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Tracy Technical Bulletin 2014-3

Retention Efficiency of the Tracy Fish Collection Facility Holding Tank Screens for 20–30 mm Fork Length Juvenile Delta Smelt during 30-Minute Fish Counts

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region and
Denver Technical Service Center

August 2014

1. REPORT DATE *(DD-MM-YYYY)*
August 2014

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Retention Efficiency of the Tracy Fish Collection Facility Holding Tank Screens for 20–30 mm Fork Length Juvenile Delta Smelt during 30-Minute Fish Counts

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Brandon J. Wu and Brent B. Bridges

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bureau of Reclamation,
Tracy Fish Collection Facility
16650 Kelso Road, Byron, CA 94514

8. PERFORMING ORGANIZATION REPORT NUMBER
Tracy Bulletin 2014-3

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Bureau of Reclamation,
Tracy Fish Collection Facility
16650 Kelso Road, Byron, CA 94514

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Available from the National Technical Information Service (NTIS)
Operations Division, 5285 Port Royal Road, Springfield, VA 22161

13. SUPPLEMENTARY NOTE

14. ABSTRACT
The retention efficiency of the woven wire mesh holding tank screens (average wire diameter = 2.1 mm, average square opening = 2.7 mm, average diagonal opening = 3.8 mm) at the Tracy Fish Collection Facility (TFCF; Bureau of Reclamation, Byron, California) for 20–30 mm fork length (FL) juvenile delta smelt (*Hypomesus transpacificus*) during 30-min collection periods was investigated. The overall holding tank screen retention efficiency for 20–30 mm FL juvenile delta smelt was 81.8 percent. Fork length and maximum body depth (MBD) were both good predictors of holding tank screen retention efficiency ($P = < 0.001$). In general, the retention of juvenile delta smelt increased with FL and MBD until 29 mm FL or 4.0 mm MBD, at which 100 percent of fish were retained by the holding tank screen. The loss of juvenile delta smelt up to 28 mm FL, with an average MBD of 3.9 mm, through the holding tank screen during this study suggests that the current screen openings at the TFCF are too large to consistently retain 20–30 mm FL juvenile delta smelt. It was estimated that 1,914 delta smelt were lost through the holding tank screens and 4,734 delta smelt passed, undocumented, through the fish count station screen during fish counts at the TFCF from 1993–2013. This suggests that the total expanded salvage of delta smelt during this period may have been reduced by as much as 26,592 fish. To avoid inaccuracies in delta smelt salvage estimates, as well as possible pump mortality at the C.W. “Bill” Jones Pumping Plant, it is necessary to eliminate the loss of delta smelt ≥ 20 mm FL through the holding tank screens, as well as all other screens that aid in the retention of fish during the salvage process at the TFCF. Results from this study suggest that it is necessary to reduce maximum screen openings to 2.1 mm (1.5-mm square opening) in order to consistently retain juvenile delta smelt ≥ 20 mm FL. This is comparable to the 2.3-mm maximum screen opening that was recommended by Sutphin *et al.* 2007 for the fish count station screen.

15. SUBJECT TERMS
salvage, screen, Sacramento-San Joaquin Delta, Delta, fish count, holding period, loss, length, body depth

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	a. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER (Include area code)
				35	Donald E. Portz, Ph.D. / 303-445-2220

Tracy Fish Facility Studies
California

Retention Efficiency of the Tracy Fish Collection Facility Holding Tank Screens for 20–30 mm Fork Length Juvenile Delta Smelt during 30-Minute Fish Counts

Tracy Technical Bulletin 2014-3

by

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U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region and
Denver Technical Service Center

August 2014

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Fisheries and Wildlife Resources Group, 85-829000
PO Box 25007
Denver, CO 80225-0007

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Fish photography by René Reyes, Tracy Fish Collection Facility, Tracy, California.
Design by Doug Craft.

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EXECUTIVE SUMMARY

The Tracy Fish Collection Facility (TFCF; Bureau of Reclamation, Byron, California) is responsible for removing fish ≥ 20 mm fork length (FL) from Sacramento-San Joaquin Delta (Delta) water prior to export through the C.W. "Bill" Jones Pumping Plant (JPP) and the Delta Mendota Canal. Prior to truck transport and release back to the Delta, fish are held in a 6.1-m diameter concrete holding tank for 8–14 h, depending on the species and numbers of fish salvaged. Water continuously flows into the holding tank and through a cylindrical, woven wire mesh holding tank screen (diameter = 2.4 m, height = 3.7 m, average wire diameter = 2.1 mm [range = 2.0–2.1 mm], average square opening = 2.7 mm [range = 2.4–2.9 mm], average diagonal opening = 3.8 mm [range = 3.4–4.3 mm]; Reyes *et al.* 2012) that acts to retain fish. This holding tank and screen technology is also used in the subsampling program (*i.e.*, 30-min fish counts every 2 h) in an effort to estimate the number of fish salvaged. Delta smelt (*Hypomesus transpacificus*)—listed by the State of California as endangered and federally listed as threatened (CDFW 2014)—are seasonally salvaged at the TFCF (Reyes 2014, personal communication). The majority of delta smelt salvaged are within the range of 20–30 mm FL (CDFW 2013); however, holding tank screen retention efficiency for this size of fish is unknown. Loss of 20–30 mm FL delta smelt through the holding tank screens during 30-min fish counts likely results in inaccurate salvage estimates, may result in pump mortality at the JPP, and ultimately reduces the number of delta smelt salvaged at the TFCF and returned to the Delta.

The overall retention efficiency of the holding tank screen for 20–30 mm FL juvenile delta smelt was 81.8 percent. Fork length (FL) and maximum body depth (MBD) were both good predictors of holding tank screen retention efficiency for 20–30 mm FL juvenile delta smelt (P = < 0.001). In general, the retention of juvenile delta smelt increased with FL and MBD until 29 mm FL or 4.0 mm MBD, at which 100 percent of fish were retained by the holding tank screen. The loss of juvenile delta smelt up to 28 mm FL, with an average MBD of 3.9 mm, through the holding tank screens suggests the current screen openings at the TFCF are too large to consistently retain juvenile delta smelt that are 20–30 mm FL. It was estimated that 1,914 delta smelt were lost through the holding tank screen and 4,734 delta smelt passed through the fish count station screen during fish counts at the TFCF from 1993–2013, suggesting the total expanded salvage of delta smelt during this period may have been reduced by as much as 26,592 fish. To avoid inaccuracies in delta smelt salvage estimates, as well as possible pump mortality at the JPP, it is necessary to eliminate the loss of delta smelt ≥ 20 mm FL through the holding tank screens, as well as all other screens that aid in the retention of fish during the salvage process at the TFCF. Results from this study suggest it is necessary to reduce the maximum screen openings to 2.1 mm (1.5-mm square opening) in order to consistently retain juvenile delta smelt that are ≥ 20 mm FL. This is comparable to the 2.3-mm maximum screen opening that was recommended by Sutphin *et al.* 2007 for the fish count station screen.

INTRODUCTION

The Tracy Fish Collection Facility (TFCF; Bureau of Reclamation, Byron, California) is responsible for removing (salvaging) fish ≥ 20 mm fork length (FL) from Sacramento-San Joaquin Delta (Delta) water prior to export through the C.W. “Bill” Jones Pumping Plant (formerly Tracy Pumping Plant; JPP) and the Delta Mendota Canal (DMC; Arthur *et al.* 1996). Prior to truck transport and release back to the Delta, fish are continuously collected and held in a 6.1-m diameter concrete holding tank for 8–14 h, depending on the species and numbers of fish salvaged. Water continuously flows into the holding tank and must pass through a cylindrical, woven wire mesh screen (diameter = 2.4 m, height = 3.7 m, average wire diameter = 2.1 mm [range = 2.0–2.1 mm], average square opening = 2.7 mm [range = 2.4–2.9 mm], average diagonal opening = 3.8 mm [range = 3.4–4.3 mm]; Reyes *et al.* 2012; Figure 1) in the center of the tank on the way to the drain. This screen acts to retain fish and is present in each of the four holding tanks at the TFCF. A rubber seal is also present at the bottom of each holding tank screen to prevent fish from passing underneath. Every 2 h a 30-min subsample (fish count) is collected in a separate holding tank and the number of fish contained therein is expanded to estimate the total number of fish salvaged during the 2 h period. Despite the fact that the majority of fish salvaged at the TFCF are 20–30 mm FL (CDFW 2013), the retention efficiency of the woven wire mesh holding tank screen during 30-min fish counts is not known for most species within this size range, including delta smelt (*Hypomesus transpacificus),* which are listed by the State of California as endangered and federally listed as threatened (CDFW 2014). When fish pass through the holding tank screens at the TFCF during 30-min fish counts, they are lost to the intake channel of the JPP; therefore, passage of 20–30 mm FL delta smelt through the holding tank screens during 30-min fish counts likely results in inaccurate salvage estimates, may result in pump mortality at the JPP, and ultimately reduces the number of delta smelt salvaged at the TFCF and returned to the Delta.

During the fish count process at the TFCF, fish contained in the fish count subsample are condensed in a fish count station. In 2004 and 2005 the effectiveness of the TFCF fish count station screen (maximum circular hole diameter = 4.8 mm; Figure 2) at retaining juvenile delta smelt was evaluated. The data indicates a large percentage (67–82 percent) of 20–30 mm FL juvenile delta smelt are passing through the fish count station screen used to condense fish during fish counting procedures (Sutphin *et al.* 2007). Fish that pass through the fish count station screen are reintroduced into a holding tank and are not necessarily lost to salvage. Despite this, they are not encountered during the fish count and are therefore not documented or reported, which likely results in inaccurate salvage estimates. The 2007 study recommended a maximum screen opening of 2.3 mm in order to retain 20 mm FL delta smelt (Sutphin *et al.* 2007). The current holding tank screen has an average square opening of 2.7 mm and an average diagonal opening of 3.8 mm (Reyes *et al.* 2012), therefore passage of

Figure 1.—Holding tank screen at the Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) that was tested to determine retention efficiency of 20–30 mm FL juvenile delta smelt during 30-minute collection periods. *Inset:* Close-up of holding tank screen material (average wire diameter = 2.1 mm, average square opening = 2.7 mm, average diagonal opening = 3.8 mm; figure from Reyes *et al.* 2012).

juvenile delta smelt through the holding tank screens is expected, although not to as great an extent as determined by Sutphin *et al.* 2007 for the fish count station screen.

The primary objectives of this study were to: 1) determine the overall holding tank screen retention efficiency for 20–30 mm FL juvenile delta smelt during 30-min collection periods, 2) determine the holding tank screen retention efficiencies for each 1-mm length category of 20–30 mm FL, as well as each 0.1 mm maximum body depth (MBD) category of juvenile delta smelt during 30-min collection periods, 3) develop probability capture curves, based on FL and MBD, for 20–30 mm FL juvenile delta smelt during 30-min collection periods, 4) estimate the number of juvenile delta smelt lost through the holding tank screen during fish counts at the TFCF from1993–2013, and 5) estimate the total reduction in expanded delta smelt salvage at the TFCF from 1993–2013 due to the passage through screens used during the fish count process.

Figure 2.—Fish count station screen (maximum circular hole diameter = 4.8 mm) at the Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) that was tested to determine effectiveness at retaining juvenile delta smelt in 2004 and 2005 by Sutphin *et al.* 2007.

METHODS

Thirty minute collection periods (n = 3) were completed in a TFCF holding tank after the insertion of approximately 400 unmeasured cultured juvenile delta smelt (7–36 mm FL; FL was assumed to equal total length [TL] if caudal fork had not developed yet). The target delta smelt length range for testing was 20–30 mm FL and only delta smelt within this range were included in analyses. To promote survivability during the test, measurements of delta smelt were not obtained until after completion of each replicate. Since the delta smelt could not be measured ahead of time, the total number of 20–30 mm FL delta smelt, as well as the composition of lengths within this range, was not known at the start of each replicate. Due to this, delta smelt within a wide length range were inserted to ensure the target lengths (20–30 mm FL) were adequately sampled. Testing was completed when no wild delta smelt were present in salvage (based on the previous 7 d of 30-min fish count data) and Delta water temperatures were adequate for delta smelt survival (14.6–17.5 °C, Reyes 2014, personal communication). The same holding tank was used for all replicates as no difference in holding tank screen retention efficiency between holding tanks was expected. Each replicate was broken into two net collections; fish that passed through the holding tank screen (it was assumed that no fish passed under the holding tank screen; Sample #1) and fish retained by the holding tank screen (Sample #2).

A custom 500-µm plankton net (1.9-m diameter x 2.7-m long with the upper 1.1 m composed of vinyl for ease of rinsing; Research Nets Inc., Bothell, Washington) was designed to sieve all water drained from the holding tank to capture fish (Figure 3). The net was attached to a steel frame that nested within the holding tank drain pit. A 3.8-cm PVC ball valve was attached to the cod-end of the net to allow easy access to the sample. The outside bottom lip of the custom steel frame was sealed with rubber foam weather stripping (1.9-cm wide x 1.1-cm thick; Frost King, Mahwah, New Jersey) to prevent loss of fish under the lip of the frame (Figure 4). Prior to testing, control replicates (n = 3) were performed to verify that ≥ 90 percent of juvenile delta smelt could be retained by, and recovered from, the 500-µm net. This was done by inserting 50 juvenile delta smelt (20–30 mm FL) directly into the net while it was seated in the holding tank drain pit. The net and frame were then lifted out of the holding tank and all available delta smelt were recovered. This control test was necessary because holding tank screen retention efficiency calculations assume that all fish in the experiment can be accounted for.

Prior to each replicate, approximately 400 delta smelt were obtained from the University of California, Davis, Fish Culture and Conservation Laboratory (UC Davis FCCL) and transported to the TFCF in 18.9-L black buckets with lids. The 500-µm net and frame were placed in a drainage pit (Figure 5), using the same 3-ton hoist intended for the fish count and haul out buckets, and the holding tank was filled. After appropriate water levels were achieved, flow into the holding tank was stopped and the unmeasured experimental delta smelt were inserted using a water-to-water method in which 18.9-L black buckets were lowered to water level with ropes and contents poured out. Holding tank valves were opened to initiate collection of water in the holding tank. Water flow into the holding tank and through the holding tank screen was maintained for 30 min to simulate a 30-min fish count. Holding tank flow rates (m^3/sec) and water depths (m) were recorded for each replicate. After the 30-min collection period, water flow into the holding tank was ceased and the holding tank was drained to an approximate depth of 0.6 m, which is the height of the unscreened bottom of the holding tank screen cylinder. This was done to prevent the loss of fish through the holding tank screen between sample collections.

The net and frame were then lifted out of the drainage pit to collect Sample #1. This sample contained fish that were not effectively withheld by the holding tank screen. While being lifted, the net was rinsed with a high pressure water source in order to consolidate the sample in the cod-end of the net. After removal from the holding tank, the net and frame were lowered and the net was inverted to remove fish and debris that were too large to be rinsed through the cod-end opening. All fish collected during this step were placed into an 18.9-L black bucket and released after being identified, measured, and documented. Debris was disposed of without identification or quantification. The net and frame were then lifted back up and the remainder of Sample #1 was collected by rinsing the net into 18.9-L buckets (Figure 6).

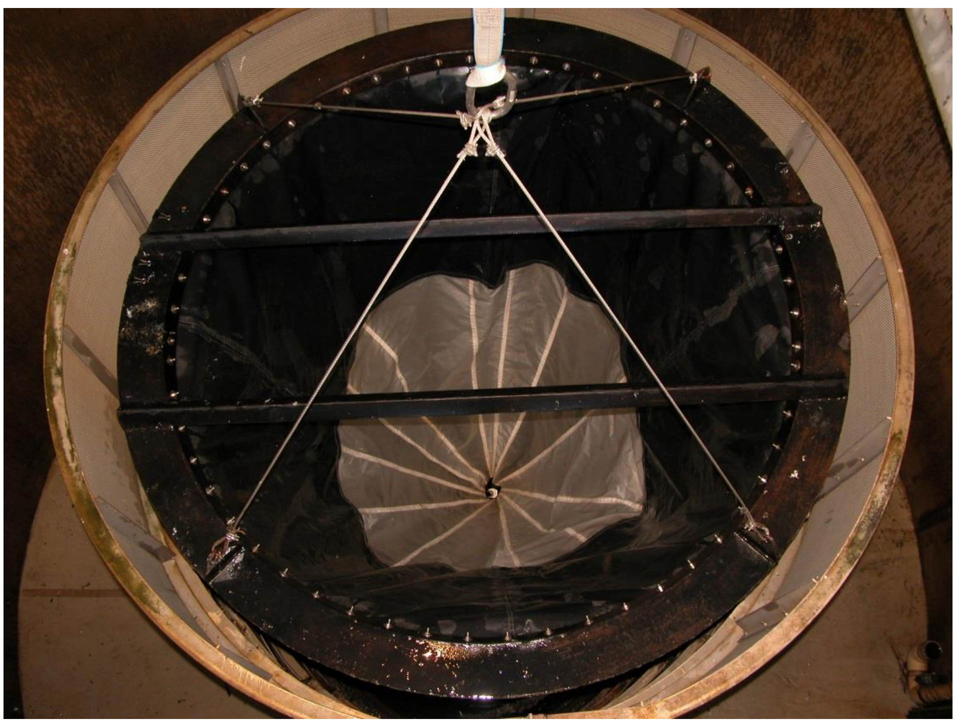

Figure 3.—Side view (top) and top view (bottom) of custom-made 500-µm net and steel frame used to test retention efficiency of Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) holding tank screens for 20–30 mm fork length juvenile delta smelt during 30-minute collection periods.

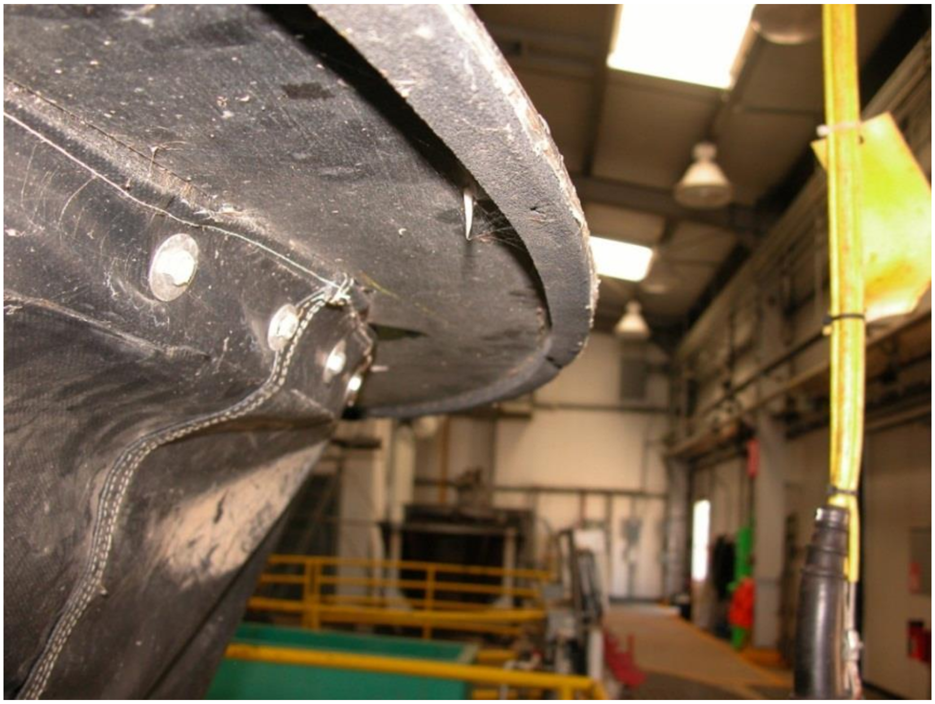

Figure 4.—Rubber foam weather stripping (1.9-cm wide by 1.1-cm thick) attached to outside, bottom lip of steel frame used, along with a 500-µm net, to test retention efficiency of Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) holding tank screens for 20–30 mm fork length juvenile delta smelt during 30-minute collection periods.

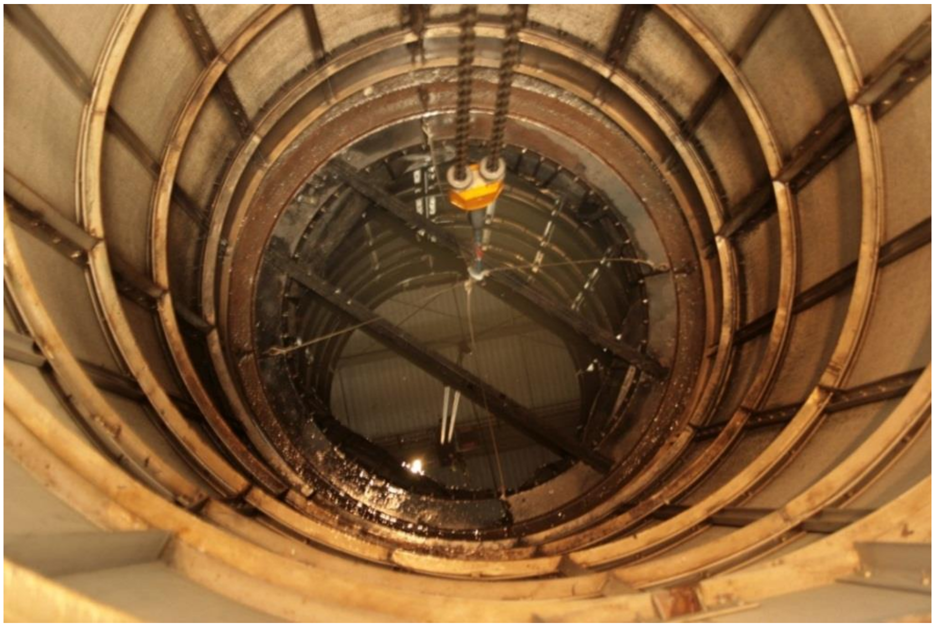

Figure 5.—The 500-µm net and frame seated in holding tank drainage pit at the Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California).

Figure 6.—Contents of 500-µm net being rinsed into 18.9-L bucket to recover fish during evaluation of Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) holding tank screen retention efficiency for 20–30 mm fork length juvenile delta smelt during 30-minute collection periods.

To recover the juvenile delta smelt remaining in the holding tank after the 30-min collection period, the net and frame were reinserted into the holding tank drain pit and the holding tank was filled until water levels inside and outside of the holding tank screen were equal. This process eliminated the problem of a sudden force of water lifting the net frame, which could result in the loss of fish underneath the net. Once equilibrium was achieved, the holding tank screen was lifted and the tank was again drained through the 500 µm net. The holding tank and holding tank screen were then rinsed using a high pressure water source and the net was removed from the holding tank drain pit. While being lifted, the net was rinsed with high pressure water in order to consolidate fish and debris in the cod-end of the net as was done for Sample #1. Sample #2 was then collected in the same manner as was previously described for Sample #1.

The samples were separately consolidated into fine meshed dip nets (0.39-mm mesh, 15.2-cm wide x 12.7-cm deep; Blue Ribbon Pet Products, Commack, New York) and stained in a 100 mg/L Rose Bengal (J.T. Baker Inc., Phillipsburg, New Jersey) solution for 5 min. After this, the samples were thoroughly rinsed and placed into separate Pyrex® dishes (33-cm long x 23-cm wide x 5-cm deep) on a light table. All delta smelt were picked out of the samples and stored in 10 percent formalin until measurements could be completed. All delta smelt collected during replicates were assumed to be experimental because replicates were intentionally performed during times when no wild delta smelt were detected in salvage.

Standard length (SL) and MBD (from the insertion of the first dorsal ray to the insertion of the first anal ray) were measured (to 0.1 mm) for all delta smelt collected using a Leica™ $MZ7_5$ stereomicroscope (Leica Microsystems, Bannockburn, Illinois) equipped with an eyepiece micrometer. If possible, FL and TL measurements of each delta smelt were also obtained (to 0.1 mm), although the caudal fin of many of the fish were damaged or frayed (presumably from the presence of debris and rinsing of the net with high pressure water) to the point that these measurements were not available. If FL and TL measurements were not available, SL measurements were converted to FL and TL using Equations 1 and 2, respectively, which were developed from measurements of larval and juvenile delta smelt (n = 601, size range = 11.2–24.5 mm FL) obtained from the UC Davis FCCL but not used in the holding tank releases (Appendix 1, Table A1-1, Figure A1-1, Figure A1-2).

$$FL = 1.14(SL)-0.96 \qquad \text{Eq. 1}$$

$$TL = 1.26(SL)-2.26 \qquad \text{Eq. 2}$$

(FL, TL and SL measurements in mm)

Data Analysis

While data was collected from delta smelt ranging in FL from 7–36 mm, only 20–30 mm FL fish were included during data analysis. Replicate holding tank samples (n = 3) contained between 54–353 delta smelt within the 20–30 mm FL range. Due to varying sample sizes, all replicates were combined for a binomial analysis (total number of 20–30 mm FL juvenile delta smelt = 478). The number of juvenile delta smelt retained in the tank (Sample #2) divided by the total number inserted into the tank (Sample #1 + Sample #2) was used to calculate holding tank screen retention efficiency. This approach was used to calculate the overall retention efficiency for 20–30 mm FL delta smelt, as well as for delta smelt of specific lengths and body depths within this range, during a 30-min collection period. To calculate the retention efficiency for specific FLs and MBDs of 20–30 mm FL delta smelt, fish were binned into 1-mm length categories (*e.g.,* 20 mm length category = 20.0–20.9 mm FL) and 0.1-mm body depth categories (*e.g.*, 2 mm depth category = 2.0–2.9 mm FL). Results from binned data were used to look for sudden changes in retention efficiency and determine the FL and MBD at which 100 percent of delta smelt were retained by the holding tank screen. Binned data also provided the number of delta smelt collected at each FL and MBD.

Logistic regression analysis (Minitab version 15) was used to develop probability capture (retention in holding tank) curves for the holding tank screen, over a 30-min collection period, based on delta smelt length (FL) and body depth (MBD). This technique provided a useful way to mathematically describe retention during a 30-min collection period as a function of FL and MBD while taking into account the number of individuals in each FL and MBD size class. In addition, a probability capture curve was developed for the fish count station screen, based on FL, using data from Sutphin *et al.* 2007.

Prior to estimating delta smelt loss through the holding tank screens during fish counts at the TFCF (assumed to be of 30-min duration) from 1993–2013, it was necessary to estimate the number of delta smelt that were excluded from salvage records from 1993–2013 because they passed, undocumented, through the fish count station screen during the fish count process. This was imperative due to the fact that, although not reported in TFCF salvage, these delta smelt were retained by the holding tank screen for the entire sample collection period and should therefore be included in analyses to prevent biased estimates of loss through the holding tank screen. An estimate of the number of fish that passed through the fish count station screen was back-calculated from TFCF fish salvage monitoring data (CDFW 2013), for each 1-mm length category of delta smelt reported in salvage (20–100 mm FL), using the mathematical formula generated from the probability capture curve developed for the fish count station screen. An estimate of the total number of delta smelt that passed through the fish count station screen from 1993–2013 was obtained by summing all categorical fish count screen passage estimates for this period.

The number of delta smelt within each 1-mm length category estimated to have passed through the fish count station screen during fish counts from 1993–2013 were added to the number of delta smelt within each 1-mm length category reported in TFCF fish salvage monitoring data from 1993–2013 (CDFW 2013). The formula generated from the probability capture curve based on FL for the holding tank screen was then applied to estimate the number of delta smelt, within each 1-mm length category, lost through the holding tank screens at the TFCF from 1993–2013, assuming 30-min collection periods were used. An estimate of the total number of delta smelt lost through the holding tank screen from 1993–2013 was obtained by summing all categorical holding tank screen loss estimates for this period, as was done for the fish count station screen passage estimates. An estimate of the cumulative number of salvageable delta smelt lost or undocumented during fish-counts at the TFCF from 1993–2013 was then obtained by summing the estimated total number of delta smelt that passed through the fish count station screen during fish counts from 1993–2013 and the estimated total number of delta smelt lost through the holding tank screen during fish counts from 1993–2013.

Since the ratio of pumping duration to sampling duration is used at the TFCF to expand fish count data to estimate the number of fish salvaged in each 2-h (120-min) period (Jahn 2011), it was possible to estimate the total extent of delta smelt salvage reduction at the TFCF from 1993–2013 due to loss through the holding tank screen or passage through the fish count station screen. This was done by expanding the cumulative number of delta smelt estimated to have been lost or undocumented during fish counts within this period by the appropriate expansion factor. Since it is assumed that 30-min collection periods were performed during fish counts at the TFCF from 1993–2013, an expansion factor of 4 (120 min pumping duration /30-min sampling duration = expansion factor of 4) was used to obtain this estimate.

RESULTS AND DISCUSSION

Conditions during testing were adequate for evaluating the retention efficiency of the holding tank screen for 20–30 mm FL juvenile delta smelt. During holding tank screen retention efficiency replicates, the mean (minimum–maximum) water flow and depth in the holding tank was 0.2 m^3/sec (0.1–0.3 m^3/sec) and 1.7 m (1.4–2.1 m), respectively, while water temperatures were 14.6–17.5 °C. The rubber seal on the bottom of the holding tank screen appeared to be nearly water tight during all replicates; therefore it was assumed that all fish lost from the holding tank passed through the holding tank screen and not underneath. The amount of debris collected in each replicate was not quantified, although debris loads present during testing allowed for continuous sampling over the entire 30-min collection period without clogging the 500 µm net.

Retention efficiency of the holding tank screen was higher than anticipated. The overall retention efficiency of the holding tank screen for 20–30 mm FL juvenile delta smelt over a 30-min collection period was 81.8 percent (range = 64–100 percent). The 18.2 percent holding tank screen loss was lower than the 67–82 percent loss estimated for 20–30 mm cultured delta smelt through the fish count station screen reported by Sutphin *et al.* 2007. This was expected due to the fact that the average opening of the holding tank screens (3.8 mm) is smaller than that for the fish count station (4.8 mm). It should be emphasized that all retention measurements during this experiment were based on a 30-min exposure time to the holding tank screen. Although not evaluated in this study, juvenile delta smelt loss through the holding tank screens is likely time dependent and prolonged holding periods, which can last up to 8 h when delta smelt are present in salvage, will likely lead to greater losses.

Although there was overall high retention for 20–30 mm FL juvenile delta smelt, holding tank screen retention efficiency appeared to be size dependent. In general, retention efficiency gradually increased with FL and MBD until 29 mm FL or 4.0 mm MBD, at which point 100 percent of fish were retained by the holding tank screen (Figures 7 and 8). The retention of delta smelt with MBDs of approximately 4 mm was expected because the diagonal openings of the holding tank screens at the TFCF range from 3.4–4.3 mm (Reyes *et al.* 2012). Although 100 percent holding tank screen retention was observed for 29 and 30 mm FL juvenile delta smelt, there were small sample sizes for these lengths (n = 28 and n = 19, respectively) and MBD was highly variable (3.6–4.5 mm and 3.7–4.8 mm, respectively [Figure 9]), suggesting that delta smelt of these sizes, and possibly larger, could also be lost through the 4.3 mm maximum holding tank screen openings. This, along with the fact that 28 mm FL juvenile delta smelt passed through the holding tank screen during this study, implies delta smelt larger than predicted by Sutphin *et al.* 2007 (< 24.7 mm FL) are being lost through the holding tank screens at the TFCF.

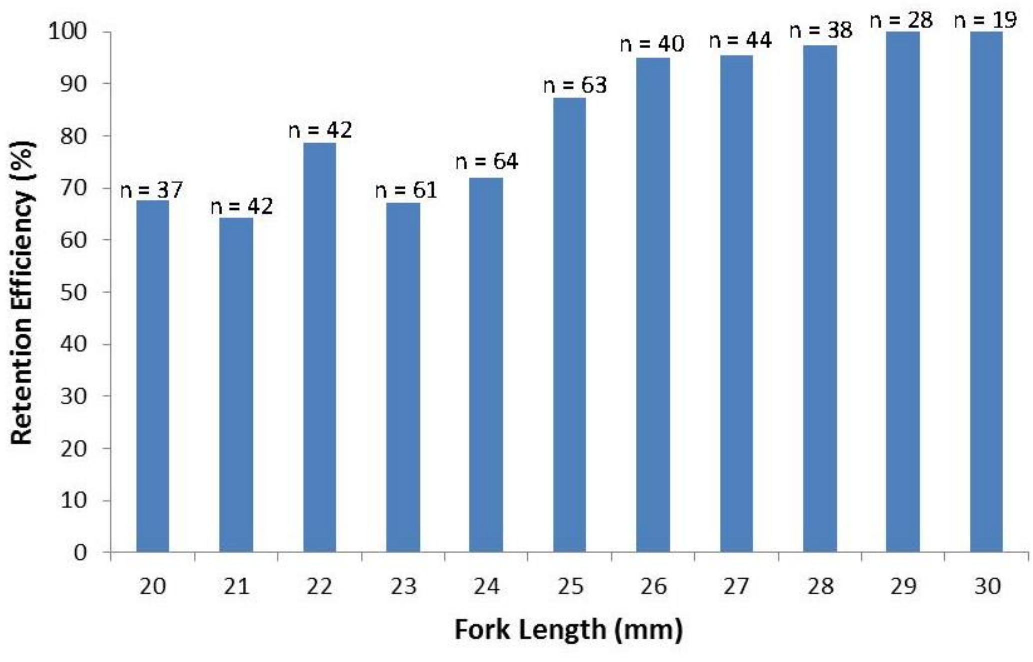

Figure 7.—Holding tank screen retention efficiency for each 1-mm length category of 20–30 mm fork length juvenile delta smelt.

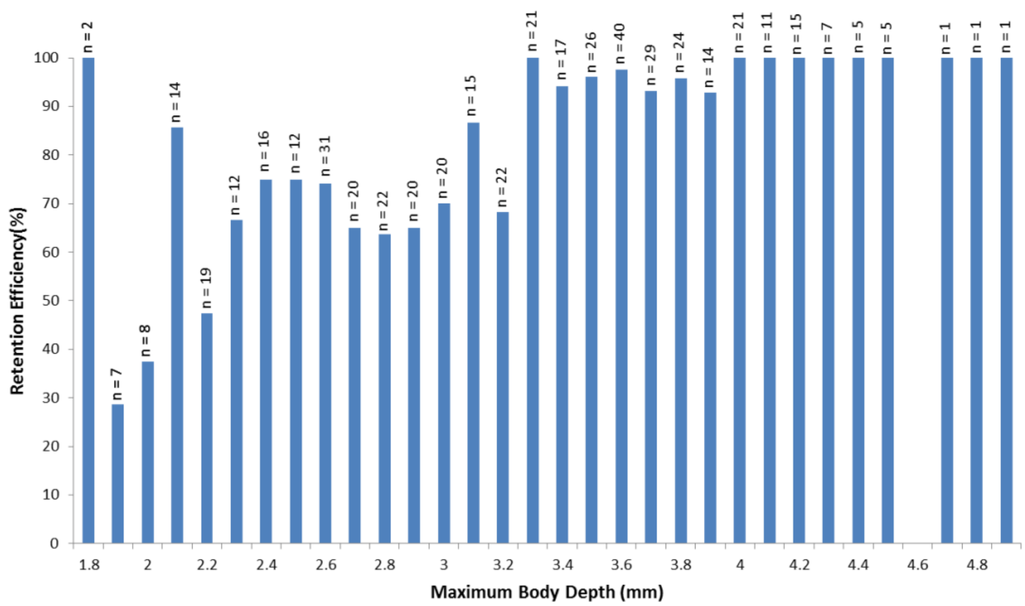

Figure 8.—Holding tank screen retention efficiency for juvenile delta smelt with maximum body depths of 1.8–5.2 mm.

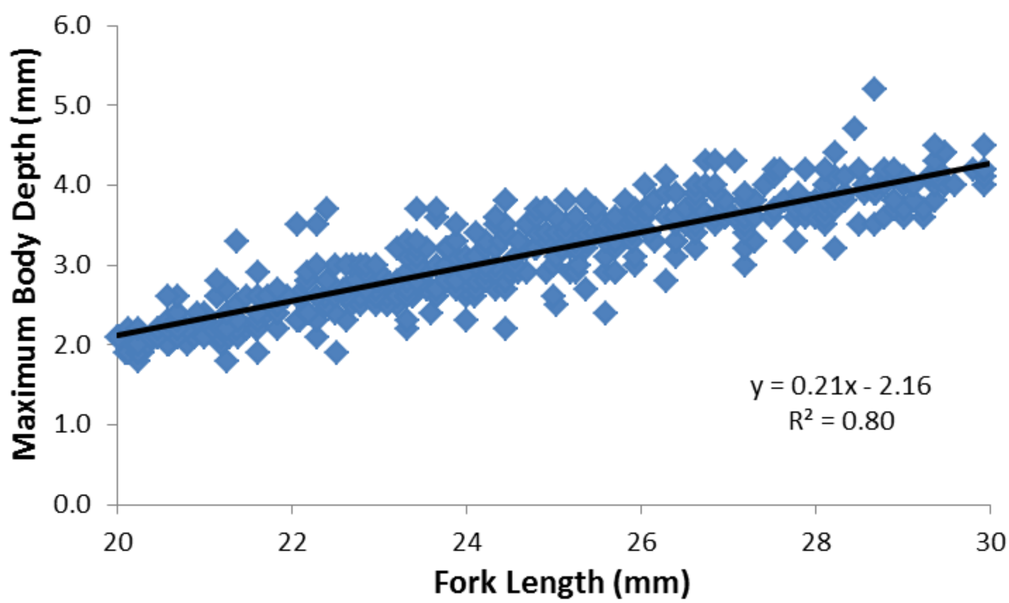

Figure 9.—Relationship between fork length and maximum body depth for 20–30 mm juvenile delta smelt.

According to results, fork length and MBD are both good predictors to estimate holding tank screen retention efficiency of 20–30 mm FL juvenile delta smelt (Logistic Regression, N = 478, P = < 0.001). However, the probability capture curves developed for juvenile delta smelt based on FL and MBD (Figures 10 and 11) demonstrate that fish retention is better predicted by MBD than FL, as the curve for MBD shows a steeper decline in capture efficiency for sizes below those found to be effectively retained by the holding tank screen. These results suggest MBD is likely the dimension that determines which fish are potentially lost through the holding tank screen at the TFCF. This was expected since the mechanism by which fish loss occurs through the holding tank screens is based on fitting through screen openings.

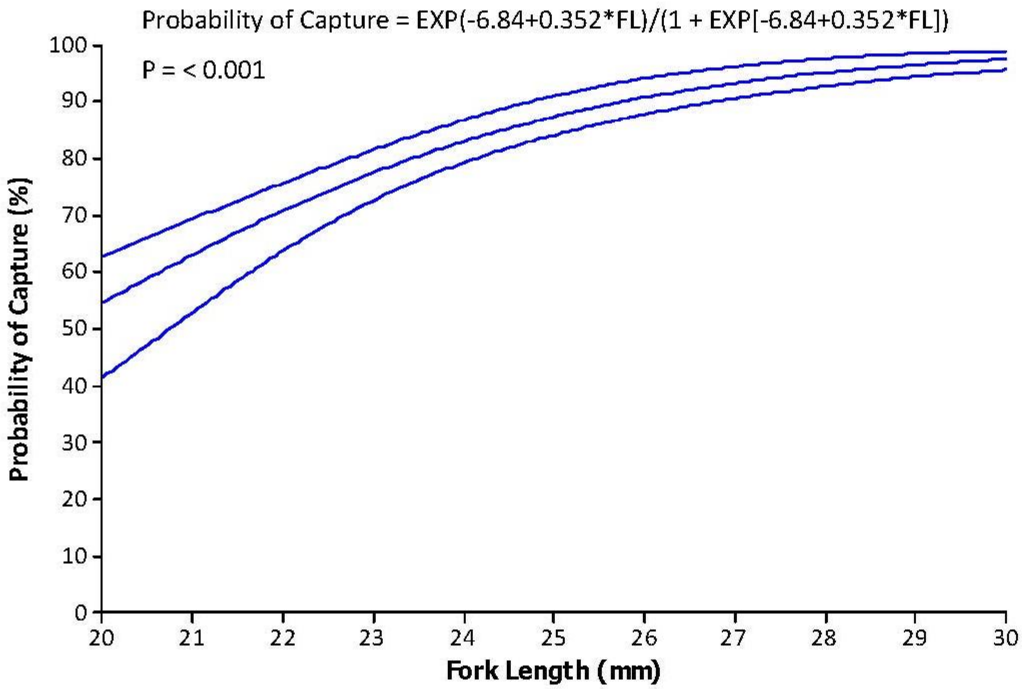

Figure 10.—Holding tank screen probability capture curve, based on fork length, for 20–30 mm fork length juvenile delta smelt during a 30-min collection period. The middle line represents the mean probability of capture, while the top and bottom lines are the 95 percent confidence interval limits.

The loss of 20–28 mm FL juvenile delta smelt through the holding tank screen during this study suggests the current maximum screen opening is too large for the consistent retention of delta smelt < 29 mm FL. Since the majority of delta smelt collected in fish-counts at the TFCF between 1993 and 2013 were 20–30 mm FL (Figure 12; CDFW 2013), a certain extent of loss likely occurred through the holding tank screens during this period.

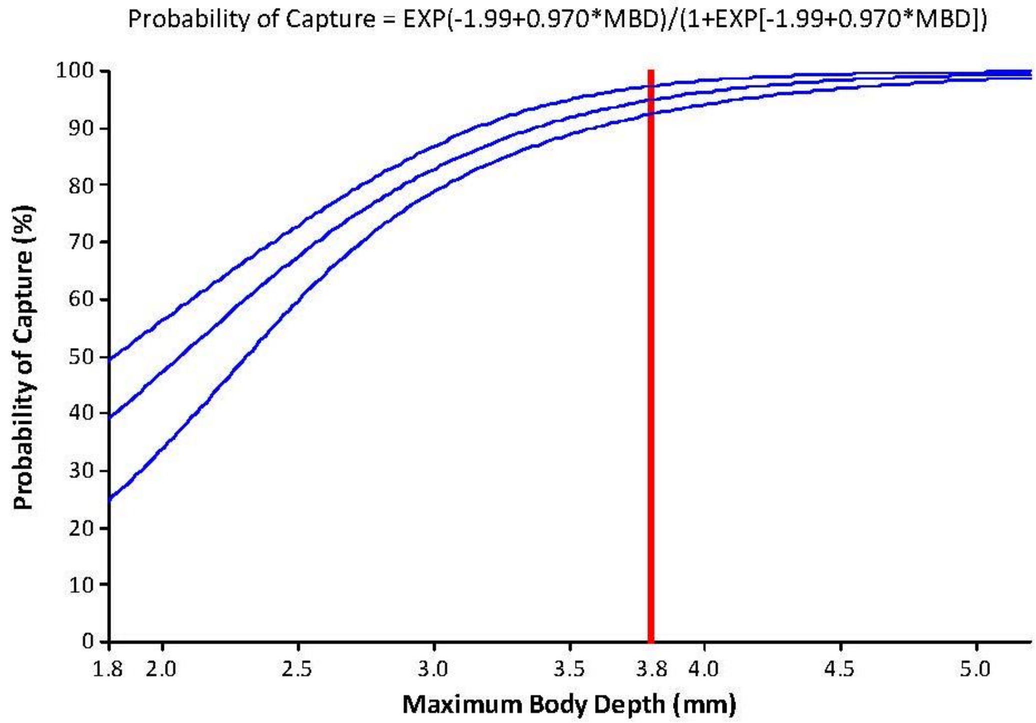

Figure 11.—Holding tank screen probability capture curve, based on maximum body depth, for juvenile delta smelt (1.8–5.2 mm maximum body depth) during a 30-min collection period. The middle line represents the mean probability of capture, while the top and bottom lines are the 95 percent confidence interval limits. The red vertical line illustrates the average diagonal opening of the current holding tank screen at the Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California).

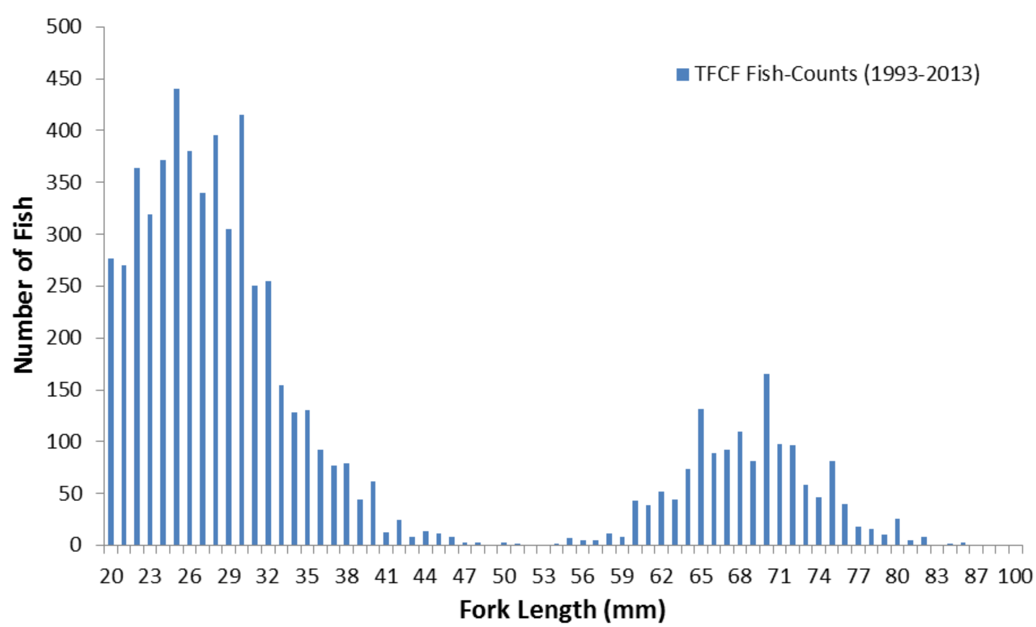

Figure 12.—Length frequency of delta smelt collected in fish counts at the Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) from 1993–2013.

An estimate of the number of salvageable delta smelt that were lost through the holding tank screen during fish counts from 1993–2013 was back-calculated from TFCF fish salvage monitoring data (CDFW 2013) and used, along with a loss estimate for the fish count station screen, to estimate the total extent of delta smelt salvage reduction at the TFCF from 1993-2013 due to loss through screens used to retain fish during the fish count process. As mentioned previously, it was important to obtain an estimate of the number of delta smelt that passed through the fish count station screen prior to back-calculating an estimate of loss through the holding tank screen. This was done using the formula from the probability capture curve developed for the fish count station screen (generated using data from Sutphin *et al.* 2007; Appendix 2, Figure A2-1) along with the aforementioned TFCF fish salvage monitoring data. It was estimated that 4,734 delta smelt were retained by the holding tank screen but passed, undocumented, through the fish count station screen during fish counts from 1993–2013 and were therefore not included in reported salvage (Figure 13). Using this estimate, along with TFCF fish salvage monitoring data (CDFW 2013) and the formula generated from the probability capture curve based on FL for the holding tank screen, it was estimated that 1,914 delta smelt were lost through the holding tank screen during fish counts from 1993–2013, assuming 30-min fish count collection periods were performed (Figure 14). Together, these estimates indicate that 6,648 delta smelt were likely lost or undocumented during fish counts at the TFCF from 1993–2013 due to passage through the holding tank or fish count screens, suggesting that the total expanded salvage of delta smelt at the TFCF during this period may have been reduced by as much as 26,592 fish. This is actually a conservative estimate because it does not include loss through the screen of the bucket used to condense and transfer fish during the fish count process. These estimates also imply that the loss of other 20–30 mm slender-bodied juvenile fish species besides delta smelt, including native listed (threatened or endangered) species (*e.g.*, longfin smelt [*Spirinchus thaleichthys*]), likely occurred through the screens used to retain fish during fish counts at the TFCF from 1993–2013.

RECOMMENDATIONS

In order to prevent the loss of salvageable (≥ 20 mm FL) juvenile delta smelt and other slender-bodied juvenile fish species, as well as the associated inaccuracies in salvage estimates and possible pump mortality at the JPP, it is necessary to reduce the maximum opening size of the holding tank screen, and all other screens that aid in the retention of fish during the salvage process at the TFCF (fish count station screen, fish count bucket screen and haul-out bucket screen). Results from this study suggest that it is necessary to reduce maximum screen openings to 2.1 mm (1.5-mm square opening) in order to consistently retain juvenile delta smelt ≥ 20 mm FL. This is comparable to the 2.3-mm maximum screen opening that was recommended by Sutphin *et al*. 2007 for the fish count screen. Instead of replacing all screens at the TFCF, the temporary use a durable

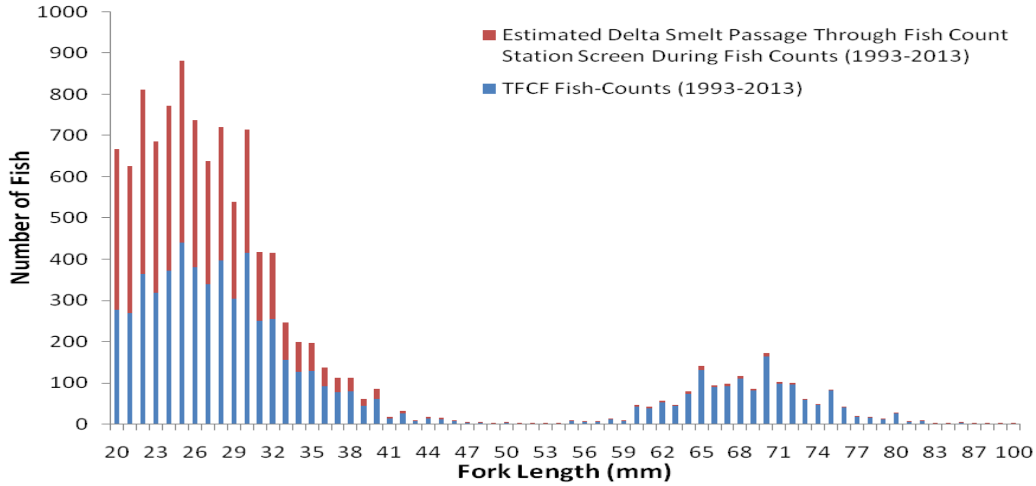

Figure 13.—Length frequency of delta smelt collected in fish counts at the Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) from 1993–2013 showing the estimated number of delta smelt that were retained by the holding tank screens but passed, undocumented, through the fish count station screen and were therefore not included in reported salvage.

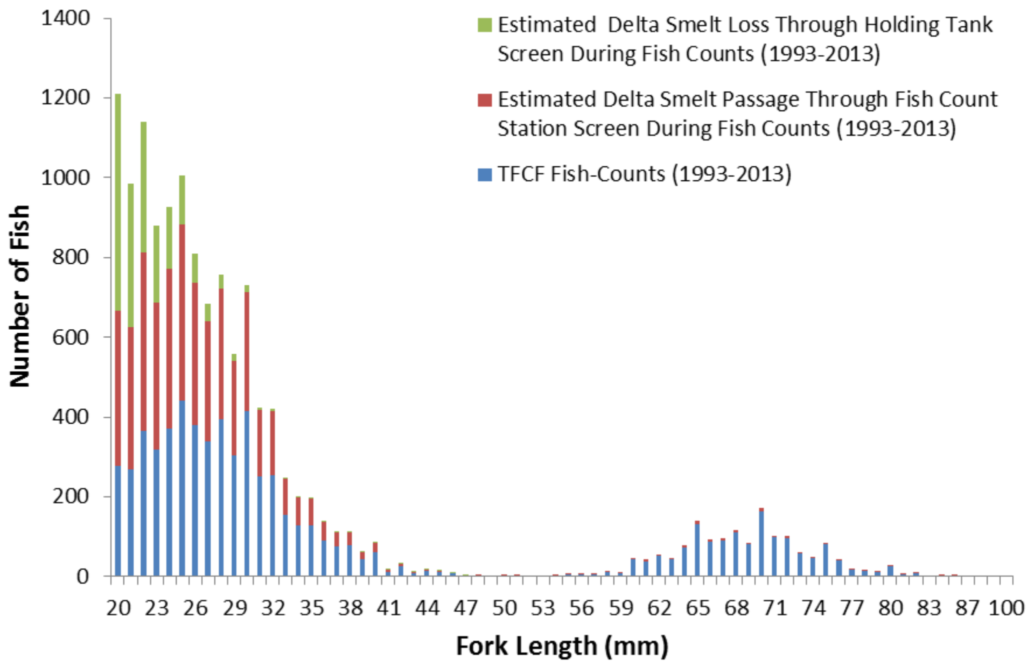

Figure 14.—Length frequency of delta smelt collected in fish counts at the Tracy Fish Collection Facility (Bureau of Reclamation, Byron, California) from 1993–2013 showing the estimated number of delta smelt that passed, undocumented, through the fish count station screen, as well as the estimated number of delta smelt lost through the holding tank screens.

nylon screen (Nitex®, Sefar, Inc., Kansas City, Missouri), as described by Reyes *et al.* 2012, should be considered to achieve maximum screen openings of ≤ 2.1 mm when listed species, including delta smelt, are present in TFCF salvage.

ACKNOWLEDGMENTS

We would like to acknowledge Joel A. Imai and the TFCF fish diversion workers for accommodating this research activity. We are grateful to René C. Reyes, Michael R. Trask, and Bradd B. Bridges for technical support and assistance with data collection during the course of this project. We thank Joan C. Lindberg, Luke T. Ellison, Galen T. Tigan, and the rest of the staff at the UC Davis FCCL for providing juvenile delta smelt for this study and assisting with the transport of these fish to the TFCF. Editorial review provided by Donald E. Portz and Zachary A. Sutphin was greatly appreciated. Funds for this study were provided by Reclamation Mid-Pacific Region office and were administered by Ronald G. Silva as the former Tracy Fish Collection Facility Improvement Program (TFFIP) manager. We would also like to give thanks to the current TFFIP manager, J. Carl Dealy, for his continued support of this project.

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APPENDIX 1

Relationships Used to Develop Equations to Convert Juvenile Delta Smelt Standard Length to Fork Length and Total Length if Fork Length and Total Length Measurements were not Available due to Damaged Caudal Fins

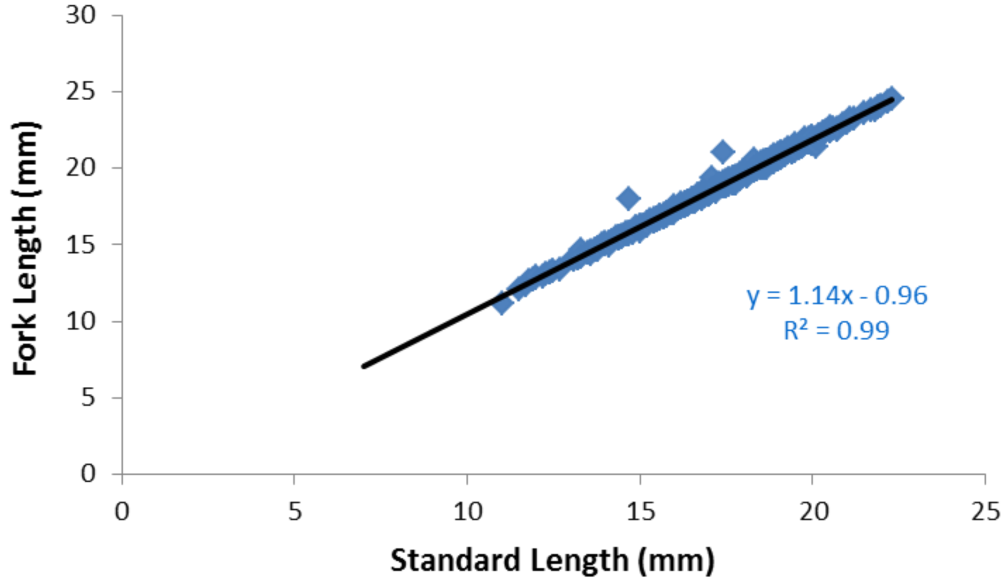

Figure A1-1.—Relationship between standard length and fork length for larval and juvenile delta smelt that were obtained from the University of California, Davis, Fish Culture and Conservation Laboratory but not used in the study (n = 601). The equation developed from this relationship (fork length = 1.14[standard length] – 0.96) was used to convert standard length to fork length when fork length measurements were not available.

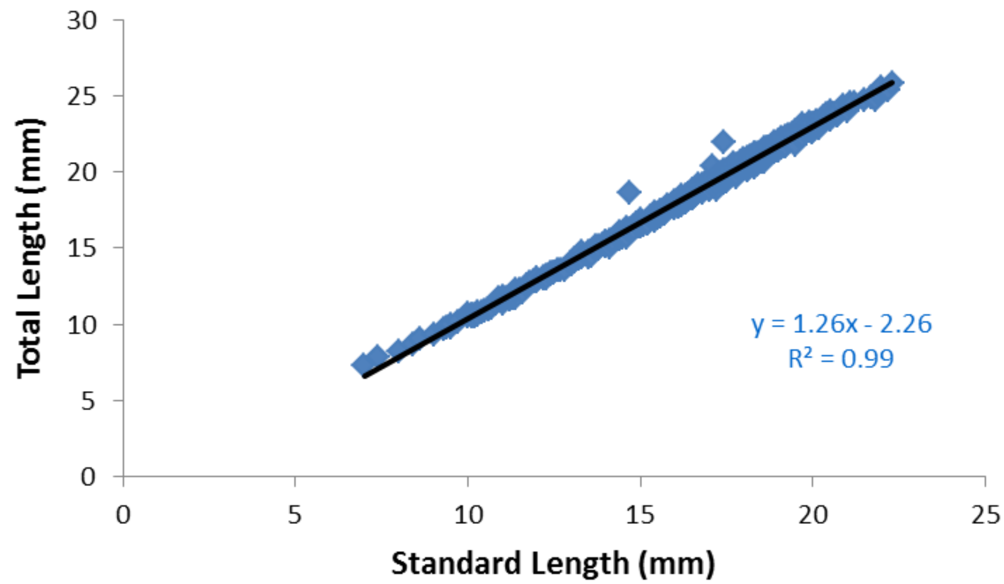

Figure A1-2.—Relationship between standard length and total length for larval and juvenile delta smelt that were obtained from the University of California, Davis, Fish Culture and Conservation Laboratory but not used in the study (n = 601). The equation developed from these measurements (total length = 1.26[standard length] – 2.26) was used to convert standard length to total length when total length measurements were not available.

APPENDIX 2

Probability Capture Curve, Based on Fork Length, Developed for Cultured Juvenile Delta Smelt in the Fish Count Station Using Data from Sutphin *et al.* 2007

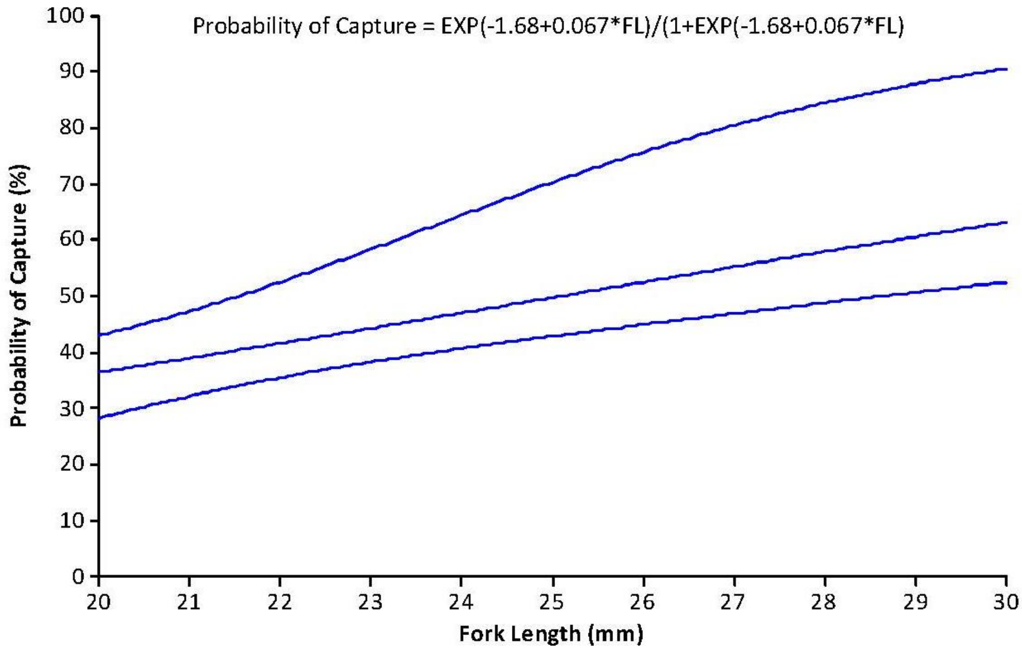

Figure A2-1.—Probability capture curve, based on fork length, developed for cultured juvenile delta smelt in the fish count station using data from Sutphin *et al.* 2007.