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Proposal Package for Tracy Fish Facility Improvement Program

Tracy Fish Facility Improvement Program
California-Great Basin · Interior Region 10

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prepared by

Bureau of Reclamation
Tracy Fish Collection Facility

Bureau of Reclamation
Technical Service Center

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Tracy Fish Facility Improvement Program

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Optimal Carbon Dioxide Concentration for Removal of Striped Bass From the Bypass Pipes and Secondary Channel

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Summary

The Tracy Fish Collection Facility (TFCF) was developed in 1956 by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) as a means of salvaging fish and returning them to the Sacramento-San Joaquin River Delta (Delta) beyond the influence of Central Valley Project's C.W. "Bill" Jones Pumping Plant (JPP). To improve the overall salvage process and efficiency of the TFCF, it is necessary to minimize fish loss throughout the facility. Many factors, including predation, contribute to the total fish loss at the TFCF (Liston et al. 1994, Fausch 2000). Predators accumulate throughout the facility, including in front of the trash rack, the primary channel, the bypass pipes, the secondary channel, and the holding tanks (Liston et al. 1994).

In 2004, an alternative predator removal method using carbon dioxide (CO_2) was approved for study. This method does not reduce daily salvage due to secondary channel downtime and is likely more efficient and safer for employees and fish than the historic predator removal method (Wu and Bridges 2014). An initial evaluation of the use of CO_2 as an alternative predator removal technique in the TFCF bypass pipes and secondary channel was completed in September 2007 and demonstrated that elevated CO_2 concentrations are effective for removing predatory fish from the bypass pipes and secondary channel at the TFCF. Results from this initial evaluation have been published as a Tracy Series Report (Wu and Bridges 2014), although the authors did not recommend a CO_2 concentration that should be used upon implementation of this method at the TFCF. To estimate the optimal CO_2 concentration for removal of juvenile and adult Striped Bass based on removal effectiveness and 96.0-h post-treatment survival, consecutive dry ice insertions were performed in the TFCF bypass pipes and secondary channel using initial treatments with varying CO_2 concentration followed by treatment with approximately 300.0 mg/L CO_2 to remove any fish that may have remained after initial CO_2 treatments. Fifteen replicates were completed for this project and used to evaluate both Striped Bass removal effectiveness and 96.0-h post-treatment survival. In addition, 5 replicates were completed during which only Striped Bass 96-h post-treatment survival was investigated.

While CO_2 concentration significantly influenced Striped Bass removal effectiveness within the range of initial CO_2 concentrations tested (i.e., 18.0–300.0 mg/L; with higher CO_2 concentrations associated with greater removal effectiveness), it did not independently appear to have a significant influence on 96.0-h post-treatment survival. In addition, size of Striped Bass (within the range of 85.4–507.7 mm average FL) did not appear to have a significant independent influence on 96.0-h post-treatment survival. It was determined that 96.0-h post-treatment survival was significantly influenced by water temperature, with higher water temperatures associated with reduced survival. Based on these results, it is recommended that the CO_2 concentration estimated to be 100% effective at removing Striped Bass (i.e., 185.0 mg/L) be used during monthly predator removals in the bypass pipes and secondary channel at the TFCF. To obtain a CO_2 concentration of 185.0 mg/L within the TFCF bypass pipes and secondary channel using current procedures, approximately 89.7 kg (197.8 lbs) of dry ice should be inserted into each bypass pipe for each treatment. If survival of Striped Bass is a concern, CO_2 predator removals should be avoided at the TFCF when Delta water temperatures exceed 20.0 °C.

Problem Statement

Predation may be significant within the primary bypass pipes and secondary channel because Striped Bass continue to reside within them. Removing these fish with the historic method is dangerous for employees, likely decreases daily salvage, and likely causes damage to the fish and/or fish mortality. An initial evaluation of the use of CO_2 as an alternative predator removal technique in the TFCF bypass pipes and secondary channel has been completed and published (Wu and Bridges 2014), although authors did not recommend a CO_2 concentration that should be used upon implementation of this method. The goal of this project is to determine the optimal CO_2 concentration for the implementation of CO_2 predator removals in the bypass pipes and secondary channel at the TFCF considering removal effectiveness and 96-h post-treatment survival.

Goals and Hypotheses

Goals:

1. Determine the optimal CO_2 concentration for a 15-minute exposure relative to removal efficiency and survival throughout the range of temperature and water quality conditions observed at the TFCF.

2. Estimate a single, set amount of dry ice (kg) that should be inserted per bypass pipe to approximately obtain the optimal CO_2 concentration within the bypass pipes and secondary channel at the TFCF.

Hypothesis:

1. All CO_2 concentrations will result in equal removal efficiency and survival over a 15-minute exposure period.

Materials and Methods

The optimal CO_2 concentration for the removal and survival of wild Striped Bass from the TFCF bypass pipes and secondary channel was investigated by performing consecutive dry ice insertions to obtain initial treatments with varying CO_2 concentration followed by treatment with approximately 300.0 mg/L CO_2. Replicates for this study were performed in concurrence with monthly facility CO_2 predator removals at the TFCF; therefore, labor and materials costs were split 50/50 with TFCF operations.

To obtain water samples for monitoring of pH and CO_2 concentration, it was necessary to install a 1/5 hp pump in the secondary channel prior to the initiation of consecutive CO_2 predator removal replicates. The secondary channel Velocity Control (VC) pumps were operated to achieve a reduced secondary flow of approximately 0.57 m3/s and water flow was initiated into an empty holding tank. Carbon dioxide (in the form of dry ice) was then be injected into the bypass pipes to obtain an initial target CO_2 concentration (approximately 25, 125, 150, 200, 250 and 300 mg/L), and reduced water flow in the bypass pipes and secondary channel was maintained for 15 minutes to increase contact

time between CO_2 gas and water. Using the submersible pump, hose, and pH meter previously described, pH was continuously monitored throughout the 15-minute minimal flow treatment period. Carbon dioxide concentration was measured from a water sample taken at the lowest observed pH to estimate the maximum CO_2 concentration that was achieved during each initial CO_2 treatment. After the 15-minute minimal water flow period, the number of secondary channel VC pumps in operation was adjusted to increase water flow (> 3.4 m3/s) in the bypass pipes and secondary channel for 15 minutes to flush lethargic fish downstream into a holding tank.

After conclusion of the 15-minute increased flow period, water flow was switched to an empty holding tank, reduced in the bypass pipes and secondary channel, and the process was repeated with the insertion of approximately 136.1 kg of dry ice per bypass pipe with the intention of obtaining a CO_2 concentration of approximately 300 mg/L in the bypass tubes and secondary channel to remove any fish that may have remained after the initial CO_2 treatment. A CO_2 concentration of approximately 300.0 mg/L was deemed appropriate to achieve 100% removal of Striped Bass from the TFCF bypass pipes and secondary channel over a 15 min treatment period since Wu and Bridges (2014) found that Striped Bass generally reached total loss of equilibrium within 10 min when CO_2 concentration in the water was ≥ 150 mg/L.

Fish collected in holding tanks were transferred to a 356 x 74 x 76-cm (l x w x h) rectangular tank (equipped with aerated, flow-through, raw Delta water) using the 1544.5-L haul-out bucket at the TFCF. Ninety-six h survival was determined for all wild Striped Bass recovered from initial CO_2 treatments. Ninety-six h survival was not investigated for non-target species. Survival and effectiveness of removal for wild Striped Bass collected during the 300 mg/L predator removal efforts that followed each tested CO_2 concentration was not determined due to the fact that fish collected in this sample were exposed to numerous CO_2 concentrations. Striped Bass saved for 96-h survival were removed from the rectangular tank using a dipnet with clear rubber mesh and placed in an ice chest containing oxygenated raw Delta water. These Striped Bass were then transported and transferred to 757.1-L circular tanks (at a density of up to 5 fish/tank) containing only aerated raw Delta water (no salt was added). Feed was withheld during the 96-h survival monitoring period.

Data Analyses

Multivariate analysis was not used during this study because this approach does not compare tests of significance; therefore, interpreting results of multivariate analysis is somewhat subjective (Minitab 2003). In addition, multivariate analysis was not employed because the data set for this study was small and there was an inability to control certain independent variables. Instead of multivariate analysis, polynomial regression analysis was employed to determine relationships between independent variables (i.e., C CO_2 concentration, water temperature, and fish size) and dependent variables (i.e., removal effectiveness and 96.0-h post-treatment survival). Since polynomial regression analysis does not investigate interactions between independent variables, ability to interpret univariate analyses during this study may be limited.

Polynomial regression analysis (Minitab 20; Minitab, State College, Pennsylvania) was used to determine if significant capture-dose and survival-dose responses existed within the range of initial CO_2 concentrations tested (18.0–300.0 mg/L). In addition, polynomial regression analysis was used to determine if removal effectiveness and 96.0-h post-treatment survival were significantly

influenced by Striped Bass size (i.e., average FL) or water temperature (°C). Scatterplots with best-fit trendlines matching polynomial regressions used for analysis (Excel 365; Microsoft Corporation, Redmond, Washington) were used to illustrate the effects of CO_2 concentration, Striped Bass size, and water temperature on Striped Bass removal effectiveness and 96.0-h post-treatment survival. A scatterplot with linear trendline (Excel 365) illustrating the relationship between amount of dry ice inserted (kg) and maximum CO_2 concentration obtained (mg/L) during historical CO_2 treatments performed at the TFCF throughout the yearly range of water temperatures observed at the facility (inclusive of CO_2 treatments outside this study [i.e., replicates from this study during which no Striped Bass were collected, published and unpublished data from Wu and Bridges 2014, and unpublished data from monthly CO_2 predator removals at the TFCF]) was used to recommend an approximate amount of dry ice (kg) that should be inserted into each TFCF bypass pipe to obtain the optimal CO_2 concentration in the bypass pipes and secondary channel.

Assumptions and Limitations

It is assumed that there will be adequate time to complete a final report in FY 2024 and that no other projects or studies will take priority or precedence during the research period.

Coordination and Collaboration

This study will be coordinated with the TFCF staff, Tracy Technical Advisory Team (TTAT), and California Department of Fish and Wildlife (CDFW). Participation and inclusion of research-related updates will be provided at regularly scheduled TTAT and Central Valley Fish Facilities Review Team (CVFFRT) meetings.

Endangered Species Issues, "Take" Considerations

Winter-run Chinook Salmon (*Onchorhynchus tshawytscha*), Steelhead Trout (*O. mykiss*), and Delta Smelt (*Hypomesus transpacificus*) were potentially encountered or affected during this experiment. Based on results from Wu and Bridges (2014), it is possible that mortality of listed species occurred when predator removals using CO_2 as an anesthetic were completed during the normal entrainment season of these species. This is because certain species, such as Delta Smelt, exhibited a lower tolerance to elevated CO_2 levels than Striped Bass and displayed up to 70% mortality over 96 h after being exposed to 100 mg/L CO_2 for 20 min. If listed species were encountered, they were immediately documented, returned to the Sacramento-San Joaquin Delta (if alive), and reported to all appropriate agencies. In order to minimize the risk of mortality to listed species, all attempts were made to complete research activity during seasonal periods in which salvage of listed species was not likely to occur. All fish take for this project was covered under the most recent National Marine Fisheries Service (NMFS) Biological Opinion (i.e., NMFS 2019), as well as the current CDFW Scientific Collecting Permit held by the biology staff at the TFCF. Although the procedures during experimentation may have led to mortality of listed species, the cumulative lethal take of listed species for the facility is likely much higher in the absence of predator removal activities.

Dissemination of Results (Deliverables and Outcomes)

The primary deliverable will be an article published as a Tracy Series Report. Data collection and analyses was completed during FY 2022, and a draft report was submitted to editors during the FY 2022 research period. External peer review was completed by the end of FY 2022 and all peer reviewer's comments/edits were considered during development of the final report, which was submitted to editors in early FY 2023. The final report is currently with Denver Technical Service Center technical writers to ensure Visual Identity and 508 compliance is met. A publication is expected to be posted to the Tracy Fish Facility Improvement Program website by mid-FY 2024. The information in the final report will be directly applicable to the CO_2 predator removals that are completed on a monthly basis at the TFCF to meet Biological Opinion requirements.

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Feasibility of Using Carbon Dioxide to Remove Resident Piscivorous Fish from the Tracy Fish Collection Facility Primary Channel

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Summary

Action IV.4.1(1)(a) of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (BiOp) mandates that the U.S. Bureau of Reclamation (Reclamation) complete studies to determine methods for removal of predators in the primary channel at the Tracy Fish Collection Facility (TFCF) with the goal of implementing measures to reduce pre-screen predation in the primary channel to ten percent or less (NMFS 2009). While a predator removal program in the secondary channel at the TFCF has been ongoing since the early 1990s, there are few options for addressing predator loads in the primary channel. Reclamation personnel have reviewed various means of moving predators through the TFCF system such as electricity, sound, light, and mechanical methods. Many of these techniques are largely ineffective for removing large piscivorous fish, expensive to install and operate, and are logistically difficult to implement

(Fausch 2000). The use of carbon dioxide (CO_2), in the form of dry ice, was recently evaluated as a predator removal technique in the bypass pipes and secondary channel at the TFCF and was found to effectively remove fish, including piscivores, from this area (Wu and Bridges 2014). This suggests the periodic use of CO_2 may also be efficacious for the removal of piscivorous fish from the primary channel at the TFCF. If so, the use of CO_2 in the primary channel could be implemented at the TFCF to meet Action IV.4.1(1)(a) of the NMFS BiOp instead of investing funds for extensive research, design, development, installation and maintenance of more complicated predator removal systems or processes.

Data collection for this evaluation was completed in FY 2019. A total of four CO_2 treatments in the primary channel were completed. The four treatments that were completed include an initial investigation to determine if acoustically tagged Striped Bass (Morone saxatilis) could be influenced or moved to a desired location within the primary channel by injecting dry ice, as well as separate investigations to determine if acoustically tagged Striped Bass could be guided into TFCF holding tanks or pushed downstream of the TFCF (where they do not have an impact on TFCF fish salvage) through an open primary channel louver panel with CO_2 treatment of the entire primary channel. Three of the CO_2 treatments in the TFCF primary channel were completed during 1 pump operation at the C.W. "Bill" Jones Pumping Plant (JPP; approximately 22.7–28.3 m3/s [800–1000 ft3/s] water flow, approximately 0.2 m/s [0.5 ft/s] water velocity) to minimize the volume of water that needed to be treated, although 1 treatment was completed during 2 pump operation at the JPP (approximately 45.3–56.6 m3/s [1600–2000 ft3/s] water flow, approximately 0.3 m/s [1.0 ft/s] water velocity) to determine if the method was feasible with increased water flows.

Preliminary results suggest that CO_2 treatment of the primary channel is a feasible technique to remove resident Striped Bass from the TFCF during 1 pump operation at the JPP, although the process is not 100% effective, is extremely labor intensive, and must be scheduled around certain uncontrollable factors (i.e., the number of pumps in operation at the JPP, tidal height, tidal direction, timing of tides, etc.). Acoustically tagged Striped Bass appeared to exhibit an avoidance response to elevated CO_2 concentrations in the TFCF primary channel and separate treatments of the entire primary channel during 1 pump operation at the JPP removed 41.7% of acoustically tagged Striped Bass by guiding them into a holding tank and 45.4% of acoustically tagged Striped Bass by guiding them downstream of the facility through an open TFCF primary channel louver panel. No fish were collected in a holding tank during CO_2 treatment of the entire TFCF primary channel with an open primary channel louver panel (all fish that were removed were pushed through the open louver panel). It appears that CO_2 treatment of the TFCF primary channel during 1 pump operation at the JPP also results in treatment of the bypass pipes and secondary channel and likely effectively removes fish from these areas as well. Treatment of the entire TFCF primary channel with CO_2 during 2 pump operation at the JPP did not yield the sustained elevated CO_2 concentrations necessary to effectively guide acoustically tagged Striped Bass from the primary channel into a holding tank and there was 0% removal during this operational condition. This suggests that the use of CO_2 for the removal of piscivorous fish from the primary channel at the TFCF may not be feasible when the JPP is operating at more than 1 pump.

Problem Statement

Action IV.4.1(1)(a) of the 2009 NMFS BiOp mandates that Reclamation complete studies to determine methods for removal of predators in the primary channel at the TFCF with the goal of implementing measures to reduce pre-screen predation in the primary channel to ten percent or less (NMFS 2009). The use of CO_2 was recently found to effectively remove fish, including piscivorous predators, from the bypass pipes and secondary channel at the TFCF (Wu and Bridges 2014). In addition, preliminary data from Wu et al. (In Draft) suggests that a CO_2 concentration of approximately 185.0 mg/L is optimal for the removal of Striped Bass from the bypass pipes and secondary channel at the TFCF, considering removal efficiency and survival. This suggests that the periodic use of CO_2 at a concentration of approximately 185.0 mg/L may also be efficacious for the removal of piscivorous fish from the primary channel at the TFCF. Due to this, the feasibility of using CO_2 at a concentration of approximately 185.0 mg/L to remove piscivorous fish from the primary channel will be investigated.

Goals and Hypotheses

Primary Goals:

1. Determine if a CO_2 concentration of approximately 150 mg/L can be reasonably obtained in the primary channel at the TFCF, within 30 min, considering the volume of water that needs to be treated and the amount of dry ice necessary.

2. Determine if a CO_2 concentration of approximately 150 mg/L increases the number of piscivorous fish removed from the primary channel during a 30-min treatment period.

3. Estimate the efficiency of removal for acoustically tagged Striped Bass in the primary channel at the TFCF using a CO_2 concentration of approximately 150 mg/L over a 30-min period.

Secondary Goal:

1. Provide a population estimate of the number of piscivorous fish in the TFCF system (primary channel, bypass pipes, and secondary channel) on the day of experimentation based on the proportion of acoustically tagged striped bass recovered, as well as numbers of wild piscivorous fish collected, during CO_2 treatment in the primary channel.

Hypotheses:

1. The injection of CO_2 in the primary channel will have no effect on the CO_2 concentration in the water due to large water volume and water flow within this component of the TFCF.

2. A CO_2 concentration of approximately 150 mg/L will not increase the number of piscivorous fish species removed from the primary channel at the TFCF.

3. A CO_2 concentration of approximately 150 mg/L in the primary channel at the TFCF will have no effect on the efficiency of removal for acoustic tagged Striped Bass.

Materials and Methods

In order to investigate the feasibility of using CO_2 to remove piscivorous fish species from the primary channel at the TFCF, it was necessary to adopt procedures described by Wu and Bridges (2014) for the secondary channel and modify them for use in an area of the facility with a larger volume of water and greater flow.

Since water flow and velocity in the TFCF primary channel are largely determined by the number of pumping units (1–5) being used for water export operations at the JPP, CO_2 treatment occurred when there was 1 or 2 pump operation at the JPP, which reduced the volume of water in the primary channel that needed to be treated. If possible, CO_2 treatments were performed when there was a slack low tide to further reduce the volume of water that was necessary to treat. Secondary channel velocity and flow rate were maximized to achieve increased water velocity and flow in the primary channel bypass entrances. The maximization of secondary channel water velocity and flow also maximized primary channel bypass ratios (velocity of water going into each bypass versus the velocity of water in the channel), which promoted entrance into the bypass pipes and, ultimately, collection of fish in holding tanks during both the control (30-min facility fish-count performed immediately prior to CO_2 treatment) and CO_2 treatment.

Approximately 2,721.6–3,628.7 kg (approximately 6,000–8,000 lbs) of dry ice was requested to be delivered to the TFCF by the supplier (Innovative Federal Operations Group, LLC, Vista, California) on the day before experimentation. Upon delivery, dry ice was stored in large, outdoor dry ice coolers (0.85 m3; Polar Tech Industries, Inc., Genoa, Illinois) until preparation for injection. These coolers were conveniently located near the head of the primary channel at the TFCF, where injection of dry ice occurred.

To determine the reaction of piscivorous fish to elevated CO_2 treatment in the primary channel, as well as estimate the efficiency of removal when using a CO_2 concentration of approximately 185.0 mg/L during a 30-min treatment period, acoustic tags (Model 795-LY; HTI-Vemco USA, Inc., Seattle, Washington) were used, along with an acoustic system consisting of acoustic tag receivers (Model 290; HTI-Vemco USA, Inc., Seattle, Washington), hydrophones (Model 590; HTI-Vemco USA, Inc., Seattle, Washington), and hydrophone cables (Model 690; HTI-Vemco USA, Inc., Seattle, Washington) installed at the TFCF. The use of this technology allowed for the production of 2-dimensional tracks of acoustically tagged fish before, during, and after CO_2 treatment of the TFCF primary channel. In addition, the use of acoustic tags and 2-dimensional tracks allowed for estimation of removal efficiency when attempting to determine if acoustically tagged Striped Bass could be pushed downstream of the TFCF through an open primary channel louver panel.

Acoustic tags were surgically implanted in at least 10 Striped Bass (number chosen to allow for at least 10% precision) that were collected from the TFCF primary channel by angling. Striped Bass were chosen due to the fact that they were the most prevalent piscivorous fish species encountered during previous predator removal studies performed in the secondary channel at the TFCF (Liston et al. 1994; Wu and Bridges 2014; Sutphin et al. 2014) and are likely the main piscivorous fish species in the primary channel as well. Surgical implantation of acoustic tags in Striped Bass occurred up to 30 days prior to release and Tricaine Methanesulfonate (MS-222) was used as an anesthetic.

After surgical implantation of acoustic tags, Striped Bass were hand-carried to a wheeled recovery tub (228.6-L, 78.7-cm long x 50.8-cm wide x 57.1-cm deep) containing oxygenated 16 °C well water and transported to outside 1.2-m diameter (757-L) black tanks containing aerated, 16 °C well water where they were held at a density of up to two fish per tank. At least 1 week prior to release, tanks were gradually switched from well water to treated Delta water to appropriately acclimate fish. Two hours prior to release, Striped Bass were netted, transferred to perforated garbage cans containing approximately 37.9 L of treated Delta water, and transported to the head of the TFCF primary channel for release. Release of Striped Bass into the primary channel occurred 1 day prior to treatment with CO_2. This was done to demonstrate and verify that Striped Bass in the TFCF primary channel would not willingly move downstream through the facility and into a holding tank within 24 h. To prevent experimental Striped Bass from moving upstream through the 56-mm spaced trash rack at the upstream end of the facility, it was necessary to use only fish greater than 375 mm fork length (FL), which is the minimum size estimated by Sutphin et al. (2014) at which passage through the trash rack is restricted based on data collected at the TFCF. If possible, Striped Bass greater than 485 mm FL were used because Striped Bass up to this length have been found to move upstream through the 56-mm spaced trash rack at the TFCF (Karp et al. 2017). To prevent experimental Striped Bass from moving into the canal downstream of the primary louvers after being released in the primary channel, it was important to refrain from cleaning the primary louvers until after the predator removal in the primary channel was completed.

Prior to the start of CO_2 treatment, 149-W (0.2-hp) submersible pumps (Model 316; Carry Manufacturing, Inc., Munger, Michigan) were installed (at mid-water depth) throughout and downstream of the TFCF (i.e., in the primary channel, secondary channel, and intake canal to the JPP) to provide water samples for monitoring CO_2 and pH over time. The location, number, and configuration of submersible pumps varied based on the objective of each CO_2 treatment. Flow was maximized in the secondary channel to increase velocity at the primary channel bypass entrances and maximize primary channel bypass ratios to effectively guide fish from the primary channel into a bypass pipe and, ultimately, into a holding tank. When attempting to determine if acoustically tagged Striped Bass could be pushed downstream of the TFCF into the intake canal to the JPP, the louver panel immediately upstream of bypass 4 was lifted prior to CO_2 treatment of the primary channel.

To treat the TFCF primary channel, approximately 2,721.6–3,628.7 kg (approximately 6,000–8,000 lbs) of dry ice was distributed and inserted at multiple locations upstream of the trash rack at the head of the primary channel. Dry ice insertion was completed using 1–2 front-end loaders, 1–2 forklifts with tipping bins, 1-2 trash rack cleaning devices, a backhoe, and manual insertion. During insertion of dry ice, all personnel were required to wear appropriate personal protective equipment including, but not limited to, life jackets, harnesses, gloves, safety glasses, and hardhats.

Hydraulic measurements, including primary channel flow, primary channel velocity, primary channel depth, secondary channel flow, secondary channel velocity, secondary channel depth, holding tank flow and holding tank velocity, were recorded from facility meters during each trial. During the initial CO_2 treatment of the TFCF primary channel to determine if acoustically tagged Striped Bass could be influenced or moved to a desired location within the primary channel, CO_2 and pH measurements were taken every 2 min from the TFCF sampling stations using hand-held titration cells (K-1910 [range = 10–100 mg/L CO_2] and K-1920 [range = 100–1000 mg/L CO_2], CHEMetrics Inc., Midland, Virginia) and a pH meter (Model pH 110, Oakton Instruments, Vernon Hills, Illinois), respectively. During the other 3 CO_2 treatments of the TFCF primary

channel, pH loggers (Model SDL100; Extech Instruments, Nashua, New Hampshire) were used to obtain pH measurements every 10 seconds. A CO_2 vs. pH curve was then developed in a laboratory setting by bubbling gaseous CO_2 (using a compressed gas CO_2 cylinder and a microbubble diffuser [MBD100; Pentair, Apopka, Florida]) into a sample of raw Delta water collected prior to each CO_2 treatment in the primary channel. The formula from the CO_2 vs. pH curve was applied to the pH measurements taken by the pH loggers to estimate CO_2 concentration.

When determining if acoustically tagged Striped Bass could be influenced or moved to a desired location within the TFCF primary channel by injecting dry ice, treatment only occurred in the north side of the TFCF primary channel. Acoustic tag detections and/or 2-dimensional tracks were used to investigate Striped Bass behavior in the primary channel during CO_2 treatment. The information obtained during this evaluation was used to guide following research efforts.

When determining if acoustically tagged Striped Bass could be guided into TFCF holding tanks during CO_2 treatment of the primary channel, the number of piscivorous fish collected in a holding tank during the 30-min CO_2 treatment was compared to the number of piscivorous fish collected in a holding tank during the 30-min fish count performed immediately prior to CO_2 treatment (control) to determine if the use of CO_2 in the primary channel increases the total number of piscivorous fish removed from the primary channel. A chi-square test (Minitab version 15) was used to determine if there was a significant difference between the proportions of piscivorous fish collected in holding tanks during the 30-min fish-count (control) and CO_2 treatment. The percentage of acoustically tagged Striped Bass removed from the TFCF primary channel (collected in holding tanks) was used to estimate the efficiency of removal when using a CO_2 concentration of approximately 185.0 mg/L. The proportion of acoustically tagged Striped Bass recovered in holding tanks during CO_2 treatment in the primary channel was used along with the numbers of wild Striped Bass collected to estimate the Striped Bass population in the TFCF system (primary channel, bypass tubes, and secondary channel) on the day of experimentation, which was a secondary objective of this study. To obtain a Striped Bass population estimate using this method, it will be necessary to collect at least 1 acoustically tagged Striped Bass and 1 wild Striped Bass in a TFCF holding tank during CO_2 treatment of the primary channel.

When determining if acoustically tagged Striped Bass could be guided out of the TFCF primary channel through an open louver panel with CO_2 treatment, the most downstream primary channel louver panel was lifted while water continued to be collected in a holding tank. The continued collection of water in a holding tank was necessary since the TFCF must salvage fish whenever pumping is occurring at the JPP. Acoustic tag detections and/or 2-dimensional tracks were used, along with the number of acoustically tagged Striped Bass collected in a holding tank, to estimate removal efficiency. The use of acoustic tag detections and/or 2-dimensional tracks was necessary to determine the number of acoustically tagged Striped Bass removed from the TFCF primary channel through an open louver panel during CO_2 treatment. The number of acoustically tagged Striped Bass guided out of the TFCF through an open primary channel louver panel and the number of acoustically tagged Striped Bass collected in a holding tank were summed to estimate total removal efficiency from the TFCF primary channel when a louver panel is lifted during CO_2 treatment with a concentration of approximately 185.0 mg/L. The number of acoustically tagged Striped Bass guided out of the TFCF through an open primary channel louver panel and/or collected in a holding tank during the 30-min CO_2 treatment was compared to the number of acoustically tagged Striped Bass that left the TFCF through an open primary channel louver panel or were collected in a holding tank during the 30-min period immediately prior to CO_2 treatment (control) to determine if the use of

CO_2 in the primary channel increases the total number of piscivorous fish removed. A chi-square test (Minitab version 15) was used to determine if there was a significant difference between the proportions of acoustically tagged Striped Bass removed between the control and CO_2 treatment. It was not possible to estimate the Striped Bass population in the TFCF system (primary channel, bypass pipes, and secondary channel) on the day of experimentation because no Striped Bass (acoustically tagged or wild) were collected in a TFCF holding tank. In order to obtain a Striped Bass population estimate using this method, it was necessary to collect at least 1 acoustically tagged and 1 wild Striped Bass in a TFCF holding tank during CO_2 treatment of the primary channel with an open primary channel louver panel.

Assumptions and Limitations

This evaluation could only be completed during 1 or 2 pump operation at the JPP and 1-week notice of these pumping conditions was needed to order dry ice and have it delivered to the TFCF. One or two pump operation at the JPP was necessary for a minimum duration of 2 days to complete each replicate. Tidal conditions were considered to reduce the volume of water that needed to be treated. It was necessary to collect wild Striped Bass for use during this evaluation and hold them in the Tracy Aquaculture Facility (TAF); therefore, it was necessary to maintain the TAF so that it was operational. For each replicate, it was necessary to verify the HTI acoustic telemetry systems at the TFCF were fully operational and an appropriate number of personnel (10–12 individuals) were available to perform injection of dry ice into the primary channel at the TFCF. Appropriate safety equipment (dry ice gloves, eye protection, etc.) was used when performing dry ice injections. It was necessary for the Biological Resources group at the TFCF to adjust secondary channel flow during each replicate. In addition, it was necessary to prepare and maintain a contract for dry ice supply and delivery. It is assumed no other projects or studies will take priority or precedence during the FY 2024 research period and that there will be ample opportunity to prepare and finalize a Tracy Technical Bulletin for this evaluation.

Coordination and Collaboration

This study was coordinated with the TFCF biological and operations staff, Tracy Technical Advisory Team (TTAT), California Department of Fish and Wildlife (CDFW), and HTI-Vemco USA, Inc. Participation and inclusion of research-related updates were provided at regularly scheduled TTAT meetings.

Endangered Species Issues, "Take" Considerations

To minimize the risk of mortality of listed species, all attempts were made to complete research activity during seasonal periods in which listed species were not typically present at the TFCF. Despite this, 2 Chinook Salmon (*Onchorhynchus tshawytscha*; 1 fall-run and 1 spring-run according to length-at-date) and 3 Delta Smelt (*Hypomesus transpacificus*) were collected in a holding tank throughout the course of this evaluation. The number and species of fish guided out of the TFCF primary channel through an open louver panel with CO2 treatment is unknown and could have included winter-run and spring-run Chinook Salmon, Steelhead Trout (*O. mykiss*), Delta Smelt, and

other species. Based on results from Wu and Bridges (2014), it is possible that mortality of these species may have occurred because certain species, such as Delta Smelt, do not tolerate elevated CO2 levels as well as other fish (Delta Smelt exhibited 70% mortality over 96 h after being exposed to 100 mg/L CO2 for 20 min). All listed species encountered were immediately documented, processed according to current protocol, returned to the Sacramento-San Joaquin Delta (if alive), and reported to all appropriate agencies. All fish take for this evaluation was covered under the most recent National Marine Fisheries Service (NMFS) BiOp, as well as current CDFW Scientific Collecting Permits held by the Biological Resources staff at the TFCF. Although the procedures during experimentation may have led to mortality of listed species, the cumulative lethal take of listed species for the facility would likely be much higher in the absence of predator removal activities in the primary channel at the TFCF.

Dissemination of Results (Deliverables and Outcomes)

A Tracy Technical Bulletin will be the final deliverable of this study. Updates and presentations of progress will be provided internally and upon request by TTAT and other interagency technical forums. While no progress on report preparation was made during the FY 2023 research period (due to precedence of salvage activity and other TFFIP publications), a draft report is expected to be produced during FY 2024 and a final publication is anticipated by the end of FY 2025. Information will be gained on the successes and limitations of this predator removal technique at the TFCF. This knowledge will help guide future development and implementation of predator removal procedures at the TFCF and other fish facilities.

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Loss of Juvenile Chinook Salmon During Cleaning of the Primary Channel Louvers at the Tracy Fish Collection Facility

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Summary

The Tracy Fish Collection Facility (TFCF) was developed in 1956 by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) as a means of salvaging fish and returning them to the Sacramento-San Joaquin River Delta (Delta) beyond the influence of Central Valley Project's C.W. "Bill" Jones Pumping Plant (JPP). Many factors, including loss of fish through the TFCF

primary channel louver array (98.1-m long x 7.0 m high with 36 louver panels [2.6 m wide x 7.0 m high] each consisting of 84 vertical louver bars [63.5 mm x 4.8 mm] spaced 2.5 cm apart; Reclamation 1956, Reyes et al. 2018), contribute to total fish loss at the TFCF (Karp et al. 2017, Wu et al. 2021). Loss of fish through the TFCF primary channel louver array can occur during regular facility operation or during cleaning of the primary channel louvers. To prevent excessive fish loss through the TFCF primary channel louvers due to undesirable primary channel hydraulic conditions during regular facility operation, it is necessary for the operations staff at the TFCF to clean the primary channel louvers at least once per day. Cleaning the primary channel louvers involves individually lifting and reseating each of the 36 primary channel louver panels to spray debris (i.e., submerged aquatic vegetation) off the louver slats, which creates a temporary 2.6-m wide void in the primary channel louver array that entrained fish can be lost through.

The primary channel louver array is separated into 4 sections (sections 1–4 [from upstream to downstream]) with each section associated with a respective secondary bypass pipe intake (bypass pipes 1–4 [from upstream to downstream]) and consisting of 9 louver panels (Figure 1). Since the primary channel louver array is oriented 15° to water flow in the primary channel (Reyes et al. 2018), the width of the TFCF primary channel gradually decreases as you move downstream; therefore, the rate of fish loss may be different for individual louver panels and/or sections of louver panels within the primary louver array because the probability of a fish encountering the primary channel louver array (during regular operation or cleaning) is increased as primary channel width decreases.

While the loss of fish through the TFCF primary channel louvers during regular facility operation has been thoroughly investigated with various fish species and life stages (i.e., juvenile Chinook Salmon [*Oncorhynchus tshawytscha*; Hallock 1967, Hallock et al. 1968, Karp et al. 1995, Sutphin and Bridges 2008, Karp et al. 2017, Wu et al. 2021], juvenile Steelhead Trout [*O. mykiss*; Karp et al. 2017], adult Delta Smelt [*Hypomesus transpacificus*; Sutphin and Svoboda 2016], juvenile Sacramento Splittail [*Pogonichthys macrolepidotus*; Sutphin and Bridges 2008, Karp and Lyons 2015], juvenile Striped Bass [*Morone saxatilis*; Hallock 1967, Hallock et al. 1968, Karp et al. 1995], adult Threadfin Shad (*Dorosoma petenense*; Hallock 1967, Hallock et al. 1968, juvenile American Shad [*Alosa sapidissima*; Hallock 1967, Hallock et al. 1968], juvenile White Catfish [*Ameiurus catus*; Hallock 1967, Hallock et al. 1968], and juvenile White Sturgeon [*Acipenser transmontanus*; Karp and Bridges 2015]), the extent of fish loss that occurs when the TFCF primary channel louver panels are lifted, sprayed, and reseated for cleaning has not yet been thoroughly researched and/or directly quantified (only Karp et al. 2017 and Wu et al. 2021 briefly discuss this subject matter). While there is already a Tracy Fish Collection Facility Improvement Program-funded research project aimed at investigating loss of fish during cleaning of the TFCF primary channel louvers using DIDSON sonar technology (Bark, In Progress), an experiment with an alternative approach is being proposed to estimate loss of juvenile Chinook Salmon during cleaning of the primary louvers at the TFCF. Information will be gained on the extent of juvenile Chinook Salmon loss that occurs during cleaning of the TFCF primary channel louvers. This information will potentially help refine placeholder loss values used when calculating juvenile Chinook Salmon loss at the TFCF. In addition, the knowledge gained from this experiment may help determine the need for future construction and/or development efforts at the Tracy Fish Collection Facility.

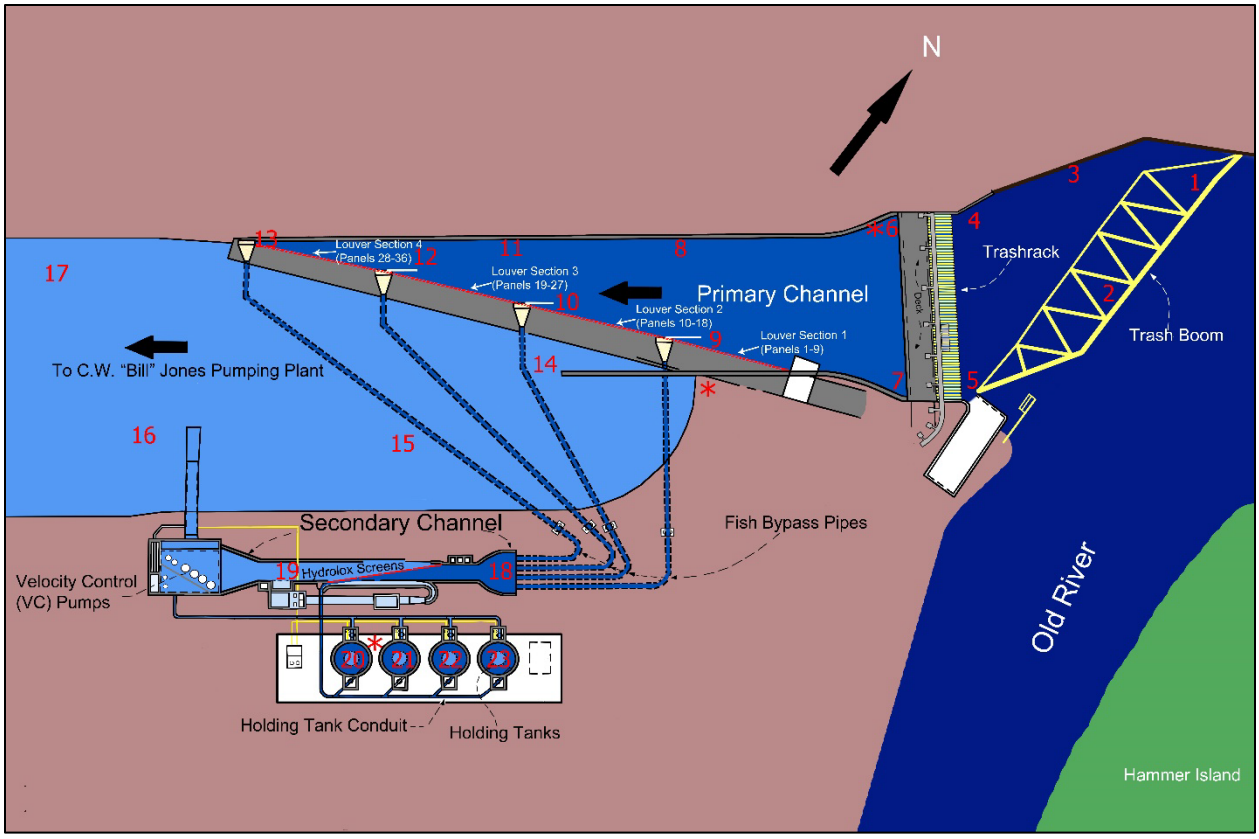

Figure 1.– Diagram of the Tracy Fish Collection Facility showing primary channel louver sections 1–4, locations of the 23 acoustic telemetry hydrophones that will be used during this experiment (red numbers), and locations of acoustic tracking stations (red asterisks).

Problem Statement

Loss of fish through the TFCF primary channel louver array contributes to total fish loss at the TFCF (Karp et al. 2017, Wu et al. 2021) and can occur during regular facility operation or during cleaning of the primary channel louvers. While the loss of fish through the TFCF primary channel louvers during regular facility operation has been thoroughly investigated with various fish species and life stages, the extent of fish loss that occurs through the TFCF primary channel louver array when the primary channel louver panels are lifted, sprayed, and reseated for cleaning has not yet been thoroughly researched and/or directly quantified (only Karp et al. 2017 and Wu et al. 2021 briefly discuss this subject matter). While there is already a Tracy Fish Collection Facility Improvement Program-funded research project aimed at investigating loss of fish during cleaning of the TFCF primary channel louvers using DIDSON sonar technology (Bark, In Progress), an experiment with an alternative approach is being proposed to estimate loss of juvenile Chinook Salmon during cleaning of the primary louvers at the TFCF.

Goals and Hypotheses

Goals:

1. Estimate loss of juvenile Chinook Salmon during cleaning of each of the 4 sections of primary channel louver panels at the TFCF (each section of primary channel louver panels consists of 9 louver panels).

2. Estimate loss of juvenile Chinook Salmon during cleaning of each individual primary channel louver panel within each section of primary channel louver panels at the TFCF (each section of primary channel louver panels consists of 9 louver panels).

3. Estimate loss of juvenile Chinook Salmon during cleaning of all 36 primary channel louver panels in the TFCF primary channel louver array.

4. Determine if loss of juvenile Chinook Salmon during cleaning is significantly different among the 4 sections of primary channel louver panels at the TFCF.

5. Develop estimates for juvenile Chinook Salmon salvage efficiency, primary channel louver efficiency (during cleaning), secondary channel screen efficiency, passage time, total predation loss, predation in the primary channel, and predation in the secondary channel.

Hypotheses:

1. There will be no loss of juvenile Chinook Salmon during cleaning of the primary channel louver panels at the TFCF.

2. Loss of juvenile Chinook Salmon during cleaning will be comparable among the 4 sections of primary louver panels at the TFCF.

Materials and Methods

Loss of fish during cleaning of the TFCF primary channel louvers will be investigated using juvenile Chinook Salmon with surgically implanted predation detection acoustic tags (PDATs; Model V3D-Predation; 307 kHz frequency; HTI-Vemco USA, Inc., Seattle Washington). If possible, externally marked (i.e., photonically tagged) juvenile Chinook Salmon will also be used during this experiment to obtain increased sample size and greater test power. Juvenile Chinook Salmon will be used as test subjects for this experiment because this species and life stage is routinely salvaged at the TFCF, and the spring and winter runs of this species are state and federally listed under the Endangered Species Act (ESA) as threatened and endangered, respectively (CNDDB 2022).

Juvenile Chinook Salmon will be obtained from a state (Mokelumne River Hatchery [Clements, California]) or federal fish hatchery (Coleman National Fish Hatchery [Anderson, California]), held in 1,514.2-L (400.0-gal) circular tanks within the Tracy Aquaculture Facility (TAF), and provided recirculated, temperature controlled, aerated, treated (filtered, protein fractionated, settled, and

UV sterilized) Delta water. Fish will be fed floating 1.5-mm classic fry pellets (Skretting, Tooele, Utah) at approximately 2.5% body weight per day, although feed will be withheld for at least 24.0 h prior to surgical implantation of PDATs.

All releases for this experiment will be performed when ambient Delta water temperature is appropriate for juvenile Chinook Salmon (i.e., less than 25 °C [Poletto et al. 2016]). In addition, all releases will be performed when the JPP is operating at maximum pumping capacity (i.e., when 5 JPP pumps are in operation) to maximize interaction of test fish with the primary channel louver array (Wu et al. 2021). To the greatest extent possible, all releases will be performed at comparable primary channel water depth and tidal stage so primary channel flow and velocity are similar among releases/replicates. It will be necessary to complete 3 replicates for this experiment, with each replicate consisting of a release of juvenile Chinook Salmon for each of the 4 sections of the TFCF primary channel louver array (i.e., there will be 4 releases per replicate). The order that each section of primary channel louver panels will be tested during each replicate will be randomly determined and each section of primary channel louver panels will be tested before performing additional replicates for any one section of louver panels. This paired approach will be necessary to be able to develop estimates of total cumulative loss during cleaning of all 36 primary channel louver panels in the TFCF primary channel louver array by summing data from the 4 releases that a replicate consists of.

Each release will involve the insertion of 10 juvenile Chinook Salmon with surgically implanted PDATs (and potentially 100 juvenile Chinook Salmon with a unique external tag specific to that release) into the TFCF primary channel (evenly distributed behind the TFCF trashrack) while louver panels within section 1, 2, 3, or 4 of the primary channel louver array are sequentially (from upstream to downstream) lifted, cleaned (using the automatic spray wash system of the primary channel louver cleaner), and reseated (Figure 1). To replicate standard operating procedures, the bypass pipe immediately downstream of the louver section being cleaned will be closed prior to fish release and will remain closed for the duration of the cleaning activity for that section of louvers. Fish release and initiation of louver cleaning will occur simultaneously. The times that each individual louver panel within a section is lifted and reseated, as well as the total time for cleaning of the entire section of louver panels, will be recorded. The time that the final (most downstream) louver panel in a section is reseated will be considered the end of the release period.

Experimental Chinook Salmon will be followed acoustically using 23 fixed acoustic telemetry hydrophones (Model 590; HTI-Vemco USA, Inc., Seattle, Washington), numerous hydrophone cables (Model 690; HTI-Vemco USA, Inc., Seattle, Washington), 3 acoustic tag receivers (Model 290; HTI-Vemco USA, Inc., Seattle, Washington), and 3 laptop computers (assorted models; Dell Inc., Round Rock, Texas) installed throughout the TFCF (Figure 1). Experimental Chinook Salmon will be tracked for 18.25 h after the end of each release period since this was the maximum trigger time reported for Model V3D-Predation tags in a laboratory setting (Slusher 2021, Sears 2022 [personal communication]). If PDATs trigger within 18.25 h after the end of the replicate, the fish will be considered to have been preyed upon in the TFCF primary channel. On the contrary, if PDATs do not trigger within 18.25 h after the end of the replicate, it will be assumed that the fish did not participate in the experiment (i.e., the fish will be categorized as a non-participant). All fish with untriggered PDATs collected in a TFCF holding tank will be recovered to verify that the tag is still in a live experimental Chinook Salmon. Any fish with untriggered PDATs detected and/or recovered in a TFCF holding tank after the experimental period during which it was released will be considered non-participants. Hydrophone voltage (and potentially processed and positioned data

animations) will be used to determine if PDATs detected downstream of the primary channel louver array were potentially lost through the 2.6-m wide void that is created when a louver panel is lifted. In addition, the timing of acoustic tag detections downstream of the primary channel louvers versus the timing of individual louver panel cleaning will be used to determine if PDATs were potentially lost during cleaning. The number of fish collected in a holding tank, the number of fish that passed downstream of the primary louver array, the number of fish lost to predation in the primary channel, and the number of non-participants will be determined for each replicate.

After a fate is determined for each experimental Chinook Salmon in a release group, the percentage of juvenile Chinook Salmon lost during cleaning of an entire section of 9 louver panels can be calculated using Equation 1 (Eq. 1). In this equation, fish lost to predation in the primary channel and fish determined to be non-participants are removed from the release group because fish with these fates did not have an opportunity to interact with the primary channel louver array.

Loss During Cleaning of Entire Section of Louver Panels =
(# of Fish Detected Downstream of Primary Louver Array/[# of Fish Released
- # of Fish Preyed Upon in Primary Channel - # of Non-Participants])*100 (Eq.1)

Assuming loss through each individual primary channel louver panel within a section of louver panels is the same, loss during cleaning of each individual louver panel within a section of louver panels can be calculated from the estimated percentage of juvenile Chinook Salmon lost during cleaning of an entire section of louver panels using Equation 2 (Eq. 2). In this equation, the loss value obtained from Eq. 1 for an entire section of primary channel louver panels is divided by 9 to obtain an estimate of loss for each individual louver panel in a section.

Loss During Cleaning of Each Individual Louver Panel in a Section =
Loss During Cleaning of Entire Section of Louver Panels/9 (Eq.2)

Total cumulative loss while cleaning of all 36 primary channel louver panels in the TFCF primary channel louver array will then be estimated for each replicate. This will be done by combining data for the 4 releases of experimental Chinook Salmon within that replicate (i.e., by combining data for each section of louver panels).

Data Analyses

For each replicate, loss of juvenile Chinook Salmon during cleaning of each section of louver panels (i.e., section 1, 2, 3, and 4; consisting of 9 primary channel louver panels) will be estimated first. Loss of juvenile Chinook Salmon during cleaning of each individual primary channel louver panel within each section of louver panels will then be calculated. Total loss while cleaning of all 36 primary channel louver panels in the TFCF primary channel louver array will be estimated for each replicate by combining data for the 4 releases of experimental Chinook Salmon within that replicate (i.e., by combining data for each section of louver panels).

Since data for this experiment is categorical (not normally distributed), non-parametric statistics will be used to 1) determine if there are significant differences in primary channel flow and velocity during testing of the 4 sections of primary channel louver panels that comprise the TFCF primary channel louver array, and 2) determine if loss of juvenile Chinook Salmon during cleaning of an entire section of primary channel louver panels is significantly different among the 4 sections of

primary channel louver panels. A Kruskal-Wallis one-way ANOVA on rank transformed data (Minitab 19; Minitab, State College, Pennsylvania) will be used to determine if there are significant differences in primary channel flow and velocity during testing of the 4 sections of primary channel louver panels. Likewise, a Kruskal-Wallis one-way ANOVA on rank transformed data (Minitab 19; Minitab, State College, Pennsylvania) will be used to determine if there are significant differences in loss estimates of juvenile Chinook Salmon among the 4 sections of primary channel louver panels at the TFCF. A Dunn's test (Minitab 19; Minitab, State College, Pennsylvania) will be used to identify individual sections of the primary channel louver panel with significantly different primary channel flow, primary channel velocity, and/or juvenile Chinook Salmon loss estimates.

Assumptions and Limitations

It is assumed the TAF will be capable of holding juvenile Chinook Salmon on a year-round basis for this experiment, and that juvenile Chinook Salmon will be available from a state or federal fish hatchery. It is assumed that hatchery origin juvenile Chinook Salmon behave in a similar manner as wild juvenile Chinook Salmon, and that surgical implantation of acoustic tags does not affect juvenile Chinook Salmon behavior. It is also assumed the array of HTI-Vemco USA, Inc. receivers, hydrophones, and hydrophone cables that is currently installed throughout the TFCF will be maintained and operational for this experiment. In addition, it is assumed there will be sufficient opportunity to collect data (i.e., there will be adequate periods of 5 JPP pump operation for data collection), and that an appropriate number of TFCF biology and operations personnel (a minimum of 7 individuals) will be on site and available to prepare for and complete replicates for this experiment. It is also assumed no other projects, experiments, or activities will take priority during the 2024-2025 research season.

It will be assumed untriggered PDATs detected downstream of the primary channel louver array were still in live experimental Chinook Salmon upon passage (i.e., it will be assumed experimental Chinook Salmon were not preyed upon prior to passing downstream of the primary channel louver array). It will also be assumed fish containing PDATs that trigger in the TFCF primary channel within 18.25 h after the end of the replicate were preyed upon in the TFCF primary channel, and that fish containing PDATs that do not trigger in the TFCF primary channel within 18.25 h after the end of the replicate did not participate in the experiment (i.e., fish will be categorized as a non-participant). Any fish with unknown fate will be removed from the release group for that replicate since the fate of unknown fish are either 1) loss to predation or 2) non-participation, and the numbers of fish with these fates are subtracted out of the denominator in Eq. 1 because they do not have a chance to interact with the primary channel louver array.

Equal loss will be assumed for each individual primary channel louver panel within a section of louver panels, which will allow for estimation of loss during cleaning of each individual primary channel louver panel within a section. In addition, it is assumed total cumulative loss of juvenile Chinook Salmon during cleaning of all 36 primary channel louver panels can be adequately estimated by combining data for the 4 releases of experimental Chinook Salmon within each replicate (i.e., by combining data for each section of louver panels).

Coordination and Collaboration

This study will be coordinated with the TFCF staff (biology and operations) and the Tracy Technical Advisory Team (TTAT). Participation and inclusion of research-related updates will be provided at regularly scheduled TTAT and/or Central Valley Fish Facilities Review Team (CVFFRT) meetings.

Endangered Species Issues, "Take" Considerations

Winter run Chinook Salmon, spring run Chinook Salmon, Steelhead Trout, Longfin Smelt (Spirinchus thaleichthys), and Delta Smelt may be encountered during these experiments. If ESA-listed species are encountered, they will be immediately documented, returned to the Delta (if alive), and reported to all appropriate agencies. To minimize the risk of mortality to listed species, all attempts will be made to complete research activity during seasonal periods in which salvage of listed species is not likely to occur. All fish take for this project is covered under the most recent National Marine Fisheries Service Biological Opinion as well as current CDFW Scientific Collecting Permits held by the biology staff at the TFCF.

Dissemination of Results (Deliverables and Outcomes)

While the chillers used to maintain appropriate water temperature in TAF recirculating tanks are now operational, juvenile Chinook Salmon cannot currently be held within the Tracy Aquaculture Facility (TAF) due to upcoming installation of a TAF influent water treatment system. Juvenile Chinook Salmon will not be requested from a state or federal hatchery until installation of the TAF influent water treatment system is complete. Unfortunately, this will likely postpone initiation of data collection for this experiment because requests for fish from state and/or federal hatcheries often need to be submitted a year in advance.

Upon completion of TAF influent water treatment system installation, juvenile Chinook Salmon will be requested from a state or federal fish hatchery. Pickup of juvenile Chinook Salmon from a hatchery will likely occur no earlier than FY 2024. If fish are obtained during FY 2024, data collection for this experiment may begin during the FY 2024 research period and extend into FY 2025. Data will be analyzed upon completion of data collection (i.e., during FY 2025 or FY 2026) and updates will be provided at TTAT and/or CVFFRT meetings. The primary deliverable will be an article published as a Tracy Series Report. A draft report for peer review is anticipated to be completed by the end of FY 2026, while a final published report is expected to be posted to the Tracy Fish Facility Improvement Program website in FY 2027.

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