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Why We Do a "Post-VAMP Shoulder" for Delta Smelt

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Introduction

The delta smelt (*Hypomesus transpacificus*) is endemic to the San Francisco Estuary and the Sacramento-San Joaquin Delta, which has undergone a profound transformation over the past 150 years. This small euryhaline planktivore is generally found near the surface in open waters in or just landward of the region of fresh and saltwater mixing (Moyle, 2002). Delta smelt are listed as threatened under the federal Endangered Species Act (ESA) of 1973. Although highly variable, delta smelt fall abundance indices have exhibited a marked decline over the past 30 years.

Several monitoring methods are used to obtain information on the various life stages of delta smelt and its abundance and distribution in the Delta, including fall and spring midwater trawls (the latter evolved into the Kodiak Trawl survey), beach seining, the Chipps Island trawl, and 20-mm surveys. Non-survey indicators related to delta smelt abundance or distribution include year-type hydrology (wet vs. dry), location of the salt/freshwater mixing zone (X2), water quality, water temperature, rate of export pumping, and incidental take at the Central Valley Project (CVP) and State Water Project (SWP) export facilities. Delta smelt are vulnerable to entrainment at the CVP and SWP export facilities as larvae, juveniles, and adults.

In this article I describe some of the management tools developed to protect delta smelt and other fishes, the biological basis for their development and use, and present some preliminary indications of their success in protecting delta smelt.

What is the Environmental Water Account?

The Environmental Water Account (EWA) is a key component of CALFED's water management strategy. Created to address the problems of declining fish populations and water supply reliability, the EWA aims to protect both fish and water users by providing for more flexible water project operations in the Bay-Delta. The EWA buys water from willing sellers or diverts surplus water when safe for fish, then banks, stores, transfers, and releases it as needed to protect fish and compensate water users for deferred diversions.

To benefit delta smelt, water from the EWA allows curtailment of water project export pumping, which directly reduces incidental take at the CVP and SWP pumps in the south Delta. Pumping curtailments from January through March minimize take of pre-spawning and spawning adult delta smelt, which are considered the most critical life stage. In an annual species these adults represent the individuals who have successfully avoided death occurring at earlier life stages to achieve reproductive maturity. Actions taken in April through June minimize take of late-spawning adults or larvae and juveniles. After June, delta smelt emigrate from the south delta and are no longer vulnerable to entrainment by the pumps.

What is the Vernalis Adaptive Management Program?

Pursuant to the San Joaquin River Agreement (SJRA), the Vernalis Adaptive Management Program (VAMP) is designed to protect fall-run Chinook salmon in the San Joaquin River by improving smolt survival through the Delta. Through the VAMP, information is gathered on the relative effects of flows in the lower San Joaquin River, water project export pumping rates, and the operation of a fish barrier at the head of Old River on Chinook salmon survival. The VAMP provides fisheries benefits during a 31-day April-May pulse flow period by reducing export pumping and increasing flows on the San Joaquin River and its tributaries.

In addition to the SJRA, flows on the lower San Joaquin River are regulated by biological opinions issued by US Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA) Fisheries and by the State Water Resources Control Board's Decision 1641. Springtime pulse flows are required, with a coincident reduction of exports, to support habitat quality, protect larval delta smelt, and assist the out-migration of juvenile Chinook salmon. Water to support these pulse flows is provided by acquisitions from the San Joaquin River tributaries under CVPIA §3406(b)(3) and by CVP water pursuant to CVPIA §3406(b)(2).

What is the "Post-VAMP shoulder" and Why Do We Do It?

Simply stated, extending export curtailments beyond the VAMP spring pulse flow period (usually ending May 15) is referred to as the post-VAMP shoulder. The post-VAMP shoulder is intended to improve habitat and afford delta smelt larvae the opportunity to move north and west toward rearing areas in Suisun Bay, Suisun Marsh, and the lower Sacramento River. Water that is not exported during the post-VAMP shoulder curtailment must either be accounted for under CVPIA §3406(b)(2) or reimbursed by the EWA.

As hydrologic models improved over time, our understanding of Delta processes has evolved from the belief that the Delta is a riverine flow dominated system to one that is tidally dominated except during brief periods of high river flow. Nonetheless, analysis has shown that positive central Delta flows may benefit delta smelt larvae hatched in the central Delta by reducing entrainment at the export pumps (Nobriga and others, 2001). The hypothesis behind the post-VAMP shoulder is that, should the CVP and SWP resume full export capability immediately following the VAMP, planktonic delta smelt larvae in the south Delta would in many years suffer very high entrainment losses. While quantitative relationships between Delta flows and fish migration are still under investigation, it is thought that the post-VAMP shoulder provides habitat conditions that promote western migration of young delta smelt and improve their overall survival.

A recommendation to implement a post-VAMP shoulder is made following interagency discussion at the staff level, both by the b(2) Interagency Team (b(2)IT)[1] and the Data Assessment Team (DAT)[2], and with the advice of the Delta Smelt Work Group[3]. These teams consider factors including incidental take at the pumps, Delta conditions, and the distribution and abundance of delta smelt as indicated by various monitoring measures. The DAT formulates a recommendation, which is submitted to the Water Operations Management Team (WOMT)[4] for discussion and decision making. When the post-VAMP shoulder is implemented, the temporary fish barrier at the head of Old River is removed and tidal operation of the south Delta temporary barriers is suspended to maximize migration opportunities for young delta smelt. Export reductions are maintained until incidental take of delta smelt declines, 20-mm surveys indicate that delta smelt distribution is primarily north and west of Franks Tract, or south Delta water temperatures warm to a point at which delta smelt survival is negatively affected.

1. The b(2)IT was established to implement and account for expenditures of environmental water made available by section 3406(b)(2) of the Central Valley Project Improvement Act. It consists of staff-level representatives of the CVPIA implementing agencies.
2. The DAT consists of staff from the five EWA implementing agencies, plus representatives from the academic and stakeholder communities.
3. The Delta Smelt Work Group was established in the 1995 USFWS Biological Opinion on the Operations Criteria and Plan for the Central Valley Project and the State Water Project. It is an interdisciplinary team of experts from state and federal agencies, academia, and the stakeholder community.
4. The WOMT consists of management-level decision makers from the five EWA implementing agencies.

Decision Criteria

The decision criteria for implementation of the post-VAMP shoulder are found in the delta smelt decision tree, as presented by Nobriga and others (2001). Factors to consider include (1) the previous year's fall midwater trawl index, (2) abundance of juvenile delta smelt in the south Delta, (3) incidental take levels, (4) below-normal or dry hydrology, and (5) the length of the spawning season, as indicated by water temperatures in the south Delta (Table 1). The extent and duration of the post-VAMP shoulder would depend upon the level of concern, as well as upon available EWA water resources, the degree to which juveniles appear to be migrating north and west based on 20-mm survey data, and temperatures in the south Delta.

In the case of the 2003 post-VAMP shoulder, concern was high as the 2002 FMWT was the fifth lowest since 1967. USFWS convened the Delta Smelt Work Group (Work Group) on May 12 to discuss the potential to institute a post-VAMP shoulder. Although the fourth survey of the 20-mm survey indicated an improvement in distribution of larval fish over previous surveys (Figure 1), overall numbers sampled were very low, resulting in a heightened level of concern. Noting that the expected benefits from export curtailments would fall off sharply after May 31 as the south Delta continued to warm, the Work Group recommended that most of the remaining EWA assets be applied to a VAMP shoulder, saving very little for potential fish actions in June. The Work Group recommended (1) breaching the Head-of-Old-River Barrier immediately following the conclusion of the VAMP and tying open the flap gates on the agricultural barriers, (2) restricting CVP and SWP exports to a combined 1,500 cfs through May 18, and (3) ramping up exports beginning May 19 to a rate at which combined exports did not exceed the San Joaquin River flow at Vernalis (approximately 2,000 cfs). The fifth period of 20-mm sampling completed on May 24 indicated that a substantial fraction of juveniles were still migrating toward rearing habitat in Suisun Bay, and most were north and west of Franks Tract, where they were generally regarded as being beyond the influence of the export facilities (Figure 1). As south Delta water temperatures climbed and EWA debt began to accumulate, the Management Agency biologists recommended that export pumping begin ramping up to full capacity beginning on May 28.

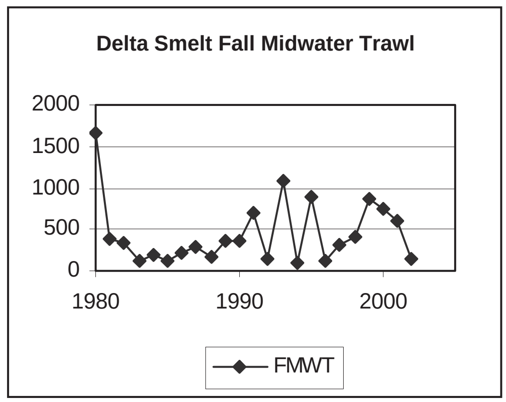


Figure 1 Trends in abundance of delta smelt, as indicated by the Fall Midwater Trawl, calendar years 1980-2002.

Table 1 Factors leading to the recommendation of a post-VAMP shoulder since the inception of the Environmental Water Account.

Decision Criterion[a]	*2001*	*2002*	*2003*
FMWT-1[b]	Low concern	Low concern	High concern
Distribution (20mm) and Abundance	Central and South Delta, lower Sacramento River	Central and South Delta, lower Sacramento River	Central Delta, lower Sacramento River, Suisun
Incidental Take[c]	Low concern	Concern	Concern
Hydrology	Dry	Dry	Dry early, Wet late
South Delta Temperature[d]	Warming → Warm	Warming → Warm	Warming → Warm

[a] See Nobriga and others 2001 (delta smelt decision tree) for explanations of decision criteria

[b] Indicates the value of the fall midwater trawl index for the previous year; for the purposes of this paper only, concern was assessed as "high" if the value was below the median value of 394, moderate if the value fell between the median and the mean, and "low" if the value exceeded the mean of 565

[c] From the 1995 USFWS biological opinion; for the purposes of this paper only, concern was assessed as "high" if take approached or exceeded the reconsultation level and "low" if take did not exceed the heightened-concern level

[d] South Delta water temperatures for May 1-3: 10-15 °C = Cool, 16-20 °C = Warming; > 20 °C = Warm

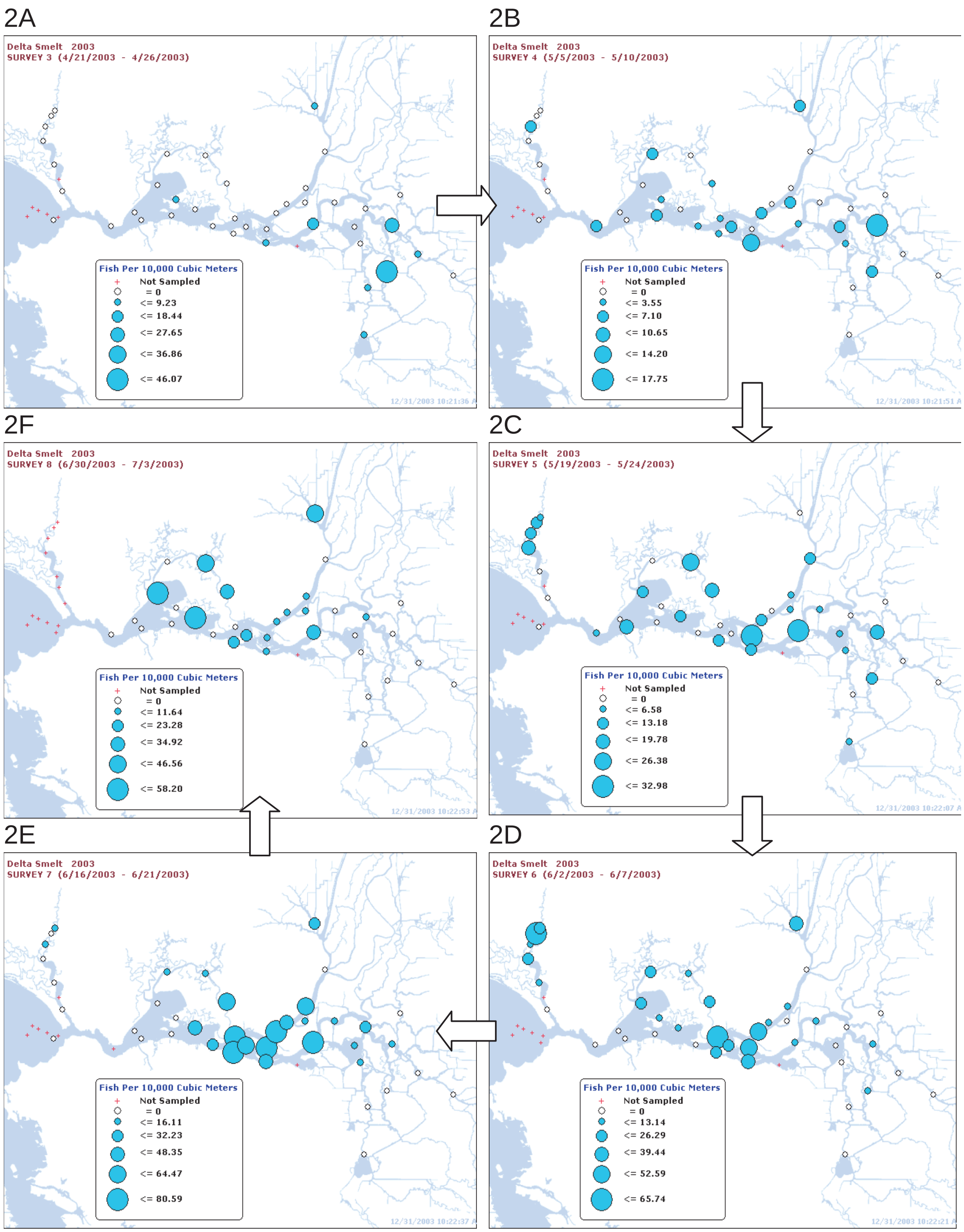


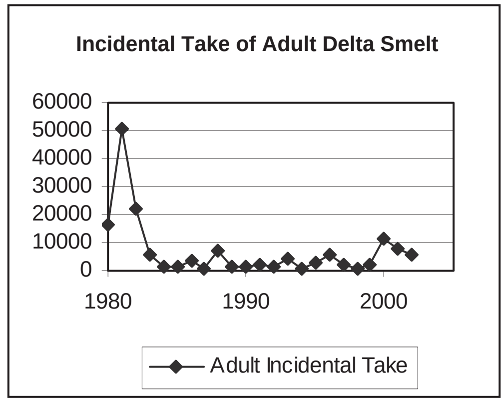
Figure 2 Results of surveys 3 through 8, covering the post-VAMP period, 2003 (clockwise from upper left).

Is the Post-VAMP Shoulder Effective?

The purpose of the post-VAMP shoulder is to afford delta smelt larvae the opportunity to migrate from their hatching areas in the south Delta to rearing habitat in Suisun Bay, Suisun Marsh, and the lower Sacramento River. Currently, quantitative relationships between Delta flows and fish migration are still under investigation. Nonetheless information obtained from the Department of Fish and Game's 20-mm survey has provided qualitative indicators of success. Figure 2 illustrates the north- and westward movement of delta smelt during the post-VAMP shoulder in 2003; 20-mm plots from 2001 and 2002 exhibit a similar pattern. However, because directed investigations have not been conducted, it would be premature to conclude that this apparent movement occurs as a result of the post-VAMP shoulder.

Factors that influence incidental take (i.e., loss that results from, but is not the primary purpose of, operation of the state and federal export facilities, presently estimated from daily salvage) of delta smelt at the pumps have not been definitively described. However, delta smelt take appears to increase with their relative abundance the previous fall, as indicated by the FMWT (compare Figures 1 and 3, and Table 2). All that can be said with certainty is that, in the three years in which the EWA has provided a post-VAMP shoulder (2001-2003), incidental take of delta smelt has not reached the reconsultation level (Table 3).

Incidental take of delta smelt exceeded the reconsultation level in the post-VAMP period (May) in 1996, 1999, and 2000, years of above-normal hydrology (Table 3). Had the appropriate tools existed in 1996, 1999, and 2000, a post-VAMP shoulder may have been appropriate, after due consideration of the decision criteria.



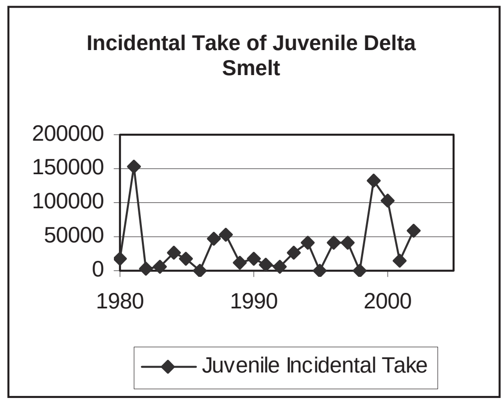


Figure 3 Trends in incidental take of delta smelt, calendar years 1980-2002.

Table 2 Coefficients of correlation for calendar years 1980-2002.

	Adult take[a]	*Juvenile take*[b]	*FMWT*	*FMWT-1*
Adult take	1			
Juvenile take	0.532954	1		
FMWT	0.141327	0.069574	1	
FMWT-1	0.673357	0.60474	-0.11846	1

[a] Estimated as the total incidental take for January, February, and March for a given year
[b] Estimated as the total incidental take for April, May, and June

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Table 3 Combined salvage of delta smelt at the South Delta Export Facilities since the 1995 USFWS Biological Opinion.

Year and Water Year Type	*1995 (AN[a])*	*1996 (AN)*	*1997 (AN)*	*1998 (AN)*	*1999 (AN)*	*2000 (AN)*	*2001 (BN[b])*	*2002 (BN)*	*2003 (BN)*	*Reconsultation Level*	
FMWT (year-1)	899	127	303	420	864	756	603	139	210	Below Normal	Above Normal
December	54	0	18	281	16	126	192	1,129	2,800	8,052	733
January	2,057	4,189	0	130	28	802	181	5,231	9,561	13,354	5,379
February	481	1,290	1,730	24	1,466	7,831	3,870	280	1,494	10,910	7,188
March	16	155	1,159	592	564	2,746	3,772	225	483	5,386	6,979
April	24	111	32,828	48	410	1,746	520	372	504	12,354	2,378
May	0	30,399	7,876	4	58,929	49,500	13,170	47,361	16,324	55,277	9,769
June	0	9,441	228	66	73,368	50,490	2,418	11,926	10,156	47,245	10,709
WY Total	2,632	45,733	43,931	1,269	154,651	70,216	24,466	66,548	41,334		

[a] Above-normal year as defined by the USFWS 1995 Biological Opinion on the effects of long-term operation of the Central Valley Project and State Water Project (USFWS 1995)

[b] Below-normal year (USFWS 1995)

Length-Weight Relationships for 18 Fish Species Common to the San Francisco Estuary

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Introduction

Historically, the Department of Fish and Game (DFG) has used abundance indices (a relative index that reflects the numbers of fish) from the Summer Townet Survey (TNS), Fall Midwater Trawl Survey (FMWT), and the San Francisco Bay Study (SFBS) to track the trends in abundance of various species in the San Francisco Estuary. Abundance indices are easy to calculate and can provide insight into the relationship between young fish abundance and important environmental variables, such as outflow (see Turner and Chadwick 1972 for an example with striped bass [*Morone saxatilis*], Stevens and Miller 1983 for examples with Chinook salmon [*Onchorhynchus tshawytscha*], American shad [*Alosa sapidissima*], longfin smelt [*Spirinchus thaleichthys*], and delta smelt [*Hypomesus transpacificus*]).

Despite their long usage, abundance indices have one drawback: each fish caught is treated as 1 unit regardless of size (length) or condition (the "well being" of a fish, Anderson and Neumann 1996). The relationship between fish length (routinely collected) and mass (traditionally referred to as weight in fisheries science) is nonlinear (Anderson and Neumann 1996). Abundance indices do not take this nonlinear aspect into account. Therefore, there may be biological relationships that abundance indices are incapable of revealing or explaining. The weight of a fish can be used to calculate two different indices: biomass and condition.

Biomass indices are another relative index reflecting the mass of a collection of fish (such as a year class) rather than numbers (as with abundance indices). Biomass indices can take into account the nonlinear nature of mass and, when used for trend analysis, could reveal relationships with important environmental variables (such as outflow, see above) that may not be detected using abundance indices.

Condition indices give an indication of the overall condition or "fatness" (or as Anderson and Neumann 1996 put it, "well being") of an individual fish, rather than a group of fishes. Condition indices are determined by dividing the actual weight of a fish by some reference weight (Anderson and Neumann 1996) for a given length. Therefore it is possible to determine the average condition index for a given year class or a subset of a year class, based on region for example. The mean condition index could then be related to environmental variables, such as prey density, to help deter-