Adaptive Management of Fall Outflow for Delta Smelt Protection and Water Supply Reliability

I. INTRODUCTION

In 2008, the US Fish and Wildlife Service (Service) issued a Biological Opinion (BiOp) on Central Valley Project (CVP)/State Water Project (SWP) operations that concluded that aspects of those operations jeopardize the continued existence of delta smelt and adversely modify delta smelt critical habitat. Among other requirements, the Reasonable and Prudent Alternative (RPA) that was issued with the BiOp calls for the adaptive management of fall Delta outflow (hereafter "Fall outflow") following "wet" and "above normal" water-years. The Service determined that the Fall outflow element of the RPA is required to alleviate both jeopardy to delta smelt and adverse modification of delta smelt critical habitat. The Fall outflow action is expected to improve habitat suitability and contribute to a higher average population growth rate of delta smelt.

The RPA prescription is expressed in terms of X2, the nominal location of the 2 ppt isohaline (Jassby et al. 1995). The RPA calls for Delta outflow to be managed such that fall X2 must average either 74 km or 81 km upstream from the Golden Gate during each of September and October, respectively, if the water year containing the preceding spring was classified as wet or above normal. There is an additional storage-related requirement to enhance outflow in November that does not have a specific X2 target. The RPA states that the performance of the action shall be investigated with a research and monitoring program containing a feedback loop allowing it to be adjusted from learned information (i.e., adaptive management).

At the time the BiOp was issued, the Bureau of Reclamation (Reclamation) responded with a "provisional acceptance" letter. In 2009-10, Reclamation and the Service developed and initiated a package of studies designed to increase understanding about Fall X2 and support a passive form of adaptive management.

Reclamation has further reviewed the science underlying the Fall outflow requirement in order to better understand the uncertainties and to consider how efficient adaptive management might proceed. Based on those considerations, and because the costs of implementing the Fall outflow action are high, Reclamation has drafted a framework for active adaptive management. By adopting a more aggressive, active approach, Reclamation hopes to achieve more rapid learning – thereby finding the best and most efficient action faster – while alleviating adverse modification of delta smelt critical habitat and avoiding jeopardy.

The adaptive management plan includes a description of how adaptive management works and how an aggressive scientific studies element can responsibly be incorporated into it, a statement of management goals, and a draft of the set-up elements. Since a starting point for the management is logically required, Reclamation has reviewed the rationale for the action and considered initial management alternatives.

This plan implements critical recommendations made by the National Academies of Science panel in its March 2010 report (available at http://www.nap.edu/catalog.php?record_id=12881). By laying out a framework for rigorous, science-based adaptive management, we hope the plan will enable us to learn what we need to know about the effects of Fall outflow, so that the most appropriate conservation action can be identified and implemented at lowest possible water cost.

We have addressed a number of questions, issues, and recommendations made by various stakeholders and the California Department of Water Resources. Their advice was solicited in order to help improve the quality and implementability of this plan. Reclamation appreciates the constructive input that was received.

This plan is designed to formalize and strengthen the adaptive management process that was begun with the 2010 draft studies plan. It will require ongoing development during implementation. The plan presented here provides a framework for work that is to follow. We are completing plans for augmented monitoring first, in order to place crews in the field annually beginning this year. We expect development and implementation of the more difficult modeling components to occur on an ongoing basis.

This plan deals with only one aspect of the broad issue of Delta outflow. As one of the primary determinants of the characteristics of the ecosystem, Delta outflow patterns are important year-round, and affect many species. Delta outflow is a topic of discussion in several ongoing public processes, including the Bay-Delta Conservation Plan development, the Delta Stewardship Council's Delta Plan development, the State Water Resources Control Board's Delta Flow Criteria proceedings, and the Environmental Protection Agency's advance notice of proposed rulemaking for water quality issues in the Bay-Delta. We expect that as these processes move forward, linkages and interactions that arise between fall outflow management for delta smelt and other aspects of outflow management will be addressed as circumstances and Reclamation's regulatory obligations require.

II. Background

A. Delta smelt

Delta smelt is undoubtedly the most estuary-dependent native fish species that lives in the San Francisco Estuary (Moyle et al. 1992; Bennett 2005). Most delta smelt complete the majority of their annual life cycle in the low salinity zone (LSZ) of the estuary and use the freshwater portion of the estuary only for spawning and juvenile rearing (Figure 1; Dege and Brown 2004, Bennett 2005). Because it is endemic to the San Francisco Estuary, the continued existence of the species is dependent upon its ability to successfully grow, develop, and survive in the LSZ.

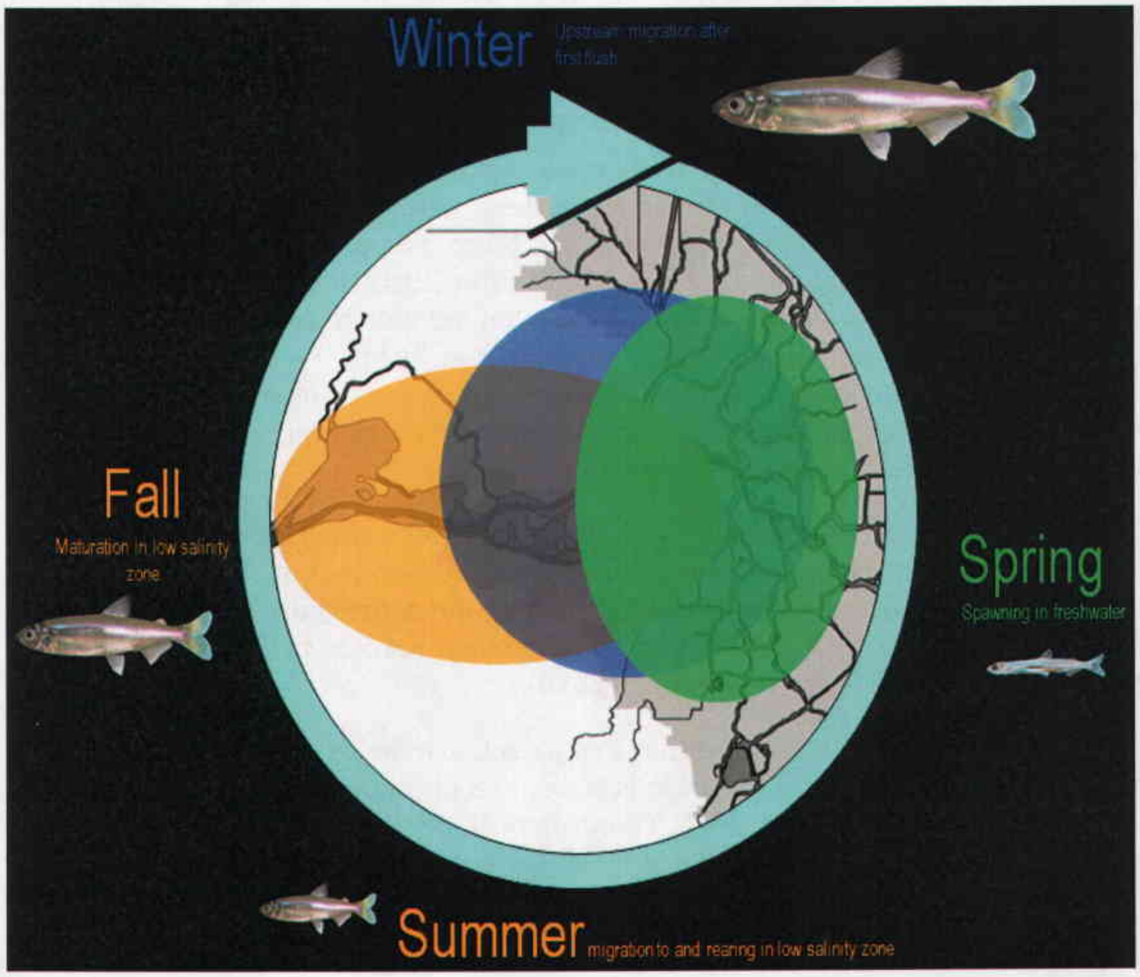

Figure 1. Simple conceptual diagram of the delta smelt life cycle (modified from Bennett 2005).

Delta smelt distribution and life history was first described by Moyle et al. (1992). A number of recent studies have examined delta smelt habitat use in more detail.

Bennett (2005) described general patterns of delta smelt habitat use by life stage. Dege and Brown (2004) described the effects of outflow on the distribution of larval and young juvenile delta smelt and noted the initial upstream and eventual close association between young delta smelt distribution and X2. Feyrer et al (2007, 2010) described the habitat associations of delta smelt during fall months (September-December) based on forty years of sampling data collected by the Fall Midwater Trawl Survey. Nobriga et al. (2008) described habitat associations during summer months (June-July) based on the forty plus years of sampling data collected by the Summer Townet Survey. Kimmerer et al. (2009) expanded on these studies by examining the habitat associations of delta smelt for each of the major IEP fish monitoring surveys. Finally, Sommer et al. (2011) examined delta smelt distribution shifts from fall through the spring months. Together, these studies demonstrate that most delta smelt reside in the low salinity zone in the summer and fall, with a center of distribution at approximately the 2 psu isohaline, but move upstream during winter and spring months when spawning and early development occur in freshwater.

Sommer et al. (2011) also noted the year-round presence of delta smelt in an upstream freshwater region of the system in the general Cache Slough/Sacramento Deep Water Shipping Channel, suggesting that there is a portion of the delta smelt population that may not utilize the low salinity zone. Historically, delta smelt were also present in the south Delta in the summer, but are now found there only in the winter and spring (Nobriga et al. 2008, Sommer et al. 2011). Fisch (2011) determined that individuals collected from this region were not genetically unique relative to delta smelt captured from other regions of the system; rather, there is a single, panmictic delta smelt population in the estuary.

Against a background of highly variable abundance, delta smelt have suffered a long-term abundance decline (Figure 2; USFWS 2008, Sommer et al. 2007; Thomson et al. 2010). The decline spans the post-1966 portion of the "post-reservoir period" described in Baxter et al. (2010) and was particularly marked in the "POD [Pelagic Organism Decline] period" (Baxter et al. 2010).

Long term trend analyses confirm that a step decline in pelagic fish abundance marks the transition to the POD period (Manly and Chotkowski 2006, Moyle and Bennett 2008, Mac Nally et al. 2010, Thomson et al. 2010, Moyle et al. 2010) and may signal a rapid ecological regime shift in the upper estuary (Moyle et al. 2010, Baxter et al. 2010).

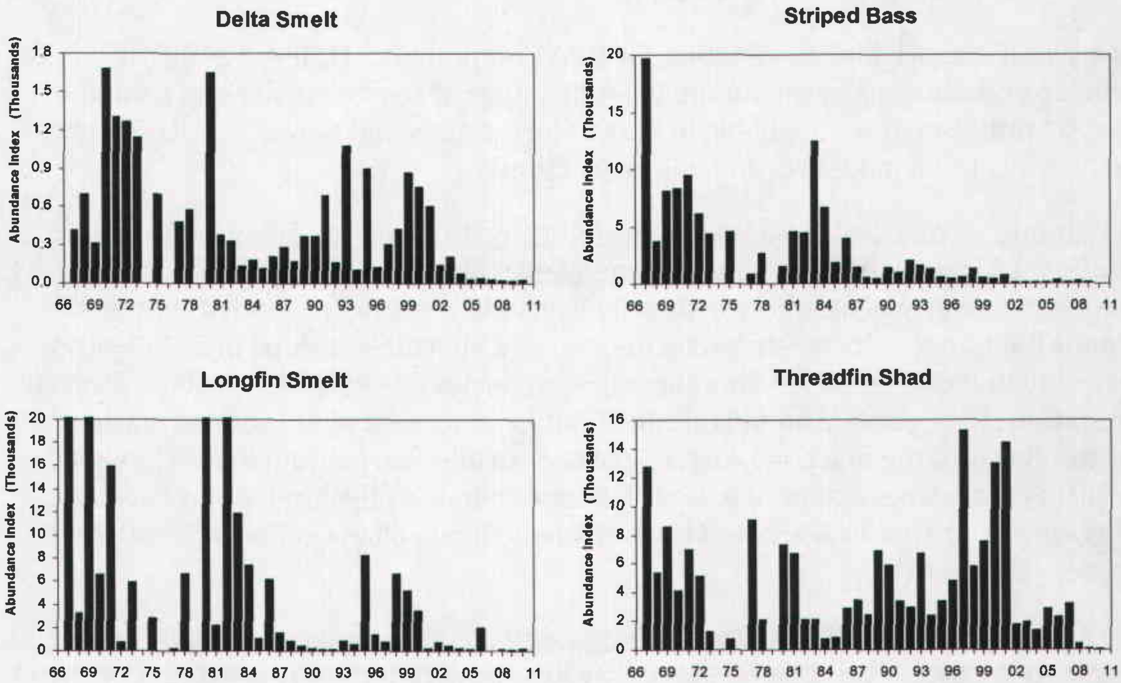

Figure 2. Trends in abundance indices for four pelagic fishes from 1967 to 2010 based on the Fall Midwater Trawl, a California Department of Fish and Game survey that samples the upper San Francisco Estuary. No sampling occurred in 1974 or 1979 and no index was calculated for 1976. Note that the y-axis for longfin smelt represents only the lower 25% of its abundance range to more clearly portray the lower abundance range.

The decline of delta smelt has been intensively studied as part of the POD investigation (Baxter et al. 2010; Sommer et al. 2007). The POD investigators have concluded that among several causes habitat degradation predominates.

> "We hypothesize that degradation of habitat is the fundamental cause of delta smelt decline and that it affects the species mainly through effects on growth and subsequent reproductive potential rather than immediate mortality. Both abiotic and biotic aspects of habitat suitability have declined over time. This has led to smaller, less healthy adults, which have lower per capita fecundity. These ecosystem challenges have probably been exacerbated by periodic high entrainment loss. We hypothesize that habitat degradation has reduced carrying capacity. Thus, entrainment losses at historical levels could have increased in importance because the population is smaller. Large-scale water diversion may also influence delta smelt carrying capacity through seasonal effects on Delta outflow" (Baxter et al. 2010, p. 54).

B. The 2008 Outflow RPA Action

As we read the original explanation for RPA Component 3 (USFWS 2008), it develops conclusions based on the following lines of reasoning derived from the best scientific analyses available in 2008. More details and newer results are given in the conceptual model section below (Section 4).

(1) Abiotic, or physical habitat used by delta smelt during the fall months has diminished in availability because of changes in water project operations. An analysis of historical monitoring data by Feyrer et al. (2007) revealed that the abiotic habitat of delta smelt can be defined as a specific envelope of salinity and turbidity that changes over the course of the species' life cycle. Over time, project operations have pushed and maintained fall X2 upstream of the wide expanse of Suisun Bay into the much narrower Sacramento and San Joaquin River channels, reducing the spatial extent of habitat falling within the physical habitat envelope. This may be further exacerbated by predicted climate change effects (USBR 2008; Feyrer et al. 2011).

(2) There is a discernible effect of good-quality abiotic habitat availability and delta smelt abundance. Fall habitat suitability has shown a long-term decline (Feyrer et al. 2007). Variation in abiotic habitat variables in the fall explained about 20% of the variance in subsequent juvenile abundance.

(3) The BiOp also asserted that restricted habitat area is likely to increase the probability that stochastic, localized, catastrophic events might affect a large fraction of the population.

The BiOp concluded that an outflow action was needed to (1) alleviate adverse modification of delta smelt critical habitat, and (2) avoid jeopardizing the continued existence of delta smelt. Based on the analysis contained in the BiOp and RPA, Component 3 of the RPA set requirements that X2 average 74 km in each of September and October following wet years and 81 km in the same months following above normal years "to mitigate the effects of X2 encroachment upstream in current and proposed action operations, and provide suitable habitat area for delta smelt" (BiOp page 373). Component 3 also includes a storage pass-through requirement in November. The effect of the November requirement is to enhance outflow above what the projects would normally provide when there is early precipitation, but does not require that a specific X2 objective be met.

The RPA also called for the adaptive management of the fall action, and prescribed that a team be convened to develop and implement a plan. The team, which became known as the Habitat Study Group (HSG), first convened in 2009. The HSG developed a package of studies to support fall outflow management, and completed a draft report of its activities in 2010. With Reclamation funding, the HSG studies were begun in 2010 under the administration of the Interagency Ecological Program (IEP) as part of the IEP POD investigation (Baxter et al. 2010).

C. Review of RPA Action

We have reviewed the basic rationale provided in the BiOp, bringing to bear information that has become available since the BiOp was completed. New information includes the 2010 POD synthesis (Baxter et al 2010), some newly published studies bearing directly on outflow effects and other issues, preliminary results from ongoing studies, commentaries from several review panels, complaints about the RPA that were raised by the State and Federal water contractors in letters and in litigation, and commentaries by DWR and NRDC that were provided to us in May 2011.

The main questions Reclamation asks in this review are the following. What kind of action seems appropriate, given the present array of available information? What are the most important specific uncertainties that affect management decisions pertaining to Fall Outflow?

We consider the available information in five sections, each of the last four building on those before it: (1) delta smelt habitat; (2) X2 as a surrogate for delta smelt habitat; (3) evidence for associations between habitat and abundance; (4) Delta hydrology, X2 and delta smelt habitat in the fall; and (5) the specific X2 action prescribed in the BiOp. Additional details are provided in the conceptual model section below (Section 4).

(1) Delta smelt habitat

As described above, seasonal movements and use of habitat by delta smelt have been captured by IEP long-term monitoring studies and reported in multiple studies (Moyle et al. 1992, Dege and Brown 2004, Bennett 2005, Feyrer 2007, Nobriga et al. 2008, Sommer et al. 2011). Two studies (Feyrer et al. 2007; 2011) have characterized the abiotic habitat of delta smelt using the Fall Midwater Trawl (FMWT) data set. Since 1967, the FMWT has trawled at 100+ fixed stations across the estuary each month from September through December. We have assumed, as Feyrer and colleagues did, that what constitutes suitable abiotic habitat in the POD period is the same as what constituted abiotic habitat during the post-reservoir period. Feyrer et al. (2007; 2010) found that delta smelt inhabit a wide range of salinity and turbidity levels, but the probability of observing a delta smelt is greatest at low salinities, centering on about 2 psu, and at relatively high turbidity levels. They analyzed the FMWT data using a generalized additive modeling approach, which is a commonly-used tool in ascertaining the habitat associations of fishes and other organisms. Generally, the method is a semi-parametric extension of a generalized linear model and is effective for describing non-linear relationships between predictor and response variables. The same method was used by Nobriga et al. (2008) and Kimmerer et al. (2009) in their studies of delta smelt habitat.

Sommer et al. (2011) found that one measure of smelt distribution, the center of distribution, is strongly correlated with X2 (Figure 3. see also Dege and Brown 2004) during the fall months (Figure 3). These relationships appear surprisingly robust even though the FMWT survey has been criticized for not sampling with respect to the tide (see conceptual model (Section 4) below for more details about implications).

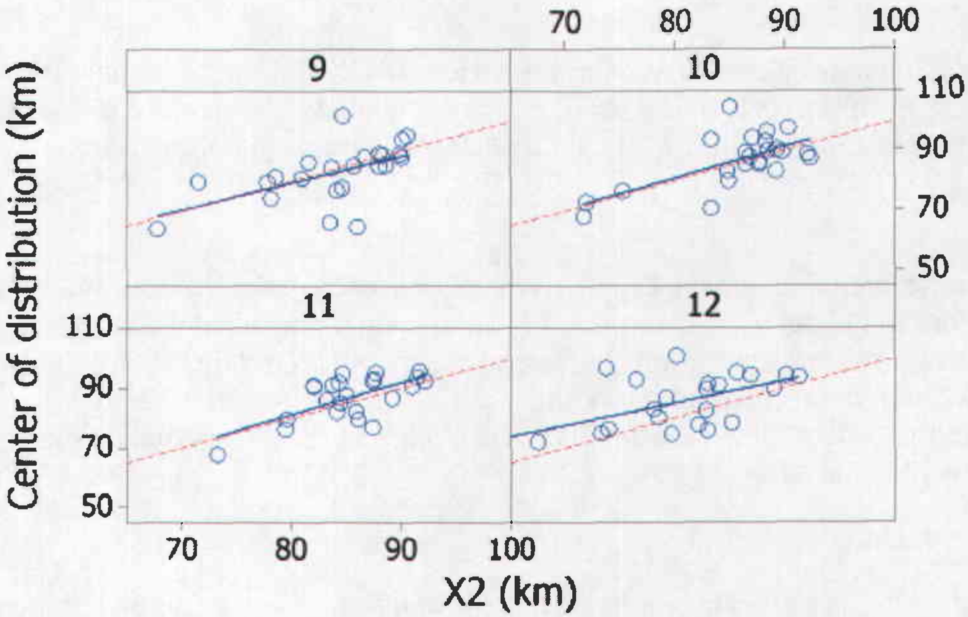

Figure 3. Center of delta smelt distribution during the fall months plotted against X2. Figure is from Sommer et al. (2011, their Figure 3) which has the following caption: "Monthly distribution of adult delta smelt in relation to salinity for the FMWT survey. The fish distribution data represent the centroid of the distribution from the FMWT (Dege and Brown 2004). Salinity is based on X2, the location of the 2-psu isohaline (Jassby and others 1995). The units for each data series represent the distance in kilometers from the Golden Gate Bridge. Hence, smaller values represent a seaward location and larger values represent a landward location. The red dotted lines show when the centroid and X2 values are equal. Centroid values above the red line represent fish distributions upstream of X2: centroid values below the line represent distributions downstream of X2. The blue lines show the fitted lines for the data, based on GLMs."

One issue that we cannot tackle in time to inform this document, but will be addressing as we proceed, arises from the fact that the FMWT samples at fixed geographical points without reference to the phase of the tides. The FMWT