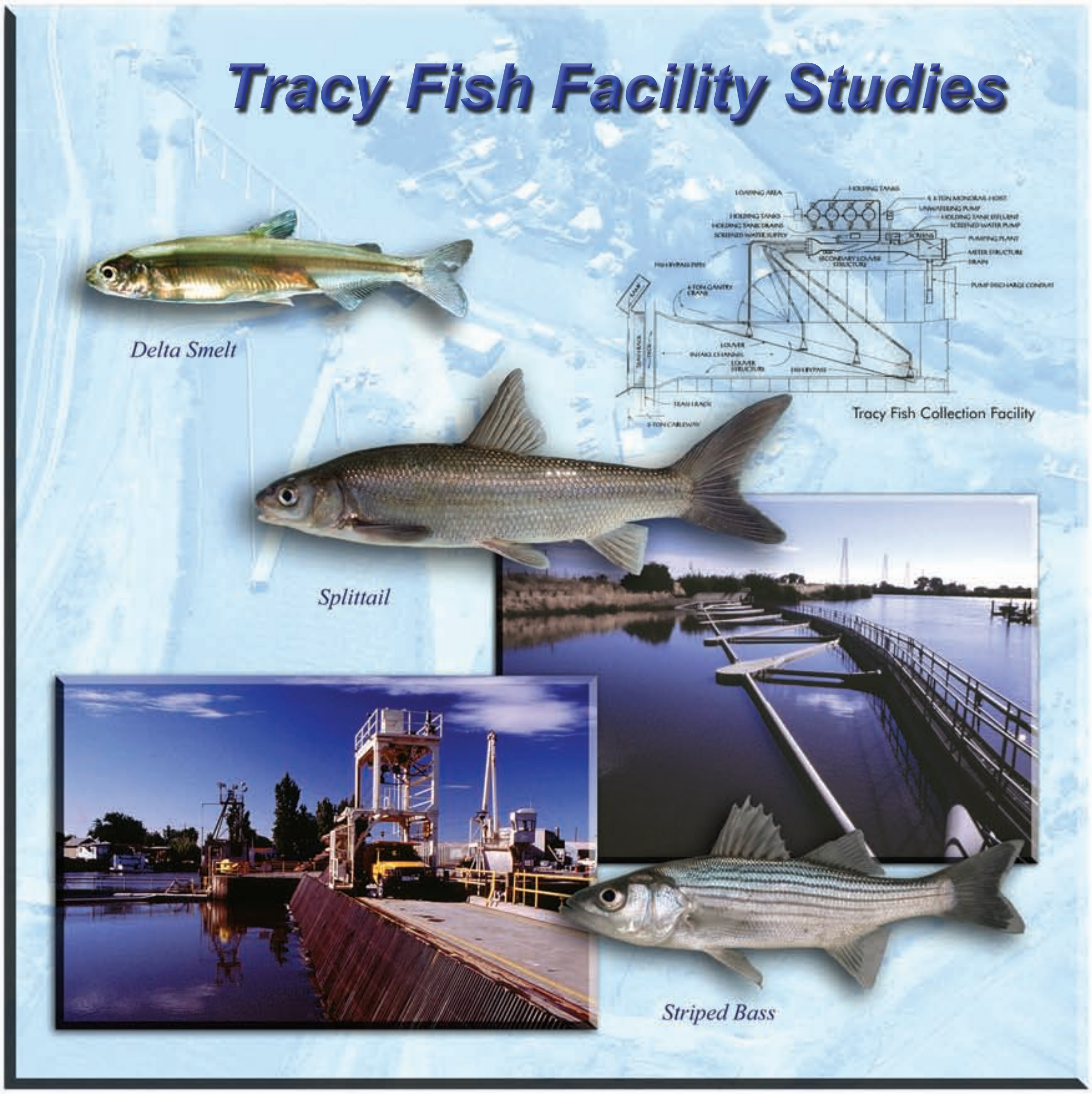
RECLAMATION

Managing Water in the West



Evaluation of Current and Historical 10-Minute-Count Screens at The Tracy Fish Collection Facility, Tracy, California

Volume 31

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

January 2007

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
January 2007

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Evaluation of Current and Historical 10-Minute-Count Screens at the Tracy Fish Collection Facility, Tracy, California

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Zak A. Sutphin, Brent B. Bridges, Bradd Baskerville-Bridges and René C. Reyes

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources Group, 86-68290, PO Box 25007, Denver CO 80225-0007
Bureau of Reclamation, Tracy Fish Collection Facility, 16650 Kelso Road, Byron CA 94514-1909
University of California at Davis, Department of Animal Science, Davis CA 95616

8. PERFORMING ORGANIZATION REPORT NUMBER
Volume 31

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Bureau of Reclamation, Tracy Fish Collection Facility, TO-410, 16650 Kelso Road, Byron CA 94514-1909

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 U.S. Department of the Interior, Bureau of Reclamation's Tracy Fish Collection Facilities (TFCF) 10-minute-count screen is a critical tool used to acquire sub-samples and provide an estimate of fish entering the facility. The introduction of a new screen in 1999, prior to fish screen retention comparisons, could possibly have altered TFCF salvage estimates. Three experiments were conducted during 2003 and 2004 to evaluate the retention efficiencies of the current and historical screens for juvenile delta smelt (*Hypomesus transpacificus*): (1) Wild Juvenile Delta Smelt Retention Comparison, (2) Evaluation of Bead Loss, and (3) Cultured Juvenile Delta Smelt Retention Comparison. In experiment No. 1 there was no significant difference between the mean number of juvenile delta smelt (20 to 30.5 mm in fork length [FL]) retained using the current (40.1 percent ± 7.4; mean ± standard error [SE], n = 6) and historical (34.5 percent ± 7.9; n = 8) screens (P = 0.70). However, delta smelt with a greater maximum body depth than the maximum hole width were recovered outside of both screens. Experiment No. 2 was conducted to determine where, aside from screen holes, these fish may have been lost. The lowest success rate for retention of beads was achieved when no seal was used (8.6 percent for 4 mm, 41 percent for 10 mm). Retention of particles was highest (100 percent for beads > 5 mm) when seals were used on the top and bottom of the screen, demonstrating that loss was occurring at both locations. In experiment No. 3 eight conditions were tested, using the two screen types. Retention was evaluated with and without seals with two size classes of delta smelt (small, 20 to 25 mm in FL and large, 25 to 30 mm in FL). Retention of the small size class was significantly lower using the current screen with seals, compared to all three other treatment types (current + seal, 3 percent; current, 18 percent; historical + seal, 13 percent; historical, 15 percent; P = 0.002). However, no significant differences were detected among treatments of the large size class (current + seal, 23 percent; current, 33 percent; historical + seal, 59 percent; historical, 44 percent; P = 0.06). Experiments Nos. 1 and 3 support the hypothesis that there is no difference in retention between current and historical screens when seals are not used. Since seals were not used historically, we conclude that the current and historical salvage data sets are comparable.

15. SUBJECT TERMS
delta smelt, fish collection facility, count screen

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**a. THIS PAGE**		26	Doug Craft
					19b. TELEPHONE NUMBER *(Include area code)* 303-445-2182

Tracy Fish Facility Studies
California

Evaluation of Current and Historical 10-Minute-Count Screens at the Tracy Fish Collection Facility, Tracy, California

Volume 31

by

Zak A. Sutphin,[1] Brent B. Bridges,[2] Bradd Baskerville-Bridges,[3] and René C. Reyes[2]

January 2007

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

[1] Bureau of Reclamation, Technical Service Center
Fisheries and Wildlife Resources Group, 86-68290
PO Box 25007
Denver CO 80225-0007

[2] Bureau of Reclamation
Tracy Fish Collection Facility
16650 Kelso Road
Byron CA 94514-1909

[3] University of California at Davis
Department of Animal Science
Davis CA 95616

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Series Editor

Doug Craft
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

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

Disclaimer

TABLE OF CONTENTS

Page

Executive Summary v
Experiment No. 1: Wild Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens v
Experiment No. 2: Bead Loss – Current 10-Minute-Count Screen v
Experiment No. 3: Cultured Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens v

Introduction 1
Objectives 3

Methodology 3
Sampling Procedures 3
Experiment No. 1: Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens 5
Experiment No. 2: Bead Loss – Current 10-Minute-Count Screen 5
Experiment No. 3: Cultured Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens 7
Statistical Analysis 7

Results 8
Experiment No. 1: Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens 8
Experiment No. 2: Bead Loss – Current 10-Minute-Count Screen 11
Experiment No. 3: Cultured Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens 12

Discussion 14

Recommendations 16

Acknowledgments 17

References 17

Tables

Table *Page*

1 Current and historical TFCF 10-minute-count screen dimensions 4
2 Experiment No. 1 results 9
3 Experiment No. 3 results 12

Table of Contents—continued

Figures

Figure *Page*

1 TFCF historical 10-minute-count screen 2
2 TFCF current 10-minute-count screen.. 2
3 TFCF current 10-minute-count bucket 4
4 Car tire used to seal the top rim of the 10-minute-count screens.................. 6
5 Foam pad used to seal the bottom rim of the 10-minute-count screens......... 6
6 The percent retention for both the historical and current 10-minute-count screens for all delta smelt 20 to 30.5 mm in FL (experiment No. 1). 8
7 The percent retention for both the historical and current 10-minute-count screens for all delta smelt at three size classes (experiment No. 1). 9
8 Best fit regression line for the FL to maximum depth relationship for wild delta smelt encountered at the TFCF (experiment No. 1). 10
9 Estimating the FL of wild delta smelt that hypothetically should be retained by both the historical and current 10-minute-count screens. 10
10 The percent of retained plastic beads using the current 10-minute-count screen with seals and a buffer 11
11 Percent retention for the historical and current 10-minute-count screen with and without seals at two size classes (experiment No. 3)......................13
12 Graph comparing FL to MBD for wild delta smelt observed at the TFCF and cultured delta smelt from the University of California at Davis FCCL. 13

EXECUTIVE SUMMARY

Experiments were conducted at the U.S. Department of the Interior, Bureau of Reclamation's Tracy Fish Collection Facility to evaluate the efficiencies of the current (perforated plate, maximum hole diameter = 4.8 millimeter [mm]) and historical (double layer of woven wire mesh, maximum hole diameter = 6.9 mm) 10-minute-count screens at retaining juvenile delta smelt (*Hypomesus transpacificus*) inside of the screens (retention).

Experiment No. 1: Wild Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens

Sampling was conducted during the 2003 and 2004 larval fish seasons (March–May). There was no significant difference between the mean number of juvenile delta smelt (20 to 32 mm in fork length [FL]) retained using the current (40.1 percent ± 7.4; mean ± standard error [SE]) and historical (34.5 percent ± 7.9) screens ($P = 0.70$). Delta smelt with a greater maximum body depth than the maximum hole width were being recovered outside of the current screen (4.8 mm), which indicates that juvenile delta smelt were being lost over or under the screen.

Experiment No. 2: Bead Loss – Current 10-Minute-Count Screen

Testing was conducted during September 2003 to evaluate where and how much particle loss was occurring using the current screen and various size classes of spherical, plastic beads. Fifty beads of each size (4.0, 4.5, 5.0, 6.0, 8.0, and 10.0 mm in diameter) were tested together, comparing five different methods of retention: no seals, top seal, bottom seal, both seals, and both seals with a water buffer. Tests with plastic beads indicated that the majority of particle loss was occurring at the base of the screen. When no seal of any type was used, the lowest success rate for retaining beads was achieved (8.6 percent for 4 mm, 40.7 percent for 10 mm). Retention of particles was highest (100 percent for beads > 5 mm) when seals were used on the top and bottom of the screen.

Experiment No. 3: Cultured Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens

Cultured delta smelt retention efficiency, testing the efficiency of the two screens, was conducted during the 2004 larval season. Eight conditions were tested, using the two screen types with and without seals, at two size classes (20.0 to 24.9 mm in FL and 25.0 to 30.0 mm in FL) of fish. The mean percentage of the small size class of fish retained when using the current screen with seals was significantly lower compared to all other treatments; current + seal 3 percent, current 18 percent, historical + seal 13 percent, historical 15 percent, P = 0.002. However, when comparing all treatments (n = 5), no significant difference was determined comparing mean percent retention of the large size class of fish (current + seal, 23 percent; current, 33 percent; historical + seal, 59 percent; historical, 44 percent; P = 0.06).

Tests using delta smelt (experiments No. 1 and No. 3) indicated no significant difference between current and historical screens when seals were not used. Historically, seals have not been used with either screen; therefore, current and historical salvage data sets are comparable. Tests with plastic beads (experiment No. 2) demonstrated that losses are occurring above and below the screens. When seals were added to the current screen, many of the delta smelt with FL of 20 to 30 mm were forced through the screen holes. This suggests that the current screen hole maximum diameter is too large to efficiently retain delta smelt < 32 mm FL.

INTRODUCTION

The Tracy Fish Collection Facility (TFCF) is located at the head of the Delta-Mendota Canal, 2.5 miles northeast of the Tracy Pumping Plant (TPP) and 9 miles northwest of Tracy, California (San Joaquin County). The U.S. Department of the Interior (Interior), Bureau of Reclamation's (Reclamation) TPP pumps approximately 1.5 million acre-feet of water from the Sacramento-San Joaquin Delta (Delta) for water users annually. The TFCF was developed in 1956 by Reclamation as a means of salvaging fish prior to encountering the TPP.

Historical fish salvage estimates from the TFCF, archived by the California Department of Fish and Game (CDFG), are used by regulatory agencies and universities to aid in studying fish populations and Delta water monitoring projects. It is important to obtain accurate annual salvage reports, because they are influential in determining the status (presence) of endangered and threatened fish species of the region. The TFCF reported an annual salvage of 6.1 million total fish in 2002, approximately 8,000 of which were delta smelt (*Hypomesus transpacificus*), a threatened osmerid endemic to the Delta (Foss, 2002). Delta smelt salvage estimates from the TFCF help govern the pumping rates for the TPP, which, in turn, could potentially influence the population of delta smelt and other fish species of the Delta.

A testing program to develop operational criteria and to measure the fish removal efficiency of various components of the TFCF, was initiated after construction in 1957 and completed in early 1959 (Bates, 1960). The efficiencies of the following facility components were studied: primary louver array, secondary louver system, trashrack, and fish haul tanks. It was concluded that the combined efficiency of all TFCF components ranged from 65 percent to 100 percent, depending on species and life stage of fish tested (Bates, 1960). However, no studies have been performed to evaluate the efficiency of the 10-minute-count screens, and no records have been found that document the equipment and mesh sizes used in the 10-minute-count process.

Daily fish salvage estimates at the TFCF are calculated from a series of 10-minute retention sub-samples taken on the even hours and are used to document TFCF fish salvage. Fish from these sub-samples are condensed into a 6-gallon (gal) pan of water with the aid of a 10-minute-count screen. Fish longer than 20 millimeter (mm) in fork length (FL) are identified (genus species) and counted, as this is considered the minimum length of fish that can be identified by TFCF fish diversion workers. Additionally, the first 24 individuals of each species encountered are measured four times daily (2 and 6 a.m., 2 and 6 p.m.). The count is expanded (multiplied by 12) to estimate the number, length, and species of fish passing into a holding tank over a 2-hour period. To achieve the highest survival rates, these numbers are used in conjunction with the Bates Tables to determine when fish density in a holding tank is equivalent to the maximum capacity of the TFCF fish-haul trucks (Bates, 1960). The Bates Tables consider oxygen consumption rates of fish as a function of fish length and water temperature to estimate maximum fish-haul truck capacity. The fish are hauled a minimum of three times a day (approximately every 8 hours) to designated release sites on the Sacramento and San Joaquin Rivers beyond the influence of State and Federal pumping plants.

For many years, the TFCF used an overlapping double layer of 0.25-inch, square mesh, hardware cloth for the 10-minute-count screen (figure 1), so that a small gap opening was available to dewater the concentrated collection (Jordan, 2004). This mesh configuration was considered efficient at concentrating fish larger than 20 mm FL into the count bucket (i.e., most fish < 20 mm would pass through the mesh and not be counted). In 1999, the screen cylinder was replaced and a new screen was built from a sheet of perforated plate with 0.38-inch (4.8-mm diameter) round holes (figure 2). The new design was stronger and was created to reduce the maintenance time spent building and maintaining count screens (Tegtmeir, 2004).

FIGURE 1.—TFCF historical 10-minute-count screen.

FIGURE 2.—TFCF current 10-minute-count screen.

Objectives

The primary objective of the project was to compare the retention efficiencies of the current and historical 10-minute-count screens to determine if historical delta smelt salvage numbers could be compared to the current delta smelt salvage data. While performing retention efficiency evaluations, it was discovered that losses were occurring over and under the screens; therefore, the secondary objective was to determine if and where particles with diameters between 4.0 mm and 10.0 mm were escaping. A final objective of this report was to document the design, materials, and measurements of both the current and historical 10-minute-count screens.

METHODOLOGY

Sampling Procedures

All trials were conducted to emulate the 10-minute-count procedure performed by TFCF Fish Diversion Workers. Ten-minute-count samples were collected from holding tank No. 2, which is a 20-foot (ft) [6.1-meter (m)] diameter, 15.5-ft (4.7-m) deep, conical bottom concrete tank, during April and May in 2003 and 2004. When in use, the tanks are only partially filled and depth is tidally dependent. Fish are typically held in 8,460 gal (32,000 liters [L]) of water at a depth of 4 ft (1.3 m). Water from the holding tank was concentrated into a 125-gal (473-L), 10-minute-count bucket. The count bucket is a round, open-top, steel tank that is 3 ft (0.9 m) in diameter, with a conical bottom and is approximately 4 ft (1.3 m) deep; complete with attached lifting beam, flanged lip on the open end, and dewatering screen (figure 3) (Reclamation, 1956). A 3-ton capacity hoist was used in all experiments to position the count bucket over the 10-minute-count screen. The bucket was lowered leaving a 5-mm gap between its base and the 10-minute-count screen (figure 3). Water samples were released from the count bucket through a 6-inch (15.2-cm) diameter drain at the base of the bucket into an empty 10-minute-count station. Samples were concentrated into a 6-gal (23-L) pan at the 10-minute-count station using one of the two cylindrical 10-minute-count screens.

The 10-minute-count station consists of a 55-gal (210-L) steel drum with a floating assembly inside. The floating assembly consists of a metal pan attached to the top of a float. The 10-minute-count screen nests inside the metal pan that retains the condensed 6-gal (23-L) sample. When the count bucket is raised, the floating pan raises the screen above the water level so that it can be removed.

The two 10-minute-count screens share similar structural design but vary in mesh size and type. The historical 10-minute-count screen (figure 1), in operation from 1959 through 1999, was constructed of a double layer of 0.25 inch (wire diameter = 0.53 mm) hardware cloth (maximum hole diameter = 6.9 mm, 0.27 inch). The current 10-minute-count screen (figure 2) consists of a cylindrical sheet of perforated aluminum plate (hole diameter = 4.8 mm, 0.19 inch). Both screens have an inner diameter of 43 centimeters (cm) (16.9 inches), a height of 59 cm (23 inches) and are supported by an aluminum frame (table 1).

FIGURE 3.—TFCF current 10-minute-count bucket.

TABLE 1.—Current and historical TFCF 10-minute-count screen dimensions

Screen types	Mean Hole diameter (mm)[1]	Maximum hole diameter (mm)	Minimum hole diameter (mm)	Percent open area	Wire diameter (mm)	Hole shape
TFCF current	4.75	4.82	4.64	29.6	N/A	Circle
TFCF historical	3.10	6.93	0.10	67.9	0.53	Rectangle

[1] The mean hole diameter is the average of four lengths, generated from the two corners and the two perpendicular mid-section diagonals.

When the 10-minute-count bucket is released into the 10-minute-count station, fish can end up at three locations: inside the count screen (pan), or two areas outside of the count screen (overflow or under the pan). Fine mesh aquarium nets (0.5 mm, 0.2 inch, square mesh) were used to collect fish inside and under the pan. The station overflow was concentrated into a 1-gal (3.8-L) sample using a 500-µm mesh screen on a square frame (24 in^2, 61 cm^2). After each trial, the screen was inverted, rinsed, and checked for samples. These three samples were placed into glass pans (9x13 in) with ½ inch of water and labeled. Samples were identified and counted (fish or beads), and FL, total length, and maximum body depth (MBD) measurements were taken for all delta smelt.

Experiment No. 1: Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens

Wild juvenile delta smelt samples were collected in April and May 2003 to evaluate the retention efficiency of both screens. Current and historical 10-minute-count screens were used in experiment No. 1 (table 1). No seals were added to either screen. Six and eight samples were collected using the current and historical 10-minute-count screens, respectively.

Experiment No. 2: Bead Loss – Current 10-Minute-Count Screen

Bead retention efficiency was used to determine the location and severity of particle loss using the current 10-minute-count screen. Samples for experiment No. 2 were collected in April and May 2003. Seals were periodically used on the upper and bottom rims of the screen to identify where particles were being lost. A tire, 6 inches (15.2 cm) wide and 20 inches (50.8 cm) in diameter was used to seal the top rim of the screen (figure 4). A 20 inch (50.8 cm) diameter, 1 inch (2.5 cm) thick circular foam pad was used to seal the bottom rim of the screen (figure 5). When seals were in place, the 10-minute-count bucket was lowered onto the screen, creating a tight seal.

Fifty beads of each size (1.6, 2.2, 2.5, 3.0, 4.0, 4.5, 5.0, 6.0, 8.0, and 10.0 mm) were counted in duplicate and inserted together into the top opening of the 10-minute-count bucket. Depending on the treatment, different subsets of beads were used. Filtered delta water was always used to fill the count bucket prior to bead insertion.

Four initial trials were conducted using beads with diameters of 1.6, 2.2, 2.5, 3.0, 4.0, and 4.5 mm. An inner layer of 1.5-mm square mesh window screen (0.06 inch, 1.6 mm diagonal) was glued inside the current 10-minute-count screen. Both top and bottom seals were used with normal release conditions. These four trials were performed to determine if the seals were effective at preventing small diameter beads (1.6-4.5 mm) from escaping the confines of the 10-minute-count screen.

Twenty-six additional trials were performed using beads ranging in diameter from 4.0 to 10.0 mm. Four trials were conducted using the 10-minute-count screens without seals, with a fast release of water from the count bucket (normal operation). Six trials were conducted with no seals, but the operator allowed for a slow release of the 125-gal (473-L) sample (not normal operation). These six trials were conducted to determine how the speed of water, during release, influenced bead retention. Sixteen more trials were conducted with various combinations of top and bottom screen seals. Seals were placed on the upper rim, the lower rim, and seals were used in combination on the upper and lower rims of the 10-minute-count screens. The combination of seals on the upper and lower rims was used in four additional trials with the count station tank partially filled (47 gal, 180 L). Water was added to the 10-minute-count station to see how a water buffer would influence bead retention (not normal operations).

FIGURE 4.—Car tire used to seal the top rim of the 10-minute-count screens.

FIGURE 5.—Foam pad used to seal the bottom rim of the 10-minute-count screens.

Treatment combinations for the bead experiment using the current 10-minute-count screen were:

1. Seals on upper and lower rims with 1.0-mm window screen (4 trials)
2. No seals with a fast release of water (4 trials)
3. No seals with a slow release of water (6 trials)
4. Seal on upper rim (4 trials)
5. Seal on lower rim (4 trials)
6. Seals on upper and lower rims (4 trials)
7. Seals on upper and lower rims with a full 10-minute-count station (4 trials)

Experiment No. 3: Cultured Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens

Experiment No. 3 was conducted in April and May of 2004. Cultured juvenile delta smelt, ranging from 20.0 to 30.0 mm in FL, were obtained from the University of California at Davis's Fish Conservation and Culture Laboratory (FCCL) to determine the current and historical 10-minute-count screen efficiencies with and without seals. Seals used were the same as indicated in experiment No. 2. Juvenile delta smelt were counted; placed into oxygenated, black, 5-gal (19-L) buckets; then covered and transported from the FCCL to the TFCF wet laboratory. Fish were anaesthetized using a 20 ppm Tricane Methanesulfonate (MS-222) solution and FL and MBD measurements were recorded. Measurements were made with an eyepiece micrometer (0.1-mm increments) on a Leica MZ75 microscope. Twenty fish were then transferred into a black, covered, 5-gal (19-L) bucket (3 gal, 11.4 L of water) and allowed to recover for 20 minutes. All fish were alive and appeared healthy prior to insertion. After the recovery period (20 minutes), a water-to-water transfer was used to directly insert fish into the count bucket. Within the smaller size class (20.0 to 24.9 mm), six trials each were performed for the current TFCF 10-minute-count screen with and without seals and also for the historical count screen with seals. Five trials were performed using the historical screen minus seals. Within the larger size class (25.0 to 30.0 mm), five trials each were performed for both current and historical screens with and without seals. For experiment No. 3, a quality control trial was performed for every five trials to demonstrate that all sample fish could be recovered in the count screen/station and overflow.

Statistical Analysis

Statistical analysis was performed using Minitab (version 12). Two sample t-tests ($\alpha = 0.05$) were used to compare percent retention between current and historical screens for experiment No. 1. In experiment No. 3, to meet the assumptions of the Analysis of Variance (ANOVA), normality (Anderson-Darling Normality Test) and homogeneity of variance (Bartlett's Test) were tested at each size class of fish. A one-way ANOVA was used to compare mean percent retention among treatments for both size classes of fish.

Retention data for the small size class was transformed (square root) before conducting the ANOVA. A multiple comparisons test (Tukey's Test) was used to separate differences among treatment means. Data for all fish combined did not meet the assumptions of ANOVA and were analyzed using a nonparametric test (Kruskal-Wallis Test).

RESULTS

Experiment No. 1: Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens

Percent retention (mean ± standard error [SE]) of delta smelt by screen type (current = 40.1 percent ± 7.4, n = 6; historical = 34.5 percent ± 7.9, n = 8) was not significantly different (P = 0.70, figure 6). The power of our test was low (0.06), but it would take 231 trials to achieve a power of 0.6 with the current means and variance of our data.

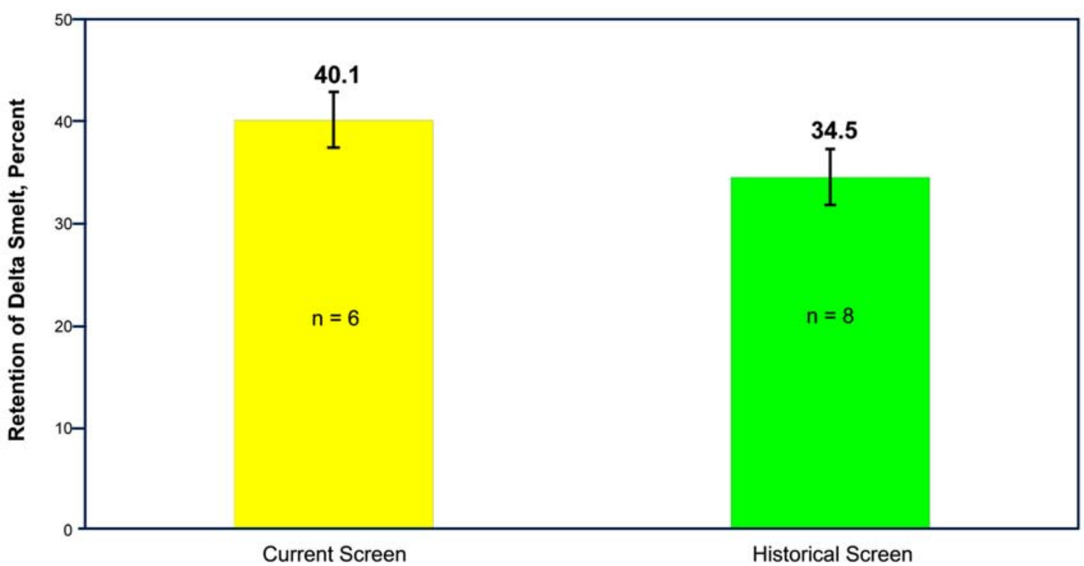


FIGURE 6.—The percent retention for both the historical and current 10-minute-count screens for all delta smelt 20.0 to 30.5 mm in fork length (experiment No. 1).

Further statistical analysis was performed to compare retention efficiencies for three size classes of smelt (20.0 to 22.9, 23.0 to 25.9 and 26.0 to 30.5 mm in FL). Percent retention of the two screen types compared by size class indicates no significant difference in retention efficiencies (P > 0.05, table 2, figure 7).

TABLE 2.—Experiment No. 1 results

Experiment No. 1: Wild Juvenile Delta Smelt Retention Comparison															
	Percent retained								Two-sample t-test						
Screen	**22.0 to 22.9 mm**	**SE**	**N**	**P**	**95 percent C.I.**	**23.0 to 25.9 mm**	**SE**	**N**	**P**	**95 percent C.I.**	**26.0 to 30.5 mm**	**SE**	**N**	**P**	**95 percent C.I.**
Current TFCF	31.5	10.3	6	0.80	7-56	37.7	7.4	5	0.60	13-62	59.4	12.9	6	0.52	32-87
Historical TFCF	28.7	8.2	8		15-43	42.3	4.5	8		44-95	69.3	19.0	8		44-95

* C.I. = Confidence interval.

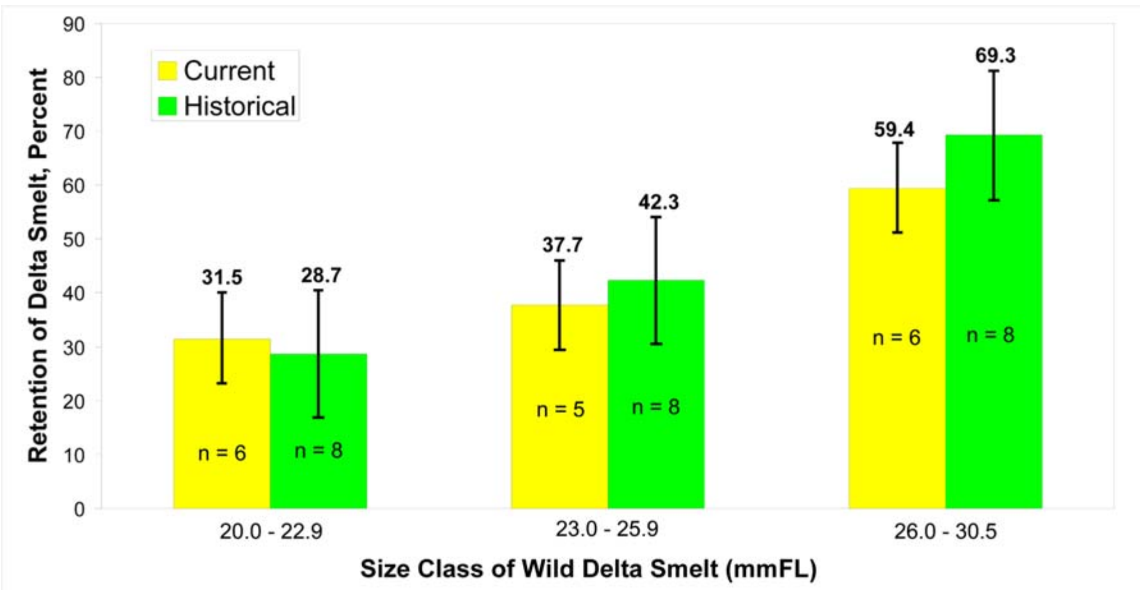


FIGURE 7.—The percent retention for both the historical and current 10-minute count screens for delta smelt at three size classes (experiment No. 1).

Over 600 wild delta smelt were collected and measured (FL and MBD). Fork length ranged from 14.0 mm to 42.0 mm. From the measurements collected, a length to body depth regression line was determined for wild juvenile delta smelt (figure 8). This regression line was used to estimate at what FL the current and historical screens could potentially retain 100 percent of delta smelt, based on the maximum hole size of the screens (figure 9). The current and historical screens have a maximum diameter of 4.8 and 6.9 mm, respectively, suggesting that fish need to be larger than 31.8 mm (current) and 50.1 mm (historical) in FL to be 100 percent retained.

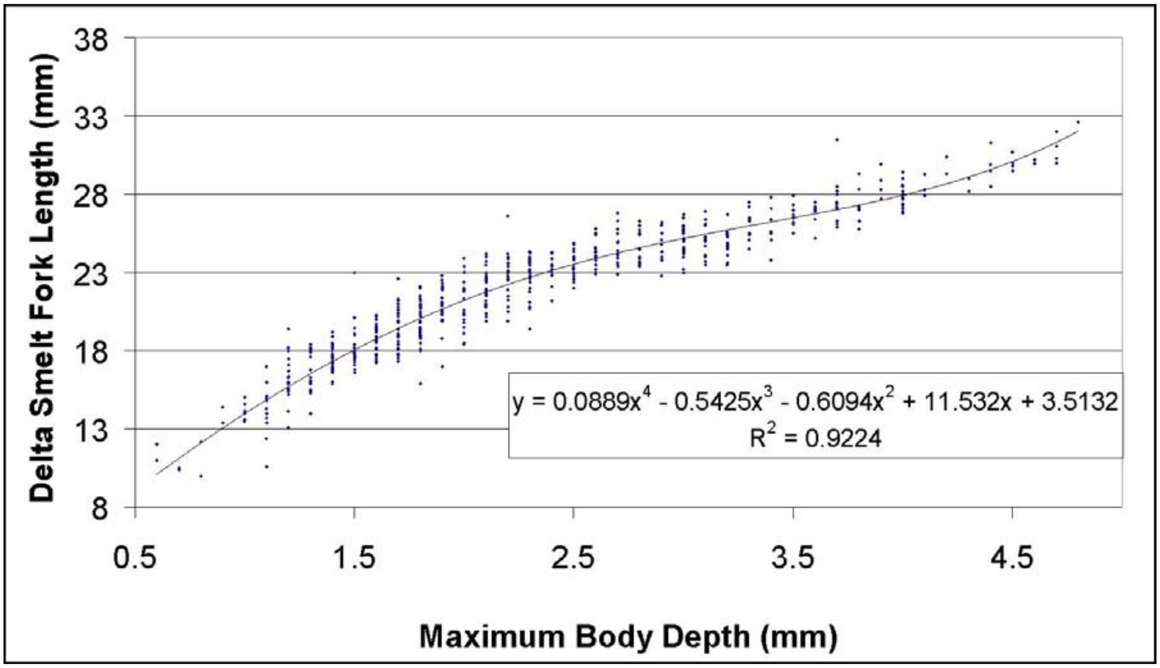


FIGURE 8.—Best fit regression line for the fork length to maximum body depth relationship for wild delta smelt encountered at the TFCF (experiment No. 1).

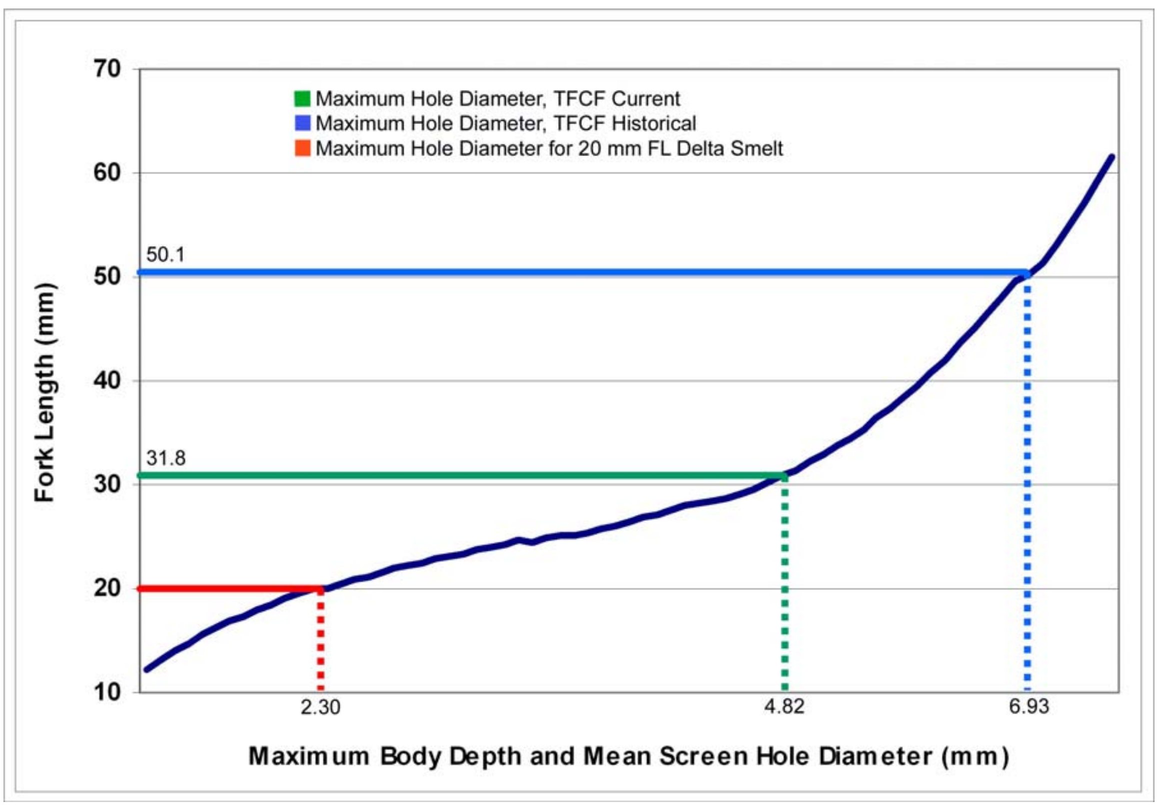


FIGURE 9.—Estimating the fork length of wild delta smelt that hypothetically should be retained by both the historical and current 10-minute-count screens.

Experiment No. 2: Bead Loss – Current 10-Minute-Count Screen

Data from experiment No. 2 indicates that the addition of seals increases the retention efficiency of particles > 5.0 mm diameter. With no seals and a normal fast release of water, success of count screen retention ranged from 8.6 percent (4.0 mm) to 40.7 percent (10.0 mm) (figure 10). Retention success using only a seal on the upper rim of the count screen and normal release of water ranged from 27.1 percent (4.0 mm) to 99.5 percent (10.0 mm), with high retention for 5.0-mm (72 percent), 6.0-mm (84 percent) and 8.0-mm (94 percent) beads. For trials using only a seal along the base, retention efficiency of the screen ranged from 13 percent (4.0 mm) to nearly 100 percent (5.0, 6.0, 8.0, and 10.0 mm). When using both a seal along the rim and base of the screen with normal release of water, retention success ranged from 36.4 percent (4.0 mm) to 100 percent (5, 6, 8, and 10 mm). When both seals and a water buffer were used in combination, efficiencies ranged from 11.9 percent (4.0 mm) to 100 percent (6.0, 8.0, 10.0 mm).

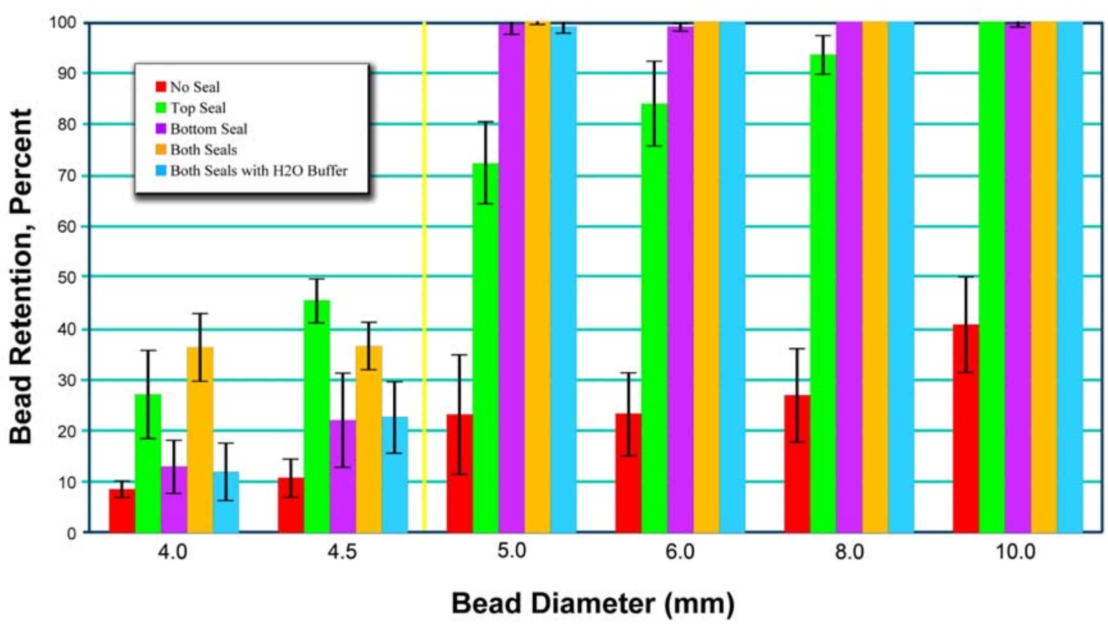


FIGURE 10.—The percent of retained plastic beads using the current 10-minute-count screen with seals and a buffer. Values represent mean ± SE for each treatment.

The current TFCF 10-minute-count screen, lined with a 1.5-mm window screen (1.1 mm, minimum opening), retained 100 percent (SE = 0.43) of 1.6 to 4.5 mm beads. In the four trials using a slow release method and no seals, retention success ranged from 13.0 percent (4.0 mm) to 94.7 percent (10.0 mm). This suggests an improvement from the fast water release.

Experiment No. 3: Cultured Juvenile Delta Smelt Retention Comparison – Current and Historical 10-Minute-Count Screens

Retention efficiencies between the current and historical 10-minute-count screens were compared using two size classes of delta smelt (20.0 to 24.9 and 25.0 to 30.0 mm in FL); sample sizes were unequal due to the availability of fish (table 3). The percentage of fish retained in the small size class was significantly lower using the current screen with seals (3 percent), compared to all other treatments (current, 18 percent; historical, 15 percent; historical + seal, 13 percent; P = 0.002; figure 11). This was the only significant difference detected among treatments in this size class. In the larger size class, no differences were detected among the treatment means (P > 0.05)

TABLE 3.—Experiment No. 3 results

Experiment No. 3: Cultured Juvenile Delta Smelt Retention Comparison											
	Percent retained					One-way ANOVA					
Screen	**20.0 to 24.9 mm**	**SE**	**N**	**95 percent C.I.**	**25.0 to 30 mm**	**SE**	**N**	**95 percent C.I.**	**Total 20.0-30.0 mm**	**SE**	**95 percent C.I.**
Current TFCF	18.3	6.1	6	8-29	33.0	9.8	5	9-57	25.0	8.4	14-36
Historical TFCF	15.0	1.8	5	12-18	44.0	13.7	5	10-78	29.5	12.0	12-47
Current TFCF + seals	3.3	2.0	6	0-7	23.0	5.8	5	9-37	12.3	6.5	4-2
Historical TFCF + seals	12.5	3.4	6	7-18	59.0	8.9	5	37-81	33.6	13.6	15-52

Measurements taken during experiment No. 3 were used to create a fork length to maximum body depth graph for cultured juvenile delta smelt versus wild delta smelt from experiment No. 1 (figure 12). A comparison of the regression lines for cultured and wild delta smelt that were between 19.4 mm and 30.2 mm FL showed no significant statistical difference in slope (P = 0.55) or y-intercept (P = 0.83).

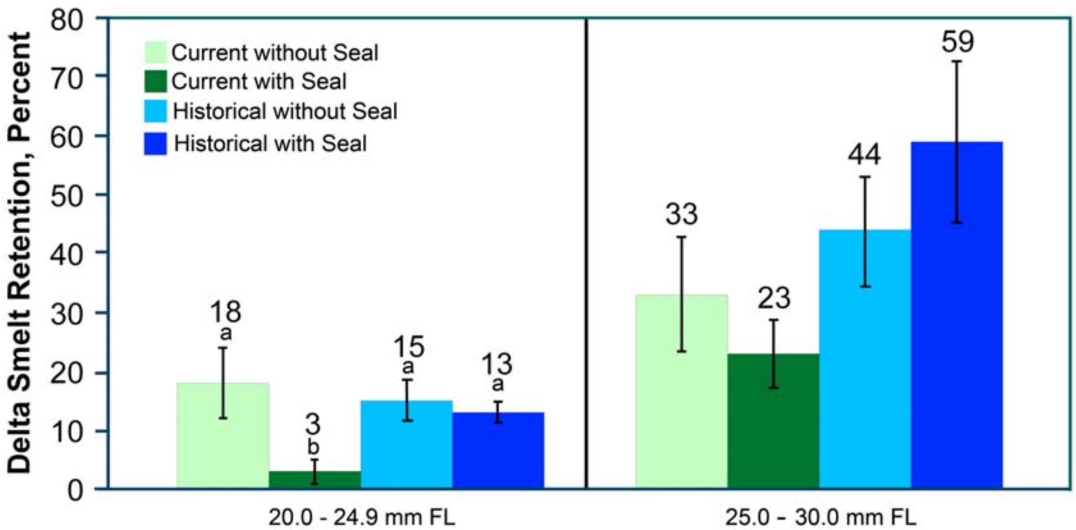


FIGURE 11.—Percent retention for the historical and current 10-minute-count screen with and without seals for two size classes (experiment No. 3). Values represent mean ± SE for each treatment. Data were analyzed using a one-way ANOVA. Tukey's test was used to compare treatment means. Different letters denote a significant difference ($\alpha = 0.05$, $P < 0.05$).

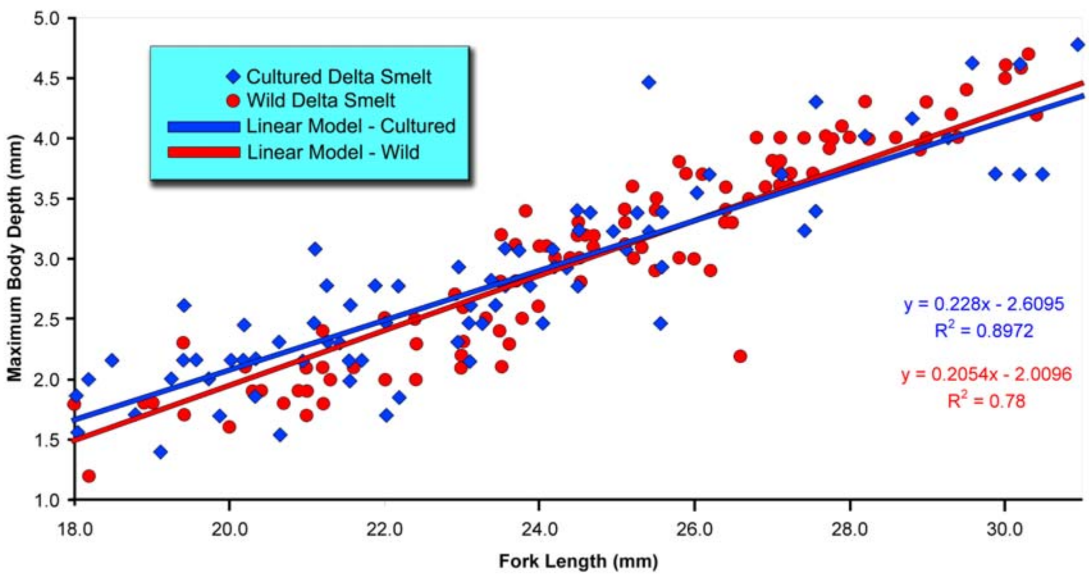


FIGURE 12.—Graph comparing fork length to maximum body depth for wild delta smelt observed at the TFCF and cultured delta smelt from the University of California at Davis FCCL. No significant difference was determined comparing regression line slope values ($P = 0.55$) or y-intercept ($P = 0.83$).

DISCUSSION

Trials comparing the collection efficiency (retention) of the current and historical 10-minute-count screens without seals (Experiment No. 1) support the hypothesis that retention of wild delta smelt (20.0 to 30.5 mm in FL) at typical debris and fish loads are not significantly different (P > 0.05). However, we cannot conclude that there is no significant difference due to the low power of our test. In addition, the experiment indicates that, for three size classes of delta smelt (20.0 to 22.9 mm = 31.5 percent, 23.0 to 25.9 mm = 37.7 percent, > 26.0 mm = 59.4 percent) and for all sizes combined (40.1 percent), the current screen underestimates the actual number of larval and juvenile delta smelt salvaged at the TFCF.

Screen hole size is a critical variable, making the 10-minute-count screen function properly and enabling accurate estimates of TFCF salvage. A FL vs. MBD graph was created from all recovered smelt as a tool for estimating the screen size needed to retain 100 percent of delta smelt with fork lengths > 20.0 mm (figures 8 and 9). The graph was also used to determine at what FL and associated MBD the current 10-minute-count screen holes (4.8 mm in diameter) could hypothetically retain all delta smelt. Wild delta smelt with a MBD of 4.8 mm (0.19 inch) have an approximate FL of 31.8 mm (1.3 inches) and, therefore, should be retained by the current screen. Hypothetically, a 2.30-mm maximum hole diameter would be required to retain all wild delta smelt with fork lengths > 20.0 mm. Therefore, it is not surprising that a large percentage of delta smelt with fork lengths 20.0 to 30.5 mm passed through the current screen.

Experiment No. 1 demonstrated that fish were not only being lost through the screen holes, but also under or over the screen. This was evident due to the collection of fish too large to pass through the screen in the overflow water. Experiments No. 2 and No. 3 were necessary to verify the locations where losses were occurring.

Trials conducted during experiment No. 2 demonstrated that the 10-minute-count screen, as currently used by the TFCF fish diversion workers, does not effectively retain samples of particles larger in diameter than the holes of the screen. Testing the current screen with no seals and allowing water to move from the 10-minute-count bucket at a high velocity (normal operating procedures) provided low retention of plastic beads (23, 25, 27, and 41 percent for 5.0, 6.0, 8.0, and 10.0 mm in diameter, respectively). Since all beads inserted are larger than the screen hole size, the results indicate that the low bead retention efficiency of the 10-minute-count screen is due, in part, to gaps below and above the screen. It should be noted that the bead retention data from experiment No. 2 was not meant as a surrogate for fish data but, rather, was used to detect locations of leaks.

Having discovered low bead retention efficiencies, new methods and count screen configurations were applied in an attempt to increase screen efficiency and to determine at which locations particle losses were occurring. Four trials were conducted using the same 10-minute-count screen configuration (no seals), but with a slow release of water. This method provided much higher percentages of retention (13 percent to 95 percent for 4.0 mm to 10.0 mm beads, respectively). Initially, it was thought that this method would suffice, improving 10-minute-count screen efficiency with no maintenance of the current structure. However, through discussions and further testing, it was shown that in order to create lower velocities, the ball within the 10-minute-count bucket could be raised no more than 50.0 mm. It was concluded that with the current unpredictable debris loads at the TFCF, a 50-mm gap between the ball and hole of the count bucket would be to small to allow for adequate debris and fish passage as water drained from the bucket.

Tests were conducted using seals on the top and bottom of the screen to determine potential retention rates for each screen type. A car tire was used to seal the top of the screen; the same method that is currently being employed by Department of Water Resources at the Skinner Fish Collection Facility (Byron, California). Trials sealing only the top rim of the screen proved efficient; however, not all beads larger in diameter than the holes of the screen were retained. These data indicated that a portion of the particles were being forced through the gaps at the bottom of the screen. To determine whether particles were being forced over the upper rim of the screen, a foam pad was inserted under the screen. This method proved efficient at retaining particles and retained over 99 percent of beads larger than 4.8 mm (maximum screen hole diameter). These two tests demonstrated that, while loss occurs over and under the screen, the largest losses of particles were occurring along the base of the screen. Once seals were placed along the top rim and base of the screen simultaneously, 100 percent of beads larger than 4.8 mm were retained.

A third experiment was conducted to determine how a live delta smelt (pliable object) would compare to the inanimate, solid bead (non-pliable object) when both current and historical 10-minute-count screens were tested with and without seals. Two size classes (20.0 to 24.9 mm in FL and 25.0 to 30.0 mm in FL) of cultured delta smelt were obtained as a surrogate to wild delta smelt. Using cultured delta smelt allowed for pretrial measuring and a known sample size at each trial. For both small and large size classes, the current and historical 10-minute-count screens mean percent retention without seals was not significantly different ($P > 0.05$). However, it was surprising that when testing percent retention of the small size class of delta smelt (20.0 to 24.9 mm), the current screen tested with seals was significantly lower compared to all other treatment types ($P = 0.002$).

Trials conducted in Experiment No. 3 demonstrated that delta smelt > 20.0 mm in FL are not effectively retained; experiments No. 2 and No. 3 demonstrated that losses are largely attributed to the maximum hole diameter and not due to the lack of seals. Retention using the current 10-minute-count screen was lower than expected at both size classes with (20.0 to 24.9 mm = 3 percent, 25.0 to 30.0 mm = 23 percent) and without seals (20.0 to 24.9 mm = 18 percent, 25.0 to 30.0 mm = 33 percent). In fact, fewer fish were retained when the seals were added, possibly due to the increased force of water through the screen holes when water was not allowed to leak over and under the screen. No comparisons of wild versus domestic delta smelt retention were possible because of large differences in susceptibility to handling stress. Though experiment No. 3 was conducted using cultured fish, the relationship between MBD and FL is comparable for cultured and wild delta smelt (figure 12), which would make it likely that retention of wild delta smelt would be similar.

The method of fish counts and TFCF operations evolves continuously. Typically, this is done to benefit procedures and fish health, but are often times implemented without official standard operating procedures or documentation. Historical reference and employee interviews at the TFCF and CDF&G, regarding fish count operations, have led us to believe that no seal of any type was ever used in conjunction with the 10-minute-count screens. If this operation holds true, these results indicate no significant difference between historical TFCF salvage data (before 1999) and current salvage data (after 1999).

RECOMMENDATIONS

Data from experiments No. 1 and No. 3 support the hypothesis that there are no differences in retention efficiencies between current and historical screens without seals for delta smelt between 20.0-30.5 mm FL. This supports the idea that current and historical salvage numbers are comparable.

Using the current screen with or without seals to perform 10-minute counts is not an efficient method for accurately sub-sampling juvenile delta smelt. In order for the TFCF to comply with 10-minute-count protocol and effectively count all fish > 20.0 mm in FL, we recommend that changes be made in the 10-minute count screen size. To increase the accuracy of the 10-minute counts, we recommend testing screen sizes with maximum hole diameters ranging from 2.3 mm to 4.8 mm, testing screens with an increased percent open area, and using seals on both the top and bottom rims of the count screen. Ideally, a 2.3-mm screen should be used, but this may not be acceptable to use at all times of the year due to seasonal changes in debris loads. Once the appropriate changes have been made to the current 10-minute-count station and screen, we recommend that cultured juvenile delta smelt (20.0 to 40.0 mm in FL) be used as a surrogate for wild delta smelt to evaluate retention efficiency of the adapted TFCF 10-minute-count screen.

If management concludes that debris loads at the TFCF do not permit the usage of a finer screen size, we recommend that seals be added to the current screen to increase the accuracy of the 10-minute counts. Though this may not increase our sampling gear's efficiency at retaining juvenile delta smelt, data from experiment No. 2 suggest that the addition of seals will increase the 10-minute-count screen's efficiency at retaining larger particles (> 5.0 mm maximum height or width), which may be more representative of the holding tank contents outside of larval fish season. Ten-minute-count samples are used in conjunction with TFCF fish hauling tables (Bates Tables, temperature and oxygen dependent) to estimate the percentage of a total truck load of fish residing in a holding tank at any given 2-hour interval. An underestimation of the total number and size of fish in a holding tank could result in deficiencies in water quality during transport.

In addition, we suggest testing the retention efficiency of the large holding tank screens as fish are retained in the holding tanks for up to 10 hours. These screens have a square mesh screen with a maximum diameter of 3.76 mm (0.15 inch). From the regression line in figure 8, we would expect that fish < 24.7 mm in FL could be lost through the holding tank screens. This analysis should be conducted prior to making improvements on the 10-minute-count screen and station.

ACKNOWLEDGMENTS

We would like to thank Gary Jordan and the TFCF fish diversion workers, for allowing our interruption of daily activities and consumption of space at the TFCF; the University of California at Davis's FCCL (and staff) for providing healthy delta smelt; Steve Bradford (Department of Water Authority) for constructing a replicate model of the historical TFCF 10-minute-count screen; Steve Foss and CDFG employees for providing important salvage data and valuable input; Johnson Wang, for identification of larval and juvenile fishes; and Lloyd Hess (Fisheries Biologist) and Ron Silva (Chief, Biologist Resources Branch) for providing general study oversight.

REFERENCES

Bureau of Reclamation, 1956. *Designers' Operating Criteria for Fish Collecting Facilities: Delta-Mendota Intake Canal,* Engineering and Research Center, Denver, Colorado.

Bates, D.W., O. Logan, and E.A. Pesonen, 1960. *Efficiency Evaluation Tracy Fish Collecting Facility Central Valley Project California.* U.S. Fish and Wildlife Service, Bureau of Reclamation.

Foss, S., 2002. *Fish Salvage at the Tracy Fish Collection Facility, 2002 Annual Report.* California Department of Fish and Game, Central Valley Bay-Delta Branch, Stockton, California.

Foss, S., 2004. *Fish Salvage Data at the Tracy Fish Collection Facility, 1989–2002.* California Department of Fish and Game, Central Valley Bay-Delta Branch, Stockton, California, personal communication.

Jordan, Gary, 2004. *Historical Tracy Fish Collection Facility 10-Minute-Count Screen Information.* Bureau of Reclamation, Tracy Fish Collection Facility, Byron, California, personal communication.

Tegtmeir, Richard, 2004. *Construction and Implementation of the Current Tracy Fish Collection Facility 10-Minute-Count Screen.* Bureau of Reclamation, Tracy Fish Collection Facility, Byron, California, personal communication.