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Fiscal Year 2026

Proposal Package for Tracy Fish Facility Improvement Program

Tracy Fish Facility Improvement Program
California-Great Basin Bureau of Reclamation Region 10

U.S. Department of the Interior

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Tracy Fish Facility Improvement Program

J. Carl Dealy, Program Manager
Bureau of Reclamation, South-Central California Area Office
Tracy Office
16650 Kelso Road
Byron, California 94514-1909

Tracy Series Editors

Zachary A. Sutphin
Bureau of Reclamation, Technical Service Center
Fisheries and Wildlife Resources, 86-68290
PO Box 25007
Denver, Colorado 80225-0007

Connie D. Svoboda, P.E.
Bureau of Reclamation, Technical Service Center
Hydraulic Investigations and Laboratory Services, 86-68560
PO Box 25007
Denver, Colorado 80225-0007

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Prepared By
Bureau of Reclamation
Tracy Fish Collection Facility and
Technical Service Center

Acronyms and Abbreviations

2D	two-dimensional
cm	centimeter(s)
CO_2	carbon dioxide
ESA	Endangered Species Act
FL	fork length
ft	foot/feet
ft/s	feet per second
ft^3/s	cubic feet per second
FY	fiscal year
h	hour(s)
JPP	C.W. “Bill” Jones Pumping Plant
kg	kilogram(s)
L	liter(s)
lb	pound(s)
m	meter(s)
m^3/s	cubic meters per second
mg/L	milligrams per liter
mm	millimeters(s)
min	minute(s)
NMFS	National Marine Fisheries Service
PDATs	predation detection acoustic tags
Reclamation	Bureau of Reclamation
TAF	Tracy Aquaculture Facility
TFCF	Tracy Fish Collection Facility
TTAT	Tracy Technical Advisory Team

Symbols

°	degrees
°C	degrees Celsius
%	percent

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

Investigators

Brandon J. Wu
Fish Biologist
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, California 94514
bwu@usbr.gov

René C. Reyes
Supervisory Fish Biologist
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, California 94514
rreyes@usbr.gov

Kevin K. Kumagai
Senior Fisheries Biologist (formerly)
HTI - Hydroacoustic Technology, Inc.
Seattle, Washington 98105
kkumagai@HTIsonar.com

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 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 fiscal year (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 operation of one pump at the C.W. "Bill" Jones Pumping Plant (JPP); approximately 22.7–28.3 cubic meters per second (m^3/s) [800–1,000 cubic feet per second (ft^3/s)] water flow, approximately 0.2 m/s [0.5 feet per second (ft/s)] water velocity) to minimize the volume of water that needed to be treated, although one CO_2 treatment was completed during operation of two pumps at the JPP (approximately 45.3–56.6 m^3/s [1,600–2,000 ft^3/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 operation of one pumpat 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 operation of one pump at the JPP removed 41.7 percent (%) 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 operation of one pump 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 operation of two pumps 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 more than one 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 milligrams per liter (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 185.0 mg/L can be reasonably obtained in the primary channel at the TFCF, within 30 minutes (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 185.0 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 185.0 mg/L over a 30-min period.

Secondary Goals:

4. Provide a population estimate of the number of piscivorous fish in the TFCF system (primary channel, bypass tubes, 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 185 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 185 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

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 operation of one or two pumps 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 kilograms (kg) (approximately 6,000–8,000 pounds [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 m^3; Polar Tech Industries, Inc., Genoa, IL) 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, WA), 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 (2D) 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 2D 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 because 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-liter [L], 78.7-centimeter (cm) long x 50.8-cm wide x 57.1-cm deep) containing oxygenated 16 degrees Celsius (^{o}C) well water and transported to outside 1.2-meter (m) diameter (757-L) black tanks containing aerated, 16^{o}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 hours (h). To prevent experimental Striped Bass from moving upstream through the 56-millimeter (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-watts (0.2-horsepower) 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, VA) and a pH meter (Model pH 110, Oakton Instruments, Vernon Hills, IL), respectively. During the other three CO_2 treatments of the TFCF primary channel, pH loggers (Model SDL100; Extech Instruments, Nashua, NH) 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 2D 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 2D 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. To obtain a Striped Bass population estimate using this method, it was necessary to collect at least one acoustically tagged and one 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 operation of one or two pumps at the JPP and 1-week notice of these pumping conditions was needed to order dry ice and have it delivered to the TFCF. Operation of one or two pumps 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 (e.g., 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 2025 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, 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 CO_2 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 CO_2 levels as well as other fish (Delta Smelt exhibited 70% mortality over 96 h after being exposed to 100 mg/L CO_2 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 NMFS BiOp, as well as current California Department of Fish and Wildlife 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. A draft report is currently being prepared, and a final publication is anticipated by the end of FY2026. 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 Primary Channel Louvers at the Tracy Fish Collection Facility

Investigators

Brandon J. Wu
Fish Biologist
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA 94514
bwu@usbr.gov

Rene C. Reyes
Fish Biologist
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA 94514
rreyes@usbr.gov

Michael R. Trask
Biological Science Technician
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA. 94514
mtrask@usbr.gov

Kandi M. Vargas
Biological Science Technician
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA. 94514
kvargas@usbr.gov

Christopher J. Foster
Biological Science Technician
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA. 94514
christopherfoster@usbr.gov

Judah S. Good
Biological Science Technician

Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA. 94514
jgood@usbr.gov

Brendan C. Moyer
Biological Science Technician
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA. 94514
bmoyer@usbr.gov

Summary

The Tracy Fish Collection Facility (TFCF) was developed in 1956 by the 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 meter [m] high with 36 louver panels [2.6 m wide x 7.0 m high] each consisting of 84 vertical louver bars [63.5 millimeters (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 degrees (°) 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 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.

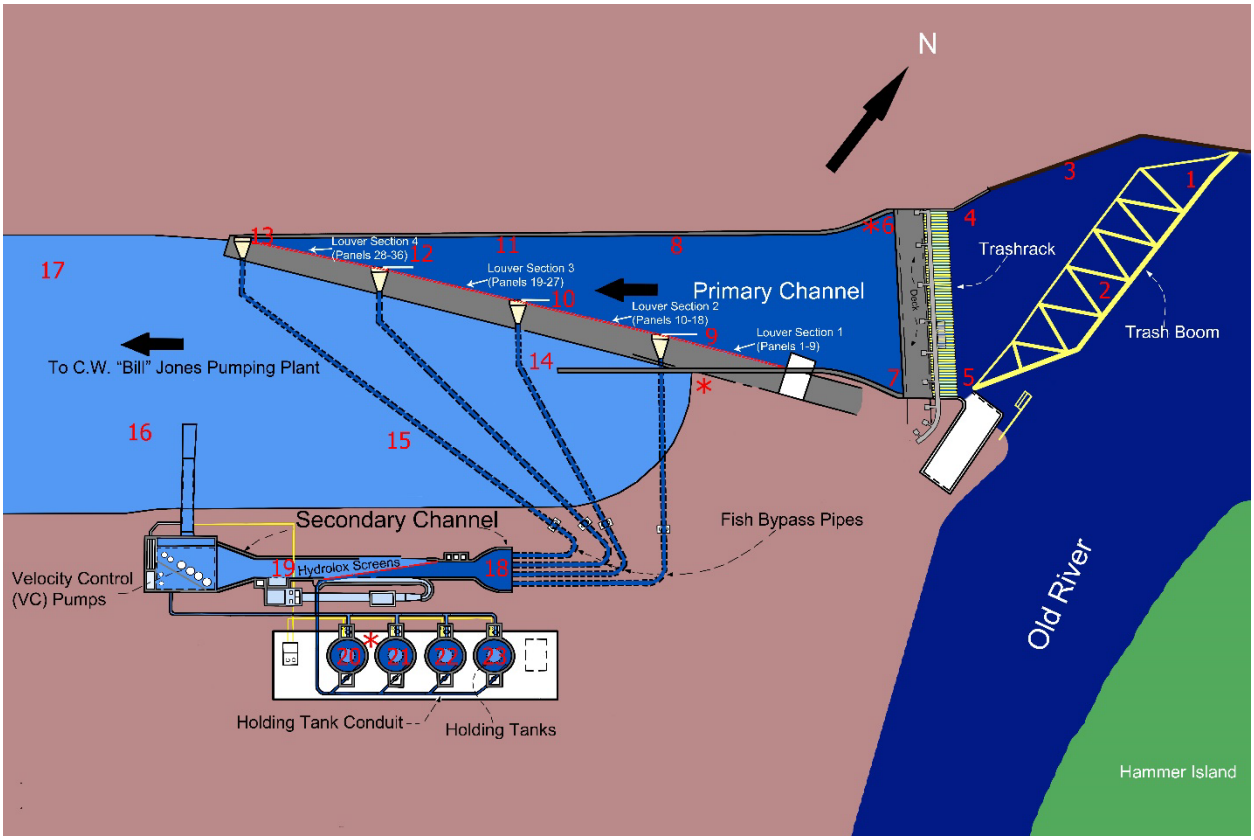

Figure 1.—Diagram of the Tracy Fish Collection Facility showing primary channel louver sections 1–4, locations of the 23 acoustic telemetry hydrophones that will be used during this experiment (red numbers), and locations of acoustic tracking stations (red asterisks).

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 and loss rate 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 cumulative loss and loss rate of juvenile Chinook Salmon during cleaning of all 36 primary channel louver panels in the TFCF primary channel louver array.
4. Determine if loss and loss rate 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 kilohertz frequency; HTI-Vemco USA, Inc., Seattle Washington). Externally marked (i.e., photonic-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-liters (L) (400.0-gallons [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, UT) 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 20° C [Araújo et al. 2023, Moyle 2002). In addition, all releases will be performed when the JPP is operating at high pumping capacity (i.e., when 4 or 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 PDAT and 100 juvenile Chinook Salmon with a unique external photonic tag specific to that release. Experimental Chinook Salmon will be released into the TFCF primary channel (evenly distributed downstream of 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), lowered, 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.

Acoustic-tagged Chinook Salmon will be followed 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). Acoustic-tagged 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 acoustic-tagged Chinook Salmon remain in the TFCF primary channel and PDATs trigger within 18.25 h after the end of the replicate, fish will be considered to have been preyed upon in the TFCF primary channel. On the contrary, if acoustic-tagged Chinook Salmon remain in the TFCF primary channel and 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). Likewise, it will be assumed experimental Chinook Salmon that swim upstream through the TFCF trash rack and out of the facility did not participate in the experiment. 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 experimental Chinook Salmon (both acoustic-tagged and photonic-tagged) collected in a holding tank, the number of acoustic-tagged Chinook Salmon that passed downstream of the primary louver array, the number of acoustic-tagged Chinook Salmon lost to predation in the primary channel, and the number of acoustic-tagged Chinook Salmon that did not participate in the study (i.e., non-participants) will be determined for each replicate. The proportion of acoustic-tagged juvenile Chinook Salmon determined to be non-participants, lost through primary channel louvers, and lost to predation will be applied to the number of photonic-tagged Chinook Salmon not collected in a TFCF holding tank to assign a fate to those fish.

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.

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

In addition, a loss rate (i.e., loss per minute of cleaning) will be calculated for each release group using the number of juvenile Chinook Salmon lost during cleaning of an entire section of 9 louver panels, the times that each individual louver panel within a section is lifted and reseated, the total time for cleaning of the entire section of louver panels, and equation 2 (Eq. 2). In this equation, the amount of time for cleaning only includes durations when one of the primary channel louver panels within each section is partially or completely lifted and does not include periods when all primary channel louver panels are seated and the primary channel louver cleaner is traveling between louver panels.

Eq. 2 Loss Rate (Loss Per Minute of Cleaning) = # of Fish Lost Downstream of Primary Louver Array/(Total Minutes for Cleaning of the Entire Section of Louver Panels – Minutes When All Primary Channel Louver Panels are Seated)

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 estimated from the calculated percentage of juvenile Chinook Salmon lost during cleaning of an entire section of louver panels using equation 3 (Eq. 3). 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.

Eq. 3 Loss During Cleaning of Each Individual Louver Panel in a Section = Loss During Cleaning of Entire Section of Louver Panels/9

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 and will include an estimated loss rate (i.e., loss per minute of cleaning). 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).

Depending on whether assumptions for parametric analysis are met, either a one-way analysis of variance (ANOVA) or the non-parametric equivalent (i.e., Kruskal-Wallis Test; Minitab 19; Minitab, State College, Pennsylvania) 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 and loss rate 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 Tukey's Test or non-parametric equivalent (i.e., Dunn's test; Minitab 19; Minitab, State College, Pennsylvania) will be used to identify individual sections of the primary channel louver array with significantly different primary channel flow, primary channel velocity, and/or juvenile Chinook Salmon loss estimates and loss rates.

Assumptions and Limitations

While the chillers used to maintain appropriate water temperature in Tracy Aquaculture Facility (TAF) recirculating tanks are now operational, juvenile Chinook Salmon cannot currently be held within the TAF due to an inoperable influent water treatment system. Juvenile Chinook Salmon will not be requested from a state or federal hatchery until the TAF influent water treatment system is fully operational. 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.

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. Loss through the TFCF primary channel louvers is assumed to be comparable at all JPP pumping rates (i.e., loss estimates developed when four or five pumps are in operation at the JPP are applicable to 1, 2, and 3 pump operation as well). 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 four or five JPP pump operation for data collection), and that an appropriate number of TFCF biology and operations personnel (a minimum of seven 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 2025–2026 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 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 California Department of Fish and Wildlife Scientific Collecting Permits held by the biology staff at the TFCF.

Dissemination of Results (Deliverables and Outcomes)

Once the TAF influent water treatment system is operable, 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 fiscal year (FY) 2026. If fish are obtained during FY2026, data collection for this experiment may begin during the FY2026 research period and extend into FY2027. Data will be analyzed upon completion of data collection (i.e., during FY2026 or FY2027) and updates will be provided at TTAT and/or Central Valley Fish Facilities Review Team 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 FY2027, while a final published report is expected to be posted to the Tracy Fish Facility Improvement Program website in FY2028.

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Assessment of Impacts and Mitigation Methods for Golden Mussel FoulingAssessment of Impacts and Mitigation Methods for Golden Mussel Fouling

Investigators

Scott O'Meara
Botanist
Hydraulic Investigations and Laboratory Services
Technical Service Center
Bureau of Reclamation
someara@usbr.gov

Laura Hertz
Biologist
Hydraulic Investigations and Laboratory Services
Technical Service Center
Bureau of Reclamation
lhertz@usbr.gov

Sherri Pucherelli
Biologist
Hydraulic Investigations and Laboratory Services
Technical Service Center
Bureau of Reclamation
spucherelli@usbr.gov

Summary

The Fish Salvage and Operations at the Tracy Fish Collection Facility (TFCF) diverts and salvages fish from water being exported from the Sacramento-San Joaquin Delta by the C.W. "Bill" Jones Pumping Plant into the Delta Mendota Canal. Both the TFCF and pumping plant are integral parts of the Bureau of Reclamation's (Reclamation) Central Valley Project, which provides water for agriculture and municipalities throughout the western side of the San Joaquin Valley.

Golden mussels (*Limnoperna fortunei*) were detected in the Delta and O'Neill Forebay in October 2024, the first detection of this species in North America. Subsequent monitoring has confirmed presence of golden mussels in 30 locations throughout the California Delta and State Water Project (California Dept. of Fish and Wildlife et al. 2025), as well as at the TFCF (J.C. Dealy, personal communication).

The biology and life history of golden mussels is similar to that of dreissenid (quagga and zebra) mussels, with notable differences in the size of adults (approximately 3.0–4.5 centimeters [cm] for golden mussels compared to approximately 2.5–3.0 cm for quagga and zebra mussels) as well as the ability of golden mussels to thrive over a wider range of water quality parameters (Cataldo 2015; Karatayev et al. 2015; Morton 2015; Mackie and Claudi 2010). Impacts of golden mussel

settlement to Reclamation facilities are consequently anticipated to be similar if not greater than those experienced with dreissenid mussels, including flow restrictions, mechanical damage, and increased rates of corrosion (Reclamation 2021).

An assessment of system vulnerabilities at the TFCF reported that the trashracks, screens, pumps, conduits, valves and instrumentation are highly susceptible to mussel related impacts (Reclamation 2010). Colonization on the primary louvers, bypass entrance transitions, and bypass conduits may reduce export capacity to some extent due to a reduction in open area for adequate water flow. Additionally, even minor colonization of the primary louvers could degrade fish guidance performance, and mussels on the bypass entrance transitions and bypass conduits would have the potential to injure fish and reduce salvage efficiency.

Although available information suggest golden mussels will cause significant impacts to Reclamation facilities such as the TFCF (Boltovskoy et al. 2015b; Karatayev et al. 2015), this species is currently in the initial stages of establishment in the U.S. and many uncertainties exist. The first goal of this proposed project is to monitor golden mussel settlement at the TFCF to evaluate site-specific establishment trends and the population dynamics. Specific metrics to be evaluated include seasonal cycles, periodic and cumulative settlement intensity, and colony development and growth. These data will be valuable in informing future studies as well as strategic planning and mitigation efforts at TFCF.

Suitable methods for management of invasive mussel impacts will vary depending on the system, operating conditions, rate of mussel settlement, costs, and other considerations. The TFCF is a unique and complex facility, and applicability of established methods for dreissenid mussel mitigation to golden mussel fouling is unknown. The existing pressure-wash cleaning system of the primary louvers may reduce mussel fouling to some extent by removing juvenile mussels in early stages of settlement. However, the presence of adult golden mussels on the louvers indicates the current system is not completely effective (J.C. Dealy, personal communication). The second goal of this proposed project is development of a better understanding of the specifications of the existing cleaning system and exploration of the potential for small-scale modifications to enhance golden mussel removal.

The ability to remove mussels from critical features of the TFCF may also be enhanced by application of foul-release coatings. This type of structural coatings does not prevent mussel settlement but weakens their ability to adhere and reduces the effort necessary for removal. Reclamation has been investigating the effectiveness of foul-release coatings for dreissenid mussels for over 15 years and identified several silicone-based formulations that perform well in this regard (Gulsvig and Skaja 2022). Unfortunately, all previously evaluated coatings are no longer in production, although there are a variety of foul-release coatings currently produced that advertised as "equivalent" in terms of performance to previously tested coatings. These coatings are commonly used on ship hulls, and use of silicone-based coatings for foul-release is well established (Oliveira and Granhag 2020; Townsin and Anderson 2009; Watermann et al. 1997). However, these coatings are relatively soft and durability has not been evaluated under conditions analogous to those at the TFCF primary louvers (exposure to debris, solar radiation, and frequent pressure washing). The third goal of this proposed project is to assess the durability of foul release coatings at the TFCF primary louvers.

A relevant but separate project – the TFCF Louver Pier and Crane Improvement Project is currently being conducted with the objective to improve or replace the aging gantry crane at TFCF, a critical component of the primary louver cleaning system. The project team at Reclamation's Technical Service Center is currently in the conceptual design phase and refining alternatives. Site-specific information on invasive mussel fouling impacts and potential mitigation strategies will be important for the design team to consider in the improvement project planning and design. The fourth goal included in this proposal to collaborate with the Louver Pier and Crane Improvement Project team to provide data and guidance to incorporate invasive mussel mitigation strategies into the planning and design process.

Problem Statement

The golden mussel is a non-native freshwater/brackish bivalve native to Asia. It was discovered in the Sacramento-San Joaquin Delta in October 2024, the first known occurrence in North America. Adult golden mussels were also detected at the TFCF in 2024 (J.C. Dealy, personal communication). This species is reported to be similar to dreissenid (zebra and quagga) mussels in many aspects, including prolific breeding (Boltovskoy et al. 2015a; Mackie and Claudi 2010), rapid population expansion once established in a water body (Barnes and Patino 2020; Nakano et al. 2015), and dense colony formation (Correa et al. 2015). Golden and dreissenid mussel larvae are planktonic, floating freely in the water column until developing to a stage where they will attach to any hard surface, including trashracks, interior surfaces of conduits, pumps, and other infrastructure that is in regular contact with raw water (Corea et al. 2015; Mackie and Claudi 2010). Once attached to a substrate mussels form byssal threads that secure them in place, and removal is difficult and expensive.

In response to the initial detection of golden mussel in the Sacramento-San Joaquin Delta, the state of California has formed the Golden Mussel Task Force and developed a comprehensive Golden Mussel Response Framework to address this invasive species threat. The framework

report emphasizes the significance of impacts the golden mussel poses to ecosystems, water conveyance systems, infrastructure, agriculture, economy, and water quality (California Dept. of Fish and Wildlife et al. 2025).

Invasive mussel fouling is a significant issue for Reclamation facilities, reducing flow capacities and functionality of equipment, potentially leading to unplanned outages and significant increases in maintenance requirements. Shell debris from mussel die-off can also be problematic, causing obstructions and degrading coatings, seals, and machined surfaces. Specific impacts at Reclamation facilities have included increase in frequency of high-temperature alarms at pumping and hydropower plants due to mussel fouling of cooling systems, flow capacity reductions and headloss from fouling at intakes, and inoperability due to shell debris clogging of small-diameter systems such as fire suppression lines. Facilities have responded to invasive mussel impacts in various ways, including installation of ultra-violet light treatments or filtration systems, dosing with copper compounds or chlorine, and a general increase in staff time for cleaning and maintenance (Reclamation 2021).

Available literature suggests impacts from golden mussels will be comparable or more severe than those experienced from dreissenid mussels at Reclamation facilities (Boltovskoy et al. 2015b; Karatayev et al. 2015; Mackie and Claudi 2010; Reclamation 2021). An invasive mussel vulnerability assessment for the TFCF was conducted in 2010 and reported that features of the facility regularly exposed to raw water including the trashracks, screens, pumps, conduits, valves and instrumentation are highly susceptible to mussel related impacts. The primary louver panels were identified as an ideal arrangement for mussel fouling, and even minor colonization could degrade the hydraulic and biological performance of fish guidance as well as export capacity to some extent. Of particular concern are the louver bypass entrance transitions and bypass conduits, as these features cannot be isolated and drained and mussel accumulation on surfaces within the facility have the potential to injure fish and reduce salvage efficiency (Reclamation 2010).

Goals and Hypotheses

Goals:

1. Monitor early infestation trends of golden mussels at TFCF.
2. Evaluate the TFCF primary louver cleaning system for capacity to remove mussels attached to the louver panels and potential modifications to enhance cleaning performance.
3. Assess the durability of foul-release coatings under conditions at the TFCF primary louvers.
4. Provide guidance and data to the TFCF Louver Pier and Crane Improvement Project for incorporation of invasive mussel mitigation measures.

Hypotheses:

The goals of this proposal do not explicitly align with statistical analyses for evaluation of hypotheses statements. The golden mussel is in early stages of establishment in North America and many uncertainties exist. Existing literature suggests golden mussel impacts to Reclamation facilities will be comparable or greater than those experienced from dreissenid mussels, and that critical features of the TFCF are particularly vulnerable to degradation in performance due to golden mussel fouling. The scope of this proposal is therefore focused on data collection to assess early infestation trends and explore the feasibility of potential mitigation strategies to maintain the functionality of the facility.

Materials and Methods

Methods presented are preliminary and are subject to modification in coordination with TFCF staff.

Settlement Monitoring

Monitoring golden mussel settlement intensity will be conducted by deploying settlement plates (approximately 6 inch (in.) square PVC) at various locations and depths at the TFCF and observing settlement over time. Specific locations and setup for settlement plates will be discussed with TFCF staff, with prioritization to areas that are accessible, will not interfere with operations, and are representative of conditions at vulnerable features. Ideally, this would include directly attaching plates flush with the upstream bars of the primary louvers as well as other vulnerable features such as the log boom, trash rack, secondary louvers, or fixed wedge-wire screen of the screened water supply. Duplicate sets of plates will be installed at each location to monitor for both periodic (settlement observations conducted and plates cleaned quarterly) and cumulative (settlement observations only) settlement of golden mussels.

Data collection will occur quarterly to assess golden mussel settlement intensity. Settlement intensity is defined as the rate at which colonization occurs and quantified by a measure of settlement per unit area per time of exposure to fouling. The measure of settlement can be quantified in various ways depending on the nature of fouling. Relatively light fouling can be quantified by counting the number attached by size classification. Heavier fouling or moderate fouling with high numbers of very small organisms may be more effectively quantified by removing all organisms and recording dry weights. In addition, percent coverage can be quantified with a digital photograph analysis of the areas covered by organisms per total area of the sample.

Proposed TFCF golden mussel settlement monitoring methods:

- Digital photographs of all settlement monitoring plates for percent cover estimation.
- Settled mussels on cumulative settlement monitoring plates will be counted per size class (size classification regime to be determined).

- Periodic settlement plate monitoring will include individual settled mussel counts by size class, followed by scraping plates for dry weight measurements.

Accumulation of debris and non-mussel biofouling is expected to occur on the settlement monitoring plates. It is not anticipated that this will prohibit settlement data collection entirely, but modifications to the methodology may be required.

Cleaning System Evaluation

Specifications for the current cleaning system of the primary louvers will be sought out and evaluated based on existing guidelines for mussel removal. Available guidelines are primarily directed at watercraft decontamination and may not address certain aspects of the cleaning process specific to the TFCF primary louvers such as nozzle specifications (angle and orifice size), power-washing duration and frequency, and spray aspect to the surface (i.e., direct, perpendicular, or oblique to settlement substrate). These parameters may be proposed for further evaluation in future continuation of this project depending on the results of the settlement monitoring and the direction of the TFCF Louver Pier and Crane Improvement Project. Potential modifications to the existing cleaning system to be explored include nozzle design, pump capacity/spray pressure and output, and timing and duration variations.

Foul-Release Coating Durability

Coating manufacturers have indicated availability of three coatings with foul-release properties. Steel plates be applied with coatings and attached flush with the upstream bars of the primary louvers. A minimum of 5 repetitions for each coating will be installed and evaluated across the primary louvers. Potential variations in the exposure of the louvers to the power-wash system will be evaluated and placement of the foul-release coated plates will be stratified accordingly. Logistics for attachment of the plates to maintain their position during the cleaning process as well as retrieval for data collection will be confirmed in collaboration with TFCF staff. Plates will be examined and photographed quarterly to quantify percent coating removed versus remaining adhered to the steel plate for the durability assessment.

Analysis

Summary statistics (means and standard errors) will be calculated for mussel settlement plate monitoring and foul-release coating durability testing. Should this project be continued into subsequent years, additional data collection may be applicable to hypothesis testing via statistical analyses such as a comparison of mean golden mussel settlement between treatments over time (e.g., coating formulations, power-washing regimes, etc.)

Assumptions and Limitations

Golden mussels have only recently been discovered in North America and many uncertainties exist. It is possible that the golden mussel population at the TFCF may not significantly increase in the next few years, or ever. It may be difficult to obtain sufficient settlement data to fully describe population dynamics in the timeline of this proposed study. Additionally, the habitat conditions specific to the TFCF primary louvers may not support significant mussel populations and fouling intensities may not justify the costs of installing coatings or other preventative mussel treatments to be incorporated in TFCF Louver Pier and Crane Improvement Project.

The logistics of testing foul-release coating and durability under the conditions experienced at the primary louvers may prove to be difficult. Durability testing may be conducted using similar water pressures and duration to replicate the existing cleaning method. This testing could potentially be conducted in Reclamation's hydraulics laboratory at the Denver Federal Center, although the ability to replicate specific environmental conditions such as non-mussel biofouling, debris exposure, and water quality parameters is currently unknown.

Coordination and Collaboration

The researchers will be working closely with Allen Skaja and Carter Gulsvig, who are coatings experts at the Technical Services Center. Allen and Carter currently have limited capacity to take on this project but are willing to provide their expert guidance in obtaining coatings, identification of a capable contractor for coating applications, and refinement of analysis methods if necessary.

Coordination with the TFCF Louver Pier and Crane Improvement Project staff are currently being conducted and will continue with additional information added as this proposed project proceeds.

Endangered Species Issues/"Take" Considerations

The foul-release coatings selected for this test are non-toxic and will have no environmental impact. Settlement plate monitoring will be conducted in a manner that will not interfere with operations or cause harm to endangered species.

Dissemination of Results (Deliverables and Outcomes)

Results will be summarized in an official report and published in the Tracy Series that will be disseminated to all interested parties. The results can be shared at Tracy Technical Advisory Team meetings as requested. The results of this research will also be shared with the

Reclamation Invasive Mussel Task Force, Invasive Mussel Collaborative, and all other interested invasive mussel working groups. Information will also be shared with managers at facilities that are interested in preventive control measures for golden mussels.

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