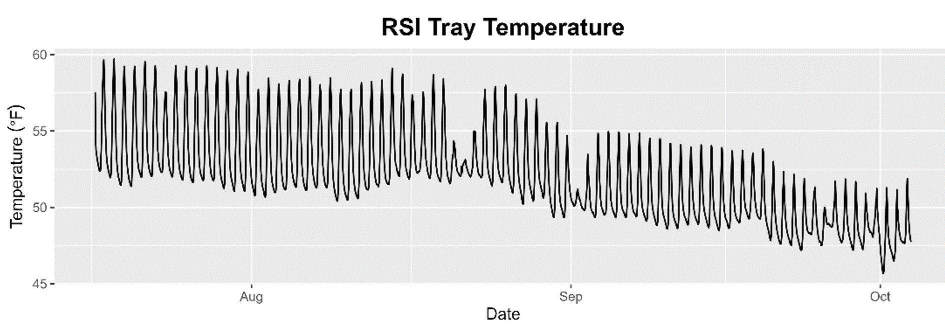

Figure 5: The water temperature, in degrees Fahrenheit, inside the Heath Tray system (RSI Tray). Temperature was recorded every hour in 2023.

Figure 6: Recently developed winter-run Chinook Salmon fry in a Heath Tray that have absorbed their yolk sack.

Figure 7: Fully developed winter-run Chinook Salmon fry being transferred from the Heath Tray system to the circular tank in 2023.

Figure 8: Mesh seine material connection between the inclined plane trap and fish weir utilized to maximize capture efficiency.

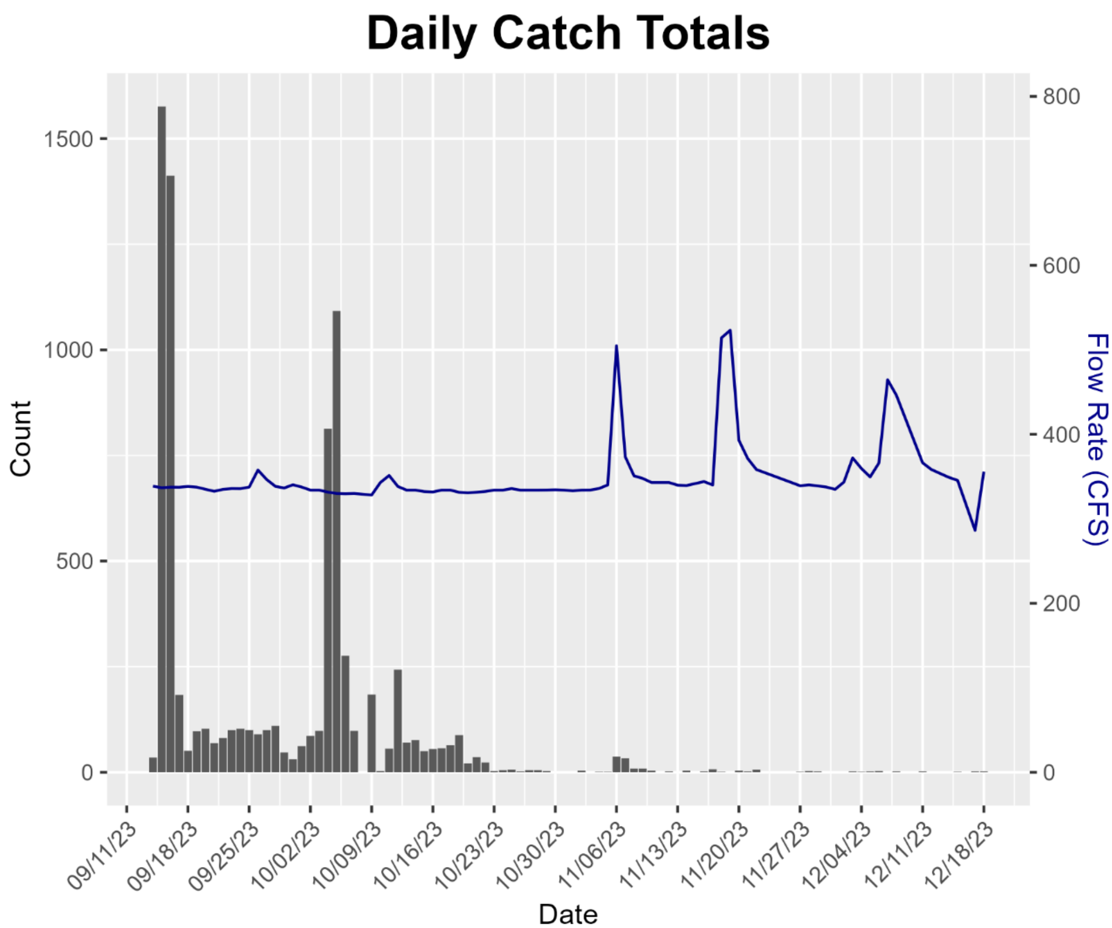

Figure 9: Daily catch totals of winter-run Chinook Salmon fry and the average daily flow rate recorded at the lower McCloud River streamgage (CDEC Station ID MSS) in 2023.

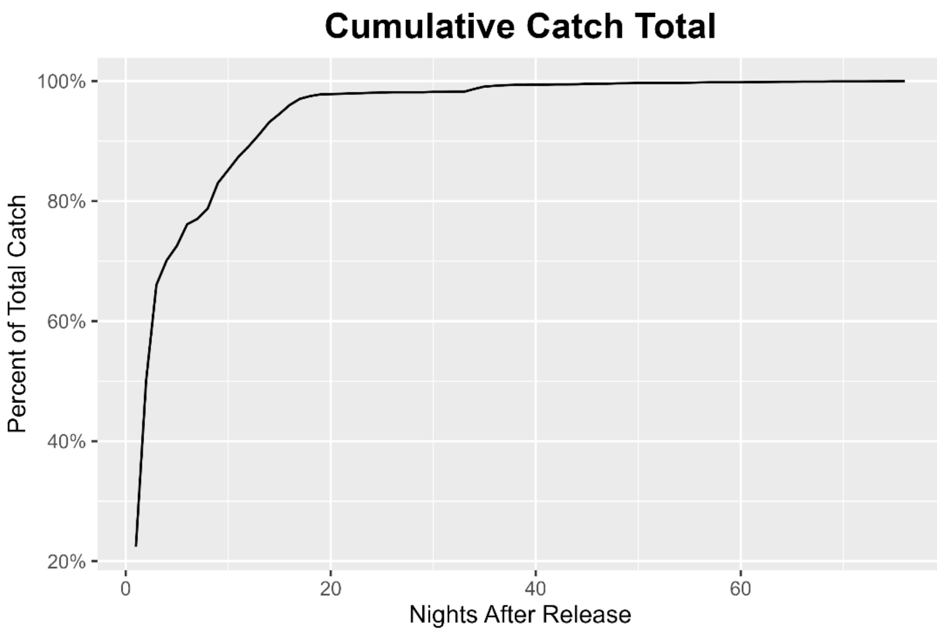

Figure 10: Cumulative percent of total winter-run Chinook Salmon fry caught each day after a Heath Tray system release event in 2023.

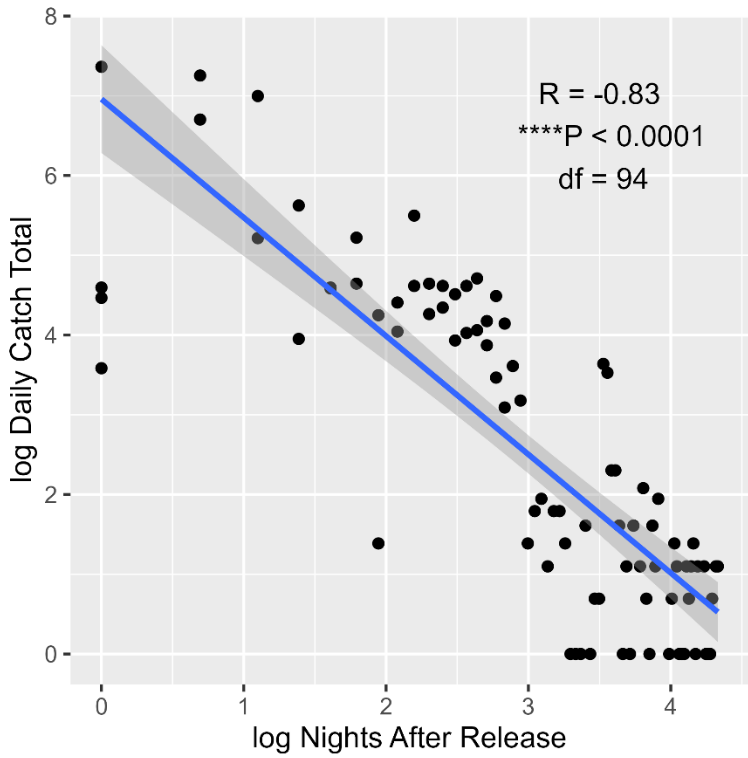

Figure 11: The correlation between logarithmic daily catch total and logarithmic nights after a Heath Tray system winter-run Chinook Salmon fry release plotted with a linear regression line.

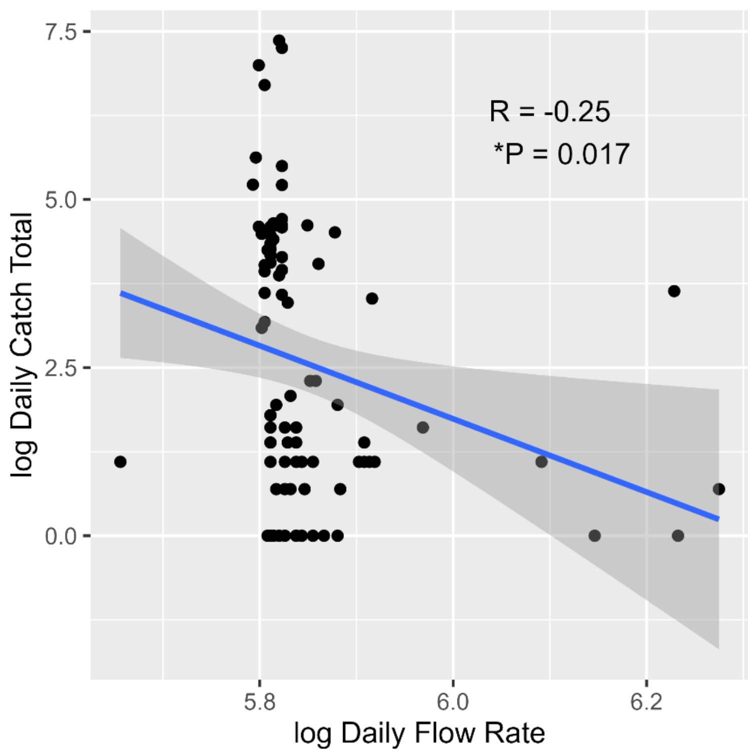

Figure 12: The correlation between logarithmic juvenile winter-run Chinook Salmon daily catch total and logarithmic daily flow rate plotted with a linear regression line.

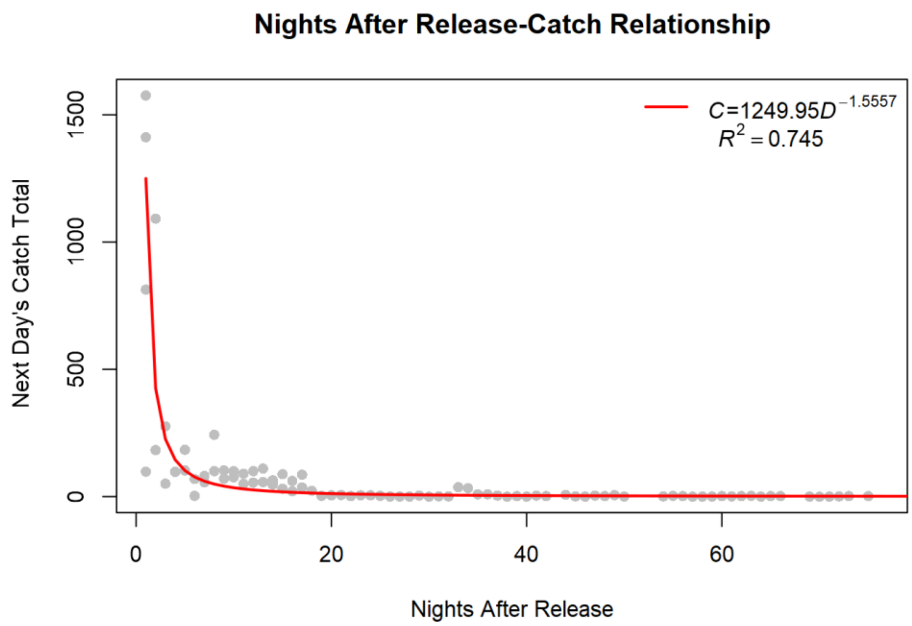

Figure 13: The model between nights after release of winter-run Chinook Salmon from the Heath Tray system and the next day's catch plotted against the data on the original scale dimensions.

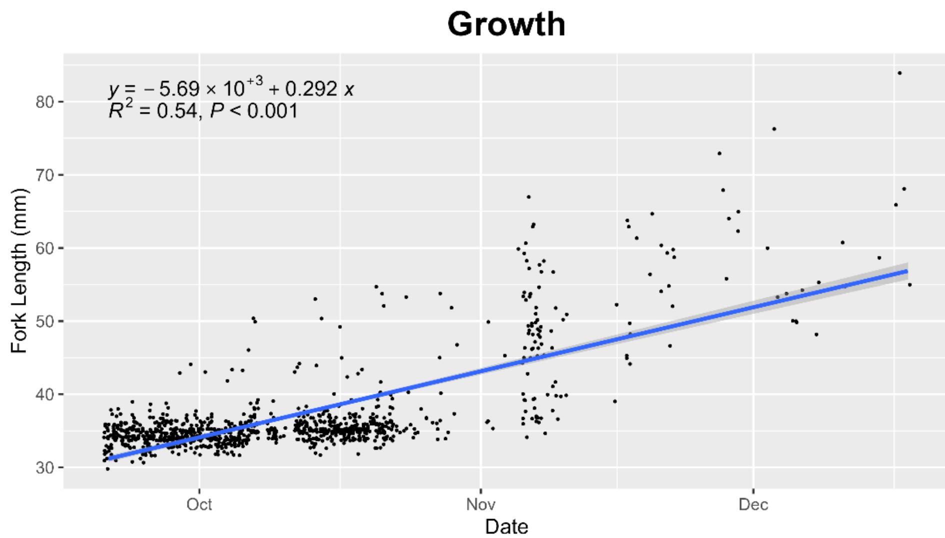

Figure 14: The linear regression of fork lengths of juvenile winter-run Chinook Salmon trapped in lower McCloud River by date in 2023.

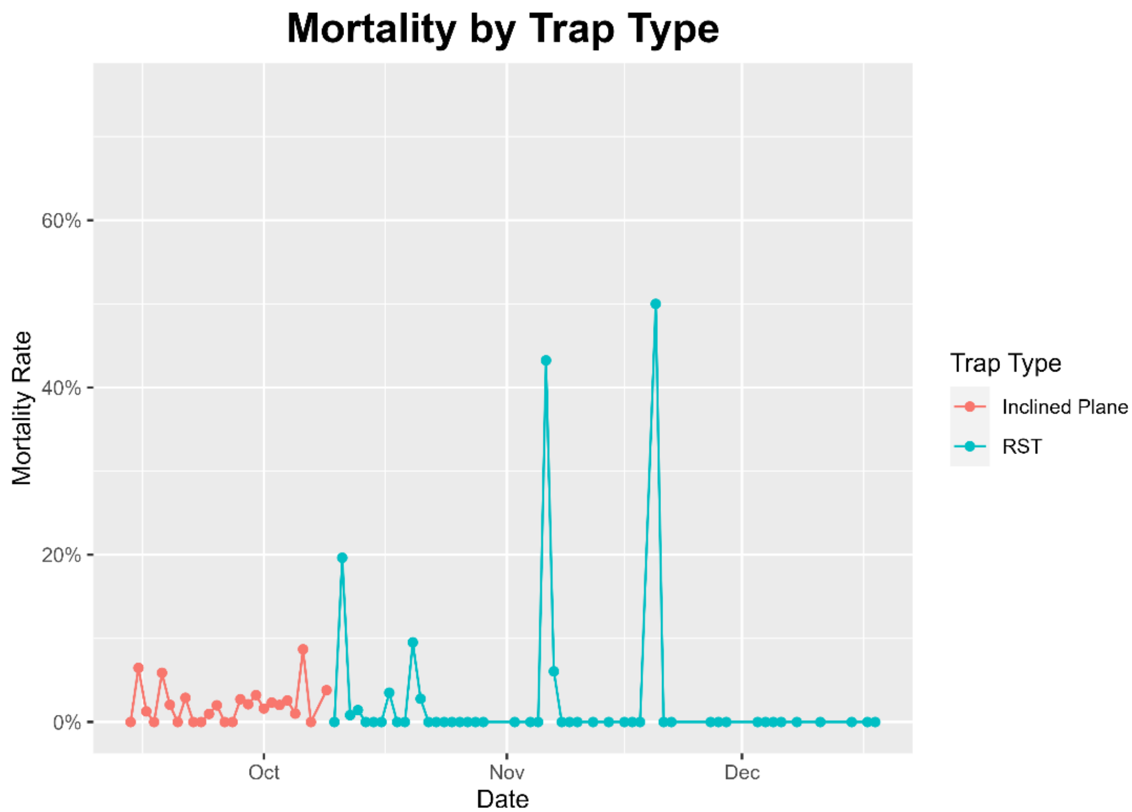

Figure 15: Daily juvenile winter-run Chinook Salmon mortality rate for each trap type in 2023.

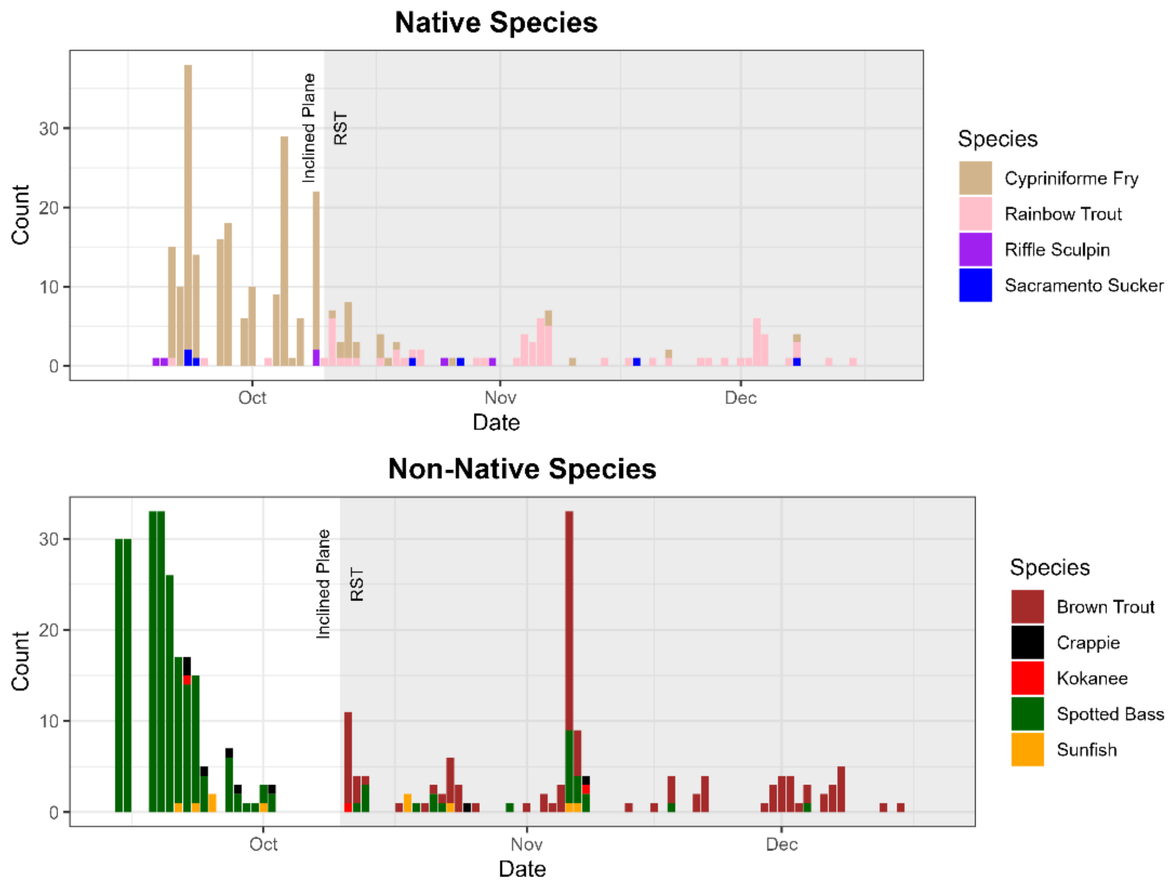

Figure 16: Daily counts of native and non-native bycatch observed during the McCloud River trapping season in 2023.