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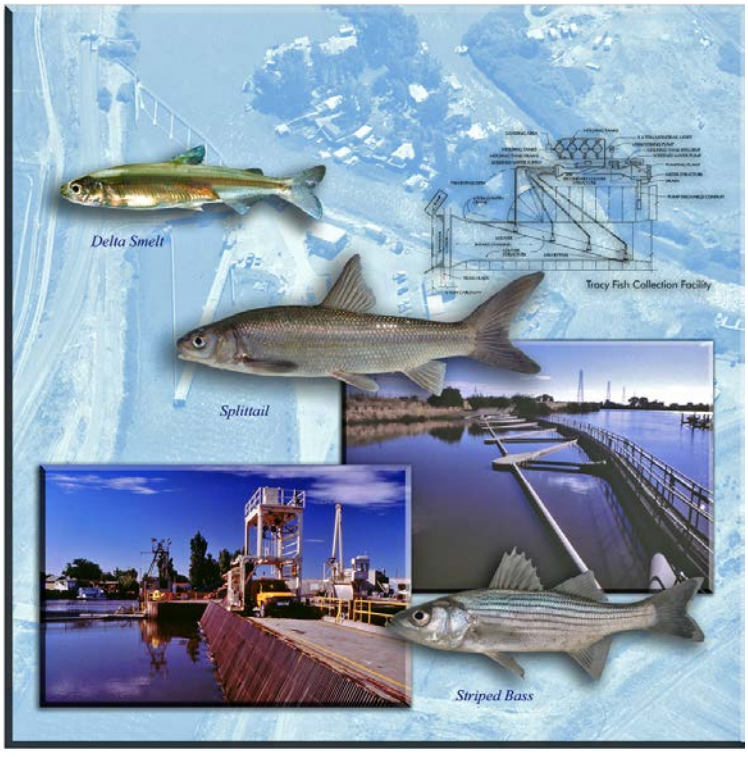
Evaluation of Holding Tank Conditions on Delta Smelt Survival at the Tracy Fish Collection Facility, Byron, California



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The U.S. Department of the Interior, Bureau of Reclamation, Tracy Fish Collection Facility (TFCF) in central California was designed in the mid-1950s to divert, collect, hold, and return salvaged fish to the Sacramento-San Joaquin River Delta. Wild fish diverted from entrainment into the C.W. "Bill" Jones Pumping Plant are collected and held in large, circular in-ground holding tanks for up to 24 h awaiting transport and release. Twelve trials were conducted using delta smelt (*Hypomesus transpacificus*) to further test holding conditions at the TFCF. Delta smelt are listed as threatened under the Endangered Species Act and are one of the most vulnerable fish species salvaged at the TFCF. Delta smelt survival was 97.1 percent through 96-h holding. There was little evidence of injury or mortality due to holding tank confinement. These experiments, in addition to those conducted previously with Sacramento blackfish (*Orthodon microlepidotus*) and juvenile Chinook salmon (*Oncorhynchus tshawytscha*) suggest that the current holding environment at the TFCF is relatively benign for salvaged fish under the conditions tested.

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Tracy Fish Facility Studies
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Evaluation of Holding Tank Conditions on Delta Smelt Survival at the Tracy Fish Collection Facility, Byron, California

Tracy Technical Bulletin 2015-4

by

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Tracy Fish Facility Improvement Program

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Executive Summary

The U.S. Department of the Interior, Bureau of Reclamation Tracy Fish Collection Facility (TFCF) in central California was designed in the mid-1950s to divert, collect, and return salvaged fish to the Sacramento-San Joaquin River Delta, from flows enroute to the C.W. “Bill” Jones Pumping Plant. Diverted fish are held in circular in-ground holding tanks up to 24 h (depending on species, number and size of fish) while awaiting transport and release. Twelve trials were conducted using delta smelt (*Hypomesus transpacificus*) to test holding conditions at the TFCF. Delta smelt are listed as threatened under the Endangered Species Act (USFWS 1993), endangered by the State of California (CDFG 2010), and are one of the most sensitive fish species entrained at the TFCF to handling and holding (Swanson et al. 1998). Little evidence of acute mortality and external injury due to holding tank confinement was found. Delta smelt survival was 97.1 percent through 96-h holding. Mortality due specifically to the fish transfer bucket process was 2.1 percent. Mortality to predation in the holding tanks was not observed although it has been noted in others (Karp *et al*. 1993, Karp and Lyons 2008). These experiments, in addition to those conducted previously with Sacramento blackfish (*Orthodon microlepidotus*; Karp and Lyons 2008) and juvenile Chinook salmon (*Oncorhynchus tshawytscha*; Portz 2007), suggest that the holding environment at the TFCF is relatively benign for salvaged fish under the conditions tested.

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Introduction

The Bureau of Reclamation Tracy Fish Collection Facility (TFCF), located in the southern Sacramento-San Joaquin Delta (Delta), was designed to divert, collect, and return salvaged fish from export flows enroute to the C.W. "Bill" Jones Pumping Plant for irrigation, municipal, and industrial use (JPP; Bates and Vinsonhaler 1957, Bates *et al*. 1960). The TFCF is situated at the head of the intake canal leading to the JPP and uses a system of louvers, bypasses, and collection tanks to salvage fish. Although the facility originally was designed to salvage juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and striped bass (*Morone saxatilis*; Bates and Vinsonhaler 1957, Bates *et al*. 1960), today, millions of fish from over 50 species may be salvaged annually (California Department of Fish and Wildlife annual salvage reports, ftp.delta.dfg.ca.gov/salvage).

The collection/holding component confines diverted fish with entrained aquatic vegetative debris up to 24 h depending on fish density (species, number, and size) and debris load derived from the salvage subsampling procedure (Bates *et al.* 1960). The tanks are drained more frequently and the salvage trucked and released in the Delta when Endangered Species Act listed species are present (USFWS 1995). This study was the final component to an evaluation of the fish-holding system at the TFCF and complements other studies of the Collection, Handling, Transport, and Release Program (J. Morinaka 2010, personal communication, Karp and Lyons 2008).

Four in-ground collection/holding tanks, 6.1 m (20 ft) wide, 4.6 m (15 ft) deep, and 132,000-L (35,000-gal) capacity, are used to collect and hold salvaged fish (Figure 1). Tank water depth 0.6–2.7 m (2–9 ft) and velocity (0.1–1.4 m/s [0.3–4.6 ft/s]) vary with tide stage and pump rates (Karp and Lyons 2008, B. Wu 2011, personal communication). The tanks are concrete with epoxy-coated sides and bottom to reduce fish injury from contact. Fish and aquatic vegetation continuously enter one tank at a time through a 50.8-cm (20-in) diameter pipe at the bottom. Water flows counterclockwise and drains through a center cylindrical screen, while fish and diverted aquatic material remain in the circulating water. Following fish collection, and prior to fish transport, incoming flow is switched to an alternate holding tank, and water in the holding tank is partially drained. A solid band circling the bottom of the cylindrical screen maintains about 1,900 L (500 gal) of water in the tank. After draining, the screen is lifted and fish and remaining water drain into a 1,544.4-L (408-gal) fish transfer bucket (Figure 2). This collection is transferred to a 9,085-L (2,400-gal) fish transport truck for return to the Delta.

Salvaged fish may spend up to 24 h in the holding tanks, and may sustain life-threatening injuries from contact with the screen or tank components, debris, and transfer to the fish transfer bucket (Swanson et al. 2005; Karp and Lyons 2008). Holding time is limited to 8 h when delta smelt are present (USFWS 1995). Previous research found holding conditions caused minimal external

Figure 1. Holding tank (132,000-L, 35,000-gal), Tracy Fish Collection Facility, Byron, California.

Figure 2.—Fish transfer bucket (1,544-L, 408-gal), Tracy Fish Collection Facility, Byron, California.

damage to Sacramento blackfish (*Orthodon microlepidotus*; Karp and Lyons 2008). The primary objective of this research was to evaluate the effects of TFCF holding conditions on adult delta smelt (*Hypomesus transpacificus*) survival. A second objective was to examine effects of the fish transfer process on delta smelt survival. Adult delta smelt were chosen for this study because they are salvaged at the TFCF and do not tolerate handling/holding as well as other species (Moyle 2002, Swanson *et al.* 1996, Swanson *et al.* 2005). Thus, delta smelt served as one of the more sensitive species salvaged at the TFCF. Delta smelt are listed as a threatened species by the US Fish and Wildlife Service (USFWS 1993) and have endangered status by the State of California (CDFG 2010).

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Methodology

In 2004-2006, cultured adult delta smelt (Figure 3) were obtained from the University of California Davis Fish Conservation and Culture Laboratory in Byron, California and transported to the TFCF aquaculture facility in 19 L (5 gal) black buckets. Fish were held indoors for two months prior to use in 750 L (198 gal) temperature controlled (12 ± 1.5°C) tanks on a semi-recirculation system supplied with ozone disinfected Delta water. Un-ionized ammonia and nitrite were maintained below 0.02 and 0.2 ppm, respectively. Fish density was maintained below 1 fish/L and room photoperiod was set for 10 h light: 14 h dark. Tanks received 9.5 lpm (2.5 gpm) of flow with continuous aeration from a 4×4×12 cm diffuser stone. Fish were fed EPAC-CW (Inve Nutrition, Salt Lake City, Utah; 600–800 micron) ad libitum with an auto feeder. Excess feed was siphoned from the bottom of the tanks, and tank sumps were cleaned daily.

Figure 3. Delta smelt, Tracy Fish Collection Facility, Byron, California.

Release-recovery experiments and immediate, 24-h, 48-h, 72-h, and 96-h post treatment survival (modified from Raquel 1989) were used to evaluate holding tank conditions on hatchery raised delta smelt. One week prior to experiments, groups of 25 fish were anaesthetized using 50 mg/L tricaine methanesulfonate (MS-222; Argent Chemical Laboratories, Redmond, Washington) and marked with fluorescent pigment (BIOMETRIX SYSTEM -1000, New West Technology, Arcata, California) on anal, dorsal, or caudal fins; note green color in base of dorsal fin, Figure 3; Sutphin 2008). A total of 8 groups, 70 fish per group, were marked with a unique pigment color and fin location. Following tagging, fish were held in unique groups in outdoor flow-through, black, polyethylene 750 L (198 gal) tanks in ozone-disinfected Delta water.

A total of 160 fish (80 treatment, 80 control) were used in each 8-h replicate (8-h trials were selected because delta smelt are returned to the delta after 8 h salvage collection):

8-h group –
20 uniquely marked fish into holding tank (treatment)
20 uniquely marked fish into 96-h follow-up tank (control)

4-h group –
20 uniquely marked fish into holding tank (treatment)
20 uniquely marked fish into 96-h follow-up tank (control)

0-h group (0 velocity) –
20 uniquely marked fish into holding tank (treatment)
20 uniquely marked fish into 96-h follow-up tank (control)

Fish transfer bucket only group –
20 uniquely marked fish into fish transfer bucket (treatment)
20 uniquely marked fish into 96-h follow-up tank (control)

Prior to each release, fish were visually inspected as they were counted into 18.9-L (5-gal) buckets (10 fish/bucket) for transport to the holding tank area. Any fish with obvious external damage or abnormal behavior was rejected and replaced with another fish. Fish were transferred between holding tanks and buckets using water-to-water transfer (*i.e.*, aquarium nets with bowls glued into the base). For each replicate, water was diverted into holding tank 4 as this did not interfere with facility operations. At time 0 (beginning of the 8-h replicate), the first group of 20 delta smelt was released. Four hours later the second uniquely marked group was released into the same holding tank. At the end of 8 h, flow was diverted to another holding tank and the third group of 20 experimental fish was released (used to evaluate effects of concentrating salvaged fish into the fish transfer bucket). The holding tank was then drained, the fish transfer bucket securely seated into the drain, and the holding tank screen was lifted. Fish (and diverted material) were drained into the fish transfer bucket for recovery. The final group of experimental fish was released directly into the fish transfer bucket to evaluate effects of emptying the transfer bucket. The fish transfer bucket was moved above a 1900-L (500-gal) rectangular sorting tank, and the contents released. Water from the sorting tank was slowly drained through 2 mm screened discharge until the remaining water depth was about 30 cm. All experimental delta smelt were recovered with water-to-water transfer and placed into 18.9-L (5-gal) buckets for transport to the 96-h recovery tank. Stomach contents of any potential fish predators were examined for experimental fish. Control fish were counted at the same time as the corresponding group of treatment fish into two 18.9-L (5-gal) buckets and transported to the 96-h tank and released. Control fish were handled identically to the treatment fish except they were not exposed to the holding tank and fish transfer bucket. Fish in the transfer bucket only experiments were only exposed to the fish transfer bucket and draining process.

We recognize that addition of the 4-h group to the 8-h group may have caused some additional stress to the latter group, but believed the likelihood of negative

interaction was unlikely. In addition, fish continually enter a holding tank during the course of facility operation.

Control and treatment fish from each 8-h replicate were held in a common recovery tank (1,800 L, 476 gal), and provided untreated Delta water for 96 h to ensure they were exposed to the same conditions. Untreated Delta water was used in place of ozonated water to promote natural infections that could develop from experimental-caused abrasions. Water in these tanks was partially drained each day and mortalities recovered. All mortalities were measured (FL) and tag color/location noted. After 96 h, the tanks were drained completely, and all fish were anesthetized, measured (FL), and tag color/location was noted. Delta smelt were not fed and the tanks were not cleaned for the 96-h recovery period to reduce additional damage or stress from cleaning activity.

Holding tank water velocity was taken 0.6 m (2 ft) below the water surface throughout the 8-h experiment using a Marsh-McBirney portable flowmeter (Hach Company, Loveland, Colorado). Holding tank debris was collected and weighed (BW30 Series CAS kg scale; CAS Corporation, Seoul, South Korea) at the end of the 8 h period. All wild fish were counted and a subsample was measured.

Data Analyses

Immediate, 24-, 48-, 72- and 96-h post treatment survival was determined based on recovered live and dead fish. Fish were only measured at the end of the 96-h period to minimize injury/stress. Although 20 fish were intended to be released per treatment, actual counts after the 96-h period varied from 16–22 per group (extra fish likely due to counting error at the beginning as fish were quickly transferred with most attention being paid to external appearance and swimming ability and only an approximate number was recorded). Some fish may have been lost in the recovery process as the bucket rim seal and drain seal were not always perfectly flush. Therefore, mortality data were standardized for the number of fish remaining after 96-h in each test. These data were not normally distributed and Wilcoxon Signed Rank Test and Kruskal-Wallis One-Way Analysis of Variance (Statistix 8, Analytical Software) were used for analyses.

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Results and Discussion

A total of 1,790 delta smelt averaging 73.4 mm FL (39–115 mm FL; Table 1) were used in 12 replicates (915 control fish, 875 treatment fish; some fish were presumably lost in the fish recovery process and thus not measured). Of these, 97.1 percent of all delta smelt survived handling, holding tank conditions, fish recovery, and 96-h post-treatment holding.

Table 1. Total number and size (mm, fork length, FL) of delta smelt from holding tank experiments, November 2007–December 2008, Tracy Fish Collection Facility, Byron, California

Date	Total number delta smelt used in holding experiments	Mean fish lengths (mm) FL (Range, mm FL)
November 2007	452	59.0 (39–75)
March 2008	472	72.6 (50–90)
November 2008	392	80.3 (56–100)
December 2008	474	82.2 (64–115)
Total	**1,790**	**73.4 (39–115)**

Of the 52 fish that died, 16 (30.8 percent) were from the control groups and 36 (69.2 percent) were from the treatment groups. These mortalities represented 1.7 percent and 4.1 percent of the total number of fish in the control and treatment groups, respectively (Table 2). No obvious lacerations or other external injury was noted in the immediate mortality group (n = 12; 23.1 percent of all mortalities).

Table 2. Summary of delta smelt mortality by experiment (8-, 4-, 0-h holding duration, fish transfer bucket only) holding tank studies, 2007–2008, Tracy Fish Collection Facility, Byron, California. Number in parentheses is mortalities/total number fish.

Experiment	Control (percent)	Treatment (percent)
8-h holding duration (n = 10)	2.0 (4/202)	3.7 (7/189)
4-h holding duration (n= 12)	2.9 (7/241)	5.7 (13/228)
0-h holding duration (n=12)	1.3 (3/236)	3.6 (8/223)
Fish transfer bucket (n=12)	0.8 (2/236)	3.4 (8/235)
Total	**1.7 (16/915)**	**4.1 (36/875)**

There was no statistical difference in 96-h mortality within the control (8-, 4-, 0-h; P = 0.756, Kruskal-Wallis) and treatment (8-, 4-, 0-h; P = 0.422, Kruskal-Wallis) 96-h. This suggests that time in the holding/collection tank (8, 4, or 0 h) did not affect delta smelt mortality. However, treatment mortality was twice that of the control groups (P = 0.007, Wilcoxon Signed Rank Test). Thus, while overall mortality was low (approximately 2 percent of mortality was attributed to

handling/fish condition), holding tank induced mortality did occur. Of the fish that died, more than half (55.8 percent) died within the first 24 h (Appendix 1). However, there was no statistical difference in mortality among immediate, 24-, 48-, 72-, and 96-h holding duration (P = 0.376, Kruskal-Wallis) which suggests post-experimental holding time did not adversely affect survival.

Mortality was low in the transfer bucket experiments (2.1 percent of both control and treatment groups; Table 2). Although four times as many fish died following transfer bucket handling relative to the control groups, a statistical difference was not detected (Wilcoxon Signed Rank Test, one-tailed P = 0.094). The absence of statistical significance may have been due to the small sample size (12 replicates). No potential predators were collected during the experiments although predation in the holding tanks has been noted in other studies (Karp *et al*. 1993, Karp and Lyons 2008).

Delta water temperatures ranged from 11.1–16.7 °C (52–62 °F). Debris load varied depending on time of year and was generally heaviest in November after the south Delta barriers were removed (Table 3). Wild fish salvage also varied and densities were highest in November when large numbers of threadfin shad (*Dorosoma petenense*) were present. Holding tank velocities averaged 0.3 m/s (1.0 ft/s) and ranged from 0.2–0.4 m/s (0.8–1.5 ft/s). As noted in Karp and Lyons (2008), holding tank velocities were highest during the initial tank filling and during low tide periods. We did not test for effects of debris load, wild fish density, or tank velocities on fish survival because of the low incidence of mortality.

Table 3. Summary of wild fish and debris entrainment per hour during the delta smelt holding experiments, November 2007–December 2008, Tracy Fish Collection Facility, California.

Date	Holding Period (h)	Mean Debris Load[1] - Kg/h	Mean Debris Load[1] - lb/h	Mean Number of Fish/h	Tank Velocity - m/s	Tank Velocity - ft/s
11/6/07	8	0.7	1.5	6.5	0.2	0.8
11/7/07	8	0.9	1.9	70.6	0.3	1.1
11/8/07	8	1.2	2.6	16.8	0.3	0.9
3/18/08	8	1.6	3.4	6.5	0.4	1.5
3/19/08	8	1.4	3.2	7.1	0.3	0.9
11/3/08	8	0.3	0.7	0.6	0.3	0.9
11/4/08[1]	4	1.5	3.2	82.9	0.4	1.3
11/5/08[1]	4	2.3	5.0	39.8	0.2	0.8
12/10/08	8	1.0	2.2	2.0	0.2	0.8
12/11/08	8	1.4	3.0	2.3	0.2	0.6
12/12/09	8	1.5	3.4	3.8	0.2	0.6

[1] Debris load was standardized per h because all trials did not last 8 h. Experiments on November 4–5, 2008 were limited to 4-h duration because of higher debris loads and wild fish densities. Debris and wild fish data were lost for the March 20, 2008 replicate.

Conclusions

In this study, 96-h delta smelt survival was 97.1 percent and predation on experimental Delta smelt in the holding tank was not detected. The high survival suggests that the circular holding tank environment, at least for confinement to 8 h, was not significantly harmful to small (~73 mm FL) salvaged fish. This observation agrees with findings reported by Portz (2007) of relatively low stress levels (low plasma cortisol levels) in juvenile Chinook salmon confined in a laboratory model of the holding tank. Karp and Lyons (2008) also reported that most Sacramento blackfish (92.2 percent) exhibited <5 percent scale loss in TFCF holding tank experiments.

In regards to the fish transfer bucket experiments, some mortality occurred. However, overall mortality was low, and in fact, in 7 of 12 trials, 100 percent of the delta smelt survived the recovery process and the 96-h holding duration. Immediate survival was similarly high in previous experiments with Sacramento blackfish (Karp and Lyons 2008).

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Appendix 1 - Data Summary

Date	Experiment	Immediate Mortality	24 h Mortality	48 h Mortality	72 h Mortality	96 h Mortality	Total
11/06/2007	Control	0	0	0	0	0	0
11/06/2007	Treatment	2	0	1	0	0	3
11/07/2007	Control	0	0	0	1	0	1
11/07/2007	Treatment	0	1	0	2	1	4
11/08/2007	Control	0	0	0	0	0	0
11/08/2007	Treatment	5	1	0	0	1	7
03/18/2008	Control	0	0	0	0	0	0
03/18/2008	Treatment	0	4	0	0	1	5
03/19/2008	Control	0	1	0	0	0	1
03/19/2008	Treatment	0	0	0	0	1	1
03/20/2008	Control	0	1	1	0	1	3
03/20/2008	Treatment	0	0	1	0	0	1
11/03/2008	Control	0	1	1	1	0	3
11/03/2008	Treatment	1	0	1	1	0	3
11/04/2008	Control	0	0	0	0	2	2
11/04/2008	Treatment	0	0	2	0	0	2
11/05/2008	Control	0	0	0	1	0	1
11/05/2008	Treatment	0	0	0	0	0	0
12/10/2008	Control	0	1	0	1	0	2
12/10/2008	Treatment	0	3	1	0	0	4
12/11/2008	Control	0	1	0	0	0	1
12/11/2008	Treatment	2	0	1	0	0	3
12/12/2008	Control	0	2	0	0	0	2
12/12/2008	Treatment	2	1	0	0	0	3