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Evaluation of Fish Behavior Upstream and Downstream of the Mitten Crab Traveling Screen at the Tracy Fish Collection Facility

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region and
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The Bureau of Reclamation Tracy Fish Collection Facility in central California was designed in the mid-1950s to divert, collect, hold, and return salvaged fish to the Sacramento-San Joaquin River Delta. A vertical traveling screen was installed in the secondary louver channel in 1999 to remove the invasive Chinese mitten crab (*Eriocheir sinensis*) before they were concentrated into the fish holding and release components. Studies at that time found that the screen efficiently removed crabs while allowing some fish passage through the secondary channel. Using controlled experiments, fish passage in the secondary channel was further evaluated while the traveling screen was in operation. These experiments suggested that using the screen to remove entrained aquatic debris did not significantly reduce secondary channel louver efficiencies. In fact, louver efficiency was high (>75 percent) in all experiments. However, the number of experimental fish that were released but not recovered (and therefore not participating in the experiment) was generally high (42.5 percent), even in best conditions of higher velocity and screen raised out of the flow (39.4 percent). This suggests that a fish crowding system may help to move fish through the primary channel bypasses and secondary channel. No recovered experimental fish were injured. These data suggest that a vertical traveling screen can be used during periods of high debris while allowing for safe fish passage.

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Tracy Fish Facility Studies
California

Evaluation of Fish Behavior Upstream and Downstream of the Mitten Crab Traveling Screen at the Tracy Fish Collection Facility

Tracy Technical Bulletin 2015-2

by

Cathy Karp[1] and Judy Lyons[2]

[1] Bureau of Reclamation
Denver Technical Service Center
Fisheries and Wildlife Resources Group
PO Box 25007
Denver, CO 80225-0007

[2] 466 S. Oak Ct.
Littleton, CO 80127

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Tracy Fish Facility Improvement Program

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Tracy Series Editor

Donald E. Portz, Ph.D.
U.S. Department of the Interior – Bureau of Reclamation
Technical Service Center
Fisheries and Wildlife Resources Group, 86-68290
PO Box 25007
Denver, CO 80225-0007

Cover

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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, hold, and return salvaged fish to the Sacramento-San Joaquin River Delta. One problem faced by the facility is increasing and changing aquatic debris loads which foul the louvers, holding tanks, and fish transport trucks. A vertical traveling screen was installed in the secondary channel in 1999 to remove the invasive Chinese mitten crab (*Eriocheir sinensis*) before they were concentrated into the fish holding and release components. Studies at that time found that the screen efficiently removed crabs while allowing some fish passage through the secondary channel. Using controlled experiments, fish passage in the secondary channel was further evaluated while the traveling screen was in operation. These experiments found that using the screen to remove entrained aquatic debris did not significantly reduce secondary channel louver efficiencies. In fact, louver efficiency was high (>75 percent) in all experiments. However, the number of experimental fish that were released but not recovered (and therefore not participating in the experiment) was generally high (42.5 percent), even in best conditions of higher velocity and screen raised out of the flow (39.4 percent). This suggests that a fish crowding system may help to move fish through the primary channel bypass pipes and secondary channel. No recovered experimental fish were injured. The collection of three injured wild fish may have been related to screen operation or placement of a steel plate on the channel floor used to improve debris removal. These data suggest that a vertical traveling screen can be used to remove debris during periods of high debris entrainment while allowing for safe fish passage.

INTRODUCTION

The Bureau of Reclamation has an active fish salvage improvement research program at the Tracy Fish Collection Facility (TFCF) in Byron, California. One aspect under study is the use of a vertical traveling screen in the secondary channel to remove debris. This screen was installed in 1999 to assist in removal of the Chinese mitten crab (*Eriocheir sinensis*) from the secondary channel. Mitten crabs invaded in the Sacramento-San Joaquin delta in 1996, and were inundating the TFCF by fall 1998. As the mitten crab invasion declined, the traveling screen and associated debris removal components were modified to remove all types of aquatic debris (Boutwell and Sisneros 2006, L. Hanna, personal communication). Aquatic weed tests in 2004/2005 found up to 56 percent of the incoming debris was removed when the screen was operating (Boutwell and Sisneros 2006; TFCF unpublished data). Salvage evaluation studies found that entrained fish were generally not impacted by the screen on their way into the holding tanks (White *et al.* 2000, White *et al.* 2005). Using controlled experiments, our objectives were to determine if the vertical traveling screen reduced louver efficiency or injured fish in the secondary channel when used to remove aquatic debris.

METHODOLOGY

The vertical traveling screen was located in the upper end of the secondary channel and when lowered, spanned the 2.4m (8 ft) width of the channel. The screen was angled 15^{o} off vertical, rotated counterclockwise, and was run at 0.04 m/s (8 ft/minute) for all experiments (as recommended by TFCF staff; Figure 1). The screen mesh was plastic coated cabling with rectangular shaped openings (3.8 cm ×14.0 cm [1.5 in wide × 5.5 in high]). Rows of horizontal brushes (5.1 cm (2.0 in) long) on the screen face redirected debris and other entrained material to a conveyor belt. A perforated steel plate (38.1mm [1.5 in] holes), placed on the floor of the secondary channel just upstream of the lower edge of the screen (when in the water), was used to create two test conditions: crab removal (crab) = traveling screen 30.5 cm (12.0 in) off the channel floor and downstream edge of plate inclined 33.0 cm (13.0 in), producing a 76.2 mm (3 in) gap between the 2 sets of rollers and a 19.1 cm (7.5 in) gap between the edge of the plate and the lower edge of the screen, and aquatic debris removal (plant) = traveling screen down (10.2 cm off the channel bottom to allow space for the brushes) and steel plate flat (no gap between the brushes on the screen and steel plate; Figures 1, 2b, and 2c). We also tested secondary channel louver efficiency with the steel plate flat and the traveling screen out of the water (= control, Figure 2a). The two test conditions were selected because each was previously found to be effective for their target (*i.e.*, crab or aquatic plant removal). Aquatic debris/mitten crabs/fish removed by the brushes on the traveling screen were lifted away from the secondary channel

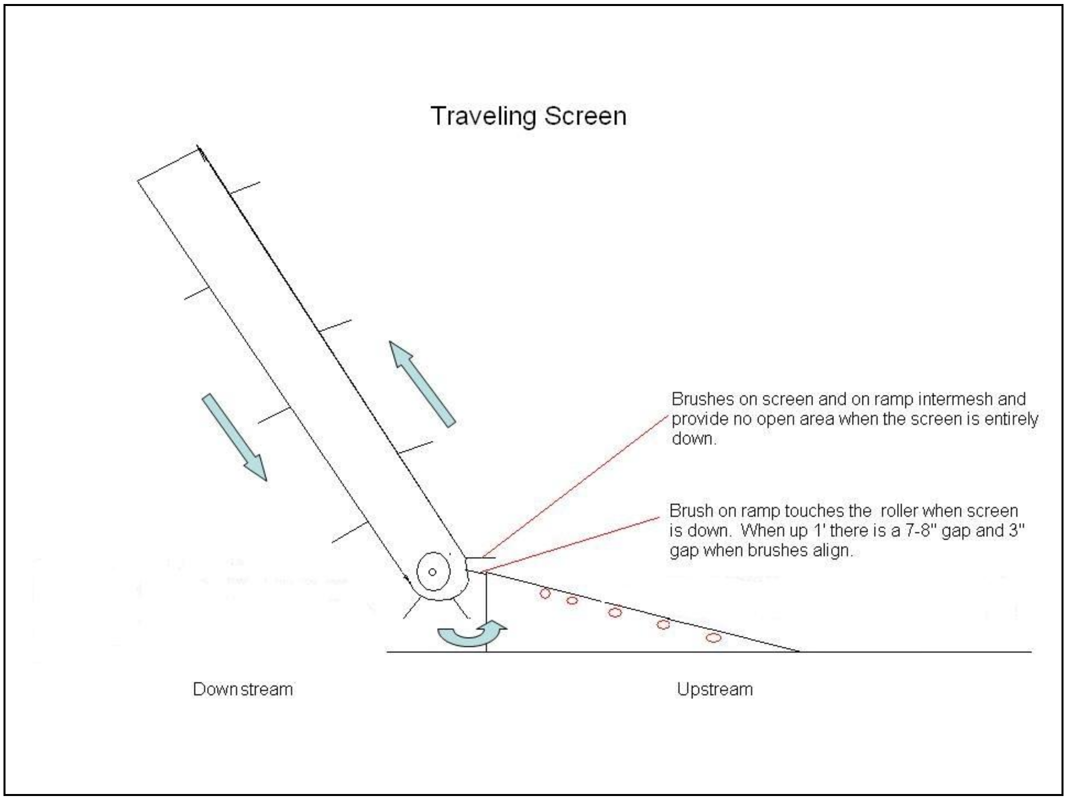

Figure 1.—Schematic of the vertical traveling screen, Tracy Fish Collection Facility, Byron, California.

Figure 2a.—Vertical traveling screen out of the water (control condition).

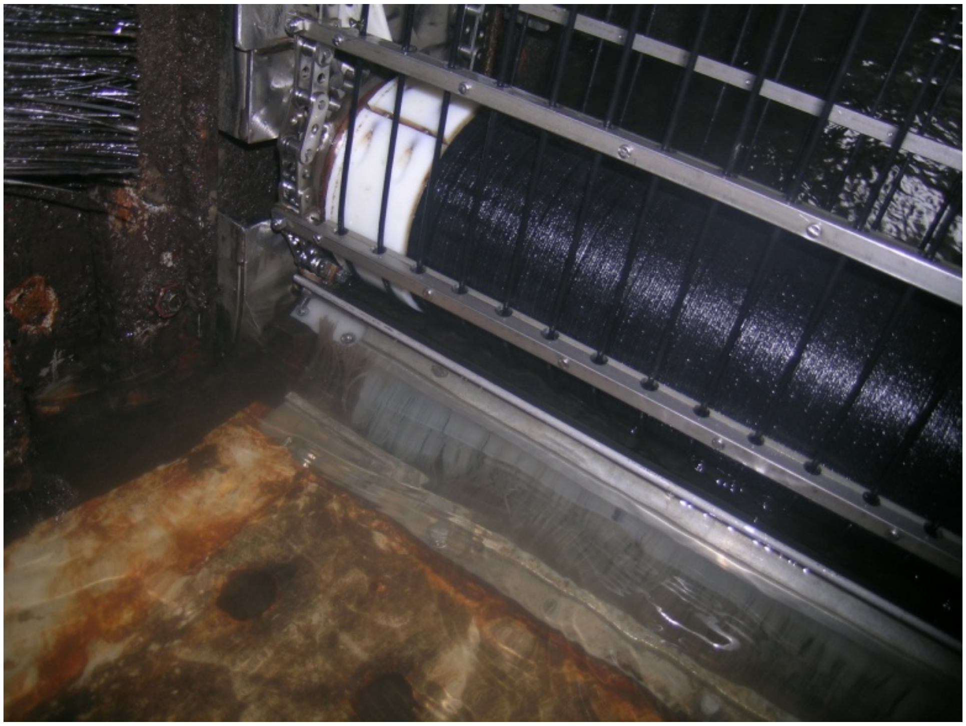

Figure 2b.—Vertical traveling screen all the way down, steel plate flat (plant condition).

Figure 2c.—Vertical traveling screen 30.5 cm off the secondary channel, floor-steel plate inclined 33.0 cm (crab condition). Note 7.6 cm gap between 2 sets of brushes.

by a conveyor belt and collected in a swimming pool for the duration of the experiment. A sieve net (2.7 m [8.8 ft] high, 2.5 m [8.1 ft] wide and 7.6 m [25 ft] long) located behind the secondary channel louvers was used to collect fish passing through the louvers. Experimental design included releasing uniquely marked groups of fish into each of the 4 primary bypass tubes (10 fish each for 40 fish per release, one species at a time) using a 10.2 cm (4.0 in) pipe inserted 1 m into the upper part of the bypass transition box, and running the secondary channel for 30 min under one of the 3 conditions (control, crab, plant). In addition, uniquely marked groups of fish were released in front of the sieve net (10 fish per release) and into the holding tank (10 fish) prior to each replicate. The latter two groups were used as a control for the fish recovery process because fish may be missed during the holding tank drain and sieve net fish recovery. At the end of the 30 min recovery period, the holding tank and sieve net were switched to a different setup to prepare for a new release. These were then drained and experimental fish recovered. A recovery period of 90 min was allowed for determination of louver efficiency for each release.

Experimental fish included a range of species and sizes to cover a range of behaviors: juvenile Chinook salmon (*Oncorhynchus tshawytscha*; n = 1,322, 60–215 mm Fork Length [FL]); splittail (*Pogonichthys macrolepidotus*; n = 1,360, 67–182 mm FL), striped bass (*Morone saxatilis*; n = 696, 130–270 mm FL), and white sturgeon (*Acipenser transmontanus*; n = 357, 115–240 mm FL*)*. These species were selected as they may occur in the wild entrainment and were easily obtainable. Only experimental fish < 3.8cm [1.5 in] wide were used to potentially fit through the traveling screen mesh openings. Juvenile Chinook salmon were obtained from the Mokelumne River Fish Hatchery (California Department of Fish and Wildlife), white sturgeon from the Stolt Sea Farm in Elverta, California, and striped bass and splittail were collected on-site at the TFCF. All experimental fish were held in flow-through 750-L (198-gallon) tanks in a mix of ozone purified well (18–19^{o}C) and Delta water and fed Silver Cup salmon feed.

One week prior to experiments, fish were anaesthetized using 50-ppm tricaine methanesulfonate (MS-222) and marked with fluorescent microbeads (New West Technology, Santa Rosa, California) on anal, dorsal, or caudal fins. Prior to each set of releases, the secondary channel was drained and flushed and the louvers cleaned. Secondary channel velocity was determined using TFCF meters.

Data Analysis

For each release, louver efficiency was calculated from the following formula:

Secondary channel louver efficiency =
(# fish collected in the holding tank /holding tank efficiency)/([# fish collected in the holding tank/holding tank efficiency] + [# fish collected in the sieve net/sieve net efficiency])

The number of nonparticipants, or experimental fish that were not recovered (i.e., fish that may have remained in the facility plumbing for the experimental period, moved upstream and out of the facility, moved through the louvers into the intake canal, or been predated [and remained in the channel]) was determined by subtracting those that were recovered in the holding tank and sieve net from the number released for the experimental period. These fish were not included in the above calculation. Louver efficiency and nonparticipant 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.

RESULTS AND DISCUSSION

A total of 97 tests were conducted at the three conditions (34 control, 31 plant, and 32 crab screen; Table 1). All four species were used to test each screen condition. Secondary channel velocities were maintained at 0.8 m/s (2.5 ft/s) for the striped bass experiments (as required by regulatory agencies [California State Water Resources Control Board 1978, NMFS 2004, USFWS 2004]) but ranged from 0.7 to 0.9 m/s (2.3 to 3.1 ft/s) for the other species. Secondary channel louver efficiencies were high (>75 percent) for all experiments. Louver efficiency among the three test conditions was similar (Kruskal-Wallis, P = 0.052), but slightly higher when the screen was not in use (98.4 percent vs 95.2 and 95.3 percent, Table 1). This suggests that operation of a vertical traveling screen for aquatic debris removal would not significantly inhibit entrained fish from moving through the secondary channel.

Up to 95.8 percent of the experimental fish were not recovered in the experiments (about 43 percent per release; Table 1). The high proportion of nonparticipation was not statistically different among screen conditions (Kruskal-Wallis, P = 0.285), nor when channel velocity was relatively higher (> 0.7 m/s, 2.3 ft/s; Wilcoxon Rank Sum Test, P = 0.053). The high proportion of missing experimental fish, even during tests when the traveling screen was out of the water and channel velocity was high (0.9 m/s, [3.0 ft/s]), suggests that some form of fish crowding may be beneficial in the primary bypass pipes and secondary channel. For example, flushing of the primary bypasses and netting in the secondary channel following one set of releases yielded 93.5 percent of the missing fish for those experiments. No experimental fish were removed by the screen. No mitten crabs were observed during the experiments. Three wild fish were noted to have injuries, possibly caused by the screen rotation or placement of the steel plate (Figure 3).

Table 1.—Summary of secondary channel velocities, louver efficiencies, and percent unaccounted for the traveling screen tests, Tracy Fish Collection Facility, Byron, California

Treatment	Number of Experimental Releases	Secondary Channel Velocity (Mean, Range, [m/s])	Secondary Channel Louver Efficiency (Mean, SD, Range [Percent])[1]	Unrecovered fish[2] (Mean, SD, Range [Percent])
Control (Traveling screen out of the water/steel plate flat)	34	0.8, 0.7–0.9 (2.7 ft/s, 2.3–3.1 ft/s)	98.4, 2.7 91.3–100	39.4 25.3 0–87.5
Plant (Traveling screen all the way down/steel plate flat)	31	0.8, 0.7–0.9 (2.7 ft/s, 2.3–3.1 ft/s)	95.2, 6.3 80.8–100	49.4 29.0 0–95.8
Crab (Traveling screen 30.5cm [12 in] off the secondary channel floor/steel plate inclined 33.0 mm [13 in])	32	0.8, 0.7–0.9 (2.7 ft/s, 2.3–3.1 ft/s)	95.3, 6.4 77.3–100	39.2 23.9 0–87.5

[1] Efficiencies calculated after 1.5 h. SD = standard deviation
[2] Unrecovered fish include all experimental fish that were not recovered.

CONCLUSIONS

The vertical traveling screen was tested to determine if secondary channel louver efficiency was reduced when the screen was in operation. These experiments found that screen operation did not significantly reduce louver efficiency. In fact, louver efficiency was high (>75 percent) in all experiments. However, the number of experimental fish that were released but not recovered (and therefore not participating in the experiment) was generally high (42.5 percent), even in best conditions of higher velocity and screen raised out of the flow. This suggests that a fish crowding system such as higher velocities in the secondary channel may help to move fish through the primary channel bypasses and secondary channel. No recovered experimental fish were visibly injured. The collection of three injured wild fish may have been related to screen operation or placement of the steel plate. These data suggest that the secondary channel traveling screen can be used (screen lowered all the way down) during periods of high debris while allowing for safe fish passage.

Figure 3.—External injuries observed in traveling screen experiments.

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APPENDIX 1

Data Summary

Date	Treatment	Velocity (ft/s)	Velocity condition	Number Released	Holding Tank Recovery	Sieve Net Recovery	Total Recovered	Total Missing	Holding Tank Recovery (percent)	Total Missing (percent)
5/2005	3	3.05	2	40	37	3	40	0	92.5	0
5/2005	3	3.05	2	40	37	2	39	1	94.9	2.5
5/2005	3	3.05	2	40	31	7	38	2	81.6	5
5/2005	2	3.05	2	40	30	6	36	4	83.3	10
5/2005	2	3.05	2	41	34	7	41	0	82.9	0
5/2005	2	3.05	2	40	32	5	37	3	86.4	7.5
5/2005	1	3.05	2	40	37	2	39	1	94.9	2.5
5/2005	1	3.05	2	41	39	2	41	0	95.1	0
5/2005	1	3.05	2	40	35	3	38	2	92.1	5
10/2005	1	2.3	1	24	16	0	16	8	100	33.3
10/2005	1	2.3	1	24	20	0	20	4	100	16.7
10/2005	1	2.3	1	24	7	0	7	17	100	70.8
10/2005	2	2.3	1	24	3	0	3	21	100	87.5
10/2005	2	2.3	1	24	1	0	1	23	100	95.8
10/2005	2	2.3	1	24	2	0	2	22	100	91.7
10/2005	3	2.3	1	24	9	0	9	12	100	50
10/2005	3	2.3	1	24	12	0	12	12	100	50
10/2005	3	2.3	1	24	7	0	7	17	100	70.8
11/2005	1	2.3	1	40	36	0	36	4	100	10
11/2005	1	2.3	1	40	21	0	21	19	100	47.5
11/2005	1	2.3	1	40	8	0	8	32	100	80

Date	Treatment	Velocity (ft/s)	Velocity condition	Number Released	Holding Tank Recovery	Sieve Net Recovery	Total Recovered	Total Missing	Holding Tank Recovery (percent)	Total Missing (percent)
11/2005	1	2.3	1	40	25	0	25	15	100	37.5
11/2005	1	2.3	1	40	13	0	13	27	100	67.5
11/2005	1	2.3	1	40	12	0	12	28	100	70
11/2005	3	2.3	1	40	34	0	34	5	100	12.5
11/2005	3	2.3	1	40	39	0	39	1	100	2.5
11/2005	3	2.3	1	40	32	0	32	8	100	20
11/2005	2	2.3	1	40	25	0	25	15	100	37.5
11/2005	2	2.3	1	40	11	0	11	29	100	72.5
11/2005	2	2.3	1	40	6	0	6	34	100	85
10/2007	1	2.51	2	40	29	1	30	10	96.7	25
10/2007	1	2.51	2	40	28	0	28	12	100	30
10/2007	1	2.51	2	40	15	1	16	24	93.8	60
10/2007	1	2.51	2	40	14	0	14	26	100	65
10/2007	1	2.51	2	40	8	0	8	32	100	80
10/2007	1	2.51	2	40	5	0	5	35	100	87.5
10/2007	1	2.51	2	40	18	0	18	22	100	55
10/2007	1	2.51	2	40	15	0	15	25	100	62.5
10/2007	1	2.51	2	40	21	2	23	17	91.3	42.5
10/2007	1	2.51	2	40	14	1	15	25	93.3	62.5
10/2007	1	2.51	2	40	18	1	19	21	94.7	52.5
12/2007	1	3	2	40	26	0	26	14	100	35
12/2007	1	3	2	40	29	1	30	10	96.7	25
12/2007	1	3	2	40	25	0	25	15	100	37.5

Date	Treatment	Velocity (ft/s)	Velocity condition	Number Released	Holding Tank Recovery	Sieve Net Recovery	Total Recovered	Total Missing	Holding Tank Recovery (percent)	Total Missing (percent)
12/2007	1	3	2	40	29	0	29	11	100	27.5
12/2007	1	3	2	40	21	0	21	19	100	47.5
12/2007	1	3	2	40	22	0	22	18	100	45
1/2006	1	3.1	2	40	38	0	38	2	100	5
1/2006	1	3.1	2	40	32	0	32	8	100	20
10/2007	2	2.51	2	40	23	4	27	13	85.2	32.5
10/2007	2	2.51	2	40	26	0	26	14	100	35
10/2007	2	2.51	2	40	10	1	11	29	90.9	72.5
10/2007	2	2.51	2	40	12	1	13	27	92.3	67.5
10/2007	2	2.51	2	40	4	0	4	36	100	90
10/2007	2	2.51	2	40	6	1	7	33	85.7	82.5
10/2007	2	2.51	2	40	10	0	10	30	100	75
10/2007	2	2.51	2	40	9	0	9	31	100	77.5
10/2007	2	2.51	2	40	19	1	20	20	95	50
10/2007	2	2.51	2	40	21	5	26	14	80.8	35
10/2007	2	2.51	2	40	20	2	22	18	90.9	45
12/2007	2	3	2	40	27	1	28	12	96.4	30
12/2007	2	3	2	40	14	0	14	26	100	65
12/2007	2	3	2	40	30	0	30	10	100	25
12/2007	2	3	2	40	19	1	20	20	95	50
12/2007	2	3	2	40	17	1	18	22	94.4	55
12/2007	2	3	2	40	25	0	25	15	100	37.5
1/2006	2	3.1	2	40	21	1	22	18	95.4	45

Date	Treatment	Velocity (ft/s)	Velocity condition	Number Released	Holding Tank Recovery	Sieve Net Recovery	Total Recovered	Total Missing	Holding Tank Recovery (percent)	Total Missing (percent)
1/2006	2	3.1	2	40	22	0	22	18	100	45
10/2007	3	2.51	2	40	27	3	30	10	90	25
10/2007	3	2.51	2	40	25	2	27	13	92.6	32.5
10/2007	3	2.51	2	40	24	0	24	16	100	40
10/2007	3	2.51	2	40	14	2	16	24	87.5	60
10/2007	3	2.51	2	40	12	1	13	27	92.3	67.5
10/2007	3	2.51	2	40	7	1	8	32	87.5	80
10/2007	3	2.51	2	40	12	0	12	28	100	70
10/2007	3	2.51	2	40	5	0	5	35	100	87.5
10/2007	3	2.51	2	40	17	5	22	18	77.3	45
10/2007	3	2.51	2	40	17	2	19	21	89.4	52.5
10/2007	3	2.51	2	40	24	5	29	11	82.8	27.5
10/2007	3	2.51	2	40	22	1	23	17	95.7	42.5
12/2007	3	2.9	2	40	20	0	20	20	100	50
12/2007	3	2.9	2	40	19	0	19	21	100	52.5
12/2007	3	2.9	2	40	22	0	22	18	100	45
12/2007	3	2.9	2	40	16	1	17	23	94.1	57.5
12/2007	3	2.9	2	40	25	1	26	14	96.1	35
12/2007	3	2.9	2	40	18	0	18	22	100	55
1/2006	3	2.9	2	40	23	1	24	16	95.8	40
1/2006	3	2.9	2	40	25	0	25	15	100	37.5
2/2009	1	3	2	40	37	0	37	3	100	7.5
2/2009	1	3	2	40	36	0	36	4	100	10

Date	Treatment	Velocity (ft/s)	Velocity condition	Number Released	Holding Tank Recovery	Sieve Net Recovery	Total Recovered	Total Missing	Holding Tank Recovery (percent)	Total Missing (percent)
2/2009	1	3	2	40	33	0	33	7	100	17.5
2/2009	2	2.9	2	40	33	0	33	7	100	17.5
2/2009	2	2.9	2	40	37	0	37	3	100	7.5
2/2009	2	2.9	2	40	38	1	39	1	97.4	2.5
2/2009	3	3	2	38	33	0	33	5	100	13.2
2/2009	3	3	2	39	38	0	38	2	100	5.1
2/2009	3	3	2	40	32	0	32	8	100	20