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Managing Water in the West

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Effects of Life-Stage and Origin (Wild or Hatchery) on Delta Smelt Secondary Channel Efficiency at the Tracy Fish Collection Facility

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14. ABSTRACT
Operations at the Bureau of Reclamation's Tracy Fish Collection Facility (TFCF) function to salvage fish, preventing pump-induced mortality at Bill Jones Pumping Plant. Operations and hydraulic conditions at the TFCF are frequently evaluated to promote optimal conditions for fish salvage. Due to low wild population levels of delta smelt, data collection efforts undertaken to evaluate effects of TFCF operations on salvage efficiency have historically relied on mark and recapture experiments with hatchery delta smelt. Experiments were undertaken in 2002 to evaluate effects of life-stage (adult or juvenile) and origin (wild or hatchery) on delta smelt secondary channel louver efficiency (SLE) at the TFCF. There was no significant difference in SLE of hatchery juvenile delta smelt (mean ± SE = 87.5 ± 1.7%; n = 30) and wild juvenile delta smelt (90.9 ± 2.4%; n = 7), or hatchery adult smelt (96.2 ± 0.9%; n = 30) and wild juvenile smelt (ANOVA on Ranks, $P > 0.05$). However, SLE of hatchery adult and juvenile fish were significantly different (ANOVA on Ranks, $P < 0.05$). There was no significant difference in secondary louver participation (SLP) of hatchery adult (74.2 ± 4.6%) and juvenile (82.6 ± 4.3%) delta smelt (Mann-Whitney Rank Sum, $P > 0.05$). There was no significant relationship between SLE and either secondary channel velocity or bypass ratio for either life-stage of delta smelt tested (PCC, $P > 0.05$). Though a low sample size for wild juvenile delta smelt was collected (n = 7), this suggests hatchery delta smelt may serve as a surrogate for wild smelt.

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California

Effects of Life-Stage and Origin (Wild or Hatchery) on Delta Smelt Secondary Channel Efficiency at the Tracy Fish Collection Facility

Tracy Technical Bulletin 2014-1

by

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Fish photography by René Reyes, Tracy Fish Collection Facility, Tracy, California.
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EXECUTIVE SUMMARY

Delta smelt (*Hypomesus transpacificus*), a pelagic fish endemic to California's Sacramento-San Joaquin Delta (SSJD), have experienced precipitous declines in abundance, contributing to historically low population indices and a listing status of endangered under the California Endangered Species Act in 2010. Operations at the Bureau of Reclamation's Tracy Fish Collection Facility (TFCF) in the southern SSJD function to salvage fish, preventing pump-induced mortality at Bill Jones Pumping Plant. Operations and hydraulic conditions at the TFCF are frequently evaluated to promote optimal conditions for fish salvage.

Due to low wild population levels, data collection efforts undertaken to evaluate effects of hydraulic conditions on TFCF salvage efficiency have historically relied on mark and recapture experiments with hatchery reared adult delta smelt. Experiments were undertaken in May and November 2002 to evaluate effects of life-stage (adult or juvenile) and origin (wild or hatchery) on delta smelt secondary channel louver efficiency at the TFCF. There was no significant difference in secondary louver efficiency (SLE) of hatchery reared juvenile delta smelt (mean ± SE = 87.5 ± 1.7%; n = 30) and wild juvenile delta smelt (90.9 ± 2.4%; n = 7), or hatchery reared adult smelt (96.2 ± 0.9%; n = 30) and wild juvenile smelt (ANOVA on Ranks, $P > 0.05$). However, SLE of hatchery reared adult and juvenile fish were significantly different (ANOVA on Ranks, $P < 0.05$). There was no significant difference in SLP of hatchery reared adult (74.2 ± 4.6%) and juvenile (82.6 ± 4.3%) delta smelt (Mann-Whitney Rank Sum, $P > 0.05$). There was no significant relationship between SLE and either secondary channel velocity or bypass ratio for either life-stage of delta smelt tested (PCC, $P > 0.05$). Though a low sample size for wild juvenile delta smelt was collected (n = 7), this suggests hatchery reared delta smelt may serve as a surrogate for wild smelt. However, a more robust sampling design should be developed in future efforts to verify this assumption.

INTRODUCTION

Delta smelt (*Hypomesus transpacificus*) are endemic to California's Sacramento-San Joaquin Delta (SSJD), but have experienced significant declines in population abundance in recent decades, resulting in a listing status of endangered under the California Endangered Species Act in 2010 (CDFG 2010). Though there are a multitude of variables that have likely contributed to the declines of delta smelt, water delivery and diversion facilities have been cited as contributing to their decline (Moyle 2000; Kimmerer 2008). To minimize effects of water delivery on the SSJD fishery, the Bureau of Reclamation's (Reclamation) Tracy Fish Collection Facility (TFCF; Byron, CA) functions to isolate (salvage) fish from Delta Mendota Canal (DMC) water destined for the Bill Jones Pumping Plant, thereby preventing pump-induced fish mortality.

Significant research efforts have been completed to evaluate effects of TFCF operations on salvage efficiency of fish, including delta smelt. Between 2003 and 2008 a multitude of data collection efforts were undertaken to quantify effects of hydraulic conditions and, to some extent, diel variation and predator load, on TFCF salvage efficiency of delta smelt. Hatchery reared adult delta smelt (UC Davis's Fish Conservation and Culture Lab, FCCL; Byron, CA) were used for the majority of these experiments, and, if deemed a suitable surrogate for wild delta smelt, would likely be used for all future research endeavors because they provide a reliable source of fish that promotes appropriate experimental design. However, rearing under varying hatchery conditions may contribute to reduced performance and condition in some species of fish (McDonald et al. 1998; Pedersen et al. 2008; Basaran et al. 2007). Therefore, it is important to evaluate the suitability of hatchery reared delta smelt as a surrogate for wild fish.

The primary objective of this research was to evaluate the effects of life-stage, adult or juvenile, and origin, wild juvenile or hatchery juvenile, on secondary channel efficiency of delta smelt at the TFCF. The secondary objective was to determine if secondary channel velocity or secondary channel bypass ratio affected secondary channel efficiency. Results of this study will assist in determining if using hatchery reared delta smelt are a suitable surrogate for wild delta smelt during TFCF efficiency testing.

METHODS

Mark Bowen (former Reclamation Fish Biologist) was the project lead for experimental design and data collection efforts in 2002. All data reported in this document and used for analyses were a result of his coordination efforts with TFCF and Reclamation's Technical Service Center (Denver, CO). Tracy Fish Collection Facility operations, as managed by the Fish Diversion Workers, are conveyed in English units. Therefore, TFCF velocity data will be reported in English units. All other values will be reported in Metric. For clear interpretation, the English units are converted to Metric units in Appendix A.

Fish Source and Care

Adult and juvenile delta smelt transported approximately 4 km in black 19-L buckets, from the FCCL to Reclamation's Tracy Aquaculture Facility, were maintained in cylindrical tanks and provided continuous flows of aerated Delta water supplied from the DMC. Prior to experimentation hatchery reared adult smelt were provided an external mark, using a photonic marking gun (Sutphin 2008; New West Technology, Santa Rosa, CA), to permit identification of each unique release group of experimental fish. Due to the sensitive nature of delta smelt (Swanson et al. 1996), juvenile smelt were not provided an external mark prior to testing. Two techniques were used to distinguish wild from hatchery reared juvenile smelt: (1) hatchery reared smelt were provided a diet of live Artemia (San Francisco Bay Brand, Inc., Newark, CA.) prior to testing which resulted in an orange gut not perceptible in wild fish, and (2) multiple and pronounced melanophores on the dorsal region and isthmus of hatchery reared juvenile smelt are either less pronounced or absent compared to wild fish (Reyes 2014). Following marking procedures, smelt were provided 1-3d recovery in Delta water prior to testing. During holding and following marking, adult fish were fed to satiation daily using a commercially available fish food (BioKyowa 1000), and supplemented with live Artemia. Juvenile hatchery reared smelt were fed live Artemia.

Experimental Procedure

Experiments were conducted in the secondary channel at the TFCF (Figure 1) in May and November 2002. Experiments were completed in May to coincide with salvage of wild juvenile smelt at the TFCF, and additional experiments were completed in November as thermal conditions were deemed adequate for testing. The secondary channel is the second, and final, series of louvers (vertical slats 2.5 cm apart and oriented perpendicular to flow) at the TFCF designed to guide fish into holding tanks so they can be truck transported back to the SSJD and away from the water pumping plant (see Bowen et al. 2004 for thorough description of secondary channel and other facility components). Unlike the TFCF primary channel, fish that pass through the secondary louvers can be captured (or recaptured), providing a closed system for testing.

Secondary channel velocities of 1.08, 1.61, and 3.08 ft/s were targeted for testing to encompass the range of velocities commonly observed at the TFCF (TFCF secondary channel velocity criteria = < 2.5 ft/s (1.5 ft/s preferred) between June 1 and August 31, and 3.0 – 3.5 ft/s between February 1 and May 31). A secondary

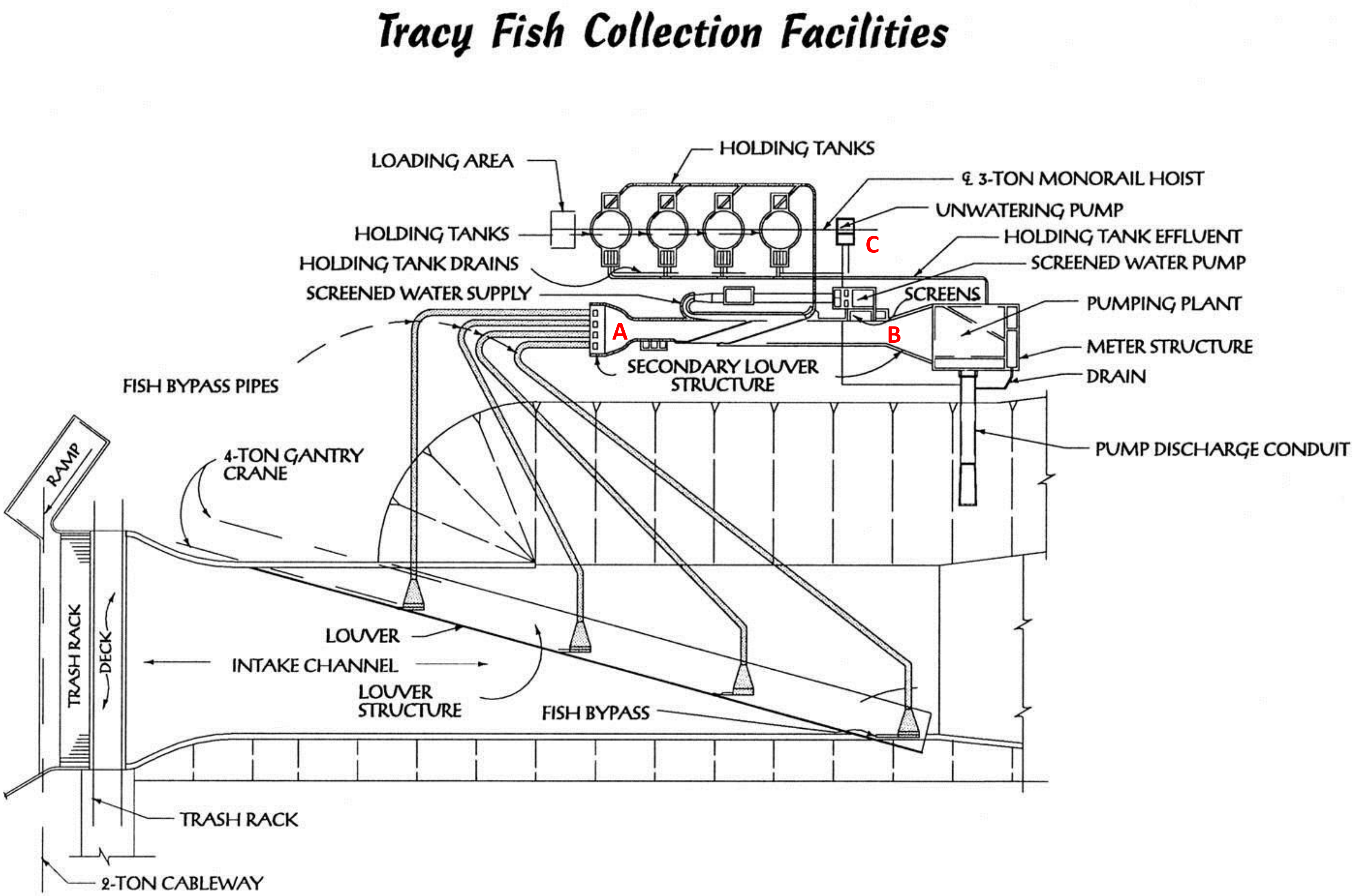

Figure 1.—Schematic of the Tracy Fish Collection Facility, depicting fish release (A) and sieve net (B) and receiving pool (C) capture locations used when evaluating secondary channel louver efficiency and louver participation of adult and juvenile (wild and hatchery reared) delta smelt (*Hypomesus transpacificus*).

channel bypass ratio of 1.6 was targeted to be representative of standard facility operations (TFCF secondary channel bypass ratio criteria = > 1). During testing in May, six of the fifteen replicate releases were conducted at night. No night studies were completed in November. In an attempt to minimize impacts of extraneous variables on secondary channel efficiency, the TFCF was cleaned of debris, from the trashrack, primary and secondary louvers, and large piscivorous fish were removed from the secondary channel while the channel was dewatered for cleaning prior to testing each day.

For each experimental replicate, 30 – 90 hatchery reared juvenile and adult delta smelt were removed from their holding tanks, using a uniquely designed dip-net to permit water-to-water transfer, transferred to a covered black 19-L bucket, and released (water-to-water) at the most accessible upstream end of the secondary channel (Figure 1). Test fish were recovered from one of two locations every twenty minutes during an hour long experimental period: (1) the secondary channel bypass leading to the holding tank building and (2) downstream of the secondary louver array (Figure 1). Fish were recovered from the secondary channel bypass using a fish-friendly pump (Figure 2; Hidrostal pump (Envirotech Pumpsystems); Helfrich et al. 2001; Helfrich et al. 2004) which transferred fish to a receiving pool (Figure 3); these were fish that were successfully louvered. Fish were recovered downstream of the secondary louver array using a sieve net (2-mm mesh; 2.4 × 2.8 m opening; Figure 4), and were deemed experimental fish that passed through the secondary louvers and were not successfully louvered. Following capture, all hatchery reared delta smelt were enumerated and measured for fork length (mm). Wild juvenile smelt were enumerated, but not measured. Water quality data was recorded semi-continuously (every 30 min) throughout data collection using a YSI multi-probe (YSI Inc., Yellow Springs, OH) installed behind the trash rack (see Figure 1) on the north side of the primary channel.

Hydraulic Calculations

Hydraulic parameters were calculated from data collected at the TFCF during the test period. Preferably, hydraulic data was directly recorded from facility instrumentation. Due to equipment failure or calibration issues, there were occasions when hydraulic data needed to be estimated.

Water depths in the secondary channel were measured with permanent ultrasonic water level sensors. Secondary channel velocity was measured with a Channel Master H-ADCP model acoustic Doppler current profiler (ADCP) installed in the secondary channel (Teledyne RD Instruments, Inc., San Diego, California). When the secondary channel flow meter was not operational, the secondary channel velocity was estimated. The secondary channel flow rate is controlled by a bank of low head velocity control (VC) pumps positioned at the downstream end of the secondary screening facility. When the flow meter was not available, the secondary channel discharge was estimated from VC pump ratings using a set

Figure 2.—Hidrostal pump used to transfer adult and juvenile delta smelt (*Hypomesus transpacificus*) from the secondary channel into a receiving pool at the Tracy Fish Collection Facility (Byron, CA) where they could be captured and processed to evaluate secondary channel louver efficiency and louver participation.

Figure 3.—Receiving pool where adult and juvenile delta smelt (*Hypomesus transpacificus*) were captured following transfer from the secondary channel at the Tracy Fish Collection Facility.

Figure 4.—Sieve net used downstream of the secondary louver arrays at the Tracy Fish Collection Facility to capture adult and juvenile delta smelt (*Hypomesus transpacificus*) that passed through the louvers.

value for each pump. The secondary average channel velocity was calculated as the secondary channel discharge divided by the cross-sectional area of the secondary channel (measured secondary channel depth upstream of the louvers x secondary channel width).

The secondary bypass ratio (SBR) is the ratio of the secondary bypass velocity to the secondary average channel velocity. The secondary bypass intake velocity is calculated as the bypass flow (discharge in bypass line flowing to the holding tanks) divided by the cross sectional area of the bypass (measured secondary channel depth upstream of the louvers x bypass width).

Secondary Channel Efficiency and Participation Calculations

Secondary Louver Efficiency (SLE)

Secondary louver efficiency quantifies the percent of fish released at the most upstream section of the secondary channel that move downstream through the secondary channel that are ultimately transferred by the fish-friendly pump into the receiving pool. This estimate measures how well the louvers are functioning. Fish holding in the secondary channel or lost to predation are removed from the SLE because these fish did not have a chance to participate in the test.

$$SLE = (RP/(RP + S)) \times 100 \quad \text{Equation (1)}$$

RP = Number of fish recovered from the receiving pool
S = Number of fish recovered in the sieve net

Secondary sieve net efficiency was not tested, but assumed to be 100% for calculations.

Secondary Louver Participation (SLP)

The secondary louver participation calculation provides a measure of how many fish participated in the test, thereby providing the level of precision available in the SLE measurement. In addition, this measurement indicates how channel velocity influences the number of fish guided downstream after release. Since the secondary channel is a closed system, it can be assumed the percentage of fish not captured in the receiving pool or sieve net were either lost to predation or took up residency in the secondary channel. Because the SLP calculation incorporates the number of released fish, an SLP estimate for wild fish was not calculable.

$$SLP = ((RP + S)/I_s) \times 100 \quad \text{Equation (2)}$$

Is = Number of fish inserted into most upstream section of secondary channel

Statistical Analyses

The majority of data did not meet the assumptions (normality and/or equal variance) to model using parametric statistics. Therefore, non-parametric alternatives were employed. Differences in fish fork length as a function of life-stage and capture location (receiving pool or sieve net) were evaluated using a One-Way ANOVA on Ranks. Similarly, differences in life-stage (adult or juvenile) and origin (wild or hatchery) SLE was evaluated using a One-Way ANOVA on Ranks. Since SLP could not be calculated with wild fish, only life-stage SLP differences in hatchery smelt were evaluated using a Mann-Whitney Rank Sum Test. The relationship between velocity and SLE and SLP, as well as bypass ratio and SLE and SLP, was evaluated using Pearson's Correlation Coefficient (PCC), and differences in life-stages were further evaluated using ANCOVA to examine differences in slope and intercept. Statistical analyses were conducted using SigmaStat 3.5 software (Systat Software Inc., Richmond, California); the significance level (α) for all analyses was set at 0.05.

RESULTS AND DISCUSSION

Range of water temperatures and turbidity levels May 13 – 17 were 18.4 – 20.7°C and 16.4 – 114.7 NTU, and November 12 – 15 were 14.3 – 15.2°C and 4.0 – 102.8 NTU. A thorough description of TFCF water quality conditions in 2002 is available in Craft et al. 2004. Mean (± standard error (SE)) fork lengths of adult smelt captured in the receiving pool (66.9 ± 0.2 mm) and sieve net (65.5 ± 2.4 mm), and juvenile smelt captured in the receiving pool (43.9 ± 0.3 mm) and sieve net (44.6 ± 2.2 mm) were not different across sample locations. However, adult fish were different in length compared to juvenile fish at both capture locations (ANOVA on Ranks, $P < 0.05$). During testing, velocities and bypass ratios ranged from 0.90 to 3.21 ft/s and 1.25 to 2.00, respectively. A full summary of measured experimental conditions is included in Appendix A.

There was no significant difference in SLE of hatchery reared juvenile delta smelt (mean ± SE = 87.5 ± 1.7%; Figure 5, n = 30) and wild juvenile delta smelt (90.9 ± 2.4%; n = 7), or hatchery reared adult smelt (96.2 ± 0.9%; Figure 5, n = 30) and wild juvenile smelt (ANOVA on Ranks, $P > 0.05$). However, SLE of hatchery reared adult and juvenile fish were significantly different (ANOVA on Ranks, $P < 0.05$; Figure 5). No wild adult delta smelt were captured during these tests, so no comparisons could be completed. There was no significant difference in SLP of hatchery reared adult (74.2 ± 4.6%) and juvenile (82.6 ± 4.3%) delta smelt (Mann-Whitney Rank Sum, $P > 0.05$). Though a low sample size for wild juvenile delta smelt was collected (n = 7) and no wild adult delta smelt were collected, this suggests hatchery reared delta smelt may serve as an adequate surrogate for wild smelt. However, a more robust sampling design should be developed in future efforts to verify this assumption.

Range of reported TFCF secondary louver efficiency values, for various species (Chinook salmon, striped bass, Sacramento splittail, etc.), aside from delta smelt, is 44 – 100% (Bates et al. 1960; Karp and Liston 1995; Bowen et al. 1998). To date, there is minimal published data on secondary louver efficiency of delta smelt. Bowen et al. (2004) opportunistically measured secondary louver efficiency of delta smelt, as well as a multitude of other species, over various diel periods, debris loads, channel approach velocities and bypass ratios, and reported a delta smelt grand secondary louver efficiency (secondary louver efficiency averaged across all replicates and measured variables) of 65%. In the current

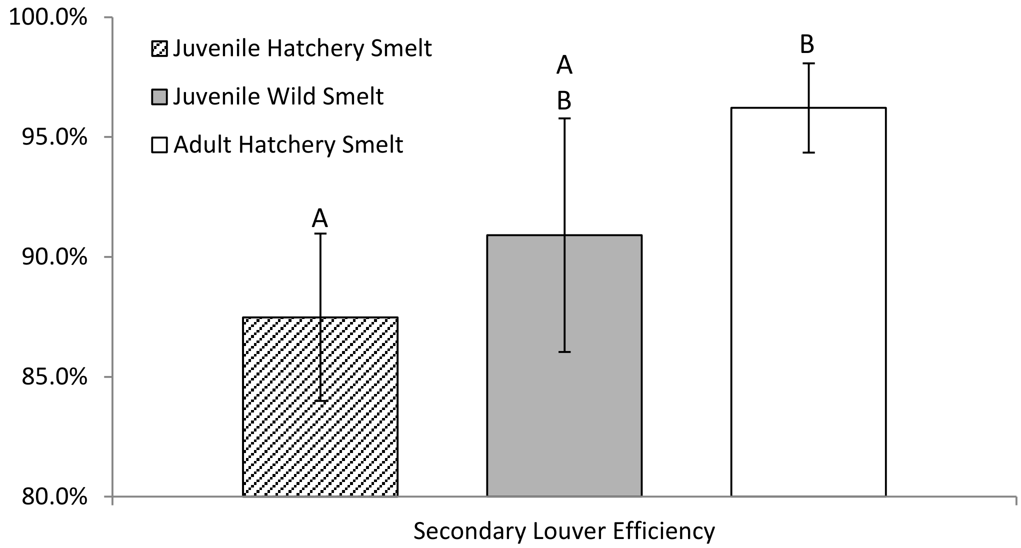

Figure 5.—Secondary louver efficiency (mean ± 2 standard errors) of hatchery and wild delta smelt, and adult hatchery delta smelt, at the Tracy Fish Collection Facility (Bureau of Reclamation; Byron, CA). The same letter above figure error bars indicate no significant statistical difference across treatment (ANOVA on Ranks, $P > 0.05$).

study the grand secondary louver efficiency of adult and juvenile delta smelt were 96.2 and 87.5%, respectively. In general, based on what is reported in Bowen et al. (2004), environmental and TFCF facility hydraulic conditions are similar to those in the current study. The major difference in methodologies between these two experiments was the current effort used a fish-friendly Hidrostal pump to transfer fish from the secondary channel into a recovery pool and Bowen et al. (2004) used gravity fed water to collect fish in a TFCF holding tank. It is possible the Hidrostal pump contributed to increased recovery of delta smelt during testing, or holding tank losses of fish are a significant contributing factor.

There was no significant relationship between SLE and either secondary channel velocity or bypass ratio for either life-stage of delta smelt tested (Pearson Correlation Coefficient, $P > 0.05$; Figures 6–9). The relationship of velocity and SLP of both adults and juvenile was significant (Pearson Correlation Coefficient, $P < 0.05$), and when modeled with a linear regression relationship suggests, within the ranges tested, SLP increases with increasing velocity (Figures 6 and 8). Lower participation at reduced flows was expected because fish are more likely to sustain position in the secondary channel at reduced flows, and not be guided into the secondary bypass. It is important to note when interpreting the R^2 value the percent of variance explained by the regression relationship is low for both adult ($R^2 = 0.23$) and juvenile smelt ($R^2 = 0.13$). Also, there was no difference in slope or intercept between life stages (ANCOVA, $P > 0.05$), supporting the Mann-Whitney Rank Sum test which suggested no differences in SLP of adult and juvenile delta smelt.

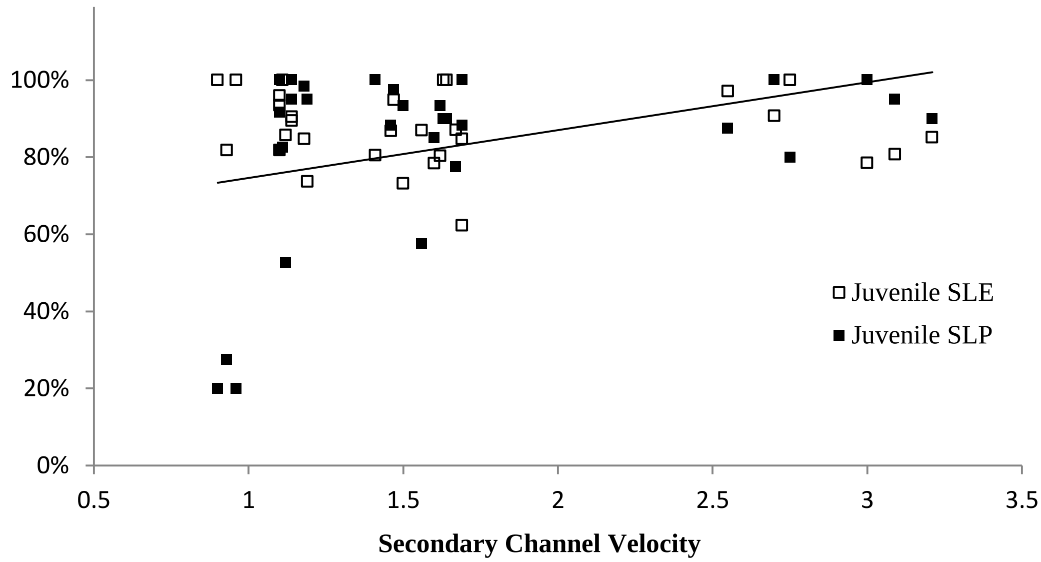

Figure 6.—Relationship of secondary channel velocity (ft/s) and secondary channel louver efficiency (SLE) and secondary channel louver participation (SLP) for hatchery reared juvenile smelt at the Tracy Fish Collection Facility (Byron, CA). There was a significant relationship between velocity and SLP (Pearson Correlation Coefficient, $P < 0.05$, $R^2 = 0.13$).

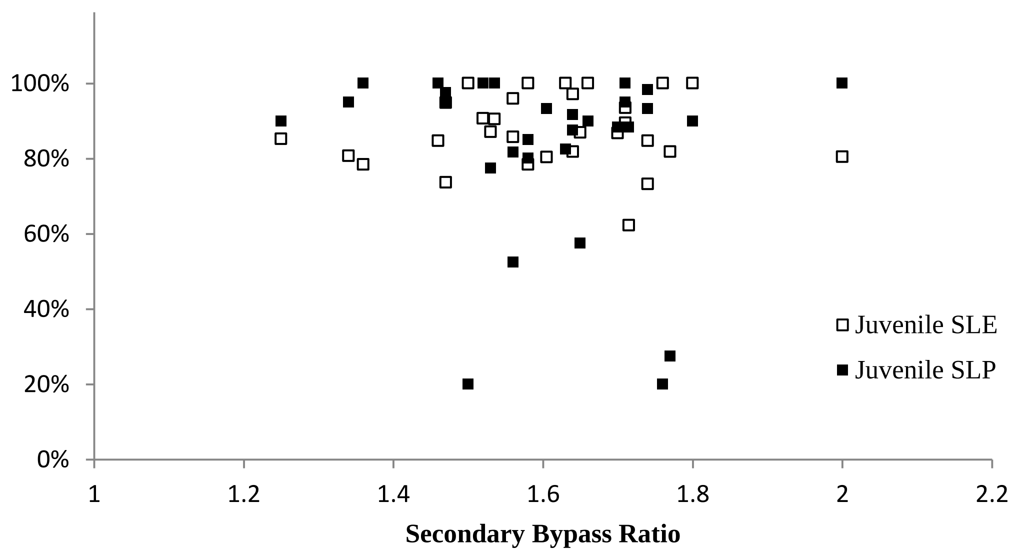

Figure 7.—Relationship of secondary bypass ratio and secondary channel louver efficiency (SLE) and secondary channel louver participation (SLP) for hatchery reared juvenile smelt at the Tracy Fish Collection Facility (Byron, CA). There was no significant relationship between bypass ratio and louver efficiency or participation (Pearson Correlation Coefficient, $P > 0.05$).

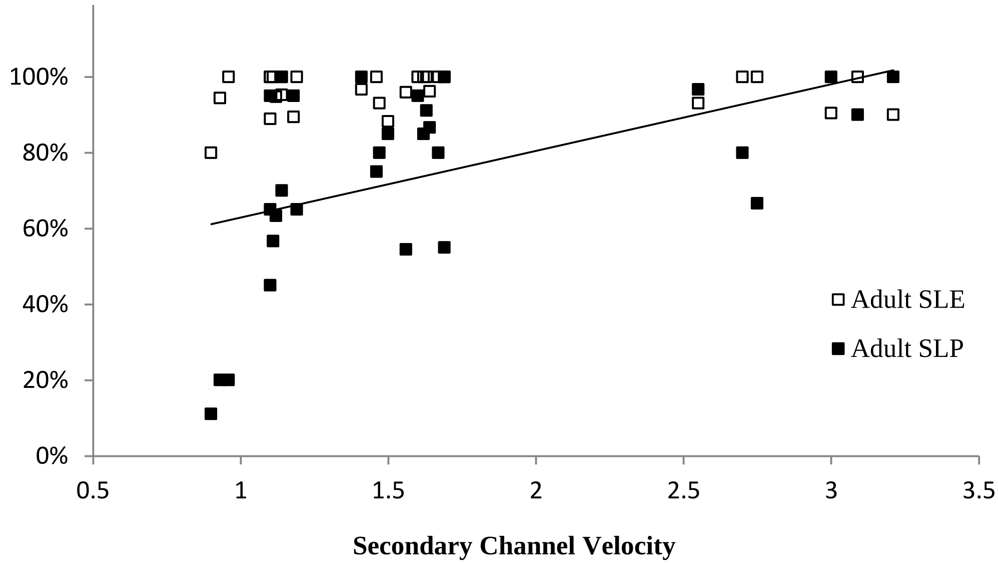

Figure 8.—Relationship of secondary channel velocity (ft/s) and secondary channel louver efficiency (SLE) and secondary channel louver participation (SLP) for hatchery reared adult smelt at the Tracy Fish Collection Facility (Byron, CA). There was a significant relationship between velocity and SLP (Pearson Correlation Coefficient, $P < 0.05$, $R^2 = 0.23$).

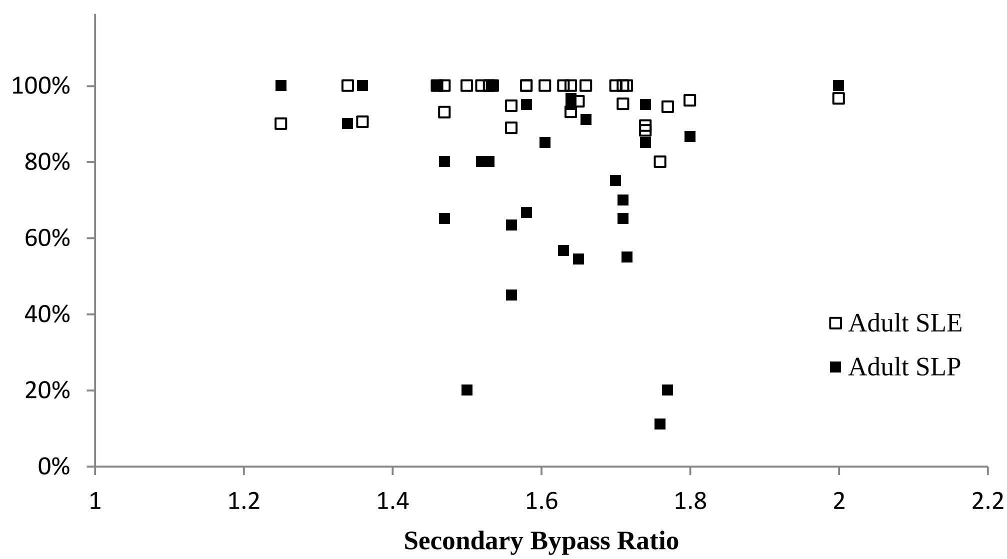

Figure 9.—Relationship of secondary bypass ratio and secondary channel louver efficiency (SLE) and secondary channel louver participation (SLP) for hatchery reared adult smelt at the Tracy Fish Collection Facility (Byron, CA). There was no significant relationship between bypass ratio and louver efficiency or participation (Pearson Correlation Coefficient, $P > 0.05$).

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APPENDIX A

Water Velocities (Mean Secondary Channel Velocity), Secondary Bypass Ratio, Diel Condition (Day or Night), Secondary Louver Efficiency (SLE), and Secondary Louver Participation (SLP) for Adult, Juvenile, and Wild Juvenile Delta Smelt at the Tracy Fish Collection Facility (Byron, California)

Month	Secondary Channel Velocity (ft/s)	Secondary Channel Velocity (m/s)	Secondary Bypass Ratio	Secondary Channel Depth (ft)	Day (D) / Night (N)	Adult SLE	Adult SLP	Juvenile SLE	Juvenile SLP	Wild Juvenile SLE
May	1.10	0.34	1.64	NA	N	100%	95%	82%	92%	92%
May	1.14	0.35	1.54	NA	N	100%	100%	90%	100%	91%
May	1.18	0.36	1.74	NA	N	89%	95%	85%	98%	94%
May	1.10	0.34	1.56	NA	D	89%	45%	96%	82%	
May	1.10	0.34	1.71	NA	D	100%	65%	93%	100%	
May	1.19	0.36	1.47	NA	D	100%	65%	74%	95%	
May	1.46	0.45	1.70	NA	N	100%	75%	87%	88%	96%
May	1.50	0.46	1.74	NA	N	88%	85%	73%	93%	95%
May	1.69	0.52	1.46	NA	N	100%	100%	85%	100%	77%
May	1.60	0.49	1.58	NA	D	100%	95%	78%	85%	
May	1.62	0.49	1.61	NA	D	100%	85%	80%	93%	
May	1.69	0.52	1.72	NA	D	100%	55%	62%	88%	
May	3.00	0.92	1.36	NA	D	90%	100%	78%	100%	
May	3.09	0.94	1.34	NA	D	100%	90%	81%	95%	
May	3.21	0.98	1.25	NA	D	90%	100%	85%	90%	92%
Nov	0.90	0.27	1.76	4.49	D	80%	11%	100%	20%	
Nov	0.93	0.28	1.77	4.16	D	94%	20%	82%	28%	
Nov	0.96	0.29	1.50	4.43	D	100%	20%	100%	20%	
Nov	1.11	0.34	1.63	5.44	D	100%	57%	100%	83%	
Nov	1.12	0.34	1.56	4.55	D	95%	63%	86%	53%	
Nov	1.14	0.35	1.71	5.69	D	95%	70%	89%	95%	
Nov	1.41	0.43	2.00	3.83	D	97%	100%	80%	100%	
Nov	1.47	0.45	1.47	5.20	D	93%	80%	95%	98%	
Nov	1.56	0.48	1.65	4.22	D	96%	54%	87%	58%	
Nov	1.63	0.50	1.66	5.27	D	100%	91%	100%	90%	
Nov	1.64	0.50	1.80	5.52	D	96%	87%	100%	90%	
Nov	1.67	0.51	1.53	4.21	D	100%	80%	87%	78%	
Nov	2.55	0.78	1.64	5.16	D	93%	97%	97%	88%	
Nov	2.70	0.82	1.52	4.30	D	100%	80%	91%	100%	
Nov	2.75	0.84	1.58	4.69	D	100%	67%	100%	80%	