EVALUATION OF CHINOOK SALMON AND CENTRAL VALLEY STEELHEAD FACILITY LOSSES AT THE TRACY FISH COLLECTION FACILITY

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Summary

Reclamation's Tracy Fish Collection Facility (TFCF), located in the southern Sacramento-San Joaquin Delta (Delta) was designed to divert juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and striped bass (*Morone saxatilis*) from Delta Mendota Canal (DMC) flows, thereby preventing entrainment loss to the downstream Jones Pumping Plant (JPP; Bates *et al*. 1960). Fish entrainment is defined as "the incidental trapping of any life stage of fish within waterways or structures that carry water being diverted for anthropogenic use" (NMFS 2010). The TFCF uses a louver-bypass system to intercept and guide fish from DMC entrainment into collection tanks, where they are held until they are truck-transported and released back to the Delta away from the immediate influence of the JPP. Fish and exported flows enter the facility underneath

a surface debris collector (trash boom), through a trash rack with 5.1 cm (2.0 in) wide bar spacing and the 25.6 m (84 ft) wide primary channel to one of four bypass entrances along the louver wall. Once inside a bypass entrance, fish move into underground concrete pipes to the secondary channel where they encounter a double louver wall. Fish guided successfully by these louvers are diverted to one of four fish collection tanks. Although the louver/bypass components were designed to screen and salvage fish from exported flows, there are several areas where fish loss can occur (in particular, louver swim-through and predation by striped bass), and the facility is not 100% effective (Karp et al. 1995; Bridges et al., in prep).

Chinook salmon and steelhead, *O. mykiss*, abundance is declining in the Delta due in part to non-native fish introductions, and habitat alterations from long-term operations at JPP and California's Harvey O. Banks Pumping Plant (Moyle 2002; NMFS 2006, 2009). Recently, the National Marine Fisheries Service (NMFS) completed a Biological Opinion stating TFCF operations are likely to jeopardize the continued existence of the endangered Sacramento River winter-run Chinook salmon, threatened Central Valley spring-run Chinook salmon and Central Valley steelhead (NMFS 2009). Our objective is to determine average daily facility loss for juvenile Chinook salmon and steelhead. Facility loss is defined in this study as the loss of acoustically tagged hatchery fish from the trash boom to the holding tanks.

Acoustic telemetry technology (in particular HTI, Hydroacoustic Technology, Inc., Seattle, WA) is being used because we need to quantify fine scale fish behavior (direction of movement, holding, travel time, residence time, swim-out, louver swim-through, and predation) in front of and within the facility. In 2013, we deployed and tested a system of 21 acoustic telemetry hydrophones at the TFCF (Figure 1), and released 144 acoustically tagged juvenile Chinook salmon and steelhead (72 of each) at the trash boom, and 36 acoustically tagged striped bass (18 in the primary channel and 18 in the channel upstream of the trash rack) at 3 different JPP conditions: high velocity (4 or 5 units), intermediate velocity (3 units), and low velocity (1 unit). Experimental fish were recovered from the holding tanks during the 24 h at each test flow. From this, we began to identify juvenile Chinook salmon, steelhead, and adult striped bass behavior (using acoustic track analysis software) in front of and within the fish facility. Differentiation of acoustic track behavior by species, concurrent with species identification in the salvage, will assist in quantifying facility entrainment and loss (including swim out, predation, and primary and secondary louver losses) for the above salmonid species.

Problem Statement

Chinook salmon and steelhead are declining in the Central Valley of California, and these species are protected by the National Marine Fisheries Service (winter and spring runs-Federal Register 70(123):37160-37204, June 28 2005; steelhead –Federal Register 63 (53):13347-13371, March 19, 1998; Federal Register 71(3):834-862, January 5, 2006).

Fall- and late-fall run Central Valley Chinook salmon are considered Species of Concern (Federal Register 69(73):19975-19979, April 15, 2004). Chinook salmon may be entrained at the TFCF from December through July, but the majority is entrained April and May (TFCF salvage data; http://www.dfg.ca.gov/delta/apps/salvage/Default.aspx). Juvenile steelhead are uncommon at the TFCF, but the majority of those salvaged also appear in the spring (http://www.dfg.ca.gov/delta/apps/salvage/Default.aspx). Recently, NMFS determined operations of JPP may adversely affect the existence of the endangered winter-run and threatened Central Valley spring-run Chinook salmon, and the Central Valley steelhead, and recommended that TFCF salvage efficiency and survival increase to a minimum of 75% for Chinook salmon and steelhead. Included in this is the need to more accurately quantify incidental take (i.e., fish entrainment losses) associated with TFCF operations.

Our study will estimate TFCF loss per 24 h period for hatchery fall-run Chinook salmon as a surrogate for winter-run and spring run races, and hatchery steelhead for wild steelhead. Key areas of interest include a determination of non-participation (or swim-out), predation in front of and within the facility, and louver related losses. These data will be used to increase accuracy in the facility loss calculation and to identify areas where reducing mortality can increase fish salvage efficiency.

Goals and Hypotheses

Goal: Determine facility loss for juvenile Chinook salmon (<175mm fork length, FL) and steelhead (about 200-225 mm FL) under normal operating and hydraulic conditions.

Null Hypothesis: Facility loss (from trash boom to holding tank, due to predation and louver loss) for juvenile Chinook salmon and steelhead is <25%.

Hypotheses:

$H1_o$: Facility loss (from trash boom to holding tank) for juvenile Chinook salmon and steelhead is not significantly greater at lower velocities.

$H2_o$: Facility loss (from trash boom to holding tank) for juvenile Chinook salmon and steelhead is not significantly greater in day than night.

$H3_o$: Facility predation on juvenile Chinook salmon and steelhead does not significantly increase with velocity, temperature or time of day.

Materials and Methods

Fish Source and Care

Approximately 1,000 fall-run Chinook salmon (~120 mm FL) and steelhead (~200 mm FL) will be obtained from the Mokelumne River Fish Hatchery

(Clements, California) in 2013. Fish will be held in flow-through 711-L tanks, provided temperature controlled ozonated and aerated well water (9^{o} C), and fed O-Range Nurse XL (Inve Aquaculture, Inc.) 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 TFCF water temperature at rates less than 2°C/d by gradually exposing test fish to ozonated Delta water 14 d before testing. A range of fish sizes will be used to approximate the average size of wild fish entrainment (a minimum of 120mm fork length is necessary for successful tag insertion).

Experimental Design

A review of past TFCF efficiency experiments, completed by Jahn (2011), suggested future efforts focus on determining overall facility survival/loss rather than focusing on specific components, e.g., louver efficiency. To comply with these recommendations and those proposed by NMFS (2009), we propose to conduct release-recapture experiments, employing the use of acoustically tagged fish, to estimate facility loss for juvenile Chinook salmon and steelhead under normal facility operations. For this research, normal operations will be considered day to day operations (e.g., louver cleaning, hydraulic control, predator removals, etc.) conducted by TFCF operators as outlined in the TFCF Policy and Standard Operating Procedures or as directed by facility management. Our study plan will estimate daily loss (to predation, passage through the louvers) from the TFCF trash boom to the holding/collection tanks. We will release acoustically tagged fish on the downstream side of the trash boom for a 24 h period under a specific JPP flow (1 [low], 3 [intermediate], or 5 [high] pump condition) in the spring when wild salmonids are typically collected in the salvage (Table 1). Variables to be measured include water temperature, light level, turbidity, primary channel depths and velocity, secondary channel depths and velocity, holding tank flow, # of secondary channel velocity control pumps and holding tank pumps, and timing of louver cleaning. Facility hydraulic data will be recorded at least hourly through each 3 day experiment (i.e., 3 consecutive 24 h periods of fish releases at 5, 3, and 1 JPP unit). Experimental fish recovery in the holding tanks will be determined at the end of the 24 h test flow period, and then the JPP pump rate will be altered for the next release (5 to 3 to 1 JPP pumps within the test period).

Fish releases will be conducted every 6 h for 24h at each flow. Specifically, 8 acoustically tagged Chinook salmon and 4 acoustically tagged steelhead will be released from 2 release sites on the trash boom at 0800 h, 1400 h, 2000 h, and 0200 h for a total of 32 Chinook salmon and 16 steelhead per 24 h at each test flow condition (5, 3, and 1 JPP unit). Each flow will be maintained for 24 h, followed by the next flow condition. Tagged Chinook salmon and steelhead will be released from the same buckets in which they were placed following surgery (2 Chinook salmon or 1 steelhead per bucket). Buckets will be transported to the release site 2 h prior to release to allow fish to acclimate to Delta flow. All

transmitters will be checked prior to release. If a transmitter is not working or the fish does not appear to be swimming normally, that fish will be removed from the release. Total number of fish released per replicate was selected based on an examination of wild fish salvage data for February-May 2008-2011 and preliminary Chinook salmon efficiency data collected in March 2011 (see Appendix A for determination of required sample size and # of replicates).

All collections into the holding tanks will be examined for acoustically tagged fish during each 3 day experiment, and stomachs of all striped bass and white catfish >300 mm FL will be examined after fish have been euthanized. Any experimental fish recovered in the holding tanks will be identified through tag code procedures and verification of photonic mark. The acoustic tag will be removed for later use (either as a live tag or as a dummy tag for the control fish, see below). The acoustic telemetry system deployed in 2013 will be used, with additional 1-2 hydrophones placed upstream of the trash boom. HTI track analysis software will be used to process 2-D acoustic tracks of juvenile Chinook salmon and steelhead, and of these fish potentially inside a predator stomach. A panel of experts familiar with 2013 TFCF fish tracks (Reclamation, HTI, and California Department of Water Resources) will review the acoustic fish tracks to agree on the fate of each tagged fish. Following this, swim-out (non-participation), louver loss, predation, and daily loss at each flow will be determined from the released tagged fish. We will also estimate travel time and residence time for the two salmonid species at different JPP flows.

Fish Processing

Surgeries will be conducted 48 h prior to each salmonid release (following guidelines in Liedtke et al. 2012). Fish will be captured from holding 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, FL) and placed in an 10-L anesthetic bath containing a 70 mg/L dose of tricaine methanesulfonate (MS-222, Argent Chemical Laboratories, Redmond, WA), 70 mg/L of sodium bicarbonate and 10 mL of Prime® water conditioner (Seachem Laboratories, Inc., Madison, GA). 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), weighed (g), and given a white photonic tag on the dorsal fin using a BMX2000 BioPhotonic Marking System and BMX2000 Photonic Marking Formulation (NEWWEST Technologies, Santa Rosa, CA). This procedure is included to distinguish our study fish from other study salmonids recovered in the holding tanks. After photonic marking, fish will be moved to the surgery station and an anesthetic mixture containing 40 mg/L MS-222, 40 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 sterilized in 3% hydrogen peroxide. All

surgical tools and acoustic tags will be thoroughly rinsed in distilled water prior to surgery and implantation. For Chinook salmon, 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 a 5-mm restricted depth stab blade with a 15-degree blade angle (Walcott Rx Products, Ocean View, NJ) will be used for steelhead incisions. An acoustic tag (possibly Model 800 micro or a new tag, Hydroacoustic Technology, Inc., Seattle, WA) and a PIT-tag (passive integrated transponder tag) will be inserted into the body cavity of the Chinook salmon or steelhead. Incisions will be closed using 5/0 Ethicon VCP303H, taper point, RB-1, 17 mm, ½ circle, 68.6-cm, violet, coated VICRYL Plus sutures and Mayo-Hegar needle holders. Following surgery, fish will be placed in a perforated 18.9-L black bucket (used for recovery, acclimation, and release, 2 salmon or 1 steelhead per bucket) contained within a 70-L tub with highly oxygenated (120-150% saturation) 16^{o} C well water (2 Chinoook salmon or 1 steelhead per bucket). The time to surgically implant the tags will be recorded for each fish. The 18.9-L perforated buckets containing experimental salmonids will then be transported to a 2,871.3-L oval flume (track width = 0.4 m, depth = 0.5 m, length = 8.2 m, Frigid Units Inc., Ohio) and held in 16^{o} C well water for 2 d prior to release. Two hours prior to each fish release, the appropriate buckets will be transported to the trash boom and floated in Delta water flow just downstream of the trash deflector.

Two groups of handling/holding control fish will be processed during each of 3 surgical sessions (i.e., 2 fish for whole process and 2 fish for holding only, per species, per day), and held for 7 days. One group will be processed as described above and a dummy transmitter inserted. The second group will be similarly handled including the photonic tag, except will not have any surgical procedure. Control fish will be held in similar perforated buckets in the oval flume for 2 days following handling, after which they will be transferred to 0.74-m diameter (168-L) black tanks containing aerated, ozonated raw Delta water at approximately 16^{o} C for 5 days.

Schedule

We propose to begin experiments in February because of possible facility structural improvements in the secondary louver channel in April and May. Each experiment will include a set of fish releases at 5, 3, and 1 JPP units. We propose to conduct from 1-4 sets of experiments in spring 2014, depending on flows and other constraints. In December 2013, the acoustic telemetry system (receivers, data loggers, laptops, hydrophones and cables) will be tested and any malfunctions fixed. Any additional hydrophones will also be installed. In late January, 25 Chinook salmon and 25 steelhead will be used to practice surgical transmitter implantation techniques, and to set up the fish holding and release systems.

Data Analyses

Fish fates (e.g. loss to predation, loss to louver passage, salvage in holding tanks, swim-out, or non-participation) will be determined from 2D acoustic tag track analysis and positioning (in conjunction with recovery of tagged fish in the holding tanks). Fish fate data will then be analyzed by calculating facility loss (and/or survival) per flow condition using the following equation, and, using hypothesis testing and regression analyses to test for relationships among facility/environmental variables and fish loss.

H= # experimental fish recovered in holding tank/24 h

T= total # experimental fish released at the trash boom – fish with a dead tag/24 h

N= # non participants/24 h

Survival (S) = H/(T-N) for each 24 h period

Loss (L) = experimental facility loss or 1-S for each 24 h period

Coordination and Collaboration

These studies will be coordinated with the California Department of Fish and Wildlife Delta diversion facilities reporting program, and the Tracy Fish Collection Facility staff. All work will be reviewed by the Tracy Technical Advisory Team (TTAT) through progress updates on request and reviews of study plans and reports. We are also working with California Department of Water Resources and Reclamation's Bay Delta Office on study design and development and testing of loss equations.

Endangered Species Concerns

Incidental "take" of ESA listed Chinook salmon, steelhead, and delta smelt is possible and such fish will be returned to the facility holding tank for truck transport to the Delta. 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)

We propose to conduct from 1-4 sets of releases (each set includes tagged salmonid releases at 5, 3, and 1 JPP) in FY14 depending on flow, facility, and budget constraints, and will present preliminary data to the TTAT in late 2014.

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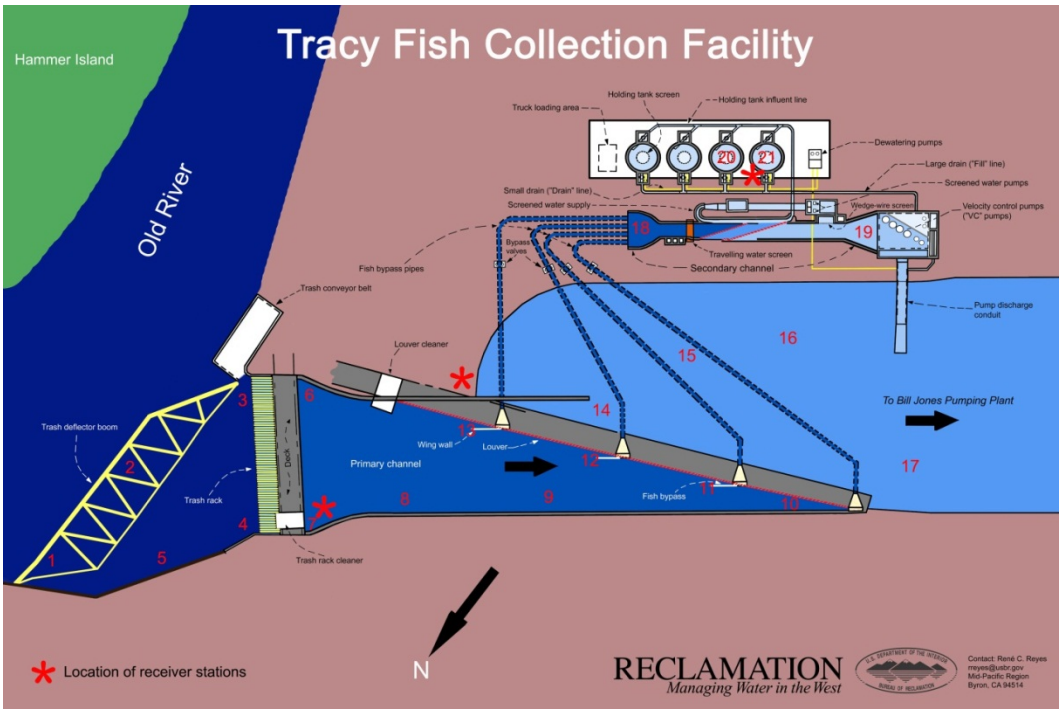

Figure 1.—Schematic of the Tracy Fish Facility, Tracy California. Numbers in red indicate locations of acoustic hydrophones.

Table 1.—Planned fish release schedule each test week (February/March)

	Tag Fish (36 Chinook Salmon/ 20 Steelhead Each Day)	Fish Release (32 Chinook Salmon/ 16 Steelhead each day)	Follow Movements
5 pump – Jones Pumping Plant (about 0.9 m/s [3.0 fps]	Day 1	Day 3	Days 3–4
3 pumps – Jones Pumping Plant (about 0.6 m/s [2 fps])	Day 2	Day 4	Days 4–5
1 pump – Jones Pumping Plant (about 0.3 m/s [1.0 fps]	Day 3	Day 5	Days 5–6

Appendix A

Using data from Chinook salmon experiments completed in March 2011 (mean WFE = 0.53), we require 36 fish (n)/release to get at least 20 fish into the holding tank/release. The following power curve (Figure A1), suggests a sample size of N = 33 at the lowest power of 0.55 (α = 0.1 and d, smallest difference desired to detect, = 0.1 or 10%).

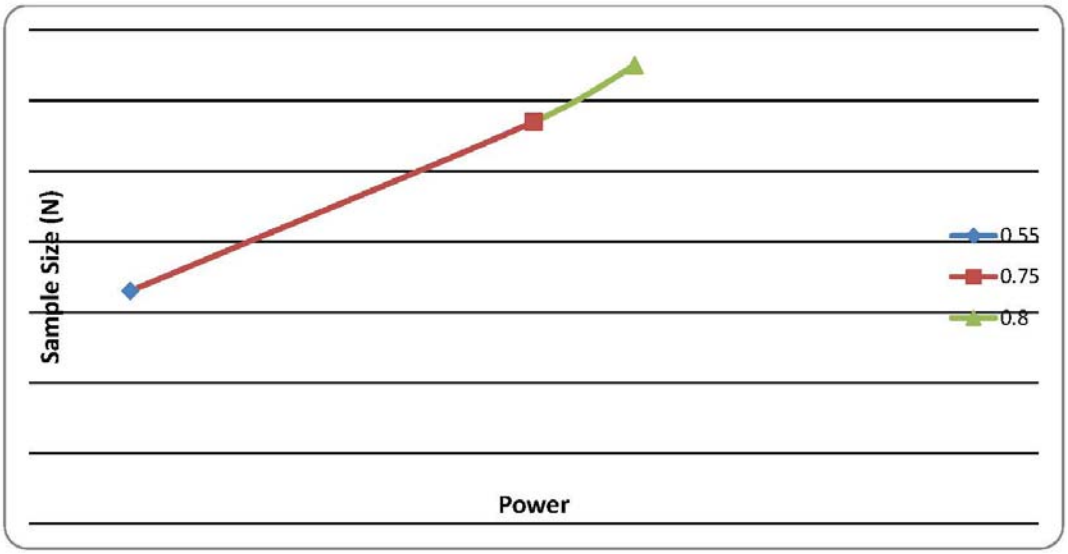

Figure A1.—Calculated sample size when d = 0.1 and power is varied from 0.55 to 0.8.

By varying d, Figure A2 suggests that a more realistic sample size of 16 is obtainable with d = 0.15 or 15%.

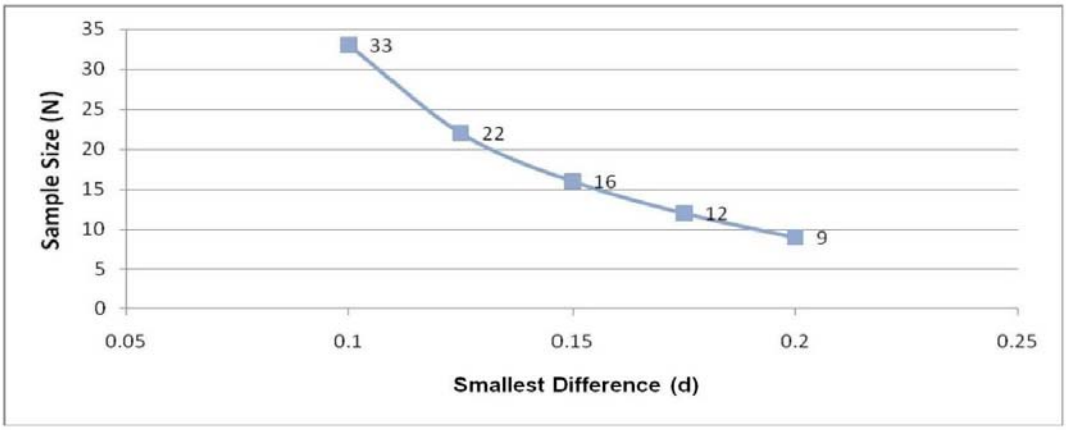

Figure A2.—Calculated sample size when d, the smallest difference it is desired to detect, is varied and power is 0.55 and α = 0.1.