



## **Mission Statements**

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

## **Tracy Fish Facility Improvement Program**

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

## **Tracy Series Editors**

Zachary A. Sutphin  
Bureau of Reclamation – Technical Service Center  
Fisheries and Wildlife Resources, 86-68290  
P.O. Box 25007  
Denver, CO 80225-0007

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

## **Cover**

Fish photography by René Reyes, Tracy Fish Collection Facility, Tracy, California.  
Design by Doug Craft.

## **Disclaimer**

Mention of commercial products does not constitute endorsement.

# Table of Contents

	Page
Determining Optimal Carbon Dioxide Concentration for Implementation of Carbon Dioxide Predator Removals in the Bypass Pipes and Secondary Channel at the Tracy Fish Collection Facility.....	1
Feasibility of Using Carbon Dioxide to Remove Resident Piscivorous Fish from the Tracy Fish Collection Facility Primary Channel.....	6
Use of Predation Detection Acoustic Tags to Estimate Juvenile Chinook Salmon Facility Efficiency at the Tracy Fish Collection Facility .....	14
Estimation of Biomass Capacity of the Tracy Fish Collection Facility Fish-Haul Trucks Based on Oxygen and Aeration System Capabilities .....	22
Evaluation of Hydrolox™ Traveling Screen at the Secondary Channel using Larval and Juvenile Delta Smelt .....	27
Development of Computational Fluid Dynamics Model to Assess Carbon Dioxide Injection System for Predator Removal .....	31
Baselines: Establishing Passive Integrated Transponder Tagging Methods in Adult Delta Smelt .....	38
Continuing Exploration of Methods to Reduce Fish Predation at Sacramento-San Joaquin Delta Release Sites.....	44
Movement of Fish in the Primary Channel to the Delta-Mendota Channel during Louver Cleaning: A Pilot Study .....	50

# Determining Optimal Carbon Dioxide Concentration for Implementation of Carbon Dioxide Predator Removals in the Bypass Pipes and Secondary Channel 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](mailto:bwu@usbr.gov)

### **Rene C. Reyes**

Fish Biologist  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[rreyes@usbr.gov](mailto:rreyes@usbr.gov)

### **Christopher L. Hart**

Fish Biologist  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[chart@usbr.gov](mailto:chart@usbr.gov)

### **Scott A. Porter**

Biological Science Technician  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[sporter@usbr.gov](mailto:sporter@usbr.gov)

### **Michael R. Trask**

Biological Science Technician  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA. 94514  
[mtrask@usbr.gov](mailto:mtrask@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  $\geq 20$  mm in length 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).

Over the years, Reclamation has discussed various means of moving fish through the system (Liston *et al.* 1994, Fausch 2000). A predator removal program in the secondary channel was studied and implemented in the early 1990's (Liston *et al.* 1994) and continued through the decade. Predators were flushed into fyke nets, seined, and dip netted out during times when the secondary channel was drained. Striped Bass (*Morone saxatilis*) were the main predatory species and fish up to 700 mm TL were removed. Other abundant predators at the facility include catfish, sunfish and gobies. Stomach analyses of some of these fish have yielded, among others, Chinook Salmon (*Oncorhynchus tshawytscha*), Delta Smelt (*Hypomesus transpacificus*), and Threadfin Shad (*Dorosoma petenense*; Liston *et al.* 1994). In recent years, predator removal activities have slowed because of logistics and the length of time the facility is down to complete the fish removal effort. In 2004, an alternative predator removal method using carbon dioxide (CO<sub>2</sub>) 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<sub>2</sub> as an alternative predator removal technique in the TFCF bypass pipes and secondary channel was completed in September 2007 and demonstrated that elevated CO<sub>2</sub> 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<sub>2</sub> concentration that should be used upon implementation of this method at the TFCF.

Seven replicates have been completed for this project during which Striped Bass removal efficiency and 96-h post-treatment survival were determined. In addition, 5 replicates have been completed during which only Striped Bass 96-h post-treatment survival was investigated. It will be necessary to complete at least 3 more replicates (at 100, 150, and 250 mg/L) to thoroughly investigate Striped Bass removal efficiency and 96-h post-treatment survival for CO<sub>2</sub> concentrations between 50 and 300 mg/L. Preliminary data collected for the optimal dose investigation suggests that the CO<sub>2</sub> concentration that results in the highest combination of Striped Bass removal efficiency and 96-h post-treatment survival is approximately 165 mg/L.

## 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<sub>2</sub> 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<sub>2</sub> concentration that should be used upon implementation of this method. The goal of this proposal is to determine optimal CO<sub>2</sub> concentrations for the implementation of CO<sub>2</sub> predator removals in the bypass pipes and secondary channel at the TFCF considering removal efficiency and 96-h post-treatment survival.

## Goals and Hypotheses

Goals:

1. Determine optimal CO<sub>2</sub> concentration for a 15-minute exposure relative to removal efficiency and survival.

Hypotheses:

1. All CO<sub>2</sub> concentrations will result in equal removal efficiency and survival over a 15-minute exposure period.

## Materials and Methods

The optimal CO<sub>2</sub> concentration for the removal and survival of TFCF predatory fish species will be investigated by removing wild Striped Bass from the bypass pipes and secondary channel with consecutive CO<sub>2</sub> injections of increasing concentration. In order to obtain water samples for monitoring of pH and CO<sub>2</sub> concentration, it will be necessary to install a 1/5 hp pump in the secondary channel prior to the initiation of consecutive CO<sub>2</sub> predator removal replicates. The secondary channel Velocity Control (VC) pumps will be operated to achieve a secondary flow of approximately 0.57 m<sup>3</sup>/s and water flow will be initiated into an empty holding tank. Dry ice will then be injected into the bypass pipes to obtain an initial target CO<sub>2</sub> concentration (100, 150, or 250 mg/L for FY2020).

After the predator removal effort is completed with a certain CO<sub>2</sub> concentration, the secondary channel will be flushed until the CO<sub>2</sub> concentration returns to an ambient level and another predator removal effort with a 300 mg/L CO<sub>2</sub> concentration can be performed. Preliminary data suggests that a 300 mg/L concentration is well over the concentration that is 100 percent effective (150 mg/L) at removing Striped Bass from the bypass pipes and secondary channel, therefore, any fish remaining after the first predator removal should be collected at the 300 mg/L concentration. This will allow us to determine the effectiveness of each CO<sub>2</sub> concentration tested.

Ninety-six h survival will be determined for all wild Striped Bass recovered from the initial predator removal efforts at concentrations of 50, 75, 100, 125, 150, 200, 250 and 300 mg/L. Ninety-six h survival will not be investigated for non-target species. Survival and efficiency of removal for wild Striped Bass collected during the 300 mg/L predator removal efforts that follow each tested CO<sub>2</sub> concentration will not be determined due to the fact that fish collected in this

sample will be exposed to numerous CO<sub>2</sub> concentrations. Three replicates will be performed at each initial CO<sub>2</sub> concentration and the CO<sub>2</sub> concentration that is determined to have the highest combination of removal efficiency and 96-h post-treatment survival will be considered the optimal dose for implementation of CO<sub>2</sub> predator removals in the bypass pipes and secondary channel at the TFCF.

#### *Data Analyses*

Logistic regression will be used to determine if a significant capture-dose response exists within the range of 0–300 mg/L. A probability-capture curve will be used to determine the probability of capture within 25 percent for each CO<sub>2</sub> concentration being tested (*i.e.*, 0, 50, 75, 100, 125, 150, 200, 250 and 300 mg/L) using Probit analysis with a logit link function. A probability-survival curve will be used to determine the probability of 96-h post-treatment survival within 25 percent. Contingency tables will be used to compare the proportion of fish that die within 96-h for each treatment. A scatterplot will be used to illustrate the relationships between CO<sub>2</sub> concentration, removal efficiency, and 96-h post-treatment survival. The CO<sub>2</sub> concentration at which best-fit trend lines for removal efficiency and 96-h post-treatment survival intercept (the CO<sub>2</sub> concentration at which there is the highest combination of removal efficiency and 96-h post-treatment survival) will be considered the optimal dose for implementation of CO<sub>2</sub> predator removals in the bypass pipes and secondary channel at the TFCF.

## **Assumptions and Limitations**

It is assumed wild Striped Bass will be available and that the Tracy Aquaculture Facility will be operational and able to adequately hold this species. In addition, it is assumed that an appropriate number of personnel (4-5 individuals) will be available to perform consecutive CO<sub>2</sub> injections in order to determine optimal CO<sub>2</sub> concentration for the removal and survival of Striped Bass. Access to appropriate safety equipment (dry ice gloves, eye protection, etc.) will be necessary to perform dry ice injections. The Biological Resources group at the TFCF will also need the ability to adjust secondary channel flow as needed for this study. It is assumed that the contract for dry ice delivery will remain active and that no other projects or studies will take priority or precedence during the FY2020 research period. Finally, it is assumed that CO<sub>2</sub> concentration is the only variable that affects Striped Bass removal efficiency and survival.

## **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**

Based on results from Wu and Bridges (2014), it is possible that mortality of listed species could occur if predator removals using CO<sub>2</sub> as an anesthetic are completed during the normal entrainment season of these species. This is due to the fact that Chinook Salmon and Delta

Smelt exhibited a lower tolerance to elevated CO<sub>2</sub> levels than Striped Bass. The dose necessary in order to move adult Striped Bass through the TFCF bypass pipes and secondary channel may be over the concentration in which Chinook Salmon and Delta Smelt exhibited 100 percent survival. Winter-run Chinook Salmon, Steelhead Trout (*O. mykiss*), and Delta Smelt may also be collected in holding tanks and encountered during these experiments. If this occurs, these fish will be immediately documented, returned to the Delta, and reported to all appropriate agencies. In order 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 2009 National Marine Fisheries Service Biological Opinion, as well as current CDFW Scientific Collecting Permits held by the biology staff at the TFCF (5/25/2017–5/25/2020).

Although the procedures during experimentation may lead 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)**

Data collection will likely be completed during the 2019-2020 research period. Updates will be provided at TTAT and CVFFRT meetings. A draft report for peer review is anticipated to be completed by the end of September 2020. The primary deliverable will be an article published as a Tracy Series Report. Information will be gained on the successes and limitations of this alternate 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.

## **Literature Cited**

- Fausch, K. 2000. *Reducing predation mortality at the Tracy Fish Test Facility: Review and analysis of potential solutions*. Tracy Fish Collection Facility Studies, Volume 12. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.
- Liston, C., C. Karp, L. Hess, S. Hiebert. 1994. *Summary of fish predator removal program and intake channel studies, 1991–1992*. Tracy Fish Collection Facility Studies, Volume 1. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Center.
- National Marine Fisheries Service (NMFS). 2009. *Biological Opinion and Conference Opinion of the Proposed Long Term Operations of the Central Valley Project and State Water Project*. U.S. Department of Commerce National Marine Fisheries Service. June 4 2009.
- Wu, B.J. and B.B. Bridges. 2014. *Evaluating the use of carbon dioxide as an alternative predator removal technique to decrease Tracy Fish Collection Facility predator numbers and improve facility operations*. Tracy Fish Collection Facility Studies, Volume 49, U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.

# 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, CA 94514  
bwu@usbr.gov

### **René C. Reyes**

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

### **Christopher L. Hart**

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

### **Kevin K. Kumagai**

Senior Fisheries Biologist  
HTI - Hydroacoustic Technology, Inc.  
Seattle, WA 98105  
kkumagai@HTIsonar.com

### **Scott A. Porter**

Biological Science Technician  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
sporter@usbr.gov

### **Michael R. Trask**

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

## 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<sub>2</sub>), 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<sub>2</sub> may also be efficacious for the removal of piscivorous fish from the primary channel at the TFCF. If so, the use of CO<sub>2</sub> 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.

In April 2015, a preliminary investigation was completed 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. To do this, it was necessary to utilize the existing hydrophone array (Hydroacoustic Technology, Inc., Seattle, Washington) in the primary channel that was previously set-up for other projects. In addition, any remaining acoustically tagged (Hydroacoustic Technology, Inc., Seattle, Washington) Striped Bass in the primary channel (approximately 11-12 fish) were used as test subjects. This preliminary investigation was completed during a slack low tide with low primary channel velocities in an attempt to minimize the volume of water that needed to be treated.

Approximately 2,268 kg (5,000 lbs) of dry ice was injected in front of the trash rack on the north side of the primary channel. Peak CO<sub>2</sub> concentrations at the north and south side of the primary channel were estimated to be 192.0 mg/L and 1.8 mg/L, respectively. Acoustic tracks of tagged Striped Bass in the primary channel showed that all fish actively avoided the CO<sub>2</sub> in the north side of the primary channel for approximately 30 mins, although this behavior could also be attributed to an avoidance response to the turbulence, disturbance, and bubbles produced during dry ice injection. Despite this, regardless of whether fish were actively avoiding high CO<sub>2</sub> concentrations in the water or avoiding the turbulence and disturbance from bubbles created by dry ice injection, acoustically tagged striped bass did show an avoidance response to dry ice injection. This suggests that the use of CO<sub>2</sub> may be effective for removing fish from the primary channel at the TFCF. Even if fish are not anesthetized by the CO<sub>2</sub> concentration achieved in the primary channel, it may be possible to move them into the bypass pipes and secondary channel where Wu and Bridges (2014) have shown they can be readily removed from the TFCF system.

Three CO<sub>2</sub> treatments have been completed for this project with another treatment planned during FY2019. Two more treatments are expected to be completed in FY2020. Preliminary results suggest that CO<sub>2</sub> treatment of the primary channel would be a feasible method to remove resident Striped Bass from the TFCF. Acoustically tagged Striped Bass appeared to exhibit an avoidance response to elevated CO<sub>2</sub> concentrations and it was demonstrated that treatment of the entire primary channel effectively removed a portion of acoustically tagged and wild resident Striped Bass.

## **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<sub>2</sub> was recently found to effectively remove fish, including piscivorous predators, from the bypass pipes and secondary channel at the TFCF (Wu and Bridges 2014). At the time of initial data collection, preliminary data for all water temperatures combined suggested that CO<sub>2</sub> concentrations of approximately 150 mg/L were 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<sub>2</sub> at a concentration of approximately 150 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<sub>2</sub> at a concentration of approximately 150 mg/L to remove piscivorous fish from the primary channel will be investigated.

## **Goals and Hypotheses**

### **Primary Goals:**

1. Determine if a CO<sub>2</sub> 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<sub>2</sub> 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 acoustic tagged Striped Bass in the primary channel at the TFCF using a CO<sub>2</sub> concentration of approximately 150 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<sub>2</sub> treatment in the primary channel.

Hypotheses:

1. The injection of CO<sub>2</sub> in the primary channel will have no effect on the CO<sub>2</sub> concentration in the water due to large water volume and water flow within this component of the TFCF.
2. A CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> to remove piscivorous fish species from the primary channel at the TFCF, it will be 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 the flow and velocity in the primary channel at the TFCF are largely determined by the number of pumping units (1–5) being used for water export operations at the C.W. “Bill” Jones Pumping Plant (JPP), trials will likely be completed when there is a slack low tide during one unit pumping operations at the JPP, which will reduce the volume of water in the primary channel that needs to be treated. Secondary channel velocity and flow rate will be maximized to achieve slightly increased velocity and flow in the primary channel bypass entrances. The maximization of secondary channel velocity and flow will also maximize primary bypass ratios (velocity of water going into each bypass versus the velocity of water in the channel), which may promote 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<sub>2</sub> treatment) and CO<sub>2</sub> treatment.

Approximately 2,268 kg (5,000 lbs) of dry ice will be 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 will be stored in large, outdoor dry ice coolers (0.85 m<sup>3</sup>; Polar Tech Industries, Inc., Genoa, Illinois) until injection takes place. These coolers will be conveniently located near the head of the primary channel at the TFCF, where injection of dry ice will occur.

To determine the reaction of piscivorous fish to elevated CO<sub>2</sub> treatment in the primary channel, as well as estimate the efficiency of removal when using a CO<sub>2</sub> concentration of approximately 150 mg/L during a 30-min treatment period, acoustic tags (Hydroacoustic Technology, Inc. [HTI], Seattle, Washington, Model 795-LY) will be used, along with an acoustic system consisting of acoustic receivers (HTI, Model 290/291 ATR), hydrophones (HTI, Model 590), and hydrophone cables (HTI, Model 690), that was previously installed at the TFCF for other projects and is still being maintained. The use of this technology will allow for the production of 2-dimensional tracks of acoustic tagged fish.

Acoustic tags will be surgically implanted in at least 10 Striped Bass (number chosen to allow for at least 10% precision) that will be 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 will occur up to 30 days prior to release and CO<sub>2</sub> will likely be used as an anesthetic to avoid prolonged holding periods associated with the use of other anesthetics (*e.g.* Tricaine Methanesulfonate [MS-222] has a minimum holding period of 21 days after treatment). Striped Bass will then be 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 will be held at a density of up to two fish per tank for up to 30 days.

At least one week prior to release, tanks will gradually be switched from well water to treated Delta water in an effort to appropriately acclimate fish. Two hours prior to release, Striped Bass will be netted (using the dip net previously described), 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 will occur 1 day prior to treatment with CO<sub>2</sub>. To prevent experimental Striped Bass from moving upstream through the 56-mm spaced trash rack at the upstream end of the facility, it will be necessary to use only fish greater than 375 mm fork length (FL), which is the minimum size estimated by Sutphin *et al.* (2014), based on data collected at the TFCF, at which passage through the trash rack is restricted. To prevent experimental Striped Bass from moving into the canal downstream of the primary louvers, it is important that the primary louvers are not lifted for cleaning after fish are introduced into the primary channel until after the predator removal in the primary channel is completed.

Prior to the start of CO<sub>2</sub> treatment, a 149-W (0.2-hp) submersible pump (Model 316, Carry Manufacturing, Inc., Munger, Michigan) will be installed, at mid-water depth, in the middle of the primary channel to provide water samples for monitoring CO<sub>2</sub> and pH over time. If possible, multiple pumps may also be installed throughout and downstream of the TFCF including in the primary channel, secondary channel, holding tanks, and intake canal to the JPP. Flow will be maximized in the secondary channel to slightly increase velocity at the bypass entrances and maximize primary bypass ratios in an attempt to guide fish from the primary channel into a bypass pipe and, ultimately, into a holding tank.

To treat the entire primary channel, approximately 2,268 kg (5,000 lbs) of dry ice will be evenly distributed and inserted at multiple locations upstream of the trash rack at the head of the primary channel. Dry ice insertion will potentially be completed using 1–2 front-end loaders, 1–2 forklifts with tipping bins, 1-2 trash rack cleaning devices, and manual insertion. During insertion of dry ice, all personnel will be 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, will be recorded from facility meters during each trial. Carbon dioxide and pH measurements will be taken every 2 min from the TFCF sampling station(s) using a submersible pump to obtain water samples, hand-held titration cells (K-1910 [range = 10–100 mg/L CO<sub>2</sub>] and K-1920 [range = 100–1000 mg/L CO<sub>2</sub>], CHEMetrics Inc., Midland, Virginia), and a pH meter (Model pH 110, Oakton Instruments, Vernon Hills, Illinois), respectively. Alternatively, pH loggers (Model SDL100; Extech Instruments, Nashua, New Hampshire) will be used to obtain pH measurements every 10 seconds while a CO<sub>2</sub> vs. pH curve will be developed, using a sample of raw Delta water collected prior to the injection of CO<sub>2</sub>, to obtain a formula that will be applied to pH measurements to estimate CO<sub>2</sub> concentration.

The number of piscivorous fish collected during the 30-min CO<sub>2</sub> treatment will be compared to the number of piscivorous fish collected in the 30-min fish count performed immediately prior to CO<sub>2</sub> treatment (control) to determine if the use of CO<sub>2</sub> in the primary channel increases the total number of piscivorous fish removed from the primary channel. A chi-square test (Minitab version 15) will be used to determine if there is a significant difference between the proportions of piscivorous fish removed during the 30-min fish-count (control) and CO<sub>2</sub> treatment. The percentage of acoustically tagged Striped Bass recovered will be used to estimate the efficiency of removal when using a CO<sub>2</sub> concentration of approximately 150 mg/L. The proportion of acoustically tagged Striped Bass recovered during CO<sub>2</sub> treatment in the primary channel will be used along with the numbers of wild piscivorous fish collected to estimate the piscivorous fish 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.

If no experimental Striped Bass are collected in the holding tanks during the CO<sub>2</sub> treatment, 2-dimensional acoustic tracks will be used to investigate Striped Bass behavior in the primary channel during treatment, which will be further used to guide future research efforts. Depending on the behavior that is observed, the CO<sub>2</sub> treatment process may be modified and repeated in an attempt to effectively guide Striped Bass to the TFCF holding tanks or downstream of the TFCF. For example, if acoustic tagged Striped Bass are found to enter the bypass pipes but not the holding tank, it may be suggested that we perform an additional CO<sub>2</sub> treatment in the bypass pipes and secondary channel after treating the primary channel in an effort to guide fish from the bypass pipes and secondary channel into a holding tank. On the other hand, if acoustic tagged Striped Bass are determined to not enter the bypass pipes or secondary channel during CO<sub>2</sub> treatment in the primary channel, it may be suggested that we lift the louver panel immediately in front of bypass 4 prior to CO<sub>2</sub> treatment of the primary channel in an effort to guide fish from the primary channel in to the canal downstream of the primary channel where there is no impact on salvageable fish. In addition, CO<sub>2</sub> treatment of the primary channel may be evaluated at higher JPP pumping rates.

## **Assumptions and Limitations**

This project can only be completed during 1 pump operation at the JPP and 1 week notice of this pumping condition is needed to order dry ice and have it delivered to the TFCF. One pump operation at the JPP will be necessary for a minimum duration of 2 days to complete each replicate. Tidal condition should be considered to reduce the volume of water that needs to be treated. It is assumed that the HTI acoustic telemetry systems at the TFCF will be fully

operational and an appropriate number of personnel (6-8 individuals) will be available to perform injection of dry ice into the primary channel at the TFCF. In addition, it is assumed that wild Striped Bass will be available and that the Tracy Aquaculture Facility will be operational. Access to appropriate safety equipment (dry ice gloves, eye protection, etc.) will be necessary to perform dry ice injections. The Biological Resources group at the TFCF will also need the ability to adjust secondary channel flow as needed for this study. It is assumed that the contract for dry ice delivery will remain active and that no other projects or studies will take priority or precedence during the FY2020 research period.

## **Coordination and Collaboration**

This study will be coordinated with the TFCF biological and operations staff, Tracy Technical Advisory Team (TTAT), California Department of Fish and Wildlife (CDFW), and Hydroacoustic Technology, Inc. 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*) may be encountered during these experiments. Based on results from Wu and Bridges (2014), it is possible that mortality of certain listed species may occur if predator removals using CO<sub>2</sub> concentrations of approximately 150 mg/L are completed in the primary channel during the normal entrainment season of these species. This is due to the fact that certain species, such as Delta Smelt, exhibited a lower tolerance to elevated CO<sub>2</sub> levels than Striped Bass and displayed up to 70% mortality over 96 h after being exposed to 100 mg/L CO<sub>2</sub> for 20 min. All fish take for this project is covered under the 2009 National Marine Fisheries Service (NMFS) BiOp, as well as current CDFW Scientific Collecting Permits held by the Biological Resources staff at the TFCF (5/25/2017–5/25/2020). If listed species are encountered, they will be 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 of listed species, all attempts will be made to complete research activity during seasonal periods in which listed species are not typically present at the TFCF. Although the procedures during experimentation may lead 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 in the primary channel at the TFCF.

## **Dissemination of Results (Deliverables and Outcomes)**

A Tracy Series Report will be prepared and published upon completion of the study. Updates and presentations of progress will be provided internally and upon request by TTAT and other interagency technical forums. A draft report is expected to be produced by the end of September 2021.

## Literature Cited

- Fausch, K. 2000. *Reducing predation mortality at the Tracy Fish Test Facility: Review and analysis of potential solutions*. Tracy Fish Collection Facility Studies, Volume 12. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.
- NMFS (National Marine Fisheries Service). 2009. *Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State Water Project*. Endangered Species Act Section 7 Consultation, National Marine Fisheries Service, Southwest Region.
- Sutphin, Z.A, R.C. Reyes, and B.J. Wu. 2014. *Predatory fishes in the Tracy Fish Collection Facility secondary system: an analysis of density, distribution re-colonization, and impact on salvageable fishes*. Tracy Fish Collection Facility Studies, U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.
- Wu, B.J. and B.B. Bridges. 2014. *Evaluating the use of carbon dioxide as an alternative predator removal technique to decrease Tracy Fish Collection Facility predator numbers and improve facility operations*. Tracy Fish Collection Facility Studies, Volume 49, U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center
- Wu, B.J., R.C. Reyes, S.A. Porter, and M.R. Trask. In Progress. *Determining optimal carbon dioxide concentration for implementation of carbon dioxide predator removals in the bypass pipes and secondary channel at the Tracy Fish Collection Facility*. Tracy Fish Collection Facility Studies, U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.

# Use of Predation Detection Acoustic Tags to Estimate Juvenile Chinook Salmon Facility Efficiency 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

### **Christopher L. Hart**

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

### **Kevin K. Kumagai**

Senior Fisheries Biologist  
HTI-Vemco USA, Inc.  
Seattle, WA 98105  
kkumagai@htisonar.com

### **Javier Miranda**

Senior Environmental Scientist  
California Department of Water Resources  
Sacramento, CA 95814  
Javier.Miranda@water.ca.gov

## Summary

The U.S. Department of the Interior, Bureau of Reclamation (Reclamation), Tracy Fish Collection Facility (TFCF; Byron, California) was designed in the mid-1950s to divert and collect fish from water destined for export by the Central Valley Project's C.W. "Bill" Jones Pumping Plant (JPP). The TFCF uses a behavioral louver-bypass guidance system in the primary channel to guide entrained fish from the primary channel into a secondary channel and a vertically rotating traveling screen (Hydrolox™, Elmwood, Louisiana) in the secondary channel to guide entrained fish from the secondary channel into a holding tank. Fish that are not successfully guided by the primary channel louvers (with 2.5-cm [1.0-in] spaced vertical slats) or secondary channel traveling screen (with 1.8-mm clear openings and 32.0% open area; Reclamation 2012) are lost downstream to the JPP (Bates and Vinsonhaler 1957, Bates *et al.* 1960). Likewise, fish preyed upon in front of or within the TFCF are also considered to be lost as they are not successfully collected in a TFCF holding tank (*i.e.*, salvaged). According to Action IV.4.1 of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion on the Coordinated Long term Operations of the Central Valley Project and State Water Project (NMFS 2009), Reclamation shall undertake actions to improve the TFCF whole facility efficiency for the salvage of Chinook Salmon (*Oncorhynchus tshawytscha*) and other species so that overall survival is greater than 75.0%.

Efforts to estimate whole facility efficiency at the TFCF using acoustic telemetry have been completed previously (Karp *et al.* 2017), although data has only been collected during 1, 3, and 5 pump operation at the JPP and acoustic tags without predation detection technology were used, which made it difficult to definitively determine if predation events had occurred. In an effort to supplement efficiency and predation estimates provided by Karp *et al.* (2017), a preliminary, proof-of-concept experiment using Predation Detection Acoustic Tags (PDAT; Model 900-PD, HTI-Vemco USA, Inc., Seattle, Washington) is being proposed. Predation Detection Acoustic Tags include a fuse of digestible (polysaccharide and gelatin) material that dissolves when the tag comes in contact with digestive fluids in a predator's stomach, which creates an open circuit that alters the tag signal and indicates that predation has occurred (Schultz *et al.* 2017). During this experiment, Chinook Salmon acoustically tagged with PDATs will be released at the trash boom upstream of the TFCF and tracked to estimate participation (fish that passed the TFCF trash rack and entered the primary channel), facility efficiencies (whole facility efficiency, primary louver efficiency, and secondary screen efficiency), predation, pre-screen loss to predation (between the TFCF trash boom and trash rack), pre-facility loss to predation (upstream of the TFCF trash rack), and passage time of salvaged fish (from the trash boom to the holding tanks) under a range of pumping conditions at the JPP.

Eight replicates were completed for this project during FY2019. In total, fourteen replicates have been completed for this project (2 at 1 JPP, 3 at 2 JPP, 3 at 3 JPP, 3 at 4 JPP, and 3 at 5 JPP) and it will only be necessary to perform 1 additional replicates in order to obtain 3 replicates at each JPP pumping condition. Preliminary results suggest that participation, whole facility efficiency, and primary channel louver efficiency increases with increased pumping at the JPP, while secondary screen efficiency remained consistently 100%. Predation and passage time of salvaged fish decreased with increased pumping at the JPP. Although there was an

increase in the pre-screen loss to predation (between primary louvers and TFCF trash rack) with increased pumping at the JPP, there was a greater decrease in pre-facility loss (upstream of TFCF trash rack) with increased pumping at the JPP, resulting in a net decrease in total predation losses. It appears that increased pumping at the JPP results in faster water velocities in the TFCF primary channel, which results in increased participation (entry into the facility) and reduced passage time of salvaged fish through the facility. Reduced passage time with increased pumping reduces the amount of time that fish interact with resident predators within the TFCF and results in a reduction in predation, which further results in an increase in facility efficiency.

## **Problem Statement**

The use of PDATs potentially allows for more definitive fate determination than photonic, floy, or Passive Integrated Transponder (PIT) tags. Due to this, PDATs will be used to complete whole facility efficiency experiments at the TFCF with juvenile Chinook Salmon. Replicates will be completed at each possible JPP pumping condition (1, 2, 3, 4, or 5 pumps in operation). An expanded hydrophone array upstream of the TFCF and/or mobile monitoring may be utilized. Acoustic tag detections will be used to determine fish fate and determine where losses are occurring. This data will be used to increase accuracy in the facility loss calculation and to identify areas within or near the TFCF where reducing mortality could increase facility efficiency.

## **Goals and Hypotheses**

Goals:

1. Estimate participation, facility efficiency, primary channel louver efficiency, secondary channel screen efficiency, predation, pre-screen loss to predation, pre-facility loss to predation, and passage time for juvenile Chinook Salmon at varying JPP pumping conditions.
2. Determine if there is a main source of juvenile Chinook Salmon loss within the TFCF system.
3. Determine if the use of PDAT tags (HTI-Vemco USA, Inc.) reduces the number of unknown fates compared to standard acoustic tags.
4. Investigate PDAT trigger time and compare to published results from Schultz *et al.* (2017).

Hypotheses:

1. Participation, facility efficiency, primary channel louver efficiency, secondary channel louver/screen efficiency, predation, pre-screen loss to predation, pre-facility loss to predation, and passage time for juvenile Chinook Salmon will not change with varying JPP pumping conditions.
2. There is no main source of juvenile Chinook Salmon loss within the TFCF system and all sources of loss reduce facility efficiency equally.
3. The use of PDAT tags will not reduce the number of unknown fates.

4. Predation Detection Acoustic Tag trigger times will not be significantly different than those published by Schultz *et al.* (2017).

## Materials and Methods

### *Fish Source and Care*

Fall-run Chinook Salmon (~120 mm FL; number to be determined) will be obtained from the Mokelumne River Fish Hatchery (Clements, California) or Coleman National Fish Hatchery (Anderson, California) and transported to the Tracy Aquaculture Facility (TAF). Fish will be maintained within the TAF in recirculating 711-L tanks, provided temperature controlled (at same temperature as hatchery), treated (settled, filtered, ultraviolet [UV] sterilized, and ozonated) Delta water, and fed at ~4% body weight per day. Water quality (temperature, pH, ammonia, nitrite, salinity, and oxygen levels) will be monitored daily. Fish will be acclimated to ambient Delta water temperature at rates less than 2°C/d prior to surgical implantation of tags and release.

### *Experimental Design*

A release-recapture experiment using juvenile Chinook Salmon acoustically tagged with PDAT tags will be completed at varying JPP pumping conditions to determine fate and estimate facility efficiencies (whole facility efficiency, primary louver efficiency, and secondary screen efficiency), predation, pre-screen loss to predation (between the TFCF trash boom and trash rack), pre-facility loss to predation (upstream of TFCF trash rack), and passage time of salvaged fish (from the trash boom to the holding tanks) during normal day-to-day operations (*i.e.*, louver and trash rack cleaning, hydraulic changes, *etc.*).

An array consisting of 23 fixed acoustic telemetry hydrophones (HTI-Vemco USA, Inc., Seattle Washington) installed throughout the TFCF will be used along with 3 acoustic receivers (Model 290 Acoustic Tag Receivers; HTI-Vemco USA, Inc., Seattle Washington). In addition, HTI-Vemco USA, Inc. receivers/hydrophones deployed by California Department of Water Resources (DWR) in Old River and Grant Line Canal and/or mobile monitoring may be used to detect fish that swam out of the hydrophone array deployed upstream of the TFCF trash rack and potentially determine if predation had occurred outside of the facility. This may be done based on the recommendation by Karp *et al.* (2017) to perform acoustic facility efficiency studies with the installation of additional receivers and hydrophones upstream of the TFCF trash boom to reduce the proportion of unknown fates. Hydrophones installed at the TFCF were connected to one of three acoustic tracking receivers using HTI-Vemco USA, Inc. Model 690 hydrophone cables. In conjunction, this equipment was used to track fish movements in front of, within, and downstream of the TFCF, including in the secondary channel and holding tanks.

For each replicate, 10 Chinook Salmon acoustically tagged with PDAT tags will be released from the midpoint of the TFCF trash boom and tracked for up to 96.0 h to determine fate. Acoustic telemetry data at the TFCF will be recorded hourly and downloaded daily and the

acoustic telemetry systems will be verified to be operational throughout the experimental period. Hydraulic data (water temperature, primary channel depth, primary channel flow, primary channel velocity, secondary channel depth, secondary channel flow, secondary channel velocity, primary channel and secondary channel bypass ratios, holding tank flow, and the number of secondary channel velocity control pumps and holding tank pumps in operation) will be recorded every 30.0 min for 2.0 h, after which hydraulic data will be recorded every 2.0 h.

All collections into the holding tanks will be examined for acoustically tagged fish during each experimental period by draining holding tanks prior to the morning haul-out. Stomachs of all Striped Bass (*Morone saxatilis*) and White Catfish (*Ameiurus catus*) >300 mm FL will be examined. Any experimental fish recovered in the holding tanks will be identified through tag code procedures and/or fish length (in the event of a dead tag battery).

### *Fish Processing*

Surgeries will be conducted at least 24 h prior to each release (following guidelines in Liedtke *et al.* 2012). Fish will be captured from TAF fish tanks using monorail nets with 6.4-mm knotless nylon mesh (40.6 cm x 40.6 cm frame, 30.5 cm depth, 1.5 m handle, Pentair Aquatic Eco-systems, Inc., Apopka, Florida) and placed in an 10-L anesthetic bath containing a 100 mg/L dose of tricaine methanesulfonate (MS-222, Argent Chemical Laboratories, Redmond, Washington), 100 mg/L of sodium bicarbonate and 10 mL of Prime® water conditioner (Seachem Laboratories, Inc., Madison, Georgia). The time until anesthetization will be recorded for each individual fish using a digital timer. After the desired extent of anesthesia is reached, the fish will be removed from the anesthetic bath, measured (FL) and weighed (g). Fish will then be moved to the surgery station and an anesthetic mixture containing 100 mg/L MS-222, 100 mg/L of sodium bicarbonate and 10 mL of Prime® water conditioner will be dispensed, along with fresh water (if necessary), using aquarium tubing placed in the fish's mouth. Surgical tools and sutures will be sterilized in 70% isopropyl rubbing alcohol, while acoustic tags will be decontaminated using a tabletop UV sterilizer (Salon Sundry M-2009, Sunrise, Florida) with 40.0 min UV exposure time. All surgical tools will be thoroughly rinsed in distilled water prior to surgery.

Acoustic tags (307 kHz, Model 900-PD, 1.0 g in air, 6.0-mm diameter x 25.0-mm long; HTI-Vemco USA, Inc., Seattle, WA) will be activated and programmed using an HTI-Vemco USA, Inc. Model 490 LP Tag Programmer. Incisions will be made using a 3-mm depth microsurgical blade with a 15-degree blade angle (Surgical Specialties Puerto Rico, Inc., Rincon, PR) and each tag will be inserted into the body cavity of a Chinook Salmon. As was done by Karp *et al.* (2017) and recommended by Liedtke *et al.* (2012), incisions will be closed with two independent sutures (2 x 3 knot) in an interrupted pattern using 4/0 Ethicon VCP303H, taper point, RB-1, 17 mm, ½ circle, 68.6-cm, violet, coated VICRYL Plus sutures and Mayo-Hegar needle holders. A modified surgeon's knot will be used to secure each suture and sutures will be trimmed using

stainless steel operating scissors. The amount of time necessary to surgically implant the acoustic tag will be recorded for each fish.

Following surgical implantation of PDAT tags, fish will be placed in 168.0-L (0.74-m diameter) black tanks containing flow-through, aerated, treated Delta water at ambient temperature. One hour prior to release, fish will be netted and transferred to perforated 18.9-L (5.0-gallon) black buckets with lids (at a density of 2 fish per bucket) containing oxygenated, treated Delta water at ambient Delta water temperature. Each bucket will be transported to the TFCF trash boom and floated in raw Delta water for final acclimation. After the 1.0-h acclimation period, fish will be released downstream of the TFCF trash boom via water-to-water transfer and tracked for up to 96.0 h.

#### *Data Analyses:*

If possible, 3 replicates (10 fish/replicate) will be performed at each JPP pumping condition (1, 2, 3, 4, or 5 pumps in operation; 150 fish total). Acoustic tag detections will be used to determine fish fate and determine where losses are occurring. The dichotomous key developed by Karp *et al.* (2017) will be modified and used to assign fates. Since PDAT tags will be used during this experiment to definitively determine if predation had occurred, it will not be necessary to develop rules (*i.e.*, cease of tag movement) to assign predation events. Equations provided by Karp *et al.* (2017) will be modified (for pre-screen loss to predation only) and used to calculate passage time (for salvaged acoustically tagged Chinook Salmon only), participation, whole facility efficiency, primary channel louver efficiency, secondary channel screen efficiency, and pre-screen loss to predation. In addition, an equation will be developed to calculate predation as well as pre-facility loss to predation. For whole facility efficiency, a low estimate (all fish of unknown fate were assumed to be predation losses) and a high estimate (all fish of unknown fate were assumed to be nonparticipants) will be provided. Likewise, a low estimate (all fish of unknown fate were assumed to be nonparticipants) and a high estimate (all fish of unknown fate were assumed to be predation losses) will be provided for predation, pre-screen loss to predation, and pre-facility loss to predation.

## **Assumptions and Limitations**

It will only be possible to complete this study when the Delta water is at an appropriate temperature for juvenile Chinook Salmon (*i.e.* Oct–May). Replicates for this project must be completed during specific JPP pump operations and it is assumed that each of the 5 pumping conditions needed will be obtained at some point during the research period. It is assumed that the HTI acoustic telemetry systems at the TFCF and the extended hydrophone array upstream of the TFCF will be fully operational. In addition, it is assumed that results and trends of this project will be valid despite the low sample size (15 replicates of 10 fish), which was necessary due to budgetary constraints. Finally, it is assumed that no other projects will take priority during the FY202 research period and that there will be time to complete data collection, analyze data, and develop a report.

## Coordination and Collaboration

This study will be coordinated with the California Department of Fish and Wildlife, Tracy Fish Collection Facility staff, HTI-Vemco USA, Inc., and DWR staff. All work will be reviewed by the Tracy Technical Advisory Team (TTAT) during progress updates on study plans and reports.

## Endangered Species Issues, “Take” Considerations

Incidental “take” of ESA listed Chinook Salmon, Steelhead (*O. mykiss*), and Delta Smelt (*Hypomesus transpacificus*) is possible during this study due to the fact that testing will likely be completed when these species are present in the south Delta. Take of ESA listed species is covered under California Department of Fish and Wildlife (CDFW) Scientific Collecting Permit Number SC-005544 (valid 5/25/2017–5/25/2020), as well as the 2009 NMFS Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (6/4/2009–Present). All ESA listed fish that are incidentally taken will be returned to Delta waters as quickly as possible and the total number of each ESA species incidentally caught or collected will be recorded and sent to the reporting agencies.

## Dissemination of Results (Deliverables and Outcomes)

Data will likely be completed during FY2020. Updates will be provided at TTAT and Central Valley Fish Facility Review Team meetings. A draft report for editor review is anticipated to be completed by the end of September 2021. The primary deliverable will be an article published as a Tracy Series Report.

## Literature Cited

- Bates, D.W. and R. Vinsonhaler. 1957. *Use of louvers for guiding fish*. Transactions of the American Fisheries Society, 86:38–57.
- Bates, D.W., O. Logan, and E.A. Pesonen. 1960. *Efficiency evaluation, Tracy Fish Collection Facility, Central Valley Project, California*. U.S. Fish and Wildlife Service. Seattle, WA, USA.
- Karp, C., B.J. Wu, and K. Kumagai. 2017. *Juvenile Chinook salmon, steelhead, and adult striped bass movements and facility efficiency at the Tracy Fish Collection Facility*. Tracy Fish Collection Facility Studies, Volume 54, Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.
- Liedtke, T.L., J.W. Beeman, and L.P. Gee. 2012. *A standard operating procedure for the surgical implantation of transmitters in juvenile salmonids*. U.S. Geological Survey Open-File Report 2012-1267, iv, 50 p.
- National Marine Fisheries Service (NMFS). 2009. *Biological Opinion and Conference Opinion of the Proposed Long term operations of the Central Valley Project and State Water Project*.

U.S. Department of Commerce National Marine Fisheries Service. June 4 2009.

Reclamation (Bureau of Reclamation). 2012. *Secondary louver structure – louver replacement*. Specifications 35 21 61 - 9, Bureau of Reclamation, Denver, Colorado.

Schultz, A.A., V.B. Afentoulis, C.J. Yip, and M.N. Johnson. 2017. *Efficacy of an acoustic tag with predation detection technology*. North American Journal of Fisheries Management, 37:3, 574–581.

# Estimation of Biomass Capacity of the Tracy Fish Collection Facility Fish-Haul Trucks Based on Oxygen and Aeration System Capabilities

## Investigators

### **Brandon J. Wu**

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

### **Zachary A. Sutphin**

Fish Biologist  
Fisheries and Wildlife Resources Group  
Bureau of Reclamation  
Denver, CO 80225  
zsutphin@usbr.gov

## Summary

The U.S. Bureau of Reclamation (Reclamation), Tracy Fish Collection Facility (TFCF) is located at the head of the Delta-Mendota Canal (DMC) 4 km NE of the C.W. “Bill” Jones Pumping Plant (JPP) and 15 km NW of Tracy, California, and was developed for salvaging outmigrating Chinook Salmon (*Oncorhynchus tshawytscha*) and Striped Bass (*Morone saxatilis*)  $\geq 20$  mm entrained by the JPP. After salvage, fish are maintained in holding tanks (6-m wide x 5-m deep) until transport back to the Sacramento-San Joaquin Delta (Delta). The schedule of fish hauling is dependent on salvage rates, debris loading, and special-status-species procedures (CDFW 2013). Prior to transport, fish accumulated in a holding tank are collected in a haul-out bucket (1544-L, 1.8-m inside diameter with a conical bottom from 0.9-m deep to 1.3-m deep) and transferred to a fish-haul truck tank (9,462-L, 4.6-m long x 2.0-m wide x 1.2-m deep). Fish are then trucked 49.9 km from the TFCF to one of two release sites located at the confluence of the Sacramento and San-Joaquin Rivers and away from the immediate influence of south Delta pumping facilities.

Maintenance of adequate dissolved oxygen (DO), total ammonia nitrogen (TAN), and carbon dioxide (CO<sub>2</sub>) levels is of particular concern during fish transport. Dissolved oxygen levels in the fish-haul trucks can affect the success of fish transportation as low DO levels can result in respiratory stress, which can affect swimming performance, equilibrium, and survival of fish (Moyle and Cech 2004, Herbert and Steffensen 2005, Portz *et al.* 2006). Elevated fish densities in the truck can also increase the rate of O<sub>2</sub> consumption, as well as CO<sub>2</sub> production, and cause hypoxic or anoxic conditions. In addition, TAN can reach toxic levels in closed transport

systems, as fish continuously produce TAN as a primary byproduct of protein metabolism and water consumption (Sutphin and Wu 2008).

Sutphin and Wu (2008) reported fish density (0.3–64.5 g of fish/L) and water quality parameters of concern in the bucket and trucks generally remained within acceptable ranges throughout the period of fish transport at temperatures between 15.2–25.3 °C. Since then, new fish-haul trucks have been designed, fabricated, and are being used at the TFCF. The new fish-haul trucks must be evaluated to estimate the biomass capacity based on the oxygen and aeration system capabilities, as well as published oxygen consumption, TAN production and CO<sub>2</sub> production rates (from Sutphin and Hueth 2015). This information may be used for the potential development of updated fish transport tables, which indicate the percent of a load (up to 100 percent) that a total number of salvaged fish within a particular size class represents. Data collection for this project was completed during the FY2018 research period. It was determined that operating only the oxygen system in the fish-haul trucks resulted in the highest rate of O<sub>2</sub> rise (0.46 mg/L per min) and likely supports the highest biomass capacity. Simultaneous operation of the compressed air and oxygen systems resulted in the next highest rate of O<sub>2</sub> rise (0.32 mg/L per min), followed by operation of only the compressed air system (0.05 mg/L per min).

Data collection for this project was completed during the FY2018 research period and data analysis was completed during the FY2019 research period. A draft report is expected to be produced by the end of September 2020. Results suggest biomass capacity of the current fish-haul trucks is approximately 296.7 kg and is likely limited by TAN.

## Problem Statement

New fish-haul trucks have been designed, fabricated, and are being used at the TFCF. This new equipment must be evaluated to estimate the biomass capacity based on the oxygen and aeration system capabilities, as well as published oxygen consumption, TAN production, and CO<sub>2</sub> production rates (from Sutphin and Hueth 2015). Evaluation of this equipment will increase the likelihood that the millions of fish that are salvaged annually, including the threatened Delta Smelt (*Hypomesus transpacificus*) and endangered Winter-run Chinook Salmon (Reclamation's Tracy Fish Salvage Records 2009), are transported to release sites using appropriate water quality parameters.

## Goals and Hypotheses

Goals:

1. Measure the rate of O<sub>2</sub> rise in the new fish-haul trucks while operating the air system only, O<sub>2</sub> system only, and both the air and O<sub>2</sub> systems simultaneously.
2. Use measured oxygen production rates along with published estimates of fish oxygen consumption, TAN production, and CO<sub>2</sub> production (from Sutphin and Hueth 2015), to develop a mass balance equation to estimate biomass capacity of the new fish-haul trucks

while operating the air system only, O<sub>2</sub> system only, and both the air and O<sub>2</sub> systems simultaneously.

Hypotheses:

1. The rate of O<sub>2</sub> rise in the new fish-haul trucks will not be different when operating the air system only, the O<sub>2</sub> system only, and both the air and O<sub>2</sub> systems simultaneously.
2. Estimates of biomass capacity for the new fish-haul trucks will not be different when operating the air system only, the O<sub>2</sub> system only, and both the air and O<sub>2</sub> systems simultaneously.

## Materials and Methods

The rate of O<sub>2</sub> rise in water containing 8 mg/L salt while running the air system only, the O<sub>2</sub> system only, and both the air and O<sub>2</sub> systems simultaneously will be determined with maximum gas flow through the airstones (approximately 6-8 L/min) after injecting nitrogen gas in the water to achieve a DO level of  $\leq 4.0$  mg/L. Sampling will be completed during times when the Delta water temperature is warm (June-Sept.) because this condition likely results in the lowest O<sub>2</sub> dissolving rate in the water and, in combination with published estimates of fish oxygen consumption, would yield a conservative estimate of biomass capacity for the new fish-haul trucks at the TFCF.

All trials will be completed in the TFCF truck pit. Air and ambient Delta water temperatures will be measured at the beginning and end of each trial using an Acu-Rite digital thermometer and a YSI-85, respectively. The truck will be completely filled with 8 mg/L salt water and nitrogen gas will be injected into the water until a DO level of 4.0, or under, is reached (measured with a YSI-85). This will be done in order to obtain a more comprehensive rate curve for each system or combination of systems. The appropriate gas system will then be turned on. Oxygen cylinders will be set to 40 psi for all trials in which the O<sub>2</sub> system will be utilized. Oxygen and Total Gas Saturation (TGS) measurements, taken with a YSI-85 and a Sweeney satumeter, respectively, will be obtained every 2 min from the mid-water column until five measurements are recorded on the plateau of the curve. The water in the truck tank will be continuously mixed during this period using a 0.5 hp submersible pump (Tsurumi, Inc., Glandale Heights, Illinois) in order to simulate the mixing associated with water sloshing during transport.

Published estimates of fish oxygen consumption, TAN production, and CO<sub>2</sub> production rates will be used along with O<sub>2</sub> measurements to develop a mass balance equation to estimate biomass capacity of the new fish-haul trucks while operating the air system only, O<sub>2</sub> system only, and both the air and O<sub>2</sub> systems simultaneously. This information may be used in the development of updated fish transport tables at the TFCF.

### *Data Analyses*

The rate of O<sub>2</sub> rise will be evaluated for each system or combination of systems using regression analysis by plotting O<sub>2</sub> concentration over time and generating a rate curve. Published estimates

of fish oxygen consumption, TAN production, and CO<sub>2</sub> production will be used along with O<sub>2</sub> measurements to develop a mass balance equation to estimate biomass capacity of the new fish-haul trucks while operating the air system only, O<sub>2</sub> system only, and both the air and O<sub>2</sub> systems simultaneously.

## **Assumptions and Limitations**

It is assumed that no other projects will take priority during the FY2019 research period and that there will be time to analyze data and develop a report.

## **Coordination and Collaboration**

All work on this evaluation will be coordinated with the TFCF Fish Diversion Operators, TFCF Biology staff, and the Denver Technical Service Center Fisheries and Wildlife Resources Group. Participation and inclusion of research-related updates will be provided at regularly scheduled Tracy Technical Advisory Team (TTAT) and/or Central Valley Fish Facilities Review Team (CVFFRT) meetings.

## **Endangered Species Issues, “Take” Considerations**

This evaluation will not involve the take of any wild fish, including species listed as endangered or threatened.

## **Dissemination of Results (Deliverables and Outcomes)**

The primary deliverable will be an article published as a Tracy Series Report. Updates will be provided at TTAT and CVFFRT meetings. Additionally, information will be gained on the successes and limitations of the fish-hauling process at the TFCF while using the new fish-haul trucks. This information will help guide future improvements to the fish transport procedures and equipment at the TFCF.

## **Literature Cited**

- CDFW (California Department of Fish and Wildlife). 2013. *Fish Facilities Unit Monitoring and Operations Projects*. California Department of Fish and Wildlife Fish Salvage Monitoring. <http://www.dfg.ca.gov/delta/data/salvage/salvageoverview.asp>. (July 2013).
- Herbert, N.A. and J.F. Steffensen. 2005. *The response of Atlantic cod, Gadus morhua, to progressive hypoxia: fish swimming speed and physiological stress*. Marine Biology 147:1403–1412.
- Moyle, P.B. and J.J. Cech, Jr. 2004. *Fishes: An Introduction to Ichthyology*. Fifth edition, Prentice-Hall, Upper Saddle River, New Jersey.

- Portz, D.E., C.M. Woodley, and J.J. Cech, JR. 2006. *Stress-associated impacts of short-term holding of fishes*. *Reviews in Fish Biology and Fisheries*, 16:125–170.
- Sutphin, Z.A. and C.D. Hueth. 2015. *Effects of loading density during transport on physiological stress and survival of Sacramento-San Joaquin Delta fishes*. *California Fish and Game* 101(2):108-130.
- Sutphin, Z.A. and B.J. Wu. 2008. *Changes in Water Quality During Fish-Hauling Operations at the Tracy Fish Collection Facility*. *Tracy Fish Collection Facility Studies*, Tracy Technical Bulletin 2008-2. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.

# Evaluation of Hydrolox™ Traveling Screen at the Secondary Channel using Larval and Juvenile Delta Smelt

## Investigators

### **René C. Reyes**

Fish Biologist  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[rreyes@usbr.gov](mailto:rreyes@usbr.gov)

### **Brandon J. Wu**

Fish Biologist  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[bwu@usbr.gov](mailto:bwu@usbr.gov)

### **Zachary A. Sutphin**

Fisheries Biologist  
Denver Technical Service Center  
Bureau of Reclamation  
Denver, CO 80225  
[zsutphin@usbr.gov](mailto:zsutphin@usbr.gov)

### **Scott A. Porter**

Biological Science Technician  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[sporter@usbr.gov](mailto:sporter@usbr.gov)

### **Michael R. Trask**

Biological Science Technician  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[mtrask@usbr.gov](mailto:mtrask@usbr.gov)

## Summary

The Tracy Fish Collection Facility (TFCF) is located at the head of the Delta-Mendota Canal in the southern region of Sacramento-San Joaquin Delta (Delta) near Tracy, California. The facility was constructed in the 1950s to salvage fish that would otherwise be entrained by the Central Valley Project's C.W. "Bill" Jones Pumping Plant (JPP). Since inception, the TFCF used behavioral louver arrays in the primary and secondary channels that were angled 15° to the flow of water with 2.5 cm (1 in) spaced vertical slats angled 90° to the direction of flow that create a disturbance in the water and guide fish into one of four recessed holding tanks (6.1 m wide, 5.0 m deep). The system was designed primarily for Striped Bass (*Morone saxatilis*) and outmigrating Chinook Salmon (*Oncorhynchus tshawytscha*). In June 2014, the secondary louver system was replaced with an engineered traveling water screen (Hydrolox™, Intralox LLC, Harahan, Louisiana).

Delta Smelt (*Hypomesus transpacificus*) is a federally listed threatened species native to the Delta (Federal Register 1993) and is salvaged at the TFCF (CDFW, ftp salvage records website). The larval, juvenile, and adult life stages are reported when they are observed during fish counts and when they are detected during larval fish sampling.

As part of Reclamation's effort to attain a whole facility efficiency of 75 % (NMFS 2009), the secondary louvers (2.5 cm opening) were replaced with a traveling water screen with smaller screen opening (1.5 mm width x 50 mm length) in 2014. Delta Smelt larvae and juveniles are expected to be guided successfully (salvaged) to the holding tanks with this new screen. Data collected from this study will determine how velocity affect larval and juvenile Delta Smelt secondary channel efficiency. The field data collection portion of the study was completed in 2016 and funds are being requested for laboratory sample processing (75% complete), data analyses and report writing.

## Problem Statement

The new traveling water screen's efficiency in guiding Delta Smelt larvae, juveniles, and adults to the holding tanks is unknown. Furthermore, the State Water Resources Control Board Decision 1485 (*i.e.*, D-1485) and the current 2009 NMFS Biological Opinion mandate that the secondary channel be operated at salmon criteria, or 3.0-3.5 fps, between February and May, months when larval and juvenile Delta Smelt are observed at the TFCF. It is unknown, however, how this speed and the new traveling screen interact and affect the diversion of larval and juvenile Delta Smelt to the holding tanks.

## Goals and Hypotheses

### *Goals:*

1. Determine if secondary channel water velocity affect the salvage of Delta Smelt larvae and juvenile to the holding tank

### *Hypotheses:*

1. Because the traveling screen has smaller opening, Delta Smelt larvae and juveniles will be diverted to the holding tank and will not be lost through the screens

## **Materials and Methods**

Because Delta Smelt is a protected species and wild Delta Smelt cannot be used, cultured Delta Smelt were obtained from the UC Davis Fish Conservation and Culture Laboratory (FCCL) and these fishes were used as surrogates for wild Delta Smelt. A memorandum of understanding was prepared with CDFW allowing the use of cultured Delta Smelt within the compounds of the TFCF for this study. In 2015, 3000 juveniles measuring 20-30 mm FL and in 2016, 10,000 individuals measuring 15-40 mm FL were used.

Five secondary channel velocities were tested to cover the full range of typical operations: 1.0, 1.5, 2.0, 2.5, 3.0 fps (or 0.3-0.9 mps). All test trials were conducted during the daytime. Predator removal using carbon dioxide following protocols published by Wu and Bridges (2014) was completed before each trial. Hydrolox™ traveling water screen efficiency and participation will be calculated using the following equations:

$$\text{Efficiency} = \text{HT}/(\text{HT} + \text{SN})100$$
$$\text{Participation} = [(\text{HT} + \text{SN})/200]100$$

Where,

HT is the number of Delta Smelt recovered in the holding tank,

SN is the number of Delta Smelt recovered in the sieve net behind the screen.

## **Coordination and Collaboration**

This study was coordinated with the UC Davis Fish Culture and Conservation Laboratory. Participation and inclusion of research-related updates will be provided at regularly scheduled Tracy Technical Advisory Team (TTAT) and Central Valley Fish Facilities Review Team (CVFFRT) meetings. Statistical analysis will be provided by the Denver Technical Service Center and a final Tracy Series Report will be prepared by the TFCF Biological Resources Section.

## **Endangered Species Issues, “Take” Considerations**

Chinook Salmon (*Oncorhynchus tshawytscha*), Steelhead (*O. mykiss*), Longfin Smelt (*Spirinchus thaleichthys*) and Delta Smelt (*Hypomesus transpacificus*) will not be collected during this experiment.

## **Dissemination of Results (Deliverables and Outcomes)**

Field data collection and separation of samples were completed in winter 2016; laboratory data collection which includes measuring specimens, identification, and data entry is 75% complete.

This portion of the data collection should be completed by July 2019 and data analysis and publication soon after. The venue for dissemination of results will be through the Tracy Series Reports. Data and metadata will be made available for digital archive. Results will be provided at TTAT and CVFFRT meetings.

## Literature Cited

California Department of Fish and Wildlife (CDFW). ftp salvage records website, <ftp://ftp.dfg.ca.gov/salvage/>

Federal Register. 1993. Department of the Interior, U.S. Fish and Wildlife Service. March 5, 1993. *Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Delta Smelt*. Volume 58, Number 42, Pages 12854-12864.

National Marine Fisheries Service (NMFS). 2009. Biological Opinion. *Endangered Species Act section 7 consultation Biological Opinion and Conference Opinion on the long-term operations of the Central Valley Project and State Water Project*. June 4, 2009.

State Water Resources Control Board (SWRCB). 1978. *Water Right Decision 1485 Sacramento-San Joaquin Delta and Suisun Marsh*. August 1978.

Wu, B.J. and Bridges, B.B. 2014. *Evaluating the use of carbon dioxide as an alternative predator removal technique to decrease Tracy Fish Collection Facility predator numbers and improve facility operations*. Tracy Fish Collection Facility Studies. Volume 49. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center. 61 pp.

# Development of Computational Fluid Dynamics Model to Assess Carbon Dioxide Injection System for Predator Removal

## Investigators

### **James Higgs**

Hydraulic Engineer

Technical Service Center, Hydraulic Investigations and Laboratory Services

Bureau of Reclamation

Denver, CO 80225

[jhiggs@usbr.gov](mailto:jhiggs@usbr.gov)

### **Bryan Heiner**

Hydraulic Engineer

Technical Service Center, Hydraulic Investigations and Laboratory Services

Bureau of Reclamation

Denver, CO 80225

[bheiner@usbr.gov](mailto:bheiner@usbr.gov)

### **Connie Svoboda**

Hydraulic Engineer

Technical Service Center, Hydraulic Investigations and Laboratory Services

Bureau of Reclamation

Denver, CO 80225

[csvoboda@usbr.gov](mailto:csvoboda@usbr.gov)

## Summary

The Bureau of Reclamation's (Reclamation) Tracy Fish Collection Facility (TFCF; Byron, California) is located at the head of the Delta-Mendota Canal in the southern region of Sacramento-San Joaquin Delta (Delta) near Tracy, California. The purpose of the TFCF is to separate fish from water pumped south at the C.W. "Bill" Jones Pumping Plant (JPP). Operations at the TFCF divert, collect, hold and return salvaged fish to the Sacramento-San Joaquin Delta (Delta) beyond the influence of the JPP.

National Marine Fisheries Service (NMFS) 2009 Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (Biological Opinion) Action Suite IV.4 specifies that Reclamation should achieve a whole facility salvage efficiency of 75% at the TFCF by reducing fish losses associated with the salvage process. Many factors, including predation by piscivorous fish, contribute to fish loss at the TFCF (Bridges *et al.* 2019 in draft).

Pilot studies began in 2006 to investigate the use of carbon dioxide (CO<sub>2</sub>) as a predator removal method for piscivorous predators such as Striped Bass (*Morone saxatilis*), White Catfish (*Ameiurus catus*) and Channel Catfish (*Ictalurus punctatus*). An initial evaluation of the use of CO<sub>2</sub> as a predator removal technique in the TFCF bypass pipes and secondary channel was published in 2014 using dry ice (Wu and Bridges 2014). Ongoing dry ice studies are being conducted through the Tracy Fish Facility Improvement Program to recommend an optimal CO<sub>2</sub> concentration for predator removals in the bypass pipes and secondary channel and to determine the feasibility of using CO<sub>2</sub> to remove predators in the primary channel (FY19 Proposal Package for Tracy Fish Facility Improvement Program).

Carbon dioxide is used as an anesthetic to force fish, including predatory fish, downstream into the holding tanks. The 2014 study demonstrated fish can be removed using a CO<sub>2</sub> dose of 250–350 mg/L and the dry ice method can be implemented at the TFCF. The CO<sub>2</sub> treatment removed significantly more fish, of all species, than the control treatment. Median length of Striped Bass collected during CO<sub>2</sub> treatment was significantly greater than that of Striped Bass salvaged at the TFCF during the week of testing. There was no significant difference in the median lengths of white catfish collected before and during CO<sub>2</sub> treatment. In comparison to current predator removal methods, this method can improve employee safety, reduce labor, reduce facility downtime, and likely increase fish survival and salvage efficiency of threatened and endangered species (Wu and Bridges 2014).

To build on current research, a Computational Fluids Dynamics (CFD) investigation is proposed. A commercially available software package, FLOW-3D from Flow Science, will be used to investigate how CO<sub>2</sub> moves through the TFCF. The numerical model can be set up to inject CO<sub>2</sub> in a variety of areas: upstream of the trashrack, in the primary channel, at the bypass entrances, or in the secondary channel. Results may inform design of a CO<sub>2</sub> gaseous injector system for predator removals. Ideally, the numerical model will provide information regarding optimization of bubbler placement, application time, and application concentration to produce desired CO<sub>2</sub> exposure throughout the facility.

## **Problem Statement**

Predation by piscivorous fish contributes to fish loss at the TFCF. Previous studies have shown that the application of CO<sub>2</sub> may be an effective method to remove predators in the bypass pipes and secondary channel. A CFD model is proposed to assess flow distribution and dead zones throughout the facility. The model may also be able to estimate CO<sub>2</sub> system performance based on diffuser type (e.g. line diffusers, point diffusers) and installation location. Performance of the diffuser system is based on adequate distribution of CO<sub>2</sub> concentrations and creation of sufficient exposure times to move predators downstream into the holding tanks for collection and removal. The volume of CO<sub>2</sub> used in model simulations may indicate the size of tanks needed for each field treatment. Subsequently, results from this numerical model may provide design parameters for field installation of a CO<sub>2</sub> gaseous injection system at the TFCF.

## Goals and Hypotheses

### Goals:

1. Develop exposure guidelines.
2. Assess flow distribution and dead zones throughout the facility.
3. Determine distribution of CO<sub>2</sub> based on diffuser type and installation location (Figure 1-4).
4. Compare variations of gas bubbler application times and sequencing to meet exposure guidelines.

### Hypotheses:

1. Exposure guidelines can be identified based on previous studies and assistance from TFCF researchers.
2. Null: Flow will be evenly distributed throughout the primary and secondary channels without dead zones.
3. Null: Diffuser type and location produces the same CO<sub>2</sub> exposure.
4. Null: Gas bubbler application time and sequencing does not affect CO<sub>2</sub> exposure.



Figure 1. Example of fine bubble linear air diffuser.



Figure 2. Example of fine bubble point air diffuser.

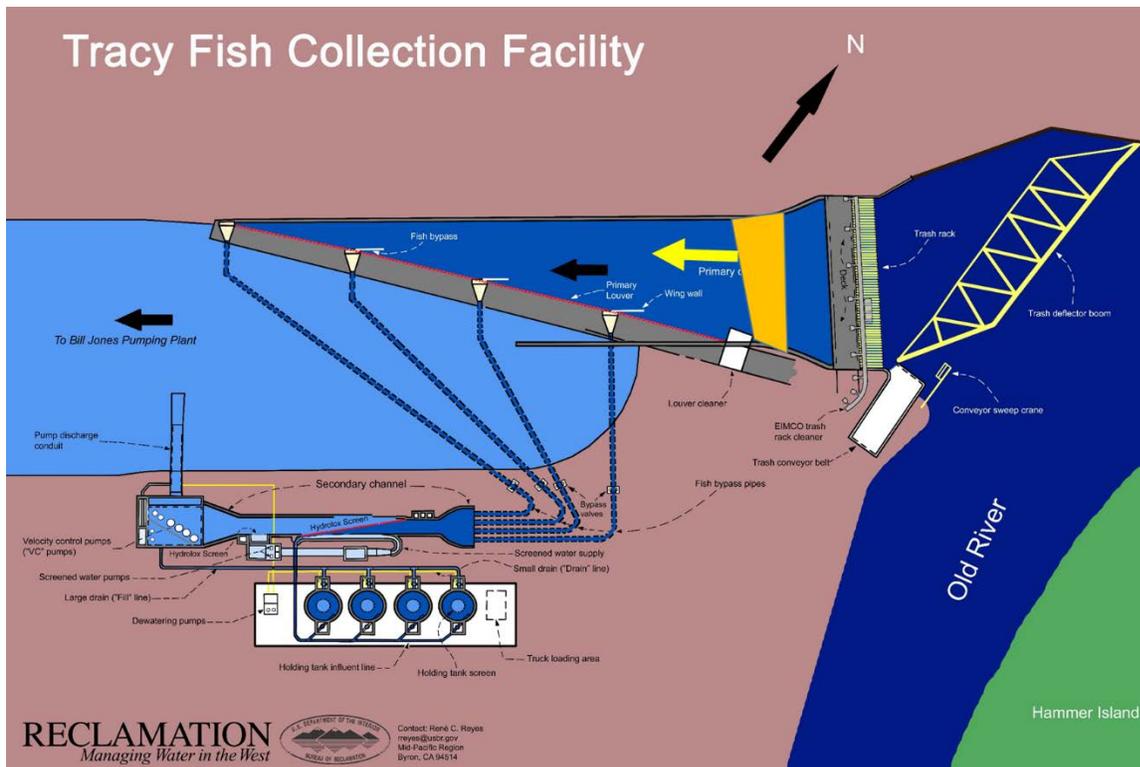


Figure 3. Simplified image of concentrated CO<sub>2</sub> moving through primary channel from fine line bubblers downstream of the trashrack.

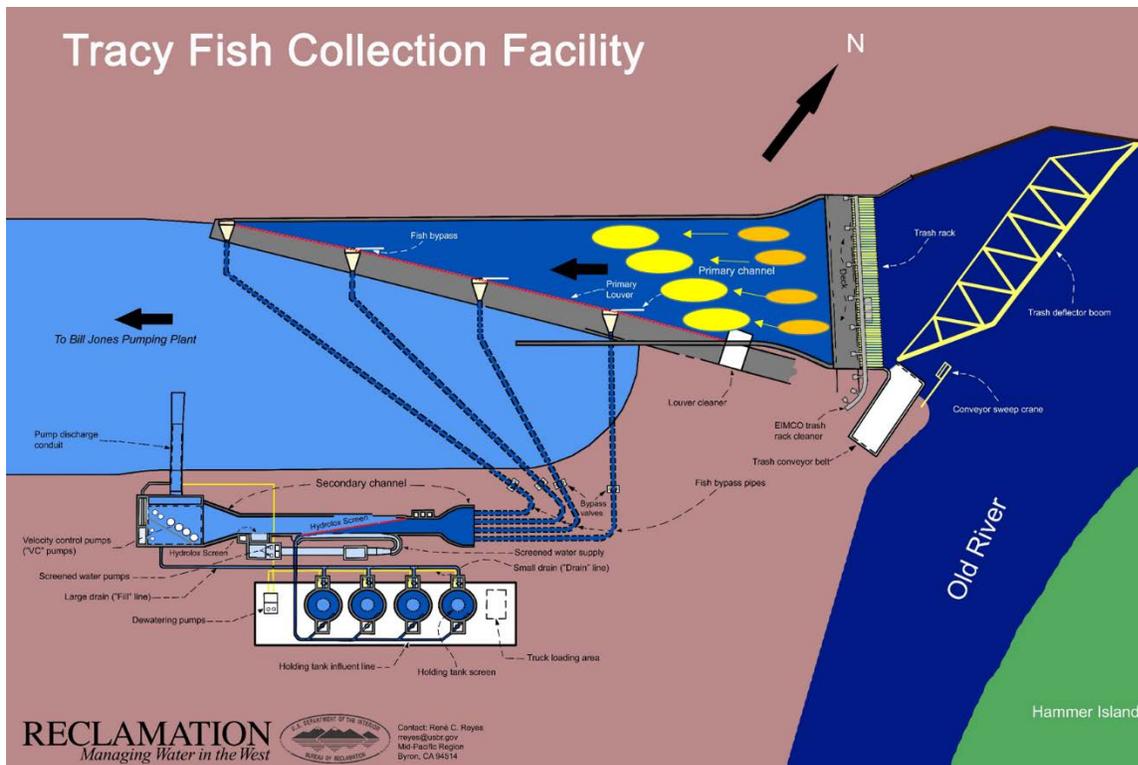


Figure 4. Simplified image of concentrated CO<sub>2</sub> moving through primary channel from fine point bubblers downstream of the trashrack.

## Materials and Methods

FLOW-3D by Flow Science is a computational fluid dynamics (CFD) model. The program is a finite difference, free surface, transient flow modeling system that solves the Navier-Stokes flow equations in up to three spatial dimensions. The flow equations are solved within an orthogonal coordinate mesh. The model is well-suited to the simulation of flows having a free water surface. The current version of FLOW-3D is 12.0.0.25, but the latest version of FLOW-3D at project initiation will be used.

A solids model will be created in AutoCAD 2018 or newer for import into FLOW-3D depicting the structures in the flow field. Existing drawings of the facility will be used to create the solids model. Recent 2019 bathymetric data inside the facility will be incorporated if large deposits of sediment are identified. Bathymetric data upstream of the facility may be incorporated to add confidence to how flow enters the facility. Boundary conditions will be set based on hydraulic data from the TFCF. It is anticipated that the model will simulate 3 flow conditions which requires information on JPP rate, velocity control and holding tank pump operation, and associated water depths for a particular tidal phase. TFCF researchers will be asked to help identify the 3 flow conditions based on situations when CO<sub>2</sub> removal may be more likely to occur. From the CFD model, flow magnitudes, distributions, and recirculation and dead zones will be identified. Simulations with tracers and/or buoyant particles can be used as an indicator of concentration distribution; however, gas transfer from the bubbles would not be modeled.

Exposure guidelines developed from past research and experience in coordination with TFCF researchers.

In order to incorporate gas transfer into the CFD model, discussions with Flow Science will be required to identify appropriate FLOW-3D modules to add into the program to properly model CO<sub>2</sub> release and to increase confidence in results. It is anticipated that various types of diffusers, locations, and application times can be simulated. Once the model is running, further refinements can be made and/or additional tasks can be added.

### **Year 1 Scope of Work**

- 1.) Develop CO<sub>2</sub> exposure guidelines and 3 simulated flow conditions to be tested (highly reliant on project personnel).
- 2.) Develop hydraulic model for FLOW-3D
  - Develop solids model using AutoCAD 2018 or newer and import into FLOW-3D.
  - Identify flow distribution and dead zones.
  - Simulate tracers and/or buoyant particles as an indicator of concentration distribution.

### **Year 2 Scope of Work**

- 1.) Incorporate gas transfer into FLOW-3D model
  - Coordinate with Flow Science on model development.
  - Utilize modules such as bubble and phase change options, density evaluation, heat transfer, drift model, neutrally buoyant probes depicting exposure history.
- 2.) Identify optimal diffuser type, location, and application time. Estimate volume of CO<sub>2</sub> required to meet concentration objectives.

### **Optional: Year 3 Scope of Work**

- 1.) Model refinement including incorporation of chemical reaction kinetics based on water quality parameters and animating moving history probes to act more like fish.
- 2.) Utilization of air injection in the model to improve fish recovery time, if needed.

## **Assumptions and Limitations**

CFD modeling depends on availability of qualified staff to develop the model and computational resources to process the FLOW-3D results. If additional modules for gas transfer require more computational resources than expected, simulations may be moved to an external private server for additional cost. Reclamation has not used many of the FLOW-3D modules proposed for Years 2 and 3. Discovery of proper values for parameters and the need for calibration has not

yet been evaluated. It is possible that successful gas transfer simulation cannot be achieved. Uncertainty in results will need to be estimated in order to confidently apply results to real-world conditions.

## **Coordination and Collaboration**

Jim Higgs will be the team lead for performing the CFD development, analysis, and documentation. Bryan Heiner and Connie Svoboda will serve as hydraulic consultants. Research efforts will be coordinated with TFCF biological staff to ensure that project work compliments and advances current research. Brandon Wu and Rene Reyes will assist by providing information on previous CO<sub>2</sub> introduction at the facility using dry ice, developing CO<sub>2</sub> exposure guidance, defining TFCF operations to simulate, and providing biological expertise. If optional model refinement is desired, water quality information will be needed.

## **Endangered Species Issues, “Take” Considerations**

No take will occur during CFD simulations.

## **Dissemination of Results (Deliverables and Outcomes)**

After development of the CFD model in Year 1, data analysis and results will be presented at the Tracy Technical Advisory Team meeting. When the gas transfer model is integrated and final results are available, a Tracy Technical Bulletin will be completed. Data and metadata will be made available for digital archival.

## **Literature Cited**

National Marine Fisheries Service (NMFS). 2009. *Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. U.S. Department of Commerce, National Marine Fisheries Service, Southwest Region. June 4, 2009.

Bridges, Brent B., Brandon J. Wu, Rene C. Reyes, Mark D. Bowen, and Raymond C. Bark. In Draft 2019. *Effects of Striped Bass Predation on Salvage of Adult Delta Smelt and Juvenile Chinook Salmon at the Tracy Fish Collection Facility*. Tracy Fish Collection Facility Studies, Tracy Volume Series 45, Bureau of Reclamation, Mid-Pacific Region.

Wu, Brandon J. and Brent B. Bridges. 2014. *Evaluating the Use of Carbon Dioxide as an Alternative Predator Removal Technique to Decrease Tracy Fish Collection Facility Predator Numbers and Improve Facility Operations*, Tracy Fish Collection Facility Studies, Volume 49, Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.

# Baselines: Establishing Passive Integrated Transponder Tagging Methods in Adult Delta Smelt

## Investigators

### **Christopher L. Hart**

Fish Biologist  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[CHart@usbr.gov](mailto:CHart@usbr.gov)

### **Kristen M. Towne**

Fish Biologist  
U.S. Fish and Wildlife Service  
Lodi, CA 95240  
[Kristen\\_Towne@fws.gov](mailto:Kristen_Towne@fws.gov)

### **Brandon J. Wu**

Fish Biologist  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Byron, CA 94514  
[BWu@usbr.gov](mailto:BWu@usbr.gov)

## Summary

The Bureau of Reclamation's Tracy Fish Collection Facility (TFCF), located in Byron, California, was developed to collect and salvage fish from the Sacramento-San Joaquin Delta (Delta) water being pumped by the Central Valley Project's C.W. "Bill" Jones Pumping Plant. Fish that are salvaged by the TFCF are hauled to designated release sites in the Delta away from the influence of the export pumps. The salvage can include a wide variety of both introduced and native fish species, including listed species such as the Delta Smelt (*Hypomesus transpacificus*; Federal Register 1993). The TFCF may potentially collect and salvage Delta Smelt throughout the year, but is usually limited to the non-summer months. The 2008 U.S. Fish and Wildlife Biological Opinion requires the Bureau of Reclamation to monitor for Delta Smelt during the months of December through July, when water is being diverted.

The Delta Smelt is a small fish, typically reaching 60–70 mm fork length (FL), endemic to the Delta. These fish typically have a 1-year life cycle and reach adulthood within 7–9 months (Moyle 2002). Delta Smelt have historically been difficult to tag because of their small size and delicate nature, so internal tags (e.g., hydroacoustic or Passive Integrated Transponder [PIT] tags) have not been used extensively (Sommer *et al.* 2011). However, technological advances have allowed for both PIT tags and hydroacoustic tags to become smaller, potentially making

them a more viable option for small fish. Very few studies have attempted to implant these tags into Delta Smelt and document their findings. Although acoustic tag implantation has yet to be successful in this species, PIT tag injection has shown some promising survival and tag retention results. Wilder *et al.* (2016) reported 95% survival to 28 d in Delta Smelt injected with Biomark MiniHPT8 PIT tags. Studies in Chinook Salmon (*Oncorhynchus tshawytscha*) have reported an increase in survival by the injection method compared to surgical implantation, but that same method also increased the rate of tag expulsion (Cook *et al.* 2014). While Wilder *et al.* (2016) presented high quality initial research into this research area, it is somewhat limited in that it only assessed one implantation method (for PIT tags) and one PIT tag size. We intend to expand on this research to determine the influence of implantation technique (i.e., injection vs surgery) across a wide range of tag burdens by using PIT tags of varying sizes. Additionally, as demonstrated in Chinook Salmon, there can be a wide variability in the results of tag effect studies that employ similar methods (Towne and Brandes [in press], Ammann *et al.* 2013, Brown *et al.* 2010, Brown *et al.* 2006), indicating the importance of determining the effect of implanted tags on the fish intended for use in future TFCF studies. The present study will allow us to refine Delta Smelt tagging techniques that will become very beneficial for future facility improvement studies by developing reference and baseline material.

## **Problem Statement**

Delta Smelt tagging techniques have not been refined or extensively studied due to the relatively recent development of tags at the present size. Therefore, there is very little information about the process and impacts to these fish. Should this research be successful in developing methods for tagging Delta Smelt, the resulting knowledge could be a valuable asset for testing TFCF efficiency with this species.

## **Goals and Hypotheses**

### *Goals:*

1. Determine the influence of tag implantation method (i.e., injection or surgical insertion) on survival and tag retention of adult Delta Smelt sourced from the UC Davis Fish Conservation and Culture Laboratory.
2. Evaluate the influence of tag burden on survival and tag retention of the adult Delta Smelt using a variety of PIT tag sizes.

### *Hypotheses:*

1. Implantation via the injection method will result in lower survival of Delta Smelt post-tagging compared to both controls and fish implanted with tags via the surgery method.
2. An increase in tag burden will significantly decrease survival and tag retention for both implantation methods.

## **Materials and Methods**

This study plan focuses on evaluating the potential for survival and tag retention to be influenced by tag implantation method and tag burden on adult Delta Smelt (*Hypomesus transpacificus*). Five hundred cultured adult Delta Smelt, roughly 70mm FL will be obtained from the UC Davis

Fish Conservation and Culture Laboratory (FCCL). Fish will be held in the experimental branch of the FCCL. During the course of the project, the study fish will be held at 12°C in a single 1,484-L circular tank, utilizing circulated treated Delta water. Treated Delta water has been settled, filtered, and UV sterilized. Temperature, dissolved oxygen (%), pH, total ammonia nitrogen, nitrates, and conductivity will be monitored throughout the study period to ensure proper water quality.

Approximately 50 fish will be used to develop the process and procedures, including establishing an appropriate dose of tricaine methanesulfonate (MS-222) to achieve and maintain stage III, plane 2 anesthesia for tag implantation, defined as loss of equilibrium accompanied with no reactivity and reduced gill ventilation and heart rate (Sneddon 2012). Once the process and procedures have been standardized, 320 fish will be divided to one of four groups: Surgery, Injection, Surgery Control, and Injection Control. Fish in the Surgery and Injection groups will be further divided to one of three PIT tag types: BioMark MiniHPT8 (8.4 mm), Biomark HPT9 (9 mm), and Biomark MiniHPT10 (10 mm; Biomark, Inc., Boise, ID). Each of the eight groups will have 40 fish. All fish will be held in a single tank for a 30 d holding period following tagging. The remaining 130 fish will be held as backup in case more practice fish are required than we anticipated, or in the event there are mortalities during the implantation procedure.

The standard operating procedure will be adapted from Wilder *et al.* (2016) and Liedtke *et al.* (2012; originally developed for use in Chinook Salmon [*Oncorhynchus tshawytscha*]). Fish will be measured to the nearest 1 mm FL, weighed to the nearest 0.1 g, evaluated for condition of eyes/fins/scales, and tagged with a visible implant alpha (VIA) tag next to the dorsal insertion for individual identification in case the fish expels the PIT tag. For PIT tags inserted using the surgical method, a small incision will be made on the linea alba anterior to the pelvic girdle. Incisions will be closed with a single suture using an absorbable suture material. For PIT tags inserted using the injection method, an appropriately sized sterilized syringe/needle (MK10/N125 for HPT9 tags, and MK165/N165 for MiniHPT8 and MiniHPT10 tags; Biomark, Inc., Boise, ID) will be used and injection sites will not be sutured. During surgery, water containing MS-222 buffered with sodium bicarbonate of the same concentration will be pumped over the fish's gills to maintain sedation. The concentration of MS-222 solution will be determined by the anesthesia exploration part of the study. Fish will have 10 min to recover in water supersaturated with oxygen between 130 and 150% before being transferred to a holding tank, where they will remain for a 30 d holding period in the treated Delta water.

Fish in the control groups will be anesthetized, weighed, measured, and evaluated in a similar fashion to the tagged groups, but will not undergo surgery or injection. These fish will be subjected to the same amount and time in anesthesia and in air as those in the tagged groups, and will undergo a similar recovery period. Fish in the control group will also be injected with a VIA tag for individual identification at the end of the holding period.

Due to the large number of fish in this study, two people will be used for tagging: one for the Surgery and Surgery Control groups, and one for Injection and Injection Control groups. Tagging will occur over a two day span, with half the fish in each group tagged on each day, for a total of 160 fish per day.

The differences in survival and differences in tag retention will be evaluated using a Fisher's exact test; groups that will be compared are detailed in Figure 1. Survival and tag retention of fish tagged on each day will be assessed for differences between them using the same tests to ensure there is no effect of tagging day. Additionally, the fish tagged by surgery will be compared to fish tagged by injection to ensure they are of similar lengths and weights using a t-test. All statistical tests will be performed in R.

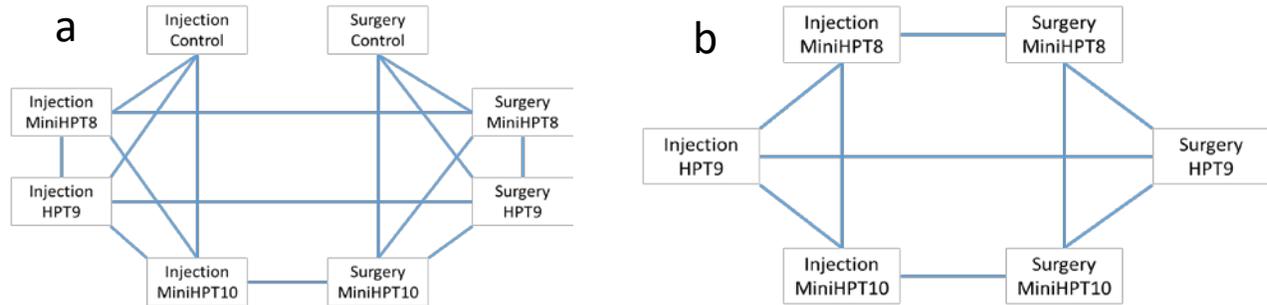


Figure 1. Schematic of groups to be compared when analyzing differences in survival (a) and tag retention (b). A line connecting two groups indicates the difference between those groups will be assessed. Proportions will be analyzed in R using Fisher's exact test.

### Assumptions and Limitations

It is assumed that the FCCL will be available and fully functional for this study to be successful. Cultured Delta Smelt from the FCCL must be available due to the limited availability of wild fish stocks. It is also assumed that all personnel will be present and able to work.

### Coordination and Collaboration

This research will be coordinated and conducted by the TFCF Biological Resources Section in collaboration with U.S. Fish and Wildlife Service and UC Davis. USFWS has successfully conducted comparable studies in the past and would be a valuable asset. The USFWS biologist will serve as co-PI, and assist with all aspects of the study, including study design, data collection, data analysis and report writing. UC Davis' participation is essential to the project's success by providing cultured Delta Smelt, fish husbandry, and an ideal location.

### Endangered Species Issues, "Take" Considerations

This study will take place entirely within the FCCL. The use of cultured Delta Smelt for this project is covered under the University of California-Davis, Fish Conservation and Culture Lab (FCCL) Federal Fish and Wildlife Permit TE-027742-5 which expires June 25, 2022.

### Dissemination of Results (Deliverables and Outcomes)

This tagging effect study was approved and funded for FY2019, but was not completed due TAF upgrade and operational issues. The TAF could not produce the required post-surgery water treatment required by this study. Shortly after a major repair on the TAF ozonation machine, the main power supply failed rendering it nonoperational. Due to the high costs of replacement parts,

repair has not been scheduled. Prior to the ozone failure, to create redundancy in the sterilization system, a whole facility UV system was purchased and was slated for install. Due to management involvement the installation has been delayed for an unknown amount of time. The PIT tags and required surgical supplies were purchased prior to the TAF failures. In an effort to save the project, the FCCL is lending the use of a portion of their facility and providing fish care at no cost to the TFFIP program.

The tagging effect study will take place in FY2020. Data analysis and results will be shared at a Tracy Technical Advisory Team (TTAT) meeting and a Tracy Series Report will be completed the following fiscal year after the study has been completed (FY 2021). If applicable, the findings will sent to an appropriate peer reviewed journal. The information gained will be utilized by future facility improvement studies.

## Literature Cited

- Ammann, A. J., C. J. Michel, R. B. MacFarlane. 2013. *The effects of surgically implanted acoustic transmitters on laboratory growth, survival, and tag retention in hatchery yearling Chinook Salmon*. *Environmental Biology of Fishes* 96:135–143.
- Brown, R. S., D. R. Geist, K. A. Deters, and A. Grassell. 2006. *Effects of surgically implanted acoustic transmitters > 2% of body mass on the swimming performance, survival, and growth of juvenile Sockeye and Chinook Salmon*. *Journal of Fish Biology* 69:1626–1638.
- Brown, R. S., R. A. Harnish, K. M. Carter, J. W. Boyd, and K. A. Deters. 2010. *An evaluation of the maximum tag burden for tag implantation of acoustic transmitters in juvenile Chinook Salmon*. *North American Journal of Fisheries Management* 30(2):499–505.
- Cook, K. V., R. S. Brown, Z. D. Deng, R. S. Klett, H. Li, A. G. Seaburg, and M. B. Eppard. 2014. *A comparison of implantation methods for large PIT tags or injectable acoustic transmitters in juvenile Chinook salmon*. *Fisheries Research* 154:213–223.
- Federal Register. 1993. Department of the Interior, U.S. Fish and Wildlife Service. March 5, 1993. *Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Delta Smelt*. Volume 58, Number 42, Pages 12854–12864.
- Liedtke, T. L., J. W. Beeman, and L. P. Gee. 2012. *A standard operating procedure for the surgical implantation of transmitters in juvenile salmonids*. U. S. Geological Survey Open-File Report 2012-1267.
- Moyle, P.B. 2002. *Inland Fishes of California: revised and expanded*. University of California Press.
- Sneddon, L. U. 2012. *Clinical anesthesia and analgesia in fish*. *Journal of Exotic Pet Medicine* 21(1):32–43.

Sommer, T., F. H. Mejia, M. L. Nobriga, F. Feyrer, and L. Grimaldo. 2011. *The spawning migration of Delta Smelt in the upper San Francisco Estuary*. San Francisco Estuary and Watershed Science [online serial] 9(2).

Towne, K., and P. Brandes. In press. *Survival, tag retention, growth, and wound healing of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) surgically implanted with a dummy acoustic tag*. San Francisco Estuary and Watershed Science.

Wilder, R. M., J. L. Hassrick, L. F. Grimaldo, M. F. Greenwood, S. Acuña, J. M. Burns, and T. C. Hung. 2016. *Feasibility of passive integrated transponder and acoustic tagging for endangered adult Delta Smelt*. North American Journal of Fisheries Management 36:1167–1177.

# Continuing Exploration of Methods to Reduce Fish Predation at Sacramento-San Joaquin Delta Release Sites

## Investigators

### Clarence Fullard

Fish Biologist  
Technical Service Center  
Bureau of Reclamation  
Denver, CO 80214  
Cfullard@usbr.gov

## Summary

Many fishes native to California's Sacramento-San Joaquin River Delta (Delta) have declined markedly in abundance from drought, habitat modification, water diversions, and other hydrological changes associated with large-scale water diversion projects (Bennett and Moyle 1996, Brown *et al.* 1996, Moyle 2002). The United States Bureau of Reclamation (Reclamation) Tracy Fish Collection Facility (TFCF) was built in the 1950s to divert and salvage juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) and Striped Bass (*Morone saxatilis*) in the Sacramento-San Joaquin River system from entrainment in the Delta Mendota Canal (Bates *et al.* 1960), which provides freshwater deliveries for the Central Valley Project (CVP). A similar system is employed to divert fish from entrainment in the nearby California Aqueduct, managed by the California Department of Water Resources (CDWR) for the State Water Project (SWP). Fishes from each salvage facility are captured and transported to downstream release sites in the Delta, away from the influence of the state and federal pumping plants.

The National Marine Fisheries Service's (NMFS) 2009 Biological Opinion (BO) determined that the long-term operations of the CVP and SWP adversely affect endangered winter-run and threatened Central Valley spring-run Chinook Salmon (NMFS 2009). The BO directs water pumping plants to increase Chinook Salmon salvage efficiency and end-of-pipe survival (*i.e.*, release site predation). Though release site predation has been a concern for decades, common methods such as netting, mark and recapture, stomach analysis, other common fisheries science methods are not easily applicable to end-of-pipe and large open systems such as the Delta, and losses due to predation at release sites has historically not been well quantified.

Starting late 2016, an interagency working group assessed the release site predation problem and worked together to develop possible tools and management/operational solutions. Since that time, the core research group (Reclamation Technical Service Center and CDWR) have been developing tools to a) develop a consistent and reliable methodology to measure release site predation, and b) reduce release site predation. The group identified variables affecting salvaged fish survival, including frequency of releases, water temperature, and near-field predator abundance. Proof-of-concept research efforts revealed limitations associated with acoustic

telemetry studies. Field demonstrations, laboratory studies, and computer simulations eliminated acoustic telemetry as a realistic option to measure release site predation. Field testing revealed predator feeding experiments as the most effective research tool available to measure release site predation loss. FY2019 project funds from the Tracy Fish Facility Improvement Program (TFFIP), and a significant fiscal contribution from CDWR are currently being used to assess the efficacy of a ~6–15 day break in releases to relieve the near-field area of heavy predator burdens, which could reduce release site predation as directed in the BO. Additionally, we are collecting data on diurnal predation variation in the Delta, which could also hold promise for a future management strategy to reduce release site predation.

Since our research group is performing summer/autumn data collection, the results of FY2019 research efforts won't be available until the end of the current fiscal year. Though we are confident in our ability to assess the efficacy of a release break on release site predation with our current tethered fish methodology, we are hesitant to propose a full-scale project for FY2020. Instead, this proposal is to spend time considering the successes of 2019 field efforts and assessing areas that can use improvement. It is unknown at this time whether any single treatment (*i.e.*, release breaks, night releases, etc.) can provide for a 50% reduction in release site predation. This proposal is offering to spend time working with the core research group through 2020 to carefully plan the next steps we may need to take to achieve up to a 50% reduction, as directed by the BO. Such ideas include a feasibility assessment of novel ideas, such as predator deterrents and novel salvage fish dispersal ideas in addition to those proposed by Karp 2016. We will consult with experts and outside agencies that have experience with such technologies and use internal engineers and other experts to lend guidance to technical feasibility at the state and federal release sites in the Delta. Our primary project partner, CDWR, has agreed with this approach and will not be funding any large-scale field research activities for 2020.

This proposal also will allow for continued analysis of 2019 data in collaboration with the CDWR and their consulting biologists. Information gained from this proposal will help fortify and bring continuity to the results of the last two years of data collection. In short, we hope to keep the initiative to reduce release site predation moving forward in 2020 which will ultimately help management operate the Tracy Fish Collection Facility in a way consistent with the Reasonable and Prudent Alternatives in the BO.

**Necessity of continued release site predation analysis efforts are contingent upon results of FY19 data. If the current treatment strategy proves successful, funds will be declined or returned to the TFFIP, or used to work with both state and federal facilities to develop a formal SOP for adopting a modified release schedule if the TFFIP manager deems it prudent.**

## **Problem Statement**

Preliminary data suggests that release site predation of salvaged fishes is a problem for the Tracy Fish Collection Facility. A core research group consisting of Reclamation Technical Service Center biologists, Tracy biologists, CDWR biologists, and consultants have been testing various methods to measure and reduce release site predation, and the results of the first full-scale year of testing will be available in late FY2019. We are testing the most logistically and biologically

feasible options for long-term sustained operations, such as a ~6–15 day release break scheme and night time releases. However, the lag time between research proposal schedule and data collection/summation in 2019 has led us to conclude that the most responsible way forward is to spend time in 2020 further assessing successes and, if necessary, areas that need improvement in our data collection methodology, and to further assess the feasibility of more complicated treatment ideas (*i.e.*, predator deterrent systems).

## Goals

Goals:

1. Synthesize and communicate the results of summer/autumn 2019 field efforts with internal and external organizations to determine the successes and failures of our 2019 research methods and identify areas for improvement.
2. Collaborate with CDWR and their consulting biologists through 2020 to develop new ideas for release site predation and perform feasibility assessments of any new treatments that can reduce release site predation (*i.e.*, release site predator deterrents). Collaboration with internal and external experts, including engineers and policy professionals will be an integral part of this goal.
3. Develop a thorough proposal in collaboration with CDWR to test a new treatment method in 2021 at the Delta release sites.

## Materials and Methods

To carry forward the efforts undertaken to understand and reduce release site predation in 2017–current, this proposal is designed to afford time to lead the research team through deliberations of our next steps based on results of 2019 field work and data analysis. **This proposal does not suggest that the current tethered fish and hydroacoustic methodology will be unsuccessful**—on the contrary, we are confident that the tools we’ve developed to measure relative predation rates in the release site areas will perform as intended. This proposal lays out a plan forward for FY2020 if the modified management strategy we’re testing in 2019 doesn’t produce the desired predation-reduction results, and to ensure that investigations into lingering questions about the efficacy of our chosen research methodology or new treatment ideas can be undertaken to reduce release site predation as required by the BO. If funded, this effort would also allow for time to advance new ideas built on 2018-2019 field experiences and develop a new proposal for refined large-scale efforts in 2021 that can better achieve the 50% reduction goal of the BO.

The topic of juvenile salmonid survival through the Delta is of key concern to multiple state and federal agencies (Herbold et al. 2018, Miranda et al. 2010). This proposal will allow collaboration with entities performing similar studies, such as the National Marine Fisheries Service Southwest Fisheries Science Center, to look for areas of mutual improvement in technique and data analysis of tethered fish experiments. Collaboration includes calls and meetings with outside agencies that currently use or have experience with predator deterrents, and verification of ideas with other Technical Service Center experts. Initial discussions have

identified electrical barriers (Noatch and Suski 2012), acoustic deterrents (Jesus et al. 2018), predator removals (Carey et al. 2012) as ideas worth investigating to assess their relevancy to the near-field area around the release sites. Most assessments of these non-physical and other predator deterrents focus on effects at larger scale problems, such as Delta-wide predation reduction, and success has at times been limited. But they may very well provide predation relief at the near-field release site areas. Reclamation has the expertise available to ensure that all ideas are properly vetted for financial, technical, and logistical feasibility.

## **Assumptions and Limitations**

This project will fund staff hours dedicated to moving the project forward in 2020 if 2019 field efforts are unable to achieve a measured 50% reduction of predation relative to ambient levels. It assumes continued cooperation with CDWR and their consulting biologists, and they've committed to a small-scale personnel effort as proposed here. Scheduling, timing, and other logistical concerns present very limited risk. If 2019 efforts prove successful, this proposal will be rescinded and/or funds will be returned unless TFFIP management requests assistance developing a MOU or other operational inter-agency agreements based on the 2019 treatment options.

## **Coordination and Collaboration**

Primary coordination will be led by Reclamation TSC Fisheries and Wildlife Resources Group. Close coordination and collaboration between TFCF and CDWR will enable thorough consideration of data analysis and deliberation of new treatment ideas. Collaboration with others in the region, including NMFS, CDFW, US Geological Survey, and US Fish and Wildlife Service will occur as we try to refine treatment methodologies for the future, and develop a proposal to test a treatment to reduce release site predation in 2021.

## **Endangered Species Issues, "Take" Considerations**

No field work is proposed during FY2020, however we will still be covered under current state and federal permits, including a Biological Opinion (NMFS 2017) and a CA scientific collection permit that enables current field work on this project.

## **Dissemination of Results (Deliverables and Outcomes)**

Research updates will be provided and/or presented at regularly scheduled Tracy Technical Advisory Team (TTAT) as the opportunities arise. The primary deliverables will be a report which includes any follow-up data analysis and summary of interagency deliberations on new treatments, including any feasibility studies completed. This information will be published as a Tracy Series Technical Bulletin, and potentially a nationally distributed scientific journal, if warranted. Information obtained from this study will be used to improve release site protocols and will advise future release site improvements.

## Literature Cited

- Bates, D. W., O. Logan, and E.A. Pesonen. 1960. Efficiency evaluation, Tracy Fish Collection Facility, Central Valley Project, California. U.S. Fish and Wildlife Service. Seattle, WA, USA.
- Bennett, W. A., and P. B. Moyle. 1996. *Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary*. San Francisco Bay: the ecosystem 1:519 - 542.
- Brown, R., S. Greene, P. Coulston, and S. Barrow. 1996. *An evaluation of the effectiveness of fish salvage operations at the intake of California aqueduct, 1979 - 1993*. Pages 497 - 518 in J. T. Hollibaugh, editor. San Francisco Bay: the ecosystem. Pacific Division, American Association for the Advancement of Science, San Francisco, CA.
- Carey, M.P., B.L. Sanderson, K.A. Barnas, and J.D. Olden. 2012. *Native invaders—challenges for science, management, policy, and society*. *Frontiers in Ecology and the Environment* 10:7 pp 373-381.
- Karp, C. and B. Bridges. 2016. A Review of Fish Release Methods at the Tracy Fish Collection Facility with Recommendations for Future Operations. April 2016. Tracy Fish Collection Facility Studies. Technical Bulletin 2016-1. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center. 32 pp.
- Herbold, B., S.M. Carlson, R. Henery, R.C. Johnson, N. Mantua, M. McClure, P.B. Moyle, and T. Sommer. 2018. *Managing for Salmon Resilience in California's Variable and Changing Climate*. *San Francisco Estuary and Watershed Science* 16:2.
- Jesus, J., M.C.P. Amorim, P.J. Fonseca, A. Teixeira, S. Natário, J. Carrola, S. Varandas, L.T. Pereira, and R. M.V. Cortes. 2018. Acoustic barriers as an acoustic deterrent for native potamodromous migratory fish species. *Journal of fish biology*, special issue accessed at <https://doi.org/10.1111/jfb.13769>
- Miranda, J., R. Padilla, and J. Morinaka. 2010. *Release site predation study*. California Department of Water Resources, California Natural Resources Agency, CA.
- Moyle, P.B. 2002. *Inland Fishes of California*. University of California Press, Berkeley.
- NMFS (National Marine Fisheries Service). 2009. *Biological Opinion and Conference Opinion of the Proposed Long term operations of the Central Valley Project and State Water Project*. U.S. Department of Commerce, National Marine Fisheries Service. June 4, 2009.
- NMFS. 2017. *Biological Opinion for the 2017-2019 Sacramento River-San Joaquin River Delta Release Site Predation Study*. Issued to Reclamation, Technical Services Center, Denver, Colorado by the U.S. Department of Commerce, National Marine Fisheries Service, Central Valley Office, Sacramento, CA. April 5, 2017. 75 pages.

Noatch, M.R., and C.D. Suski. 2012. *Non-physical barriers to deter fish movements*. Environmental Reviews 20:1, pp 71-82.

# Movement of Fish in the Primary Channel to the Delta-Mendota Channel during Louver Cleaning: A Pilot Study

## Investigators

**Raymond C. Bark**

Fish Biologist

Fisheries and Wildlife Resources Group

Technical Service Center

[rbark@usbr.gov](mailto:rbark@usbr.gov)

## Summary

The Tracy Fish Collection Facility (TFCF) was developed in the 1950's by the Department of the Interior's Bureau of Reclamation as a means to salvage fish entrained by the C.W "Bill" Jones Pumping Plant (JPP). The TFCF screens fish from the canal water, diverts them into collection tanks and transports the fish, via truck, to the confluence of the Sacramento and San Joaquin Rivers beyond the influence of the south delta export pumps. Due to the volume and rate of export pumping into the canal (up to 5,200 ft<sup>3</sup>/s), various types of fish from the Sacramento-San Joaquin River Delta are entrained including Endangered Species Act (1973) listed fish. Native fish species found in the Delta such as Chinook Salmon (*Oncorhynchus tshawytscha*), Steelhead (*O. Mykiss*) and Delta Smelt (*Hypomesus transpacificus*) are often entrained into the canal exports therefore, it is critical that these species are effectively collected and salvaged by the TFCF. Juvenile life stages of endangered and threatened species such as Chinook Salmon (54 FR 10260, 59 FR 440, 64 FR 50394), Steelhead (63 FR 13347), and adult and juvenile Delta Smelt (58 FR12854) are salvaged mostly during the winter, spring and early summer period by the TFCF (California Department of Fish and Wildlife 2017).

Fish salvaged by the TFCF must first pass through the trash-rack structure made from thick elongated steel bars designed to keep large debris from entering the facility. The spacing of the bars for the trash-rack structure are 2.25 inches (5.72 centimeters) apart which prevents large fish from entering the TFCF. However, the canal flow entrains all types of small-bodied fish into the TFCF smaller in width than 2.25 inches. Fish that pass through the trash-rack enter the primary channel where they are guided by a louver array, similar to the trash-rack but with 1-inch spacings (2.54 cm), into one of four bypasses feeding into the secondary channel. Once the fish enter the secondary channel, they are further guided into one of four holding tanks before being removed from the tank and loaded into a fish hauling truck.

Non-native prey fish such as Threadfin Shad (*Dorosoma petenense*) and American Shad (*Alosa sapidissima*) and non-native predatory fish such as Striped Bass (*Morone saxatilis*), Largemouth Bass (*Micropterus salmoides*) and Bluegill (*Lepomis macrochirus*) have been the fish most frequently salvaged in recent years while numbers of ESA listed native fish (previously listed) have been declining (Aasen, G. 2014). All of these species as well as others can potentially

escape downstream during louver cleaning. Striped Bass (*Morone saxatilis*), the top non-native predatory fish salvaged, have been found to hold within the primary channel for long periods while some eventually passed downstream of the primary channel (Wu et al. 2015) into the Delta-Mendota Channel (DMC) when the primary channel louvers were lifted for cleaning. Some of these acoustically tagged Striped Bass were also detected holding next to the primary channel guide wall where water velocities have been found to be low (Frizell and Bark 2006) and where other fish are likely to hold as well. If Striped Bass can hold for long periods in the primary channel, other entrained fish (including the ESA listed fish) may also hold and eventually escape downstream evading the TFCF salvage process altogether. The ESA listed fish that go through the primary louvers during normal operation and during louver cleaning are considered lost.

Movement of fish between the primary channel and the DMC is tied to the cleaning (and maintenance) of the primary louver panels. The louver panels are individually lifted and cleaned at least once per day (2-5 times during fall and winter) allowing fish to move upstream and downstream of the primary channel louver array. Cleaning the louvers is necessary to ensure their effectiveness in guiding fish into the secondary channel and into the collection tanks and to minimize flow restriction to the JPP. Fouled louvers also require greater amounts of electrical energy to pump the canal water uphill. Each louver panel (36 total) requires about 3-7 minutes to be lifted, cleaned, and then lowered back into place and occurs during day and year-round as necessary. Consequently, a population of Striped Bass (as well as other fish) reside in the DMC downstream of the TFCF and upstream of the JPP. This section of the DMC is about 15 feet deep, 240 feet wide and 2 ¼ miles long - ample habitat to hold many fish.

## **Problem Statement**

Because the primary louvers must be lifted for cleaning, movement of fish into the DMC may occur daily within the period when the cleaning occurs. For the entire louver array to be cleaned, a total of 108 to 144 minutes are needed which allows ample time for fish to escape downstream through any of the louver positions. The primary louvers are also cleaned from upstream to downstream, allowing fish holding near the guide wall a visual cue to escape as the openings progress towards the apex. Movement of fish holding in the primary channel and passing into the DMC may also occur when high numbers of fish are entrained and displacing others, essentially crowding them downstream and into the DMC when a louver is lifted. In a less crowded condition fish holding in the primary louver channel may also become opportunistic and learn to escape downstream when high debris loads require multiple cleanings thus, having frequent opportunities to escape downstream (or back upstream). This pilot study will determine if movement of fish holding inside the primary louver channel access the DMC (or vice-versa) when the louvers are lifted for cleaning. If possible, experimental groups of fish (e.g. Threadfin Shad) will be released during louver cleaning and observed for downstream escapement.

As part of this effort to determine fish movement between the primary channel and the DMC when the louver panels are lifted, I will also analyze the existing Striped Bass movement data collected from the Carbon Dioxide Predator Removal study conducted by Brandon Wu (and other TFCF staff). This study has focused on removing Striped Bass from the primary channel where several fish were acoustically tagged for each replicate to determine movement within the

primary channel during the experiment. As a secondary use of this Striped Bass movement data, I will cross-reference the CO<sub>2</sub> movement data with all detections of the HTI acoustic tags by the hydrophone array. Since the hydrophones (HTI) are located throughout the TFCF as well as upstream and downstream of the facility, the hydrophone array should be able to record and differentiate fish movement between the primary channel and DMC as well as in other locations within and near the TFCF.

## Goals and Hypotheses

### Goal

Determine the extent of fish loss through the primary louver channel using an acoustic/underwater fish camera when the louvers are lifted for cleaning.

Determine if the screen loss rate of experimentally released small-bodied fish (e.g. Threadfin Shad) during primary louver cleaning can be quantified.

### Null Hypotheses

There will be no fish from the primary channel escaping downstream into the DMC (or moving back upstream) into the primary channel when the louvers are lifted.

## Materials and Methods

### *Test Location and Equipment*

A DIDSON (Duel-Frequency Identification Sonar) camera will be the primary instrument used to determine movement of fish out of the primary channel and into the DMC. The DIDSON camera will be deployed immediately downstream of the primary channel, possibly near the apex where fish are crowded and movement into the DMC can be clearly determined when the louvers are lifted. This pilot study will be performed during the summer period when both high debris loads require multiple louver cleanings and large amounts of fish are entrained into the TFCF. The duration of deployment will be approximately for two-weeks covering day, night and crepuscular periods. The DIDSON camera will be mounted onto a long steel pole that will be used to lower and raise the camera into the DMC from the primary channel louver deck. A rope or steel cable will also be attached to the camera's frame to ensure retrieval from the DMC. A smaller and considerably lighter "off-the-shelf" fish camera will also be used to assist the DIDSON and can be deployed at various depths using a weighted rope.

### *Fish Source and Care*

If possible, experimental groups of fish (e.g. Threadfin Shad) will be released during louver cleaning and observed for downstream escapement. No ESA fish from the TFCF or DMC will be caught, collected or handled for this pilot study.

### *Data Analysis/Interpretation*

This pilot study will determine if movement of fish entrained through the salvage process or if fish that are holding inside the primary louver channel pass into the DMC (or vice versa) when the louvers are lifted for cleaning. The DIDSON camera uses sonar to capture movement of fish underneath the water's surface and will also record the louver panel(s) being moved. When the louver is lifted, we should be able to clearly discern whether or not fish are escaping downstream and therefore, circumventing the salvage effort. Fish that are not salvaged, including listed species, could become pray to predatory fish holding in the DMC and moving back up into the primary channel to feed when the louver are lifted thus, impacting the salvage effort. If this pilot study is successful, future efforts will focus on the ESA listed fish in effort to improve the overall TFCF salvage process.

## **Assumptions and Limitations**

The foremost limitation of the DIDSON camera is the identity of small fish captured at distance in its video imaging. The identity of fish further away from the DIDSON camera may be less discernible due to the sonar's imaging noise (i.e. grainy imaging). The secondary commercial "off-the-shelf" fish camera captures underwater images in full color where the identities of fish are more apparent but water turbidity can hinder the camera's capabilities. However, the fish camera does have an infrared mode that should help to discern species in turbid or in dark conditions. Also, the identity of some species can be deduced using certain morphometric and physical features.

## **Coordination and Collaboration**

This research will be coordinated and conducted by one member of the Fish and Wildlife Resources Group (TSC 85-829000) with the assistance of one or two TFCF Biological Resources staff. Research project updates to the Tracy Technical Advisory Team and to interested interagency members and/or groups will be through email, phone, power-point presentation or via a full proposal.

## **Endangered Species Issues, "Take" Considerations**

No ESA fish from the TFCF or DMC will be caught, collected or handled for this pilot study.

## **Dissemination of Results (Deliverables and Outcomes)**

This pilot study will determine if movement of fish holding inside the primary channel escape downstream (and proportion of experimentally released fish, if possible) to the DMC and vice-versa when the primary channel louvers are lifted for cleaning. The pilot study will be performed during FY20. Data analysis and a power-point presentation will be prepared and presented to TTAT and other interested stake holders during FY20.

## Literature Cited

- Aasen, G. 2014. *Fish Salvage at the State Water Project's and Central Valley Project's Fish Facilities during the 2013 Water Year*. Interagency Ecological Program for the San Francisco Estuary, IEP Newsletter Vol. 27 No. 2, 2014.
- Bureau of Reclamation (Reclamation). 2011. *Three-Year Summary of Fish Salvaged at the TFCF, April 1, 2000 to March 31, 2003*. Tracy Fish Facility Research, Technical Service Center. U.S. Department of the Interior, Bureau of Reclamation, Denver, CO. <https://www.usbr.gov/mp/TFFIP/glossary/fish-genus-species.html>
- California Department of Fish and Wildlife. 2017. *Fish Salvage Monitoring*. Bay Delta Region 3, Napa and Stockton, CA. <https://www.wildlife.ca.gov/Conservation/Delta/Salvage-Monitoring>
- Federal Register (58 FR12854). March 5, 1993. *Delta smelt listed as a threatened species*. Volume 58, Number 42, Page 12854.
- Frizell, K. and Bark, R. 2006. *Determining Hydraulic Conditions for Holding Areas of Large Predatory Fish within the Tracy Fish Collection Facility*. World Environmental and Water Resource Congress 2006: pp. 1-9. doi: 10.1061/40856(200)154
- National Marine Fisheries Service (NMFS). 1989. *Emergency rule, Sacramento winter-run Chinook salmon listed as a threatened species*. Federal Register (54 FR 10260). August 4, 1989. Vol. 54, Page 10260.
- National Marine Fisheries Service (NMFS). 1994. *Sacramento winter-run Chinook salmon re-classified as endangered*. Federal Register (59 FR 440). January 4, 1994. Vol. 59, No. 2, Page 440.
- National Marine Fisheries Service (NMFS). 1998. *Central Valley steelhead listed as a threatened species*. Federal Register (63 FR 13347). March 19, 1998. Vol. 63, No. 53, Page 13347.
- National Marine Fisheries Service (NMFS). 1999. *Central Valley spring-run Chinook salmon listed as a threatened species*. Federal Register (64 FR 50394). September 16, 1999. Vol. 64, No. 179, Page 50394.
- U.S. Fish and Wildlife Service (USFWS). 1993. *Delta smelt listed as a threatened species*. Federal Register (58 FR12854). March 5, 1993. Vol. 58, No. 42, Page 12854.
- Wu, B., R. Bark and W. Frizell. 2015. *Use of Acoustic telemetry to Estimate Striped Bass Residence Time and Identify Most Utilized Holding Locations within the Tracy Fish Collection Facility*. Tracy Series Volume 46, U.S. Dept. of the Interior, Bureau of Reclamation Mid-Pacific Region and the Technical Service Center.