Project Objectives

Our objectives are to:

1. Quantify prescreen loss for juvenile and adult delta smelt at Clifton Court Forebay.
2. Quantify entrainment loss for juvenile and adult delta smelt through the Skinner Fish Facility.

3. Approach and Scope of Work

To accomplish the above objectives, the following tasks are considered:

1. Project management.
2. Culture delta smelt for mark-recapture experiments.
3. Mark delta smelt for mark-recapture experiments.
4. Mark-recapture experiments for juvenile delta smelt.
5. Mark-recapture experiments for adult delta smelt.
6. Analyze and interpret results of mark-recapture experiments.

The Task and Budget Summary outlines the tasks and schedule details to be described next. The total cost-share contribution for this project is $815,208. Detailed cost-share contributions by task and year are indicated in the Description of Cost-Share / Matching Funds.

Task 1 - Project management

The target dates for the beginning and completion of this project are July 2007 (month 1) and December 2009 (month 30). Task 1 will be conducted throughout this entire period. The principal investigator (G. Castillo) and three primary staff members (R. Fujimura, J. Lindberg and B. Baskerville-Bridges) will be responsible for project implementation and for providing timely deliverables to the CALFED Science Program. As primary staff member, V. Poage will provide management advise on external project coordination. During the first month of this project we will schedule a meeting with a technical team including members from the IEP Management Team, the Central Valley Fish Facility Review Team and the EWA Science Team to further review the work plans and scope of work.

We will coordinate project wide use of quality control (QC) and quality assurance (QA) procedures outlined by Geoghegan (1996) for each task. QC procedures will be reviewed at least monthly. QA will be conducted before and after task completion in coordination with coworkers and collaborators not directly involved in this project.

The minimum study deliverables will include semiannual reports, final report, and page summaries for initial and final public audience, project closure summary report or copy of draft manuscript, presentations at CALFED Science Conference and at other events requested by CALFED Science Program staff, and copy of all published materials). In addition, we will present the preliminary and final analyses of this project to a variety of audiences, including EWA Science Group/EWA meetings, Annual IEP workshops, State of the Estuary Conference, Estuarine Ecology Team, Delta Smelt Working Group). This task will also result in at least one manuscript to be submitted for publication in a peer reviewed journal.

Task 2 - Culture of delta smelt for mark-recapture experiments.

We plan to use cultured delta smelt in our proposed mark-recapture experiments. The substantial number of delta smelt needed to conduct our proposed mark-recapture experiments far exceed the number of wild fish we would be able to capture in the wild due their limited abundance. Their recent decline in abundance would also make obtaining take authorization problematic. Comparison between cultured and wild delta smelt in terms of louver efficiency at three different speeds revealed no significant differences (Bowen 2005). This similar entrainment between wild and cultured delta smelt lends key support to use cultured delta to estimate entrainment of wild fish. No other species will be considered in mark-recapture experiments as proxy for delta smelt given the delicate nature and physiological characteristics of delta smelt (Swanson et al. 2005).

The Fish Conservation and Culture Laboratory (FCCL) is a research and development facility located in the south Delta on State Water Project land near Byron, CA. This research program was initiated to develop a methodology for the culture of delta smelt to provide live animals for research, without further depleting the wild population. The delta smelt abundance indices have continued to decline, so artificial production represents the only reliable means to create a supply of these fish for research. Capture and survival of this delicate fish from the wild is difficult at the adult stage and virtually impossible at the juvenile and younger stages.

Sub-adult delta smelt will be collected in Nov-Dec of 2007 and 2008 from the lower Sacramento River between Rio Vista and Chipps Island. These will be maintained at the FCCL and over-wintered to spawn the following spring. Wild broodfish will be fed a mixture of two dry diets (Lansy and Hikari plankton) at 1-2% body weight per day and the food will be distributed every hour using vibratory feeders.
Delta smelt will be spawned on site during 2008 and 2009 to provide 4,000 juveniles (May-June 2008), 16,200 juveniles (May-June 2009) and 11, 200 adults (January-March 2009) for the mark-recapture experiments. Relative to previous mark-recapture experiments in CCF, the short distance between the FCCL and the locations where fish will be mark and released is a unique advantage to minimize transport related losses.

Spawning typically begins in February when ambient water temperature approached 12-15°C. Eggs will be collected each week and fertilized in-vitro. After hatching the larvae will be placed into 120-L tanks at a stocking density of approximately 40/L (5,000 larvae/ tank). The larvae will be reared in recirculation systems with a water temperature of 17°C and a water exchange rate of 2-L/min. The larvae will be fed rotifers starting on 4 days post hatch (dph) until 40 dph at a prey density of 10/L. Newly hatched *Artemia* nauplii will be fed to the larvae on 10 dph and then switched to enriched *Artemia* nauplii at 20 dph (4 nauplii/L). Between 50 and 60 dph the larvae will be transferred to the juvenile system; they should be approximately 15-18 mm.

Juvenile delta smelt tanks (400-L black circular tanks) will be stocked at much lower densities (10/L). Juveniles will be maintained in these larger tanks until they reach a mean size c.a. 35± 10 mm (130 dph). Fish larger than 30 mm will also be graded and transferred to the adult facility for grow-out or the holding facility for marking. The adult facility is equipped with black fiberglass tanks (800-L circular tanks). Juveniles will be weaned at a fork length of 30 mm to a dry diet. They will be maintained in these tanks until they grow to an adult size (c.a. 60 mm ± 10 mm). This task will be conducted between month 1 and month 24. Deliverables of task 2 will be nearly 22,200 juveniles and 11,200 adult delta smelt to be used on marking development methods (juveniles) and mark-recapture experiments and controls (juveniles and adults). Results will be included in semiannual reports and the final report.

Task 3 - Marking delta smelt for mark-recapture experiments.

Juvenile and adult delta smelt will be marked in large batches using the fluorochrome calcein to distinguish them from the wild fish (e.g. Moher, 2003). This cryptic mark will be the primary mark assigned to fish released for our experiments. It is only detectable using a filtered blue light and the methods for marking delta smelt adults has already been tested by one of the co-PI's, Jerry Morinaka.

A secondary mark (photonic mark) will be used to distinguish fish released at other locations. This technology has been successfully used on adult delta smelt, but little work has been done with juveniles. A needle-free jet injector, driven by CO_2, is used to inject colored microscopic beads into the rays of the selected fins. Multiple fin locations can be targeted (dorsal, caudal, anal) using several colors, enabling numerous color x fin combinations. This process is more labor intensive, as fish are anaesthetized (75 mg/L of tricaine methanesulfonate) and individually marked. All fish will be marked one week prior to release to enable them to recover from the marking procedure. Moreover, initial work will be performed in Task 4 to evaluate feasible treatment doses and/or exposure times for juvenile delta smelt marked using calcein and photonic marking.

Task 3 will be conducted between months 1 and 24. Deliverables include marking approximately 19,600 juveniles and 11,200 adult delta smelt to be used in mark-recapture experiments and controls. Results will be included in semiannual reports and the final report.

General description for mark-recapture experiments

We will conduct mark-recapture experiments over the period when juvenile and adult delta smelt historically occur in the south Delta and the salvage facilities. Fish will be released just behind the radial gates in Clifton Court Forebay and in the trash boom of the Skinner Fish Facility (Figure 3). All recaptures will occur at the counting station located in the Skinner Fish Facility. The number of juvenile and adult cultured delta smelt needed in mark-recapture experiments planned for year two were derived from the numbers required to estimate maximum reported pre-screen losses and the numbers of fish used in the 10 previous mark-recapture experiments in Clifton Court Forebay and in the trash boom of the Skinner Fish Facility (Gingras 1997).

All recaptured fish will be collected at the Skinner fish salvage facility. Based on previous mark-recapture experiments, we expect our experiments will last from a few days to weeks. Continuous sampling will begin as soon as fish are released. Sampling could be gradually reduced after the peak recapture of fish released at different locations as been well established. Although high numbers of other salvaged species may require reducing sampling time, this possibility will be minimized by conducting the experiments away from the salvage peaks of other common species observed in recent years at the Skinner Fish Facility. Sampling will be at least hourly or every two hours until no marked fish are recovered for at least a month.

The proposed pilot mark-recapture experiments will provide initial pre-screen loss and facility efficiency estimates for delta smelt at the SWP. Total losses of fish into CCF and the fish salvage facilities are the direct result of water operations despite a significant portion of these losses may be secondary due to presumed predation in Clifton Court Forebay and within the fish facilities. Although the percent survival for salvaged delta smelt has been generally assumed to be zero, ongoing research on the terminal salvage operations of the Skinner Fish Facility should provide estimates of salvaged delta smelt survival (CALFED project funded to Robert Fujimura).. The numbers of wild delta smelt to be sampled at the salvage facilities throughout our experiments could be significantly lower than those of marked delta smelt. However, the numbers and sizes of concurrently collected wild delta smelt will be recorded for reference and potential comparisons of size composition and diel salvage patterns. Because wild delta smelt may be entering Clifton Court Forebay on a daily basis when the radial gates are opened to fill the reservoir, no abundance estimates of wild delta smelt within this reservoir will be attempted.

Task 4 - Mark-recapture experiments for juvenile delta smelt

We will conduct two mark-recapture experiments from April to early summer in years 1 and 2 when wild juvenile delta smelt of similar size are typically present (Table 1). Because the SWP and CVP salvage facilities were not designed to routinely collect and enumerate delta smelt less than 20 mm FL, salvage collection for delta smelt < 25 mm FL is known to be significantly undersampled (Jerry Morinaka, personal observation). Thus, the minimum size of marked fish to be considered in our mark-recapture experiments will be 25 mm TL. We plan to use calcein to mark most juvenile delta smelt (Figure 5.1). Calcein has been used to successfully mark adult delta smelt

and juvenile and larval stages of several other species of fish, but similar marking techniques for juvenile delta smelt have yet to be refined. We will adapt these methods for marking juvenile delta smelt during the months preceding the mark-recapture experiments in year 1. We will also conduct laboratory experiments to determine if juvenile delta smelt could be marked using photonic marking (Figure 5.2). Prior to mass-marking experiments (Task 3), a total of 600 juvenile delta smelt will be used to refine marking methods using calcein and photonic marking. We will use different treatments to determine the most effective calcein concentrations-exposure times and photonic pressure-fin ray combinations to mark juvenile delta smelt.

To differentiate recaptured delta smelt to be released behind the trash boom from those released at the radial gates (Figure 3), we plan to primarily use photonic marking at the trash boom and calcein marking at the radial gates using separate controls to account for potential marking losses. However, if photonic marking tests for juveniles prove inadequate, we will release calcein-marked fish at the trash boom before fish are released at the radial gates. To properly differentiate release locations of recaptured fish over time, we will conduct initial test releases at the trash boom to estimate the maximum time required to recover all marked fish arriving to the counting station in the salvage facility. Following marking in each mark-recapture experiment, we will hold replicated control fish in tanks to account for potential marking and handling related losses. This task will be conducted between months 1 and 24. Deliverables will include field results and data summaries of two mark-recapture experiments at Clifton Court Forebay and Skinner Fish Salvage Facility . These will be included in semiannual progress reports and in the final report.

Table 1. Number of juvenile delta smelt to be used in mark-recapture experiments. Size range 35± 10 mm FL (FL = fork length, n = number of fish). CCF = Clifton Court Forebay

Year	Test	Time	CCF	Trash Boom	Controls	Total
			n	n	nx2	
1	1	Evening-night	3,000[a]	200°	100	3,400
2	2	Evening-night	15,000[b]	1000°	100	16,200

[a] Test release at locations 3 (n= 500) and 4 (n = 2500) in CCF (Figure 3).
[b] Test release inside radial gates, (location 1. Figure 3).
Test release behind trash rack, (location 2. Figure 3).

Task 5 - Mark-recapture experiments for adult delta smelt

We will conduct two mark-recapture experiments in year two over the period when adult delta smelt normally arrive at the salvage facilities (c.a. January-March). Delta smelt will comprise one size group and adequate controls will be used to assess potential mark-related mortalities (Table 2). In addition of calcein marking, we will use a photonic marking method recently developed and successfully tested on adult delta smelt (Z. Sutphin, USBR, personal communication) . Fish released behind the trash boom (in front of the primary louvers) will be differentiated using unique photonic marks, (Figure 3). Task 5 will be conducted between months 13 and 24. Deliverables will include data summaries and summary of field results for two mark-recapture experiments at Clifton Court Forebay and Skinner Fish Salvage Facility. These deliverables will be included in semiannual progress reports and in the final report.

Table 2. Numbers of adult delta smelt to be used in mark-recapture experiments. Approximate fish size (mean and range) is 60 ± 10 mm FL. (FL = fork length, n = number of fish).

Year	Test	Release Time	Radial Gates (n)	Trash Boom (n)	Controls n x 2	Total
2	1	Evening-night	5,000	400	100	5,600
2	2	Evening-night	5,000	400	100	5,600

Task 6 - Analyze and interpret results of mark-recapture experiments

Marked fish at the radial gates and the trash boom will be recaptured at the Skinner Fish Salvage Facility. Number of marked fish arriving at the salvage facility will be estimated using procedures for fish count expansion used in routine Skinner Fish Facility salvage operations (e.g. Tillman 1993, Gingras 1997). Our replicated analyses for adult delta smelt will allow comparing standard error of replicated mark-recapture experiments for test fish of similar sizes released under similar water export levels and time of day. Survival in controls will be used to make corresponding adjustments in survival of mark-recapture experiments and in the computations of pre-screen loss and facility efficiency. The percent of pre-screen fish loss $_{(PPSL)}$ will be estimated as:

$$PPSL = 100[1 - (RGREC / R^{G}REL)^{-}(^{1} / FFFL)]$$

Where:
RG_{REC} = number of fish recaptured that were released at radial gates.
RGREL = number of fish released at radial gates.
$FFFL$ = efficiency of Skinner Fish Facility:

$$^{F}FFL = {}^{TB}REC / {}^{TB}REL$$

Where:
TB_{REC}= number of recaptured fish that were released at trash boom.
TBREL = number of fish released at trash boom.

Experimental conditions for replicated adult delta smelt experiments will be standardized whenever possible by comparing similar flows, bypass ratios, time since release and fish size. In the event some of these factors cannot be adequately

controlled, we will consider both parametric and non-parametric statistical analyses to evaluate their potential influence on pre-screen loss and fish facility efficiency results. We will consider past and ongoing research at the Skinner and Tracy Fish facilities to further account for such potential factors,. So far, experimental evidence at the Tracy Fish Facility has shown that water velocity does not significantly affect secondary louver efficiency for either juvenile or adult delta smelt (Bowen 2005). We will compute separate salvage-entrainment relations for juveniles and adults if we determine that size of fish influences pre-screen loss and/or fish facility efficiency. Because entrainment of delta smelt may not be a simple function of salvage, our mark-recapture analyses will be used along with available facility efficiency data at the Tracy Fish Facility to determine key variables needed to formulate general salvage-entrainment relations. We will consider available historical salvage (e.g. Figure 2b) and salvage-flow relations (e.g. Ruh! 2006, Smith 2006, Figure 6) to estimate entrainment for adults and juveniles. This task will be conducted between months 1 and 30. Deliverables will include initial pre-screen loss and facility efficiency estimates for delta smelt. These products will be included in semiannual progress reports, agency presentations, and in one article to be submitted to a peer-reviewed journal.

4. Feasibility

Specific reasons contributing to the success potential of this project include: 1) an interdisciplinary - multiagency team of researchers with expertise on critical aspects to implement this proposal, 2) demonstrated production of all life stages of delta smelt by primary staff, 3) long-term experimental research experience of primary staff at the Skinner Fish Salvage Facility, 3) knowledge of the most recent developments in marking techniques appropriate for delta smelt and ability to adapt one or two alternative marking methods to delta smelt.

Under the requested budget, we assumed that IEP base funding of the FCCL will be available to conduct the proposed mark recapture experiments at a substantially lower cost than would otherwise be possible. We also assumed IEP cost-share involvement by the Principal investigator (G. Castillo). Both FCCL and Principal Investigator's cost-share needs are being supported by IEP. In the event that IEP requires increased use of the Principal investigator's time for other IEP responsibilities, the principal investigator will coordinate with CALFED Science and IEP to facilitate involvement of additional IEP staff in project activities that could be delegated but remain under the supervision and guidance of the principal investigator..