AN EXPERIMENTAL APPROACH TO EVALUATE ENTRAINMENT LOSSES OF DELTA SMELT IN THE SOUTH DELTA

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Introduction

Water management operations are considered a contributing factor to the decline of delta smelt and other pelagic organisms in the upper San Francisco Estuary, where the State Water Project (SWP) and the Federal Central Valley Project (CVP) export Delta water year-round. Recognizing the need to empirically determine the magnitude of the direct export losses, the CALFED Science Program, in coordination with the Interagency Ecological Program tasked the authors to examine the feasibility of using marked cultured delta smelt to evaluate the relation between delta smelt salvage and underlying entrainment losses at the SWP in the south Delta. For an entrained fish to be salvaged, it must first pass through Clifton Court Forebay (CCF, a SWP reservoir Figure 1) and then it must be diverted at the Skinner Fish Protective Facility (SFF, Figure 2).

Figure 1. Clifton Court Forebay (CCF) and general locations of juvenile and adult delta smelt release sites in the forebay and subsequent recapture at the Skinner Fish Facility.

Study Objectives

Objectives were to obtain initial field estimates for:

1- Salvage efficiency of juvenile and adult delta smelt at the Skinner Fish Facility.
2- Percent recovery of juvenile and adult delta smelt for releases in Clifton Court Forebay.
3- Pre-screen loss for juvenile and adult delta smelt in Clifton Court Forebay.

Figure 2. Skinner Fish Protective Facility (SFF) and passageway for salvaged fish in the facility. Arrows denote release and recapture sites for marked delta smelt.

Methods

Marking

- Calcein used as primary mark for cultured juvenile and adult delta smelt (Figure 3A).
- Photonically marked cultured adult delta smelt to differentiate days of release (Figure 3B).
- Trans-generational marking (30 ppt Sr chloride hexahydrate) to detect potential offspring.

Release

- Marked Fish were released at two locations for each experiment: adjacent to radial gates in CCF (Figures 1, 4B) and trash rack in front of SFF primary louvers (Figures 2,4A).
- Released fish at SFF under export conditions to assess SFF efficiency.
- Released fish in CCF in early afternoon, irrespective of export level to assess percent recovery at SFF.

Recapture

- Fish were recaptured in regular DWR counts (Figure 5).
- Total census conducted at SFF whenever possible prior to transport of all salvaged fish to Delta release sites (Figure 6).
- Marked delta smelt co-occurred with wild delta smelt at SFF in all experiments.

Computations

Fish Facility Efficiency:

$$FFE = 100\frac{TRrec}{TRrel}$$

Where: TRrec = No. recaptured marked fish that were released at trash rack.
TRrel = No. marked fish released at trash rack.

Percent Recovery:

$$PR = 100\frac{RGrec}{RGrel}$$

Where: RGrec = No. marked fish recaptured at Skinner Fish Facility that were released at the radial gates
RGrel = No. marked fish released at radial gates

Pre-Screen Loss in CCF:

$$PSL = 100\left[1-\left(\left(\frac{RGrec}{RGrel}\right)\left(\frac{1}{0.01FFE}\right)\right)\right]$$

Where each term is as previously defined.

Results

The three mark recapture experiments conducted concurrently at the SFF and CCF revealed large to extremely large spatial and temporal differences in recapture (Tables 1A, 1B).

These highly consistent differences in recapture between CCF and SFF releases indicate that only an extremely small number of juvenile and adult delta smelt released into CCF were able to survive in CCF to be subsequently salvaged at the SFF. Moreover, no trans-generationally marked juvenile delta smelt were detected in salvage.

Mean daily water exports from CCF decreased moderately from February (experiment 1) to March (experiment 2). However, water exports in June (experiment 3) were significantly lower.

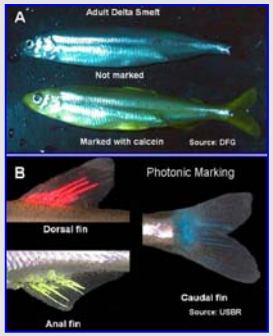

Figure 3. A: Calcein mark (5 min immersion (5.0 g/l adults; 2.5 g/l juveniles) and B: photonic marks on fins of adults.

Results (continued)

Lower June exports may have contributed to the extremely small recovery of juveniles. (Table 1 B). The percent recovery of delta smelt declined greatly between successive releases, primarily as a result of increasing pre-screen losses (Table 2).

Nearly a ten-fold increase was observed in the number of adult fish released and lost per recovered fish from February to March . A similar corresponding increase in fish lost per recaptured fish was observed from March to June (adult and juvenile stages, Table 2). Thus, the number of recovered fish in SFF salvage operations may not be assumed to be a reliable index of entrainment losses at the SWP.

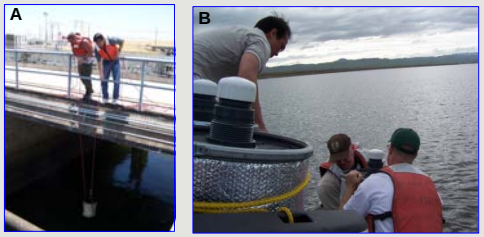

Figure 4. Delta smelt releases at the Trash rack in Skinner Fish Facilty (A) and adjacent to radial gates in Clifton Court Forebay (B).

A — Skinner Fish Facility Releases

Experiment	Life Stage	Mark	Date of Release	Recapture Days[1]	Mean Daily Export (cfs)	No. Fish Released	No. Fish Recaptured	Fish Facility Efficiency
1	Adult	A/D-Green	23-Feb-09	1	2896	100	39	39
1	Adult	A/D-White	23-Feb-09	1	2896	100	36	36
1	Adult	C/D-Blue	23-Feb-09	1	2896	100	84	84
1	Adult	A/D-Blue	23-Feb-09	1	2896	100	49	49
2	Adult	A-Green	23-Mar-09	1	2498	100	43	43
2	Adult	D-Blue	23-Mar-09	1	2498	100	45	45
3	Juvenile	Calcein	19-Jun-09	1	532	800	193	24

[1] Number of days from release to last recapture

B — Clifton Court Forebay Releases

Experiment	Life Stage	Mark	Date of Release	Recapture Days[1]	Mean Daily Export (cfs)[2]	No. Fish Released	No. Fish Recaptured	Percent Recovery
1	Adults	D-Green	24-Feb-09	24	2945	1398	75	5.36
1	Adults	D-White	25-Feb-09	10	2880	1426	33	2.31
1	Adults	C-Blue	26-Feb-09	4	2822	1382	31	2.24
1	Adults	A-Blue	27-Feb-09	7	2778	1501	32	2.13
2	Adults	A-Green	26-Mar-09	5	2233	1447	12	0.83
2	Adults	D-Blue	27-Mar-09	none	2226	1402	0	0.00
3	Juveniles	Calcein	22-Jun-09	3	957	14413	4	0.03

[1] Number of days from release to last recapture
[2] Mean over 10 days post-release

Table1. Results for delta smelt mark-recapture experiments conducted at Skinner Fish Facility (A) and Clifton Court Forebay (B), in the south Delta SWP from February to June 2009. Marked fins (A: anal; D: dorsal; C: caudal).

Figure 5. Searching for marked delta smelt in regular counts at the Skinner Fish Facility.

Figure 6. Sampling of marked delta smelt in total census at Skinner Fish Facility.

Mark-Recapture Estimates	Adults		Juveniles
	February	March	June
% Fish Facity Efficiency	53.25	44.00	24.12
% Recovery	3.01	0.42	0.03
% Pre-Screen Loss	93.59	99.10	99.89
CCF Release to Recovery Ratio[1]	38	237	3603

[1] Total number of fish released in CCF / Total number recovered at SFF.

Table 2. Summary of juvenile and adult delta smelt mark-recapture estimates for three experiments conducted at the SWP in the South Delta from February to June 2009.

Conclusions

1. **Delta smelt can be readily mass-marked to quantify entrainment losses.**
2. **Entrainment losses of delta smelt could be much higher at times compared to other species previously studied at the SWP.**
3. **Pre-screen loss was overwhelmingly the largest source of mortality for delta smelt.**
4. **CCF entrainment monitoring is needed to interpret and validate critical relations between salvage statistics and the magnitude and variability of direct delta smelt losses.**

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