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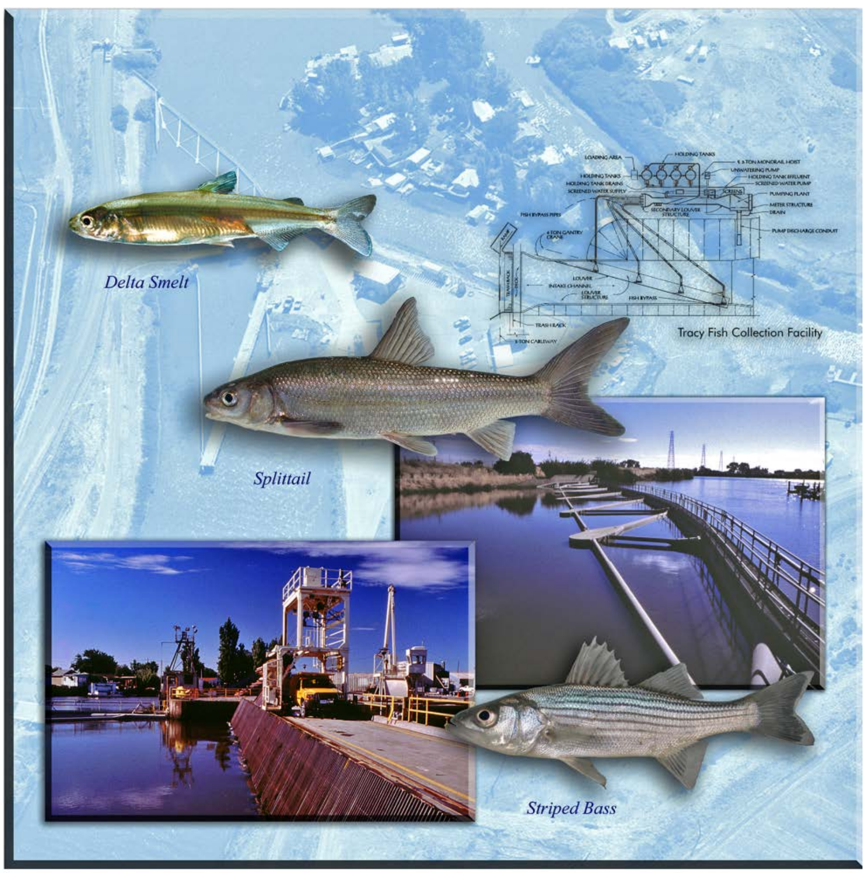
Facility Efficiency for Splittail, Tracy Fish Collection Facility, Byron, California



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The Bureau of Reclamation's 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 exported flows enroute to the C.W. "Bill" Jones Pumping Plant. TFCF fish diversion efficiency was considered high in the early decades of operation due in part to short-term pumping and low numbers of entrained fish. However, year-round pumping began following completion of San Luis Reservoir in the 1960's, and today, millions of fish comprising 50+ species may be drawn into the facility. Juvenile splittail (*Pogonichthys macrolepidotus*) louver efficiency was evaluated using release-recapture experiments. In 13 trials, secondary and primary channel louver efficiency averaged 75.1 percent and 13.2 percent, respectively. Whole facility efficiency averaged 10.4 percent. Secondary channel louver efficiency was similar to previous estimates for the species and more fish appeared to louver successfully in day than night. Whole facility and primary channel louver efficiencies were low, largely due to the high number of experimental fish not recovered in the holding tank (>73 percent). These unaccounted for experimental fish may have moved upstream out of the facility, lost through the louvers or lost to predation within the facility.

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Facility Efficiency for Splittail, Tracy Fish Collection Facility, Byron, California

Tracy Technical Bulletin 2015-1

by

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TRACY FISH FACILITY IMPROVEMENT PROGRAM

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COVER

Fish photography by René Reyes, Tracy Fish Collection Facility, Tracy, California.
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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 exported flows enroute to the C.W. "Bill" Jones Pumping Plant (JPP). The TFCF is situated at the head of the canal leading to the JPP, and up until summer 2014, used two louver bypass channels to divert and collect entrained fish. Louvers are a type of behavioral fish barrier and as such, are more or less effective for different species and life history stages. TFCF fish diversion efficiency was considered high in the early decades of operation due in part to short-term pumping and low numbers of entrained fish. However, year-round pumping at the JPP began in the 1960's following completion of San Luis Reservoir, and today, millions of fish comprising more than 50 species may be drawn into the fish facility. Juvenile splittail (*Pogonichthys macrolepidotus*) louver efficiency was evaluated using release-recapture experiments. In 13 trials, secondary and primary channel louver efficiency averaged 75.1 percent and 13.2 percent, respectively. Whole facility efficiency averaged 10.4 percent. Secondary channel louver efficiency was similar to previous estimates for the species and more fish appeared to louver successfully in the day than at night. Whole facility and primary channel louver efficiencies were low, largely due to the high number of experimental fish that were not recovered. These unaccounted for fish may have moved upstream out of the facility, may have been lost through the louvers, or to predation within the facility.

INTRODUCTION

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 C.W. "Bill" Jones Pumping Plant (JPP; Bates and Vinsonhaler 1957, Bates *et al*. 1960). These facilities were built in the 1950s to export water from the Old River channel of the San Joaquin River in central California for irrigation, municipal, and industrial uses, while diverting and salvaging entrained fish.

The TFCF is situated at the head of the DMC and, up until summer 2014, used two louver-bypass systems to intercept and guide entrained fish (Figure 1). Fish and exported flows enter the fish facility beneath a surface debris collector (trash boom), through a trash rack with 5.1-cm–wide (2.0 in) spacing, and into the 25.6-m–wide (84 ft), 6-m–deep (20 ft) primary louver channel. The primary channel louver wall is 97.5 m (320 ft) long with four 22.9 m (75 ft) sections terminating in bypass entrances (15.2 cm [6 in] wide). Once inside a bypass entrance, fish move into 0.9-m-diameter (36 in) underground pipes leading to the 2.4-m-wide (8 ft), 4.9-m-deep (16 ft) secondary channel where, until summer of 2014, fish encountered a double louver wall (9.3m [30.2 ft]). Here, diverted fish and aquatic material enter a common bypass (15.2 cm [6 in]) to one of four holding tanks. Salvaged fish are regularly removed and released back to the Delta, downstream of the influence of the pumps. Both the primary and secondary channel louver walls are angled 15^{o} to the flow and contain evenly spaced vertical slats (2.54 cm [1 in]) angled 90^{o} to the flow. Both the trash rack and the louver walls become clogged with aquatic debris and are cleaned frequently.

Louver systems act as a behavioral barrier in that fish sense the turbulence created by the slats, and move along the louver wall until they enter one of the bypasses (Hallock *et al*. 1968, EPRI 1986). The effectiveness of louvers at excluding fish depends on many factors including fish species, life history stage, swimming ability, hydraulic conditions, and debris load. Regulatory criteria were established for the TFCF to define appropriate channel and bypass velocities (California State Water Resources Control Board 1978, NMFS 2004, USFWS 2004). These include maintaining bypass ratios (BR) > 1, and maintaining secondary channel velocities between 0.9–1.1 m/s (3–3.5 ft/s) November through mid-May and < 0.76 m/s (2.5 ft/s) mid-May through October. Primary channel velocity is determined by the number of JPP pumps in operation and tide stage. Thus, there are no legal requirements for maintaining primary channel velocity.

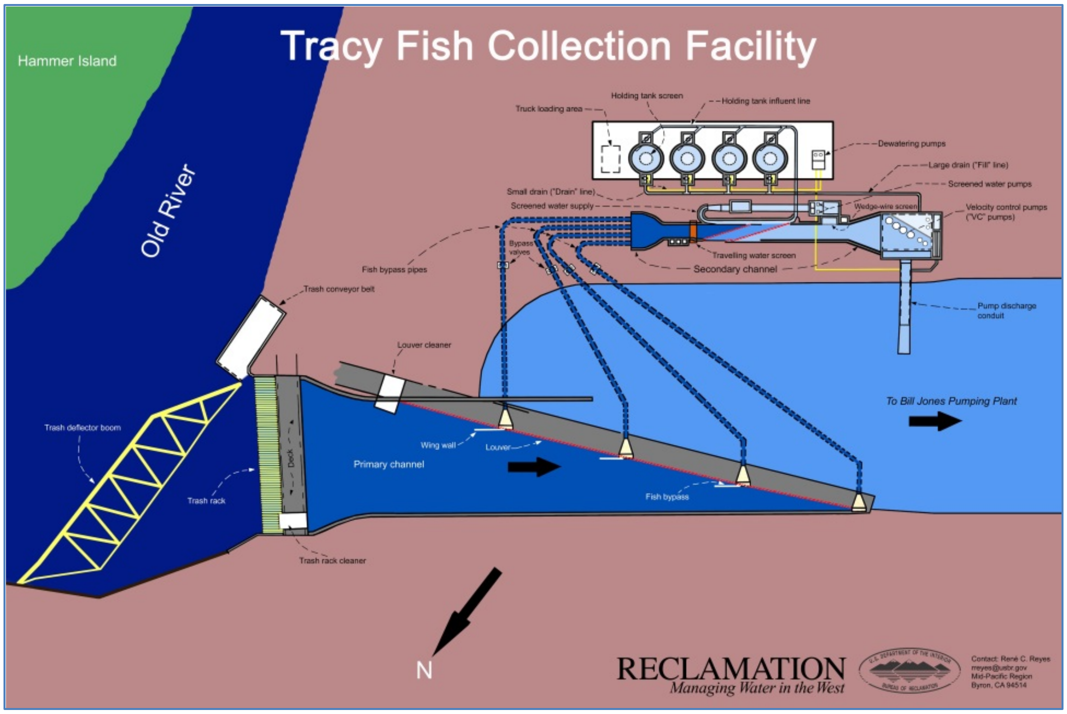

Figure 1.—Schematic of the Tracy Fish Collection Facility, Byron, California.

In the 1950s, pumping mostly occurred in the summer months and the TFCF was considered highly efficient at diverting fish from the entrained flow (Bates and Vinsonhaler 1957, Bates *et al.* 1960). Today however, both the JPP and the TFCF operate year-round, salvaging over 50 fish species under varying aquatic debris and fish entrainment conditions, and the TFCF is no longer as efficient (Karp *et al*. 1995, Bowen *et al*. 1998, Bowen *et al*. 2004, TFCF, unpublished data). The objective of this study was to determine facility efficiency for juvenile splittail (*Pogonichthys macrolepidotus*; Figure 2).

Splittail is a relatively large cyprinid endemic to California's Central Valley (Moyle 2002). Juvenile splittail generally appear in the TFCF salvage in May and June (Meng and Moyle 1995, California Department of Fish and Game 2004 annual salvage report, ftp.delta.dfg.ca.gov/salvage), particularly in higher water years (Moyle *et al*. 2004). In 1989, splittail was listed as a Species of Special Concern (Moyle *et al*. 1995) and in 1999, the U.S. Fish and Wildlife Service listed the species as threatened (USFWS 1999). However, a few years later, splittail populations were determined to be stable, and the species was removed from the endangered species list (USFWS 2003).

Figure 2.—Juvenile splittail (*Pogonichthys macrolepidotus)*. Pink mark on caudal fin is fluorescent microbead.

METHODOLOGY

Release-recovery experiments were used to estimate louver efficiency for splittail at the TFCF. Thirteen replicates were performed in fall 2004. For each replicate, a uniquely marked group of 100 fish were released downstream of the trash rack into the primary channel and a uniquely marked group of 40 fish were released at the upstream end of the secondary channel. Splittail were collected on-site June 2004, held in flow-through 750-L (198-gallon) tanks in a mix of ozone purified well (18–19^{o}C) and Delta waters, and fed Silver Cup salmon feed. Fish were acclimated, at rates not exceeding 1°C/d, to test temperatures by gradually exposing test fish to ozonated Delta water 14 d before testing.

One week prior to experiments, fish were anaesthetized using 50-ppm tricaine methanesulfonate (MS-222), measured (fork length [FL], mm), and marked with fluorescent microbeads (New West Technology, Santa Rosa , California) on anal, dorsal, or caudal fin (see pink mark on caudal fin, Figure 2). Prior to each set of releases, the secondary channel was drained and flushed, and the primary and secondary channel louvers cleaned.

A sieve net (2.69 m [8.8 ft] high, 2.5 m [8.2 ft] wide and 7.62 m [25 ft] long with 2 mm [0.8 in] mesh) located in the downstream end of the secondary channel was used to collect fish that passed through the secondary channel louvers. Experimental fish were recovered from the sieve net and holding tank every 30 min for 2 h following fish release. Four groups of 25 splittail each were released into the holding tank and in front of the sieve net to determine efficiency of the fish recovery process for this species and size.

Channel discharge, velocities, and depths were recorded using TFCF meters. Bypass ratios (the ratio of bypass entrance velocity to channel velocity) were calculated as:

- Primary channel bypass ratio = primary channel bypass discharge/combined bypass width/primary channel depth/primary channel velocity.

- Secondary channel bypass ratio = secondary channel bypass discharge/secondary channel depth/bypass width/secondary channel velocity.

Data Analysis

Louver efficiencies were calculated from the following formulas (fish recovery from the holding tanks and sieve net was considered to be 100 percent for all experiments based on 100 percent recovery of four groups of 25 fish for each location):

1. Secondary channel louver efficiency = # fish collected in the holding tank after 2 h / (# fish collected in the holding tank + # fish collected in the sieve net after 2 h) for secondary channel releases only (the numerator is fish successfully diverted by the secondary channel louvers, the denominator is the sum of fish that participated in the experiment).

2. Primary channel louver efficiency = (# fish collected in the holding tank + # fish collected in the sieve net after 2 h) / # released downstream of the trash rack (the numerator is fish successfully diverted by the primary channel louvers, the denominator is the total number of fish released into the primary channel). However, primary channel louver efficiency cannot be tested directly because of logistic constraints with netting downstream of the primary louvers.

3. Whole facility louver efficiency = # fish collected in the holding tank after 2 h / # fish released downstream of the trash rack.

The number of experimental fish that could not be accounted for 2 h following release was determined by subtracting total recoveries from the # released. Louver efficiency and # of unaccounted for experimental fish were not normally distributed and Kruskal-Wallis One-Way Analysis of Variance (Statistix 8, Analytical Software) was used to test for time of day differences.

RESULTS AND DISCUSSION

A total of 13 releases were conducted, (9 day, 4 night) with juvenile splittail (mean 43.8 mm FL, range 40–50 mm FL). Experiments were mostly conducted with five JPP pumps in operation, however, the JPP unexpectedly dropped to three pumps for a 4 hour window during 3.5 trials (Table 1). Secondary channel velocities averaged 0.9 m/s (3.0 ft/s) and ranged from 0.8 to 1.0 m/s (2.8 to 3.3 ft/s). Primary channel velocities averaged 0.8 m/s (2.8 ft/s) and ranged from 0.6 to 1.1 m/s (2.2 to 3.5 ft/s). Lowest primary channel velocities occurred when the number of JPP pumps in operation dropped from five to three. Both primary and secondary channel velocities were within the normal range found during periods (typically May-June) when wild juvenile splittail appear in the facility salvage. Primary and secondary channel bypass ratios were always > 1.

Secondary channel louver efficiency averaged 75.1 percent (43.8–89.2 percent) and primary channel louver efficiency averaged 13.2 percent (6.0–27.0 percent; Table 1). Whole facility efficiency averaged 10.4 (4.0 – 20.0 percent). Recognizing that the data set was small, louver efficiencies were significantly higher during the day than night in the secondary channel (P=0.03, Kruskal-Wallis) but not in the primary channel (P=0.9, Kruskal-Wallis). The influence of time of day on splittail secondary channel louver efficiency has also been suggested in earlier studies (Puckett *et al*. 1996, Bowen *et al*. 1998, Bowen *et al*. 2004). Whole facility and primary channel louver efficiencies were low. However, more than 73 percent of the fish released into the primary channel remained unaccounted for 2 h after release, even with slight decreases in primary channel velocity. These unaccounted for experimental fish either swam upstream out of the facility, were lost to predation, or to passage through the primary channel louvers. The number of unrecovered experimental fish was not as great in the secondary channel, but on average, about 17 percent of the secondary channel releases remained unaccounted for.

CONCLUSIONS

Early TFCF louver efficiency estimates generally focused on juvenile striped bass and Chinook salmon and were high (Bates and Vinsonhaler 1957, Bates *et al*. 1960, Hallock *et al*. 1968, Heubach and Skinner 1978). More recent evaluations suggest secondary channel louver efficiency has decreased (Karp *et al*. 1995, Bowen *et al*. 1998, Bowen *et al*. 2004). Our secondary channel louver efficiency estimate of 75.1 percent for juvenile splittail (43.8 mm mean FL) is similar to Bowen *et al.* (1998) estimate of 63.0 percent for slightly smaller splittail (31 mm mean FL), and 71.2 percent for slightly larger juveniles (70 mm mean FL, Bowen *et al*. 2004). In the latter study, the authors obtained day/night estimates (day- 81.2 percent, night- 67.9 percent) which were similar to those found here (day-81.8 percent, night- 60.1 percent). They also found secondary

Table 1.—Summary louver efficiencies for juvenile splittail, November 2004, Tracy Fish Collection Facility, Tracy, California

Time of Day	# Jones Pumping Plant Pumps	Primary Channel Louver Efficiency[1] (percent)	Secondary Channel Louver Efficiency[2] (percent)	Whole Facility Efficiency[3] (percent)	Primary Channel Velocity (m/s, ft/s)	Secondary Channel Velocity (m/s, ft/s)	Primary Channel Bypass Ratio[4]	Secondary Channel Bypass Ratio[5]	Unrecovered fish Primary Channel (percent)	Unrecovered fish Secondary Channel (percent)
Day	3–5	18	77.4	11.0	0.8, 2.6	0.9, 3.0	1.3	1.1	90	30
Day	3	21	76.7	20.0	0.7, 2.4	0.9, 2.9	1.6	1.3	85	17.5
Day	3	12	82.1	10.0	0.6, 2.2	0.9, 3.0	1.7	1.3	82	22.5
Day	3	9	86.4	6.0	0.6, 2.1	0.9, 3.0	1.8	1.4	79	25
Day	5	27	85.3	20.0	0.9, 3.0	0.9, 3.0	1.2	1.4	88	2.5
Day	5	9	77.1	8.0	0.9, 3.0	0.9, 3.0	1.3	1.5	91	7.5
Day	5	6	89.2	4.0	0.9, 3.0	0.9, 3.0	1.3	1.5	73	15
Day	5	15	85.2	12.0	1.0, 3.2	0.9, 3.1	1.2	1.5	91	12.5
Day	5	6	76.7	5.0	1.0, 3.3	1.0, 3.3	1.2	1.4	94	7.5
Night	5	10	82.1	6.0	1.0, 3.4	1.0, 3.2	1.2	1.2	93	2.5
Night	5	15	60.6	14.0	1.1, 3.5	0.8, 2.8	1.2	1.2	83	20
Night	5	7	53.8	7.0	1.0, 3.2	0.9, 3.1	1.4	1.2	85	32.5
Night	5	17	43.8	12.0	1.0, 3.3	1.0, 3.3	1.5	1.4	94	25

[1] Efficiency = (fish recovered in holding tank and sieve net)/fish released at the trash rack.
[2] Efficiency = fish recovered in the holding tank/(fish recovered in the holding tank and sieve net), for fish released into the secondary channel only.
[3] Efficiency = fish recovered in holding tank/fish released at the trash rack.
[4] Primary channel bypass ratio = primary channel bypass discharge/(combined bypass width×primary channel depth)/primary channel velocity.
[5] Secondary channel bypass ratio = secondary channel bypass discharge/(secondary channel depth×bypass width)/secondary channel velocity.

channel louver efficiency was significantly higher during the day. Puckett *et al*. (1996) also noted a possible time of day influence for juvenile splittail louver efficiency in an evaluation of salvage and pump rates. These estimates suggest that juvenile splittail louver relatively efficiently in the secondary channel at the TFCF, particularly during the day. Our experiments were not able to evaluate effects of secondary channel velocity on louver efficiency as all were conducted at relatively high velocities (0.8 - 1.0 m/s [2.8 - 3.3 ft/s]). However, in a comparison of secondary channel louver efficiencies from a range of velocities, Bowen *et al*. (2004) did not find a significant relationship between channel velocity and juvenile splittail louver efficiency. Our whole facility and primary channel louver efficiency estimates were low which was probably due to the low recovery of experimental fish.

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APPENDIX 1

Data Summary

Time of Day[1]	Jones Pumping Plant pumps	Primary Channel Velocity (ft/s)	Secondary Channel Velocity (ft/s)	Primary Bypass Ratio	Secondary Bypass Ratio	Whole Facility Efficiency (percent)	Primary Channel Efficiency (percent)	Secondary Channel Efficiency (percent)	Unaccounted Fish-Primary Channel (percent)	Unaccounted Fish-Secondary Channel (percent)
2	3	1	1	1.2	1.2	6	10	82.1	93	2.5
2	3	1.1	0.8	1.2	1.2	14	15	60.6	83	20
1	3	0.8	0.9	1.3	1.1	11	18	77.4	90	30
1	3	0.7	0.9	1.6	1.3	20	21	76.7	85	17.5
1	5	0.6	0.9	1.7	1.3	10	12	82.1	82	22.5
1	5	0.6	0.9	1.8	1.4	6	9	86.4	79	25
1	5	0.9	0.9	1.2	1.4	20	27	85.3	88	2.5
1	5	0.9	0.9	1.3	1.5	8	9	77.1	91	7.5
1	5	0.9	0.9	1.3	1.5	4	6	89.2	73	15
2	5	1	0.9	1.4	1.2	7	7	53.8	85	32.5
2	5	1	1	1.5	1.4	12	17	43.8	94	25
1	5	1	0.9	1.2	1.5	12	15	85.2	91	12.5
1	5	1	1	1.2	1.4	5	6	76.7	94	7.5

[1] 1 = day and 2 = night.