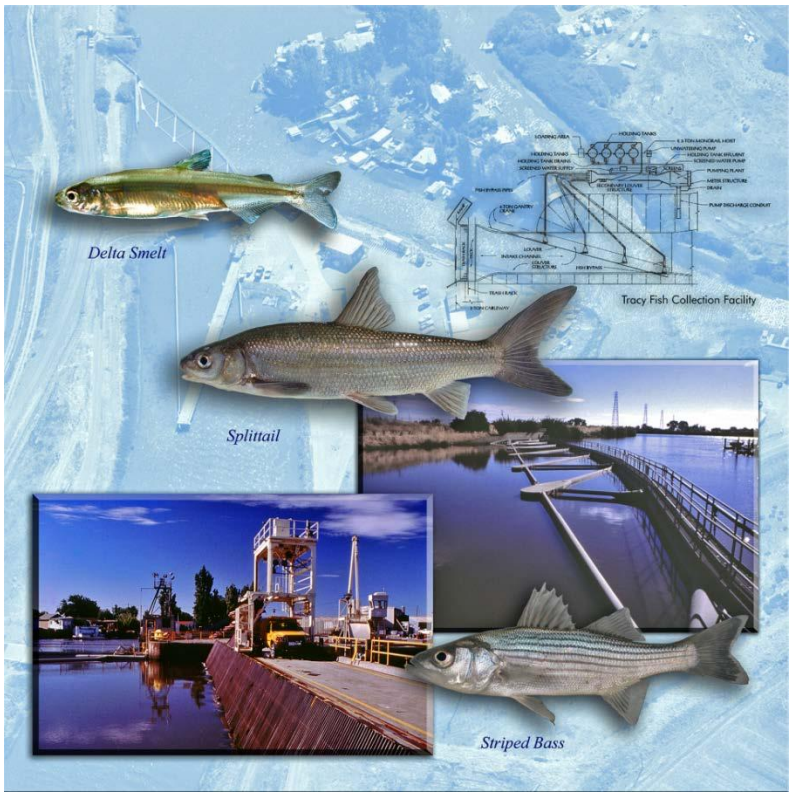
RECLAMATION

Managing Water in the West

FY19 Proposal Package for Tracy Fish Facility Improvement Program



U.S. Department of the Interior
Bureau of Reclamation
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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

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Primary Channel Immigration and Emigration of Striped Bass to and from the Delta-Mendota Intake Channel

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Summary

The Tracy Fish Collection Facility (TFCF) was developed in the 1950s by the Department of the Interior's Bureau of Reclamation (Reclamation) as a means to salvage entrained fish and then return them to the Sacramento-San Joaquin River Delta beyond the influence of C.W. "Bill" Jones Pumping Plant (JPP). Because the TFCF entrains both prey and predator fish, predators such as Striped Bass (*Morone saxatilis*) can reside inside the TFCF and downstream in the Delta-Mendota Intake Channel (DMIC) for long periods of time. Adult Striped Bass residing inside the primary channel and in the DMIC are likely to have been entrained as sub-adults or juveniles since the trash rack prevents larger fish (fish with widths greater than 2.25 inches or 5.72 centimeters) from entering. Consequently, a population of Striped Bass reside in the DMIC 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. Over time, these Striped Bass may develop a feeding strategy where they learn to access and re-populate the primary channel as a more favorable feeding location then escape back downstream when the primary louver panels are lifted for cleaning.

Striped Bass are often salvaged in relatively high numbers at the TFCF (Bureau of Reclamation 2011). Sub-adult and juvenile Striped Bass are more susceptible to flow entrainment because they have yet to develop ram gill ventilation from branchial ventilation thus, they lack the swimming ability of adult fish (Freadman 1979) and can pass through the trash rack. Striped Bass from juvenile to adult size, have been known to move erratically for extended periods (hours and days) and harbor in large numbers in front of the trash rack (Vogel 2011). Striped Bass have also been found to hold near the primary channel guide wall where water velocities have been found to be low (Frizell and Bark 2006) and inside the TFCF facility, mostly within the primary channel, for long periods (Wu et al. 2015). Wu et al. had four Striped Bass reside within the TFCF facility for the duration of the battery-life of the acoustic tag (250 – 300 days). Five other acoustically tagged Striped Bass eventually moved downstream of the primary channel (Wu et al. 2015) where, presumably, the tag's battery-life expired and they could no longer be tracked.

Striped Bass are the main piscivore salvaged at the TFCF (Bureau of Reclamation 2011) and have been found to directly impact salvage rates of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) and adult Delta Smelt (*Hypomesus transpacificus*; Bridges *et al*. 2018, *In Draft*). Sub-adult and juvenile Striped Bass depend on the various prey fish entering the primary channel as their main food source. Over time Striped Bass in the primary channel will develop into adult-sized fish becoming too large to escape upstream through the trash rack and instead, may learn to escape downstream when the primary louver panels are lifted for cleaning. Striped Bass are a long-lived species, living around 30 years (NOAA 2017), and can potentially spend most of their lifetime trapped downstream of the TFCF trash rack.

Striped Bass movement between the DMIC and the primary channel may be tied to the cleaning (and maintenance) of the primary louver panels. The louver panels are individually lifted and cleaned at least once per day potentially allowing Striped Bass to move in and out of the primary channel. Cleaning the louvers is necessary to ensure their effectiveness in guiding fish into the collection system and to minimize flow restriction to the pumping plant. Each louver panel (36 total panels) requires about 3-4 minutes to be lifted, cleaned, and then lowered back into place and occurs during day and night year round.

Juvenile life stages of endangered and threatened species such as Chinook Salmon (54 FR 10260, 59 FR 440, 64 FR 50394), Steelhead (*Oncorhynchus mykiss*) (63 FR 13347), and adult and juvenile Delta Smelt (58 FR12854) are salvaged during the winter and spring months (California Department of Fish and Wildlife 2017). During this period, these threatened and endangered species, especially juvenile Chinook Salmon (Sabal *et al*. 2016, Grossman *et al*. 2013), may become a favorable food source for the non-native Striped Bass.

Problem Statement

Striped Bass residing downstream of the primary channel louvers either passed through the louver panels (approximately 2.54 cm or 1 inch spacing) during an earlier life stage (larvae or juvenile) or moved downstream when a louver panel is lifted out of the water for cleaning. Once Striped Bass move downstream of the primary channel louvers, they may move back upstream as a feeding strategy then escape back downstream for holding. However, the rate of and timing of

movement has not been well-documented. This project will attempt to quantify their movement in order to verify if their removal from the post primary louvers is warranted. Striped Bass are known to concentrate near screened water diversions in the Delta and feed on smaller fish (Vogel 2011, Sabal *et al*. 2016) and are a major source of mortality to juvenile Chinook Salmon and other fish entrained by the South Delta water projects (Moyle 2002). Therefore, Striped Bass residing downstream of the primary louvers can contribute towards the loss of threatened and endangered fish in the primary channel on a daily and seasonal basis negatively affecting salvage rates, especially that of juvenile Chinook Salmon.

Goals and Hypotheses

Goal:

1. Determine whether or not the existing Striped Bass population in the canal downstream of the primary channel louvers are accessing the primary channel when the louvers are lifted.

Null Hypothesis:

1. There will be no movement of Striped Bass residing downstream of the primary channel louvers moving upstream and into the primary channel when the louvers are lifted.

Materials and Methods

Test Location and Equipment

Acoustically tagged Striped Bass will be electronically tracked throughout the vicinity using acoustic receivers previously installed at the TFCF. Acoustic receivers (hydrophones) are stationed at multiple locations downstream of the primary channel, inside the primary channel and secondary channel, as well as in the collection tanks and upstream of the TFCF trash rack will be used to track the movements of individual Striped Bass. The hydrophone array at the TFCF is centrally connected to a computer workstation that monitors and records acoustically tagged fish from that specific manufacturer. Therefore, the manufacturer of the acoustic tags should be chosen to match that of existing receivers at and near the TFCF. Additional receivers may need to be purchased and installed if the current equipment is removed or malfunctions or is limited in its ability to discern the specific location (i.e. inside the primary louver channel versus immediately downstream of the primary louver channel) of the acoustically tagged fish. A mobile hydrophone may be purchased and used to verify key individual fish movements for data accuracy. Striped Bass residing in the canal for the duration of the acoustic tag battery-life may be re-tagged if they can be re-captured. Weight and length measurement data will be collected again for growth rate comparison purposes along with any other pertinent information regarding the individual fish. One or more Floy tags will also be used to readily identify acoustically tagged Striped Bass.

Fish Source and Care

Striped Bass residing downstream of the primary louvers should be used as the test group (if we are able to collect some) for this study. The downstream population of Striped Bass have already

experienced the primary louver channel and are the ideal group to determine if they are accessing and repopulating the primary channel daily and/or seasonally when the primary louvers are lifted for cleaning. Striped Bass residing downstream of the primary louvers that are greater in width than the trash rack spacing's (approximately 56 mm, 2.2 inches) can be collected via angling, electrofishing, trammel or fyke netting. Once the test fish are collected, they will be acoustically tagged internally or externally with a long-term (~2 years or greater) acoustic tag. Striped Bass collected for the experiment (approximately 25-50 fish) will be placed into a large holding tank at the Tracy Aquaculture Facility (TAF) for at least one week before being acoustically tagged. Each fish will then be allowed a three week recovery period after surgically implanting or externally attaching the acoustic tag before being released, similar to the procedures as Wu *et al* (2015). Test fish will be slowly acclimated over a 1-3 day period in treated Delta water and then re-acclimated to canal water over a 3-5 day period before being released back into the canal. Test fish will also be held in an outdoor tank (if possible) to remain adapted to diel photo-periods throughout their holding period.

Data Analysis/Interpretation

Because Striped Bass are a long-lived species, movement into and out of the primary channel may only occur sporadically but could possibly be seasonal depending on both biotic and abiotic factors. However, their movements into the primary channel may occur during periods when high numbers of prey fish are entrained in effort to position themselves to a more favorable feeding location. Or, their movement may be opportunistically oriented accessing the primary channel when debris loading onto the primary louvers require multiple day and night cleanings. This project will attempt to determine if, when, and how often and possibly why movement into and out of the primary channel is occurring.

A regression analysis can be used to compare if larger (older) Striped Bass access the primary channel more often and for longer durations. The time and duration of year as well as favorable time of day of primary channel re-occupancy can also be determined though a regression analysis. Other statistical applications may be used as the project progresses and the data develops.

Assumptions and Limitations

The foremost assumption with acoustically tagging fish is that of the fish's health and behavior. Surgically implanting or attaching a foreign object to a fish can impact their health by causing a bacterial-related infection around the tagged area possibly leading to a tag-related illness and potential mortality. The tag can also impact the fish's behavior by causing discomfort in the abdomen because of its size or where it is placed or by creating additional hydrodynamic drag where it is attached. However, by allowing the fish to recover for three or more weeks will help to heal the suture wound or body-pierced area in attempt to minimize the impact to their health. The three-week duration to heal and adjust to tag placement should not alter their DMC behavior as the Striped Bass will be released back downstream of the primary louver channel, a place where they have become accustomed to living since becoming too large to swim through the trash rack and too strong to become entrained into collection tank flows. Also, by using acoustic tags with a battery-life greater than two-years should be more than enough time to allow the fish to become normalized to the tag and behave regularly.

Coordination and Collaboration

This research will be coordinated and conducted by two TFCF Biological Resources staff and one member of the Fish and Wildlife Resources Group (TSC 86-68290). Research project updates to the Tracy Technical Advisory Team and to interested interagency members and/or groups will be through email, phone or presentation. This project can be coordinated with the proposal "Feasibility of Using Carbon Dioxide to Remove Piscivorous Fish from the Tracy Fish Collection Facility Primary Channel" by principal investigator Brandon Wu.

Endangered Species Issues, "Take" Considerations

The incidental consumption of any juvenile Steelhead (*O. mykiss*), juvenile Chinook Salmon or Delta Smelt by the re-introduced Striped Bass may occur within the TFCF primary channel and in other areas of the fish screening facility.

Dissemination of Results (Deliverables and Outcomes)

This field work will determine if, when, and how often movement into and out of the primary channel is occurring and will be done in fiscal year 2019, 2020 and 2021. Data analysis and a Tracy series report will be completed after the field work has been finalized and peer reviewed (FY 2022).

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Assessing the Efficacy of a Modified Fish Salvage Release Scheme to Reduce Predation Loss of Juvenile Salmonids at State and Federal Salvage Release Sites

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Summary

Many resident and transient species of fish to California's Sacramento-San Joaquin River Delta (Delta) have declined markedly from drought, habitat modification, water diversions, and other impacts (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 via the Jones Pumping Plant (JPP; Bates *et al.* 1960), which provides freshwater deliveries for the Central Valley Project. The fish salvage process uses a louver-bypass system which intercepts fish from entrainment and pump-induced mortality at the JPP. Though the facility was designed to salvage juvenile Chinook Salmon and Striped Bass, all fishes—including non-native species—are captured and transported to downstream release sites in the Delta.

From 2000 to 2003, TFCF operations resulted in the salvage of roughly seven million fish per year (Reclamation 2009), including an annual average of 31,900 federally protected Chinook Salmon (winter and spring runs; Federal Register 70(123):37160-37204, June 28, 2005). Since that time, annual salvage of Chinook Salmon of all runs has declined to relatively low levels (Figure 1 and Table 1). The National Marine Fisheries Service's (NMFS) 2009 Biological Opinion determined that the long-term operations of the JPP adversely affects endangered winter-run and threatened Central Valley spring-run Chinook Salmon, and directed Reclamation to take actions at the TFCF to increase Chinook Salmon salvage efficiency and end-of-pipe survival (*i.e.,* release site predation; NMFS 2009). 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. Therefore, losses due to predation at release sites has not been well quantified.

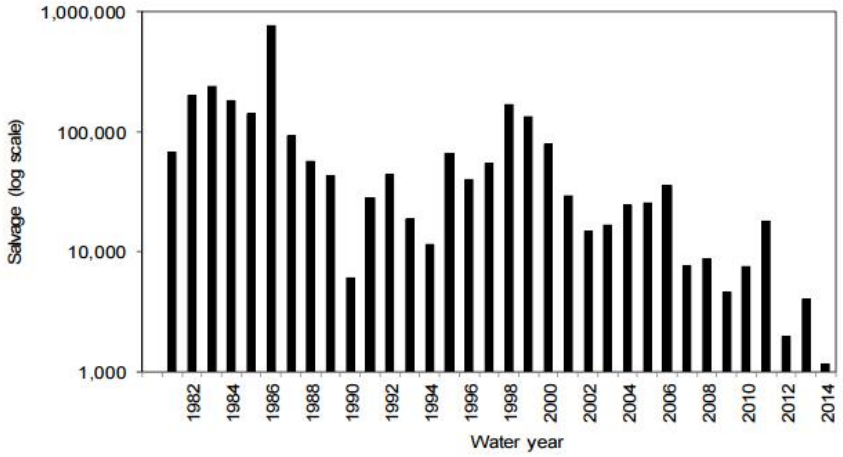

Figure 1. Annual salvage of Chinook salmon (all runs and origins combined) at the Tracy Fish Collection Facility during water years 1981-2014.

Table 1. Annual salvage of Chinook salmon (all runs and origins combined) at the Tracy Fish Collection Facility during water years 2013-2018. Data is current as of 5/10/2018.

Year	Salvage of Chinook Salmon
2013	3,714
2014	1,264
2015	106
2016	1,383
2017	23,212
2018 to date	10,857

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, our core research group (Reclamation, California Department of Water Resources, and private consultant biologists) have been developing tools to meet our goals of a) developing a consistent and reliable tool to measure release site predation, and b) reducing release site predation. The group has identified variables affecting salvaged fish survival, including frequency of releases, water temperature, and predator abundance, to name a few. Pilot and proof-of-concept phase research efforts have revealed limitations associated with acoustic telemetry studies. Field demonstrations and computer simulations, which eliminated acoustic telemetry and netting studies from contention, now point to predator feeding experiments as the key research tool to measure release site predation loss.

Problem Statement

Survival of salvaged fish at Delta release sites is likely dependent on water temperature, seasonal predator and prey assemblage variability, diurnal behavioral changes, frequency of site-specific releases (*e.g.,* number of releases per day), tides, river discharge, and total abundance of fish in each release. Miranda *et al.* (2010) conducted a release site predation study from 2007 – 2008, which concluded predation of salvaged fish does occur at California Department of Water Resources (DWR) and other fish salvage release sites, and that predatory fishes tend to remain near the release sites when the number of fish being released is consistently high. Salvaged fish were also vulnerable to bird predation when released during the daylight hours. The study determined that predation at release could have a substantial effect on salvaged fish survival. However, the study did not attempt to estimate a precise rate of predation mortality, which is a metric that is highly sought after by regulatory agencies as well as operating agencies (Reclamation and DWR).

Quantifying release site predation is a driving research question for both TFCF and DWR operations. Because of the nature of release pipe structures (dark, inaccessible) and locations (*e.g.,* deep-water, high-flow, turbid environments), traditional fisheries research techniques are ill-equipped to provide accurate assessments of salvaged fish predation rates at each release pipe. Concurrently, there have been few attempts to accurately define or describe the size of the predation area outside of release pipes, and those that have defined the area of study have done so based on sampling gear (Miranda *et al.* 2010, Tucker *et al.* 1998).

Starting in late 2016, an interagency working group assessed the possible tools and management changes that could measure and reduce release site predation. We tested and simulated acoustic telemetry studies using traditional and predation-detection acoustic transmitters, and found them to be inadequate to measure predations (or survival) changes in near-field areas. We refined a new tethering technique to measure predation as it relates to time from last release, distance from pipe, and water temperature.

Based the success of the 2018 proof-of-concept year using tethered predation experiments (Figure 2), we propose to 1) continue the use of tethered predation experiments to assess release site and non-release site (*i.e.,* baseline) predation rates in a statistically defensible manner, and 2) monitor predator abundance in the near field area using electrofishing surveys, hook and line surveys, and hydroacoustic surveys. By monitoring both predator densities and predation rates on tethered prey fish over the majority of the salmon season at the Curtis Landing Release Site and potentially the new Little Baja Release Site, we believe our techniques may be able to provide us accurate estimates of release site predation. Data will be analyzed using a Generalized Linear Model (GLM) to examine the statistical support for hypothesized factors influencing predation rates, including time-since-release, depth from surface of prey fish, distance to/from release pipe, temperature, and others.

Figure 2. The 2018 tether predation study at the Curtis Landing Release Site near Antioch, CA. Six tether lines are visible downstream and upstream of the release pipe. These studies were developed and refined to monitor near-field predation for future assessment of salvage fish predation loss in the areas immediately outside of state and federal release pipes.

Goals and Hypotheses

Goals:

1. Continually refine tethering technique to measure near-field release site predation.
2. Assess a modified release scheme strategy (13 day release site break) to reduce release site predation.
3. Determine if there are other management actions that can be undertaken to reduce release site predation by 50% of current levels.

Hypotheses:

1. H_0: The modified release frequency scheme does not significantly reduce release site predation rate of tethered fish at the Curtis Landing Release Site in summer 2019.
2. H_0: There is no significant difference in predation loss of tethered fish between the Curtis Landing Release Site and each Delta control site in summer 2019.

Materials and Methods

We will assess predation rates on tethered fish once a month for three months in summer 2019 (May, June and July) at Curtis Landing Release Site and possible 1-2 other release sites, as well as up to three control sites. At the end of each 3-day sampling week, we will perform a hook and

line and electrofishing survey to evaluate the predator assemblage at each site. Hydroacoustics surveys will also be performed each week at each of the sites. Predator assemblage data from hook and line and electrofishing surveys will be applied to the hydroacoustics output to develop a measure of the predator assemblage (species composition, body size, and density). By performing these efforts each month, we can develop a snapshot of predator densities over the juvenile salmon salvage season as it corresponds to fluctuations in predation rates at the release and control sites.

Around mid-May, increased water temperature and predator emigration lead to higher predator densities at the state and federal release sites (Miranda *et al.* 2010, 2017-2018 release site monitoring data). Higher predation rates enable easier assessment of treatment effects. We discovered during 2018 that low predation rates make assessment of modified release schemes very difficult. During May 2019, we plan to test a modified salvage release regime in which the Curtis Landing Release Site ceases releases after pre-treatment monitoring, and then we continue to monitor predation rates with tethers, and also monitor predator assemblages with hydroacoustics to develop a relationship between time-since-release and predation rate, as well as large-target abundance. This information will inform us of the amount of time needed to reduce predator densities at the release sites to reach a 50% reduction.

We will monitor for three days prior to release cutoff, and then employ a 13 day release break scheme. These breaks in release frequency will simulate future scenarios in which operations avoid using a particular release site for a certain number of consecutive days. Predation data from the tethering experiments will reveal if it is possible to reduce predation rates by 50%, and how long it will take to do so, as this metric is directed by the NMFS 2009 Biological Opinion (NMFS 2009). If May and June 2018 (FY 2018 experiment) field data and subsequent power analysis suggest it is feasible, we will perform the same experiment with a modified release regime at the Little Baja Release Site (or other release site) in June 2019. If 2018 (current year) data suggests that a high number of replicates are required to provide for narrow margins of error, we will focus efforts at Curtis Landing Release Site and reserve Little Baja for future studies. We may also test other release site treatments, such as predator removal, if a modified release scheme does not solely provide for an adequate predation rate reduction.

Our tethers will be custom built, but will resemble commercially available trotlines. They will be hook-less and will contain from top to bottom one of each:

- Float
- Main line
- Hook timers (custom built) which record the time of each predation event
- Lightweight (8lb test) monofilament tether loops attaching fish to hook timers
- Lightweight anchor (4oz)

Live fall run Chinook Salmon or Golden Shiners (pending approval from DFW and availability of >60 mm fish) will be used as tethered prey. Our current experiments are testing for differences in predation rates on Chinook Salmon and Golden Shiners, and the outcome of that experiment will guide our future prey choices. Tethers will attach to prey fish by a snap swivel through the

jaw. Hook timers (Figure 3), which are available off-the-shelf for the commercial fishing industry, were adapted for use in the Sacramento-San Joaquin River Delta in 2018, and for 2019 efforts we will obtain custom-built units constructed by the Reclamation Technical Service Center Hydropower Diagnostics and SCADA Laboratory. When predation events occur, the thin monofilament line will cut through and release the fish from the tethering unit (this is a similar technique to that tested and used by NMFS) and activate the hook timer. One to six fish will be tethered to the main line, and a group of seven tethers will comprise a tethering set (total of 21 fish per set). Six tethering sets will be fished per day at each site. Soak time for each tether is roughly ten minutes. Stationary (anchored) and floating tether sets may both be used. Boats will avoid motoring over the release site or control waters during the daily experiments in order to reduce disturbance to predators.

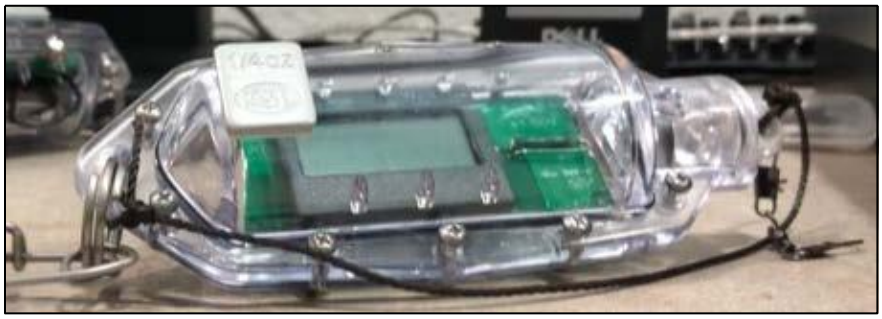

Figure 3. Lindgren Pitman LP Hook Timer HT-600. The plunger on the right side of the hook timer is held in place by a magnet, which once pulled actives a stop watch in the body of the hook timer.

We hypothesize that there will be differences in predation loss of tethered fish between control and treatment release schedules. Our control sites will help us discern Delta-wide differences in predation related to temperature, predator abundance, predator activity, or other seasonal changes from any treatment effect. By reducing the frequency of releases, we hypothesize that predator aggregations will decrease as a result of fewer stimuli (e.g., water pumps, truck noise, gates opening/closing) and rewards (*i.e.,* higher variability in release times creating long waits between feeding frenzies). Based on the recent Memorandum of Understanding (MOU) being developed between DWR and Tracy Fish Collection Facility for shared release sites, the rotational release schedule we are testing is a feasible future scenario which could be easily implemented as a measure to reduce release site predation.

We also propose to conduct a natural, or baseline predation measurement by performing tethered experiments away from the assumed predator aggregations (Miranda *et al.* 2010) at control sites with similar offshore distance and water depths (e.g., 15-50 m offshore and 4.5-7.6 m (15-25 ft) deep) as the state and federal release sites. We propose using three control sites instead of a single control site (which we are using in 2018 field efforts) to increase our ability to capture natural predator density and predation variation across the Sherman Island area. This will help elucidate whether there is a difference in predation between release sites and unaffected sites in the Delta. Water quality data will be monitored from the California Department of Water Resources Blind Point monitoring station.

Experimental fall-run Chinook Salmon or Rainbow Trout will be procured from a CDFW state fish hatchery by early March 2019 and stored at the Tracy Aquaculture Facility (TAF). Golden Shiners will be purchased from Golden State Bait and stored at the TAF. Denver TSC staff will keep two boats on hand in a Delta marina, and will travel to the release sites to conduct tethered studies monthly for six months. Tethered fish studies will occur for nine days per month in (mostly likely) June, July, and August 2019. Hook and line surveys will occur once per month, and hydroacoustic surveys will occur alongside tethering studies (3 days/week, 3 weeks/month, for 3 months).

Assumptions and Limitations

California Department of Water Resources is sharing a considerable cost of this project. They are providing crew, boats (including electrofishing boat and all electrofishing effort), and a subcontract with ESA associates who provide analytical and field support. We also plan to use field and lab support from Tracy fish biologists. Limiting factors affecting our ability to perform this experiment include poor weather (wind, in-stream debris, lightning), availability of prey fish from either state or private hatcheries, or lapses in state or federal salvage operations.

Coordination and Collaboration

Primary coordination will be led by Reclamation TSC Fisheries and Wildlife Resources Group. Close cooperation between TFCF and DWR biologists, their contractors, and operational staff will be required. Collaboration with others in the region, including the CDFW, USGS, and USFWS will occur as needed.

Endangered Species Issues, “Take” Considerations

We will use hatchery-produced Chinook Salmon for release site predation experiments, from either the Feather River or Mokelumne Fish hatcheries. There will be no increased risk of incidental take of listed Chinook Salmon in conjunction with this proposal, as transport and release operations will continue as usual, aside from introduction of experimental hatchery fish. Netting wild fish will not be a component of this research project. A previously established MOU regarding take of endangered species with the CDFW, and a NMFS Biological Opinion (NMFS 2017) will provide justification and authority for continued research objectives revolving around listed species. Re-initiation of formal NMFS ESA consultation may be needed to include an expanded field season as a research tool.

Dissemination of Results (Deliverables and Outcomes)

The primary deliverable will be a report which quantifies predation of juvenile Chinook Salmon at Delta release sites, in order to improve release site protocols and advise future release site improvements. Research updates will be provided and/or presented at regularly scheduled Tracy Technical Advisory Team (TTAT) and Central Valley Fish Facilities Review Team (CVFFRT) meetings, as the opportunities arise. Data collected from this study will be summarized and published as a Tracy Series Technical Bulletin and in one or more nationally distributed

scientific journals, such as Transactions of the American Fisheries Society, if the data warrants such publication. Results will also be presented at local and/or regional scientific conferences.

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

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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 and held at the Tracy Aquaculture Facility.
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*). Six hundred cultured Delta Smelt will be obtained from the UC Davis Fish Conservation and Culture Laboratory (FCCL). Fish will be held in the TFCF's Tracy Aquaculture Facility (TAF) and cared for by TAF technicians. 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, ozonated, 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 150 fish will be used to refine 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 refined, 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.

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.

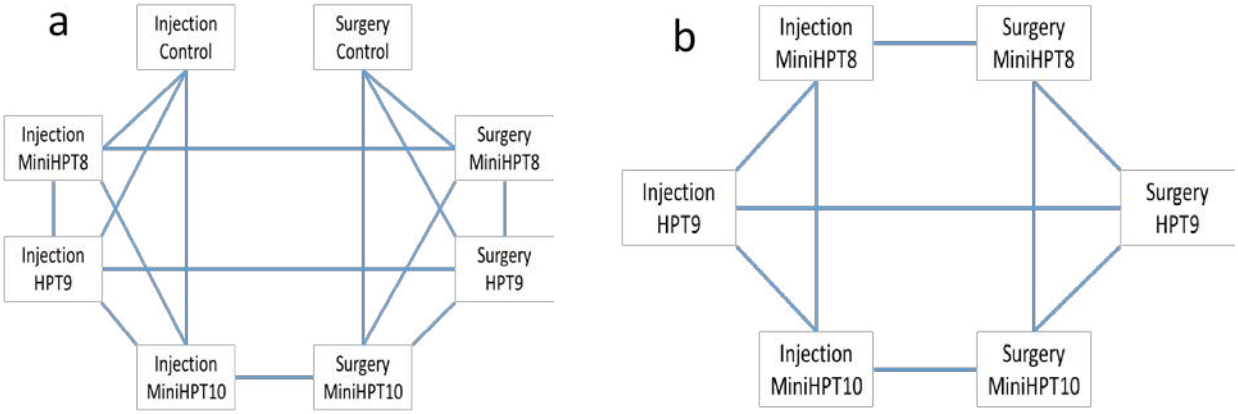

Figure 1. Schematic of groups to be compared when analyzing differences in survival (a) and tag retention (b). A line connecting two groups indicates the difference between those groups will be assessed. Proportions will be analyzed in R using Fisher's exact test.

Assumptions and Limitations

It is assumed that the TAF 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. 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.

Endangered Species Issues, "Take" Considerations

This study will take place entirely within the TAF. 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. Under the Special Terms and Conditions of the Permit, the FCCL may dispense cultured Delta Smelt to a list of authorized facilities including the TFCF for the purpose of offsite research.

Dissemination of Results (Deliverables and Outcomes)

The tagging effect study will take place in FY2019. 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 2020). If applicable, the findings will sent to an appropriate peer reviewed journal. The information gained will be utilized by future facility improvement studies.

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Whole Facility Efficiency Evaluation for Chinook Salmon at the Tracy Fish Collection Facility

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Summary

The Bureau of Reclamation's Tracy Fish Collection Facility (TFCF; Byron, CA) was constructed in the 1950s to salvage fish entrained by the Central Valley Project's C.W. "Bill" Jones Pumping Plant. The 2009 National Marine Fisheries Service Biological Opinion on the Coordinated Long term Operations of the Central Valley Project and State Water Project (NMFS 2009) "concluded the [pumping] operations were likely to jeopardize the continued existence of several federally listed species under NMFS' jurisdiction," including winter-run and spring-run Chinook Salmon (*Oncorhynchus tshawytscha*). Chinook Salmon have been declining in the Central Valley of California for some time (Yoshiyama et al. 1998), and are federally protected (winter and spring runs-Federal Register 70(123):37160-37204, June 28 2005). Fall- and late-fall run Central Valley Chinook Salmon are considered Species of Concern (Federal Register 69(73):19975-19979, April 15, 2004). The TFCF is mandated to achieve a 75 percent whole-facility salvage efficiency for juvenile Chinook Salmon (NMFS 2009; 2011). In addition, NMFS (2009) includes an action item to reduce predation in the primary channel to ten percent or less and the need to more accurately quantify incidental take (i.e., fish entrainment losses) associated with TFCF operations.

Prior whole facility efficiency evaluations have been completed but 1) these studies did not ascribe a single facility salvage efficiency estimate across operating conditions and 2) facility modifications at the TFCF have included the replacement of the secondary louvers with a Hydrolox™ traveling water screen (Vermeyen and Heiner 2016) which could have an impact on facility salvage efficiency, potentially rendering previous estimates obsolete. Concerns with previous studies correspond to the ability to appropriately provide a whole-facility salvage efficiency metric that offers a degree of acceptable precision (Jahn 2011). Previous efficiency experiments have generally relied on the ability to recover marked fish in the holding tanks (Karp et al. 1995; Karp and Bridges 2015; Karp and Lyons 2015; Sutphin and Svoboda 2016). The problem with traditional mark-recapture experiments at the TFCF is that it is difficult to ascertain predation and participation of test fish. Data has suggested fish may swim upstream of the trash rack, and not be screened through the TFCF or may hold in place within the facility, only to be collected after study periods have concluded (Karp et al. 2017). On a similar note, test fish may also be preyed upon, though without recovery of predators and the ability to recover stomach contents, past studies were unable to ascertain whether fish were lost through louvers, were preyed, or were merely nonparticipants (Karp and Bridges 2015; Sutphin and Svoboda 2016).

This study is a continuation of the Whole Facility Efficiency Evaluation for Chinook Salmon at the Tracy Fish Collection Facility from fiscal year (FY) 2018. Initial pilot evaluations have been postponed pending equipment installation at the TFCF. A solicitation for services/equipment installation of a double array passive integrated transponder (PIT) antenna at the trashrack and single PIT antenna in one holding tank at the TFCF is in process. Subsequent equipment efficiency evaluations are tentatively planned for FY 2019. Proposed herein is a phased approach of TFCF whole facility efficiency evaluation using PIT tag arrays and tagged juvenile Chinook Salmon. The use of PIT tags/arrays presents a previously unutilized method for evaluating facility efficiency. The goals of using this technology are to address concerns from previous studies, such as low sample sizes, and identify with greater precision estimates of swim-

out/participation. An initial scoping year is proposed, followed by a second-year full-scale evaluation—after a determination of the potential success of using PIT tag arrays.

Problem Statement

The 2009 NMFS Biological Opinion mandates the TFCF must meet a 75 percent screening efficiency (NMFS 2009; 2011). While Chinook Salmon salvage efficiency has been previously evaluated, structural changes to the screening mechanisms have occurred (e.g., Hydrolox™ screen), and previous studies often either did not incorporate an associated error with the reported measurements, or data was insufficient to provide a confidence interval within acceptable limits. Following installation of PIT tag arrays at the trash rack and in the holding tanks in FY 2019, equipment efficiency will be evaluated. A full-scale evaluation of Chinook Salmon salvage efficiency is proposed for FY 2020–21. Based on variance estimates from initial pilot-level efforts, the full-scale evaluation will ideally provide a salvage efficiency estimate accurate to 10 percent (95 percent confidence interval). These results will determine whether facility efficiency meets the requirements of the biological opinion and whether further facility salvage evaluations will be necessary to pinpoint areas of loss.

Goals

Goals:

1. Provide input to contractor responsible for equipment installation to ensure product will meet the needs outlined in this project proposal.
2. Evaluate PIT tag antenna efficiency at the primary channel and holding tanks.
3. Determine salvage efficiency of Chinook Salmon under normal operating conditions.

The objective of this proposal is to initiate the development of, and ultimately implement, a study design that will provide a whole-facility efficiency estimate (± standard error) for juvenile Chinook Salmon at the TFCF. This will include fish movement from the trashrack of the primary channel to salvage from the holding tanks. If necessary (i.e., salvage estimates fall below 75 percent), we will identify additional parameters within the constraints of TFCF operations that may influence salvage efficiency and provide recommendations where facility operations might be adjusted to meet NMFS mandates.

Currently, a solicitation for installation of PIT tag antennas in the primary channel (at the trashrack), and in two holding tanks, is being pursued. Following installation of this equipment, an initial efficiency evaluation will follow. After evaluating antenna efficiency, the data can be used to determine the appropriate number of fish/replicates to ensure whole-facility efficiency evaluations will yield estimates with an acceptable level of precision. Those variables contributing to facility efficiency need to be identified in order to maximize the cost/efficiency of a whole-facility efficiency evaluation. Study efforts proposed herein will be coordinated with a proposed study by Wu et al. (using acoustic predation tags) to determine within-facility predation. Using these metrics from these studies will help bridge the shortcomings of PIT tags (e.g., limited information regarding within-facility fish movements, predation, loss through

louvers). Such metrics can help determine other variables that will likely need to be considered during full-scale whole facility evaluations.

Materials and Methods

PIT tag arrays installed at various locations within the facility could allow determination of fish fate and identify areas of potential loss within the TFCF. For this study, PIT tag arrays will be installed immediately upstream and downstream of the trashrack and inside two holding tanks. The proposed double array at the trash rack will ideally allow a directionality component to be determined (i.e., fish swimming upstream of the trashrack), that would otherwise be difficult to detect with a single antenna. PIT tag antennas are generally not 100 percent efficient (Connolly et al. 2008; Beeman et al. 2012). Resultantly, preliminary testing will be necessary to evaluate each antenna efficiency. Overall salvage would be determined as a function of these efficiency estimates. In the future, PIT tag arrays could also be installed behind the primary louvers, at the downstream end of the bypass pipes leading to the secondary channel, and at the holding tank discharge pipe to provide additional information about fish movement.

Year 1: PIT Tag Array Installation/Pilot-level Efforts

1) *Coordination*: An initial scoping and development period is recommended in order to ensure the study design will address the mandates outlined in the 2009/2011 Biological Opinion. This will involve coordination with TFCF and Technical Service Center (TSC) biologists to plan and implement a whole-facility efficiency evaluation for Chinook Salmon. The purpose of this coordination effort will be to:

    a) Determine parameters to consider for whole-facility efficiency evaluations (*e.g.*, flow, tidal influence, river stage, diel period, debris loading).

    b) Discuss timing of potential study periods.

    c) Review previous TFCF and State Water Project studies to identify issues or shortcomings (e.g., lack of replicates, wide margins of error, fish participation) can be adequately addressed.

    d) Develop a defensible study design incorporating the most suitable technologies, methods, and analyses to address the NMFS Biological Opinion RPA.

2) *Technological Consultations*: In addition to coordination with biological staff, consultation with industry leaders in fish tracking technology will be necessary to determine installation options and constraints within the TFCF.

    a) In conjunction with Item 1 above, decide which locations of the facility (including upstream and downstream, as necessary) would need to be monitored to be able to determine fish movement.

    b) Determine the feasibility of equipment installation at these locations to adequately detect fish movement without interfering with normal facilities operations.

3) *Equipment installation*:

   a) Due to regional interests in potentially detecting the presence of salmon from the Sacramento-San Joaquin River Basin at the TFCF, as well as the potential benefit of using PIT tag arrays for facility efficiency evaluations, PIT tag arrays may be installed prior to the March–May pilot efforts in 2019.

   b) Coordinate with TFCF staff for equipment installation following consultation with industry experts and determination of antenna locations. For initial year efforts, a double array is proposed at the trash rack—one in front and one behind, and single arrays are proposed within the holding tanks. These locations will ideally provide directionality of fish movement in/out of the facility at the trash rack, and detect fish that have been recovered in the holding tanks.

   c) Antenna efficiency testing will be coordinated to coincide with fish releases (see below). Efficiency values are necessary to estimate the total number of fish passing each antenna since arrays are generally less than 100 percent effective.

4) *Fish releases for pilot level testing (contingent upon PIT tag array installation)*:

   a) Two thousand juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) will be procured from either the Coleman National Fish Hatchery (Anderson, California) or the Mokelumne River Hatchery (Clements, California).

   b) We will coordinate schedules to ensure fish are obtained ahead of the study period and that fish will be of appropriate size for both tagging operations and experimental releases.

   c) Fish will be maintained at the Tracy Aquaculture Facility (TAF) in tanks supplied by aerated well or treated Delta water until study use. Tagging operations (PIT tag or acoustic tag) will be coordinated with TFCF biologists and TSC staff. Approximate fish size for this study should correspond to fish typically collected during peak salmonid seasons—1993–2015 salvage data (CDFW 2015) in March, April, and May, 86, 92, and 102 mm (mean, spring-run wild Chinook, standardized across years, respectively).

      Based on fish salvage data from 1981–2012, Chinook Salmon have been recorded at the Tracy Fish Collection Facility (TFCF) across all months, though December–July are considered the primary months of presence (CDFW 2013). However, March–May are when the majority of salmon encounter the facility. This information will be considered prior to scheduling these releases.

   d) Two periods of fish releases are proposed. One trip will be tentatively planned for March (contingent upon fish being large enough to PIT tag—55 mm fork length) and the other in late May, early June. Ideally, this will help to account for a range of environmental and operational conditions typically present under normal facility operations during peak salmon collection periods.

      Twelve releases of 150 fish, spanning two trips (6 releases/replicates per trip) are proposed. Each of the six replicates will be staggered across a 24-h period to incorporate

diel influences in salvage efficiency. One-hundred fish will be released upstream of the trashrack, and an additional 50 fish will be released below the trashrack for each release. These numbers were based on previous studies that suggest a proportion of the fish released below the trashrack are recovered in the holding tanks (Sutphin and Svoboda 2016), and fish behavior upstream of the trashrack (and participation) can be quite variable (Karp et al. 2017). Subsequent detection of fish released below the trashrack will help to give an indication of swimout/non-participation. Likewise, differences between salvage of these two groups of fish, in coordination with a swimout estimate, may give an indication of predation upstream of the trashrack.

5) *Data analysis*:

   a) Following fish releases and subsequent data analysis, biologists will determine 1) if the use of PIT tag arrays will be sufficient to determine whole-facility efficiency, and 2) the total number of fish per replicate and total replicates needed for full scale efforts proposed in Year 2–3 Full-scale Implementation based on an accepted level of precision. NMFS will be consulted to determine what level of precision is necessary when reporting facility efficiency.

Year 2–3: Full-scale Study Implementation

1) Following Year 1 Pilot-level Efforts, implement a full-scale study that includes:

   a) Equipment installation/maintenance, as necessary. Additional PIT tag arrays will be considered to identify areas of potential loss within the facility, where warranted.

   b) Procurement/care of test fish following the aforementioned guidelines.

   c) Scheduled fish releases corresponding to the total number of fish/replicates determined from scoping period.

2) Analysis of the data with the appropriate metrics to determine whole-facility efficiency with the corresponding level of precision.

3) Dissemination of results: a final Tracy Series report will describe whole-facility efficiency and the associated standard error.

Assumptions and Limitations

The success of the project will depend upon the ability of industry experts to install a PIT tag arrays in the primary channel and holding tanks prior to any salvage efficiency evaluations. The estimated time of installation is the 1st–2nd quarter FY 2019. This equipment will be necessary to track fish movement through the TFCF. Furthermore, the project will require the use of test fish obtained from state/federal hatcheries. This could be an issue if there are insufficient returns of adult salmon, which it turn limits the availability of juvenile salmon. Assumptions for this project are that salvage efficiency within the facility starts at the trashrack of the primary channel and, for the purposes of this study, is successful once fish enter the holding tank. Furthermore, we assume that site conditions will neither be extreme (drought or flood) that would drastically

affect salvage efficiency at the TFCF. When interpreting the results from this study, an additional assumption would be that wild Chinook Salmon salvage is similar to hatchery fish salvage. With PIT tag arrays, it will be difficult to determine any influence of predation/participation outside of the trash rack structure. PIT tag arrays in deep water, particularly in unconstrained areas, prove difficult to construct. Efforts will be coordinated with Wu et al. to help account for predation within the facility.

Coordination and Collaboration

Study proposals will be distributed through the Tracy Fish Facility Improvement Program to state and federal agencies to ensure study designs will address the issues presented in the NMFS Biological Opinion. Technical Service Center staff will coordinate with TFCF biologists/operations for site visits and evaluations during project development/implementation.

Endangered Species Issues, "Take" Considerations

Since Chinook Salmon, Steelhead (*Oncorhynchus mykiss*), and Delta Smelt (*Hypomesus transpacificus*) may be present during the study period, incidental "take" is possible when recovering test fish in the holding tank. These fish will be returned to Delta waters as quickly as possible. The total number of each ESA species incidentally caught or collected during the experiment will be recorded and sent to the reporting agencies. The incidental take from this research is covered under the TFCF Section 10 permit.

Dissemination of Results (Deliverables and Outcomes)

If installation of PIT tag arrays at the TFCF can be completed prior to the March–May peak juvenile salmon period, pilot efforts in FY 2019 will include preliminary releases of juvenile salmon. A summary of the findings from these releases, to include feasibility of using PIT tags for whole-facility efficiency evaluation, will be completed and presented to TFCF management and the Tracy Technical Advisory Team. Researchers will provide an estimate of the number of fish/replicates needed to evaluate whole facility efficiency with an acceptable level of statistical confidence. Full-scale evaluation of whole-facility efficiency is proposed for Year 2–3 (FY 2020–21) and a TFCF Series Report will be produced following full-scale facility evaluations.

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

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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 in attaining 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 (25 % remaining), 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:

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

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*) ~~were not~~ 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 December 2018 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.

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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

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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 ≥ 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_2) was approved for study. This method does not reduce daily salvage due to secondary channel downtime and is likely more efficient and safer for employees and fish than the historic predator removal method (Wu and Bridges 2014). An initial evaluation of the use of CO_2 as an alternative predator removal technique in the TFCF bypass pipes and secondary channel was completed in September 2007 and demonstrated that elevated CO_2 concentrations are effective for removing predatory fish from the bypass pipes and secondary channel at the TFCF. Results from this initial evaluation have been published as a Tracy Series Report (Wu and Bridges 2014), although the authors did not recommend a CO_2 concentration that should be used upon implementation of this method at the TFCF.

Preliminary data collected for the optimal dose investigation suggests that the CO_2 concentration that results in the highest combination of Striped Bass removal efficiency and 96-h post-treatment survival is approximately 150 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_2 as an alternative predator removal technique in the TFCF bypass pipes and secondary channel has been completed and published (Wu and Bridges 2014), although authors did not recommend a CO_2 concentration that should be used upon implementation of this method. The goal of this proposal is to determine optimal CO_2

concentrations for the implementation of CO_2 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_2 concentration for a 15-minute exposure relative to removal efficiency and survival.

Hypotheses:

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

Materials and Methods

The optimal CO_2 concentration for the removal and survival of TFCF predatory fish species will be investigated by removing wild Striped Bass from the bypass pipes and secondary channel with consecutive CO_2 injections of increasing concentration. In order to obtain water samples for monitoring of pH and CO_2 concentration, it will be necessary to install a 1/5 hp pump in the secondary channel prior to the initiation of consecutive CO_2 predator removal replicates. The secondary channel Velocity Control (VC) pumps will be operated to achieve a secondary flow of approximately 0.57 m^3/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_2 concentration (0, 50, 75, 100, 125, 150, 200, 250, or 300 mg/L).

After the predator removal effort is completed with a certain CO_2 concentration, the secondary channel will be flushed until the CO_2 concentration returns to an ambient level and another predator removal effort with a 300 mg/L CO_2 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_2 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_2 concentration will not be determined due to the fact that fish collected in this sample will be exposed to numerous CO_2 concentrations. Three replicates will be performed at each initial CO_2 concentration and the CO_2 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_2 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 CO2 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 CO2 concentration, removal efficiency, and 96-h post-treatment survival. The CO2 concentration at which best-fit trend lines for removal efficiency and 96-h post-treatment survival intercept (the CO2 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 CO2 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_2 injections in order to determine optimal CO_2 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 FY2019 research period. Finally, it is assumed that CO_2 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_2 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_2 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)

There was minimal progress made for this project during the 2017-2018 research periods due to the fact that other projects took priority. Data will be collected to determine optimal CO_2 concentrations for the implementation of CO_2 predator removals in the bypass pipes and secondary channel at the TFCF over the next two years. Updates will also be provided at TTAT and CVFFRT meetings. A draft report for peer review is anticipated to be completed by December 2019. 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.

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

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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*) ≥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 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_2 consumption, as well as CO_2 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 (Suthphin 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_2 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_2 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_2 rise (0.32 mg/L per min), followed by operation of only the compressed air system (0.05 mg/L per min).

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_2 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 under appropriate water quality parameters.

Goals and Hypotheses

Goals:

1. Measure the rate of O_2 rise in the new fish-haul trucks while operating the air system only, O_2 system only, and both the air and O_2 systems simultaneously.
2. Use measured oxygen production rates along with published estimates of fish oxygen consumption, TAN production, and CO_2 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_2 system only, and both the air and O_2 systems simultaneously.

Hypotheses:

1. The rate of O2 rise in the new fish-haul trucks will not be different when operating the air system only, the O2 system only, and both the air and O2 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_2 system only, and both the air and O_2 systems simultaneously.

Materials and Methods

The rate of O_2 rise in water containing 8 mg/L salt while running the air system only, the O_2 system only, and both the air and O_2 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_2 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_2 system will be utilized. Oxygen and Total Gas Saturation (TGS) measurements, taken with a YSI-85 and a Sweeney saturometer, 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_2 production rates will be used along with O_2 measurements to develop a mass balance equation to estimate biomass capacity of the new fish-haul trucks while operating the air system only, O_2 system only, and both the air and O_2 systems simultaneously. This information may be used in the development of updated fish transport tables at the TFCF.

Data Analyses

The rate of O_2 rise will be evaluated for each system or combination of systems using regression analysis by plotting O_2 concentration over time and generating a rate curve. Published estimates of fish oxygen consumption, TAN production, and CO_2 production will be used along with O_2 measurements to develop a mass balance equation to estimate biomass capacity of the new fish-haul trucks while operating the air system only, O_2 system only, and both the air and O_2 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)

Preliminary work was performed in the investigation of oxygen rise in the new fish-haul trucks when using the air system only, O_2 system only, and both systems in combination (in August and September 2009, October 2011, and February, March, April and September 2014). Data collection for this project was completed during the FY2018 research period. A draft report is expected to be produced by December 2019.

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.

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

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Summary

Action IV.4.1(1)(a) of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (BiOp) mandates that the U.S. Bureau of Reclamation (Reclamation) complete studies to determine methods for removal of predators in the primary channel at the Tracy Fish Collection Facility (TFCF) with the goal of implementing measures to reduce pre-screen predation in the primary channel to ten percent or less (NMFS 2009). While a predator removal program in the secondary channel at the TFCF has been ongoing since the early 1990s, there are few options for addressing predator loads in the primary channel. Reclamation personnel have reviewed various means of moving predators through the TFCF system such as electricity, sound, light, and mechanical methods. Many of these techniques are largely ineffective for removing large piscivorous fish, expensive to install and operate, and are logistically difficult to implement (Fausch 2000). The use of carbon dioxide (CO_2), in the form of dry ice, was recently evaluated as a predator removal technique in the bypass pipes and secondary channel at the TFCF and was found to effectively remove fish, including piscivores, from this area (Wu and Bridges 2014). This suggests the periodic use of CO_2 may also be efficacious for the removal of piscivorous fish from the primary channel at the TFCF. If so, the use of CO_2 in the primary channel could be implemented at the TFCF to meet Action IV.4.1(1)(a) of the NMFS BiOp instead of investing funds for extensive research, design, development, installation and maintenance of more complicated predator removal systems or processes.

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_2 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_2 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_2 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_2 may be effective for removing fish from the primary channel at the TFCF. Even if fish are not anesthetized by the CO_2 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.

Problem Statement

Action IV.4.1(1)(a) of the 2009 NMFS BiOp mandates that Reclamation complete studies to determine methods for removal of predators in the primary channel at the TFCF with the goal of implementing measures to reduce pre-screen predation in the primary channel to ten percent or less (NMFS 2009). The use of CO_2 was recently found to effectively remove fish, including piscivorous predators, from the bypass pipes and secondary channel at the TFCF (Wu and Bridges 2014). Also, preliminary data for all water temperatures combined suggests that CO_2 concentrations of approximately 150 mg/L are optimal for the removal of Striped Bass from the bypass pipes and secondary channel at the TFCF, considering removal efficiency and survival. This suggests that the periodic use of CO_2 at a concentration of approximately 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_2 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_2 concentration of approximately 150 mg/L can be reasonably obtained in the primary channel at the TFCF, within 30 min, considering the volume of water that needs to be treated and the amount of dry ice necessary.
2. Determine if a CO_2 concentration of approximately 150 mg/L increases the number of piscivorous fish removed from the primary channel during a 30-min treatment period.
3. Estimate the efficiency of removal for acoustic tagged Striped Bass in the primary channel at the TFCF using a CO_2 concentration of approximately 150 mg/L over a 30-min period.

Secondary Goals:

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

Hypotheses:

1. The injection of CO2 in the primary channel will have no effect on the CO2 concentration in the water due to large water volume and water flow within this component of the TFCF.
2. A CO2 concentration of approximately 150 mg/L will not increase the number of piscivorous fish species removed from the primary channel at the TFCF.
3. A CO_2 concentration of approximately 150 mg/L in the primary channel at the TFCF will have no effect on the efficiency of removal for acoustic tagged Striped Bass.

Materials and Methods

In order to investigate the feasibility of using CO_2 to remove piscivorous fish species from the primary channel at the TFCF, it 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 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_2 treatment) and CO_2 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^3; 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_2 treatment in the primary channel, as well as estimate the efficiency of removal when using a CO_2 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_2 will 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 ^oC well water and transported to outside

1.2-m diameter (757-L) black tanks containing aerated, 16 ^{o}C well water where they will be held at a density of up to two fish per tank for up to 30 days.

A 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_2. 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_2 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_2 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_2] and K-1920 [range = 100–1000 mg/L CO_2], CHEMetrics Inc., Midland, Virginia), and a pH meter (Model pH 110, Oakton Instruments, Vernon Hills, Illinois), respectively. Alternatively, pH loggers (Model SDL100; Extech Instruments, Nashua, New Hampshire) will be used to obtain pH measurements while a CO_2 vs. pH curve will be developed, using a sample of raw Delta water collected prior to the injection of CO_2, to obtain a formula that will be applied to pH measurements to estimate CO_2 concentration.

The number of piscivorous fish collected during the 30-min CO_2 treatment will be compared to the number of piscivorous fish collected in the 30-min fish count performed immediately prior to CO_2 treatment (control) to determine if the use of CO_2 in the primary channel increases the total number of piscivorous fish removed from the primary channel. A chi-square test (Minitab version 15) 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_2 treatment. The percentage of acoustically tagged Striped Bass recovered will be used to estimate the efficiency of removal when using a CO_2 concentration of approximately 150 mg/L. The proportion of acoustically tagged Striped Bass recovered during CO_2 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. Additional replicates (up to 2) may be performed if Striped Bass are successfully guided to holding tanks during treatment of the TFCF primary channel with CO_2.

If no experimental Striped Bass are collected in the holding tanks during the CO_2 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_2 treatment process may be modified and repeated in an attempt to effectively guide Striped Bass to the TFCF holding tanks. 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_2 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_2 treatment in the primary channel, it may be suggested that we lift the louver panel immediately in front of bypass 4 prior to CO_2 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.

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 FY2019 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_2 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_2 levels than Striped Bass and displayed up to 70% mortality over 96 h after being exposed to 100 mg/L CO_2 for 20 min. 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. At the earliest, data collection is expected to take place in May 2018 and will likely continue into 2020. A draft report is expected to be produced by December 2020.

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Use of Predation Detection Acoustic Tags to Estimate Juvenile Chinook Salmon Facility Efficiency at the Tracy Fish Collection Facility

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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 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), and passage time of salvaged fish (from the trash boom to the holding tanks) under a range of pumping conditions at the JPP.

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). In an attempt to reduce the number of unknown fate assignments, an expanded hydrophone array upstream of the TFCF will 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 where reducing mortality can increase facility efficiency.

Goals and Hypotheses

Goals:

1. Estimate facility efficiency, primary channel louver efficiency, secondary channel screen efficiency, predation, pre-screen loss to predation, participation, 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.) and an expanded hydrophone array upstream of the TFCF reduces the number of unknown fates.
4. Investigate PDAT trigger time and compare to published results from Schultz *et al.* (2017).

Hypotheses:

1. Facility efficiency, primary channel louver efficiency, secondary channel louver/screen efficiency, predation, pre-screen loss to predation, participation, 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 and an expanded hydrophone array upstream of the TFCF 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), 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. hydrophones deployed by California Department of Water Resources (DWR) in Old River and Grant Line Canal will 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 was 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. Two hours 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 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. 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 as well as pre-screen 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 the no other projects will take priority during the FY2019 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 be collected for this study over the next two years. 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 December 2019. The primary deliverable will be an article published as a Tracy Series Report.

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