U.S. Fish and Wildlife Service's Biological Opinion on the Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)

A retrospective analysis of water operations and delta smelt protective actions taken in early Water Year 2013

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List of Abbreviations and Acronyms

BiOp	Central Valley Project/State Water Project Long-term Operations Biological Opinion
CDWR	California Department of Water Resources
cfs	Cubic Feet per Second
CVP	Central Valley Project
DCT	Delta Conditions Team
DSM2	Delta Simulation Model, a one-dimensional numerical model that simulates non–steady state hydrodynamics in a network of riverine and estuarine channels
FMWT	Fall Midwater Trawl
HOL	Station name of the river gauge located on the Old River at Holland Cut, BiOp RPA turbidity criteria station
IRP	Independent Review Panel
ITL	Incidental Take Limit
NTU	Nephelometric Turbidity Units
OMR	Old and Middle River Flow (combined, in cubic feet per second)
RMA	Resource Management Associates

PPT	Station name of the river gauge located on the lower San Joaquin River at Prisoners Point, BiOp RPA turbidity criteria station
Projects	Central Valley Project and State Water Project
Reclamation	U.S. Bureau of Reclamation
RPA	Reasonable and Prudent Alternative
Service	U.S. Fish and Wildlife Service
SRH	Station name of the river gauge located on the Sacramento River at Hood
SRV	Station name of the river gauge located on the Sacramento River at Rio Vista
SWG	Smelt Working Group
SWP	State Water Project
VCU	Station name of the river gauge located at Victoria Canal in the south Delta; BiOp RPA turbidity criteria station
WOMT	Water Operations Management Team, composed of state and federal agency managers
WY	Water Year (October 1 – September 30)
X_2	Distance from Golden Gate Bridge to the two parts per thousand isohaline

Executive Summary

In December 2012, U.S. Fish and Wildlife Service (Service) called for the implementation of the Reasonable and Prudent Alternative Action 1 of the Biological Opinion on the Coordinated Operations of the Central Valley Project and State Water Project (Projects) (BiOp). The events that led to the Service's call for Action 1 are consistent with both the current understanding of delta smelt biology, and are incorporated into the effects analysis of the BiOp.

Throughout their lives, delta smelt remain in close association with turbid water, and are cued to begin a spawning movement from the Sacramento-San Joaquin river confluence area in response to increasing freshwater flow from winter precipitation. Therefore, delta smelt may follow a pathway of turbid water into the central and south Delta during these winter storms. The Sacramento Valley experienced high levels of precipitation in late November and early December 2012. Sacramento River flows increased soon thereafter, bringing an influx of fresh and turbid water into the Delta.

The hydrodynamic influence of Projects' pumping on Delta waterways is indexed well by the net flow in Old and Middle rivers (OMR); the more negative the OMR flows, the higher the risk of delta smelt entrainment. In December 2012, Projects' exports were high, and average daily OMR flows were averaging at approximately -7,800 cfs. As expected, delta smelt began to be salvaged soon after the winter storm on December 12, 2012, and the Service called for the implementation of Reasonable and Prudent Alternative (RPA) Action 1 on December 17, 2012.

Action 1 is designed to prevent movement of turbid water and adult delta smelt into the south and central Delta by limiting exports such that OMR flows be no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25%). As a result, salvage decreased after implementation of Action 1, though turbidity did not. The elevated central and south Delta turbidity likely enabled some delta smelt to stage and spawn in the San Joaquin River and possibly some south Delta channels as well.

Delta smelt remained in the south and central Delta after implementation of Action 1. Delta smelt salvage continued into January and February, which required implementation of subsequent delta smelt protective actions throughout the remainder of the delta smelt entrainment season. The actions were successful in keeping the Projects under their Incidental Take Limit, though they also resulted in a reduction in the Projects' ability to export water.

Having implemented Action 1 for the first time in water year (WY) 2013, the Service is interested investigating opportunities to fine-tune the onset criteria to provide greater or equal protection to delta smelt, while potentially affording the Projects increased flexibility in management of water operations and possibly increased water deliveries through the remainder of the WY.

The Service is working with our partners and stakeholders to review WY 2013 and evaluate if different scenarios of OMR management other than what is specifically prescribed in RPA Action 1 could have resulted in increased water deliveries through the remainder of the WY, while still affording equal protection for delta smelt throughout the adult entrainment season. The Service expects the collaborative investigation that is underway will make considerable progress during the coming months, and is asking the Independent Review Panel (IRP) for feedback on our evaluation of a more aggressive and preemptive implementation of Action 1. The Service expects to continue in this effort, and expects to provide the IRP with more comprehensive analysis next year.

Questions for the IRP's consideration:

1. How well did implementation of RPA Action 1 meet the intended purpose of the Action?
2. How can implementation of RPA Action 1 be adjusted to more effectively meet its objectives?

Introduction

The U.S. Fish and Wildlife Service (Service) is evaluating the implementation of the Reasonable and Prudent Alternative (RPA) Component 1, Action 1of its Long-term Operations Biological Opinion to the Central Valley Project and State Water Project (Projects) (BiOp) in WY 2013. In addition, the Service is reviewing the onset criteria associated with Action 1 to determine if there are opportunities to incorporate efficiencies that provide greater or equal protection to delta smelt, while affording the Projects the ability to better manage water operations and possibly increase water deliveries through the remainder of the delta smelt entrainment season.

Biological Background

During the fall, most delta smelt rear in the estuary's low-salinity zone and the turbid waterways around the lower Yolo Bypass, particularly Liberty Island and the adjacent reach of the Sacramento Deepwater Shipping Channel (Figure 1, Sommer et al. 2011; Sommer and Mejia 2013). During the winter, sexually immature delta smelt disperse toward spawning habitats from the Sacramento-San Joaquin river confluence area in response to increasing freshwater flow from winter precipitation ("first flush," Bergamaschi et al. 2001). These fish will stage near spawning habitats while their gametes ripen in preparation for spawning, which typically occurs between February and May (Bennett 2005; Rose et al. 2013). Spawning locations vary based upon freshwater discharge (Hobbs et al. 2005; 2007). In high freshwater discharge years, spawning is more widely distributed throughout the Delta, Suisun Marsh, and downstream into the Napa River; in low freshwater discharge years, spawning tends to be concentrated in the Delta east of Chipps Island.

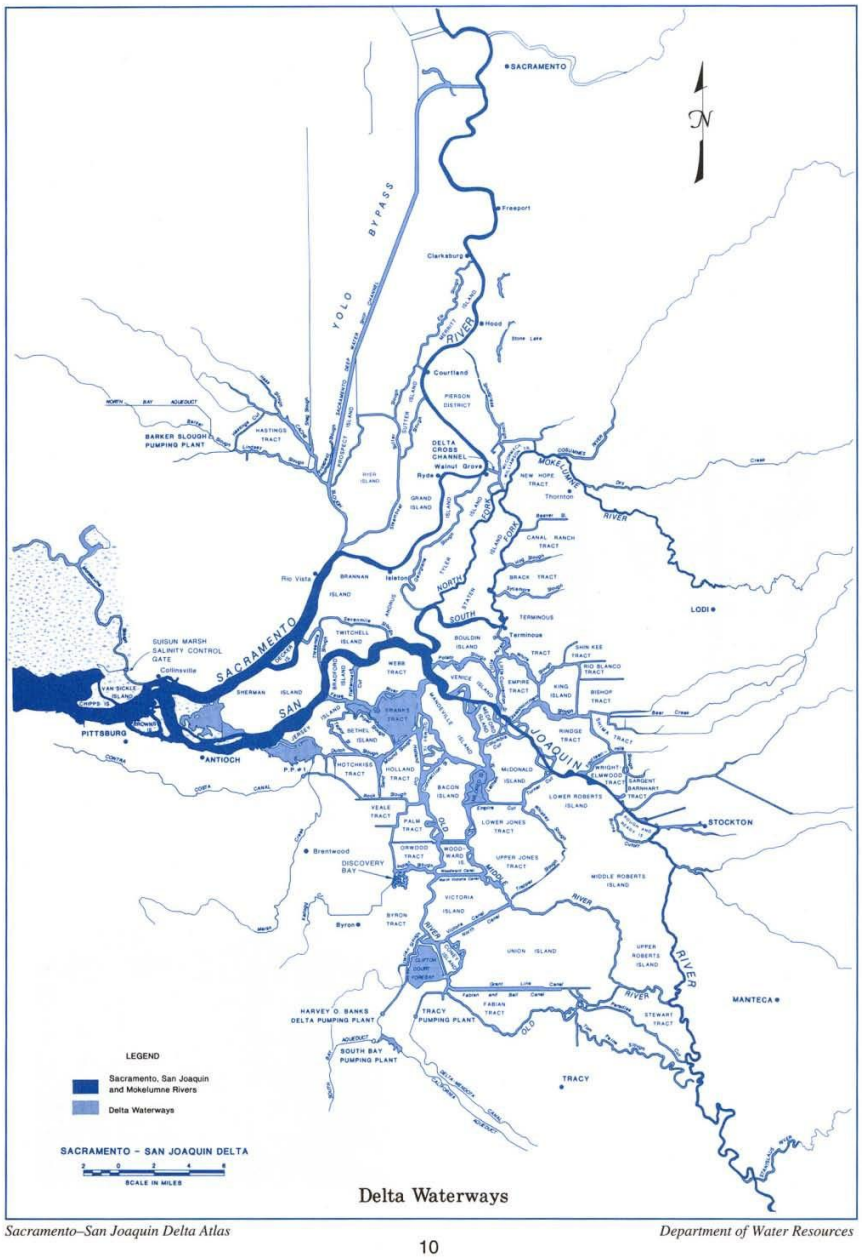

Figure 1. The Sacramento-San Joaquin Delta.

Delta smelt become vulnerable to entrainment when pre-spawn adults move upstream from the Sacramento-San Joaquin river confluence into the San Joaquin River and the south Delta. The risk of entrainment increases the closer the fish get to the south Delta pumping plants (Kimmerer and Nobriga 2008; Kimmerer 2008). The proportion of the adult population that migrates into the central and south Delta varies from year to year, but is highest in years like 2012-2013 when the first flush distributes turbidity throughout the Delta waterways and particularly when

southward transport of the fish is facilitated by negative OMR flows. The best available estimates of the proportion of adult delta smelt entrained are estimated to have varied from 3% to 38% from 2002 to 2006 (Kimmerer 2008 as modified by Kimmerer 2011).

Delta smelt that are entrained by the Projects' pumps may pass though the Projects' fish salvage facilities, where salvaged fish are identified and counted (Brown et al. 1996). An index of total entrainment is calculated by extrapolating these catch data from the subsample of water sampled for fish counts by the total volume of water diverted during that sample period. Historically, the peak salvage of adult delta smelt occurs during the month of January (Grimaldo et al. 2009). However, the timing and magnitude of salvage is highly variable and heavily dependent upon hydrodynamic conditions occurring coincident with migration and delta smelt abundance (Deriso 2011).

When Project exports are high coincident with the first flush of turbid [>12 Nephelometric Turbidity Units (NTU)] freshwater into the Delta, salvage of pre-spawn adult delta smelt can be very high. This occurred in WYs 1993 and 2003. In other years, there are no large salvage spikes, but entrainment continues over a relatively long duration resulting in high overall cumulative salvage. Alternatively, there may be multiple entrainment spikes in years where the timing of migratory cues is diffuse or occurs in episodes. Examples of such entrainment years would include WYs 2004 and 2005.

Regulatory Background

Reasonable and Prudent Alternative

The BiOp's RPA has five components that address both direct and indirect mortality of adult and juvenile delta smelt (Table 1). The RPA components are designed to prevent and reduce entrainment of delta smelt at the Projects' fish salvage facilities; provide adequate habitat conditions that allow adult delta smelt to successfully migrate and spawn in the Delta; provide adequate habitat conditions that will allow larvae and juvenile delta smelt to rear; and provide suitable habitat conditions that will allow successful recruitment of juvenile delta smelt to adulthood.

Table 1. The RPA incorporates 5 components that address Projects' effects on delta smelt and its critical habitat.

Component 1	Protection of the adult delta smelt life stage
Component 2	Protection of larval and juvenile delta smelt
Component 3	Improve habitat for delta smelt growth and rearing
Component 4	Habitat restoration
Component 5	Monitoring and reporting

The three actions of RPA Components 1 and 2 are implemented and managed adaptively using specific onset and offramp criteria (Table 2). Actions 1 and 2 are designed to protect adult delta

smelt from entrainment, and Action 3 is designed to protect larval and juvenile delta smelt from entrainment. These protections are afforded through the setting of target Old and Middle River (OMR) flow requirements to protect delta smelt from being entrained into the south and central Delta, and ultimately to the Projects. The Service employs technical experts to evaluate the risk of delta smelt entrainment when determining OMR flow requirements.

Table 2. Component 1 and Component 2 of the BiOp's RPA

		Objective	Trigger	Timing	OMR Flows
Component 1	**Action 1 (a)**	A fixed duration action to protect pre-spawning adult delta smelt from entrainment during the first flush and to provide advantageous hydrodynamic conditions early in the migration period.	SWG may recommend a start date	Dec 1 to Dec 20	-2,000 cfs
	Action 1 (b)		Turbidity or Salvage	Dec 20 to Action 2	
	Action 2	An action implemented using an adaptive process to tailor protection to changing environmental conditions after Action 1. As in Action 1, the intent is to protect pre-spawning adults from entrainment and, to the extent possible, from adverse hydrodynamic conditions	The end of Action 1 or (if Action 1 is not triggered), the SWG may recommend a start date	Immediately following Action 1	-1,250 to -5,000 cfs
Component 2	**Action 3**	Minimize the number of larval delta smelt entrained at the facilities by managing hydrodynamics in the central Delta flow levels pumping rates spanning a time sufficient for protection of larval delta smelt. The action is adaptive and flexible within appropriate constraints	Temperature or Onset of Spawning	Upon meeting trigger criteria	

Component 1, Action 1

Action 1 is a fixed duration action designed to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period. Action 1 has two elements (Part A and Part B), differentiated only by timing and criteria for implementation; hard criteria are specified for Part B, only (Table 3).

Table 3. Action 1: Adult migration and entrainment during the first flush.

		Timing	Criteria
Action 1	Part A	December 1 to 20	Based upon an examination of turbidity data from Prisoners Point, Holland Cut, and Victoria Canal and salvage data from CVP/SWP, and other parameters important to the protection of delta smelt including, but not limited to, preceding conditions of X_2, FMWT, and river flows; the SWG may recommend a start date to the Service. The Service will make the final determination.
	Part B	After December 20	The action will begin if the 3-day average turbidity at Prisoners Point, Holland Cut, and Victoria Canal exceeds 12 NTU. However, the SWG can recommend a delayed start or interruption based on other conditions such as Delta inflow that may affect vulnerability to entrainment.

The interaction of flow, turbidity, temperature, and season leads to migration patterns that are difficult to predict yearly and first flush salvage events are variable in any given WY. Action 1 is designed to provide flexibility and maximum protection for delta smelt and is based on Delta conditions rather than a specific date. Part A of Action 1 covers the period (December 1 to December 20) when first flush salvage events have been historically uncommon. Part B of Action 1 (after December 20) covers a period when first flush salvage events have been historically more common. Part B is triggered when turbidity increases above 12 NTU. The Service can bypass implementation of the trigger if it is determined that the triggered conditions are unlikely to initiate smelt migration (eg. wind-induced turbidity).

The Smelt Working Group

The Smelt Working Group (SWG) is a fisheries technical team that evaluates biological and technical issues regarding delta smelt entrainment risk and develops recommendations for consideration by the Service. The SWG meets regularly during December through June, which is historically when delta smelt salvage has occurred. If the SWG agrees that a protective action is warranted after evaluating the suite of real time data that are important to the protection of delta smelt, including delta smelt distribution and developmental stage field data, delta smelt salvage data, current Delta hydrodynamic conditions, and projected operations, the group will submit a recommendation for protective action to the Service.

The Delta Conditions Team

The Delta Conditions Team (DCT) consists of scientists and engineers from state and federal agencies, water contractors, and environmental groups. This group meets regularly to review the real time operations and Delta conditions, including data from new turbidity monitoring stations and new analytical tools such as the Delta Simulation Model 2 (DSM2) turbidity simulation model, and the delta smelt behavior model developed by Resource Management Associates, Inc. (RMA). The DCT supplied the DSM2 turbidity forecast modeling results to the Service and SWG in WYs 2012 and 2013 for use in assessing delta smelt entrainment risk.

Service Determination
The Service reviews the recommendation of the SWG and the advice of the DCT as it considers if a protection action is necessary under RPA Component 1 and Component 2. If the Service agrees that a protective action is necessary, it will present a draft determination to the Water Operations Management Team (WOMT), which is composed of state and federal agency managers. The Service incorporates input from the WOMT, and issues the final determination to the U.S. Bureau of Reclamation (Reclamation) and California Department of Water Resources (CDWR) for implementation by the end of that day. For a summary of SWG recommendations and Service determinations from WY 2013, refer to http://www.fws.gov/sfbaydelta/cvp-swp/smelt_working_group.cfm.

Incidental Take Limit
In the BiOp, the Service calculated expected salvage levels due to Projects operations under the RPA, using historic salvage from 2006 through 2008, when similar water operations were in effect. The Service calculated a Cumulative Salvage Index (CSI) for each of the three years by dividing observed salvage by the previous fall midwater trawl (FMWT) index. The CSI was averaged across the years 2006 to 2008. Estimated salvage in any given year is expected to vary as a function of population size; therefore, take is calculated using a multiplier of the average CSI * the FMWT index for each water year.

On February 15, 2013, the Service was notified that the BiOp included incorrect historic salvage data in the calculation of the ITL, and on February 22, 2013 issued a memo providing the correction (see http://www.fws.gov/sfbaydelta/documents/memorandum_ocap_incidental_take_statement_correction_2013-02-22.pdf). Prior to February 22, the adult delta smelt take number for WY 2013 was reported to be 305 individuals. With the correction to the ITL calculation, the WY 2013 adult delta smelt take number was revised to 362 individuals.

Statement of Interest
Between November 25 and December 18, 2012, Projects' exports were producing OMR flows between -4,550 cfs and -9,400 cfs, (average was approximately -7800 cfs). At the same time, large storms caused a first flush of turbidity that was quickly distributed widely throughout the Delta (Figure 2 and Figure 3). The Service called for implementation of RPA Action 1 on December 17, 2012 to protect pre-spawning adult delta smelt from entrainment. This was the first time that Action 1 of the RPA had been implemented.

The Service has reviewed its implementation of Action 1 in December 2012, and is interested in identifying potential adjustments to the action and implementation procedures, as is described in the BiOp (p 279):

> The specific flow requirements, action triggers and monitoring stations prescribed in the RPA will be continuously monitored and

> evaluated consistent with the adaptive process. As new information becomes available, these action triggers may be modified without necessarily requiring re-consultation on the overall proposed action.

The Service is leading an investigation of the onset criteria for Action 1 to determine if it could be improved such that efficiencies are created in both the provision of protection to delta smelt, and also in the enhanced management of water deliveries through the remainder of the WY. As part of this evaluation, the Service has requested input and assistance from the DCT to conduct an analysis of turbidity forecasting simulations to model Delta conditions in December 2012. Preliminary results of these simulations are presented in this report.

The primary focus of the Service's report to the Independent Review Panel (IRP) is to provide a review of water operations and delta smelt actions taken in December 2012, and request feedback on some preliminary assessments to determine if earlier OMR management would have afforded equal or greater protection for delta smelt throughout the adult entrainment season while allowing increased water deliveries through the remainder of the WY.

<u>Questions to the IRP</u>

1. How well did implementation of RPA Action 1 meet the intended purpose of the Action?
2. How can implementation of RPA Action 1 be adjusted to more effectively meet its objectives?

The Service expects the collaborative investigation that is underway to make considerable progress during the coming months, and will be developing a more comprehensive analysis to present to the IRP next year. At this time, the Service is asking if the IRP agrees that the physical science modeling results support the direction the scientific inquiry is taking.

Review of Implementation of Action 1 in WY 2013

The Sacramento Valley received heavy precipitation during three early winter storms from late November through the end of December (Figure 2). Sacramento River flows increased soon after the late-November to early-December storm, bringing an influx of freshwater into the Delta. During this time, combined daily Projects exports averaged near 10,000 cfs, resulting in highly negative OMR flows (Figure 3).

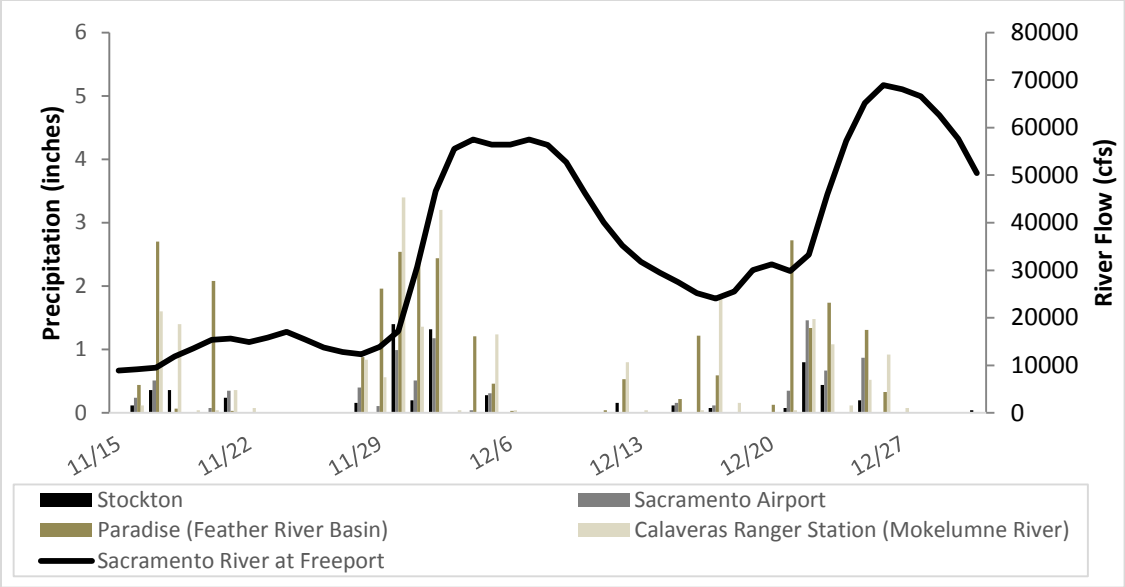

Figure 2. Precipitation (in inches) at locations in the Sacramento Valley and Sacramento River flow at Freeport from November through December 2012

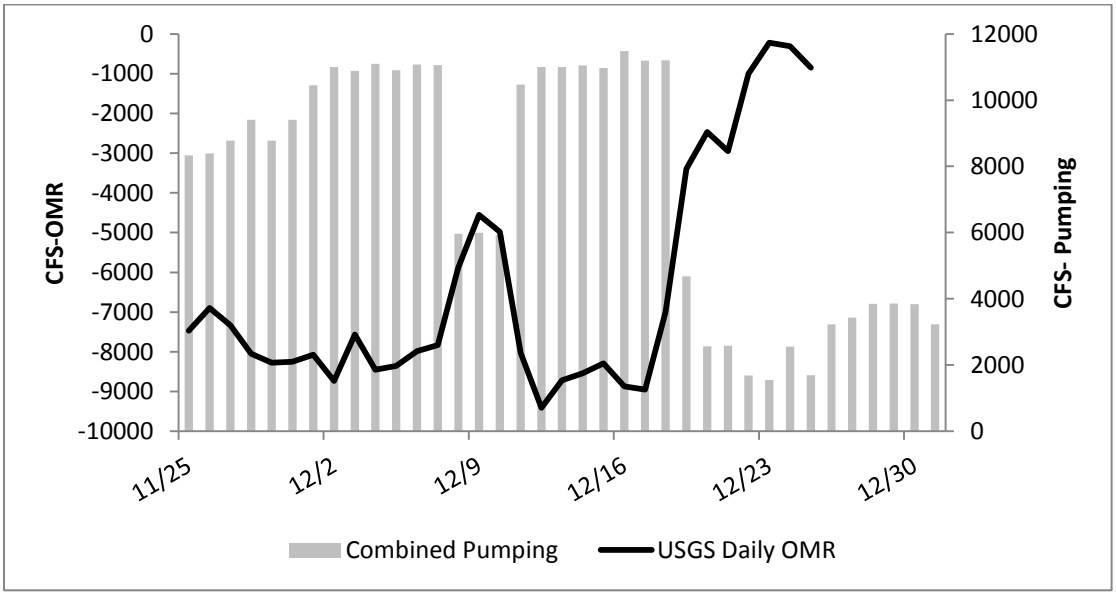

Figure 3. Combined Projects' pumping and daily average Old and Middle River (OMR) flows from late November to the end of December.

In early December, the Service and the SWG begin to monitor Delta conditions from these early winter storms. The high flow observed on the Sacramento River at Freeport from the late November mid-December storm, resulted in correspondingly high turbidities in the lower Sacramento River (Figure 4). In addition to the turbidity readings at the Action 1 criteria stations Prisoners Point, Holland Cut, and Victoria Canal, (Figure 5), the SWG also monitored turbidity gauge stations throughout the south and central Delta to obtain a better picture of Delta-wide

turbidity. It was apparent that these early December storms were generating a first flush event, and that entrainment of adult delta smelt into the south and central Delta was extremely likely given the negative OMRs (see http://www.fws.gov/sfbaydelta/cvp-swp/smelt_working_group.cfm for a complete list of SWG recommendations).

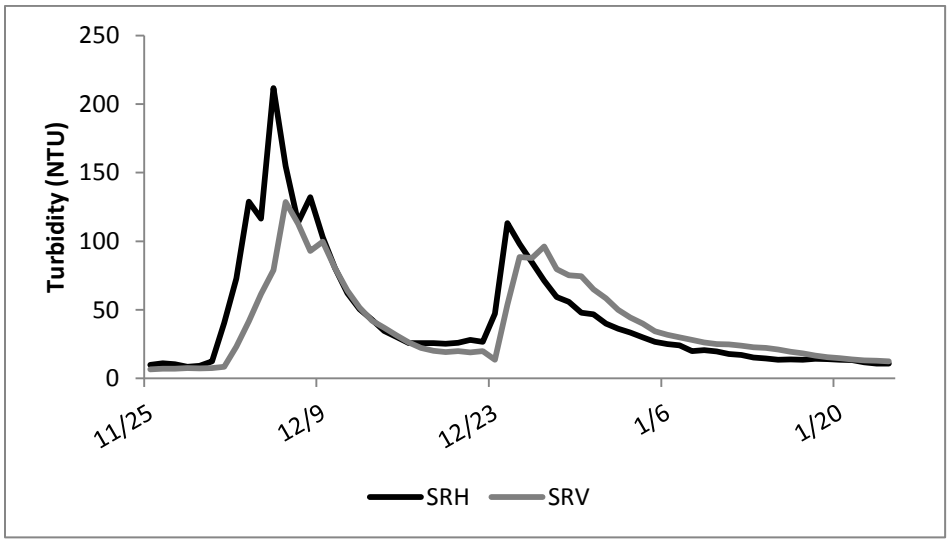

Figure 4. Turbidity data, in NTUs, from the gauge at Hood (SRH) and Rio Vista (SRV) on the Sacramento River

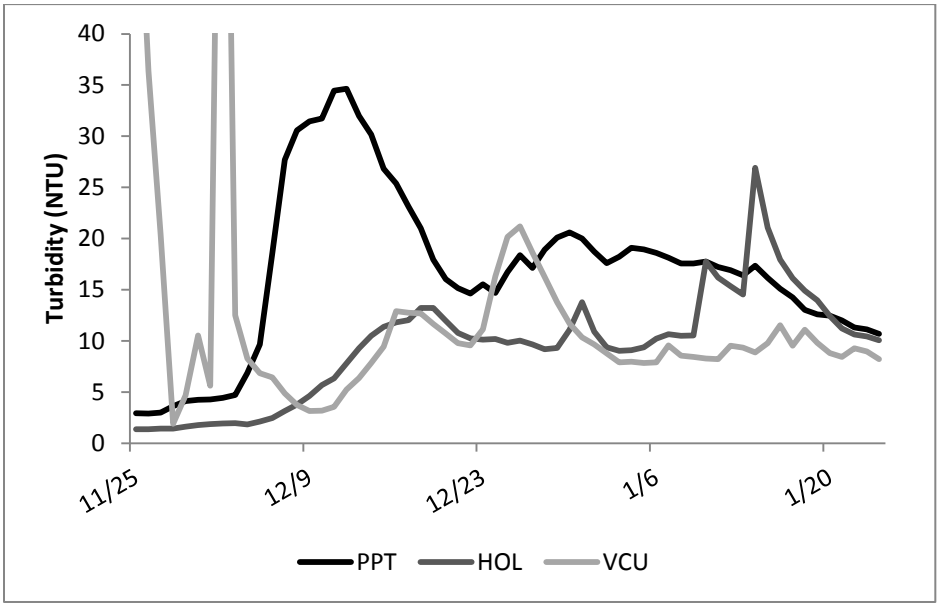

Figure 5. Turbidity data, in NTUs, at Prisoners Point (PPT), Holland Cut (HOL), and Victoria Canal (VCU), the Action 1 Part B turbidity criteria stations. The gauge at VCU experienced two dramatic spikes in turbidity in the last week of November and the first week in December, as indicated in the figure. These are likely attributable to localized wind-driven suspension of sediment.

The first delta smelt salvage of WY 2013 occurred on December 12, 2012. While the 12 NTU turbidity trigger of Action 1 Part B had not been exceeded, the SWG recommended that the Service implement Action 1 Part A of the BiOp on December 17, 2012 because of the relatively high number of salvaged fish over the five consecutive days through December 17, the high level of Projects' exports resulting in very negative OMRs, and the expectation that the Projects' Incidental Take Limit (ITL) would be low given the low delta smelt fall abundance data. The Service concurred in its December 17 determination, and implementation of the 14-day action began on December 19, 2012 (Table 4).

Table 4. Timeline leading to implementation of Action 1.

	December 7	December 12	December 17	December 19
Increased river flows and turbidity into the Delta caused by winter storms	Service calls for the SWG to meet	First salvage of adult delta smelt	Service determination to start Action 1	Implementation of Action 1

Action 1 was implemented in its entirety, and on December 31, 2012, the SWG recommended that the Service maintain the Action 1 flows of -2,000 cfs as a transition into Action 2, due to continued salvage, the high degree of uncertainty regarding delta smelt distribution from a lack of field data, and elevated turbidity readings throughout the Delta. The Service concurred with the recommendation in its December 31, 2012 determination (All WY 2013 Service determinations can be accessed at http://www.fws.gov/sfbaydelta/cvp-swp/smelt_working_group.cfm). Old and Middle River flow limits were subsequently relaxed to -3,500 cfs on January 4, based on decreasing south and central Delta turbidity and lower salvage of delta smelt.

While turbidity readings increased at central and south Delta stations during implementation of Action 1, salvage markedly decreased. A total of 86 delta smelt (expanded salvage) was salvaged from December 12, 2012, through January 1, 2013.

Summary of implementation Action 1

The events that occurred in December 2012 are consistent with what is expected based on delta smelt life history, and accounted for by the structure of the BiOp's Action 1 as a flexible conditions-based protective action to address the dependency on water year type, and Delta conditions to cue a delta smelt upstream spawning movement. Project exports were very high coincident with the first flush of freshwater and turbidity into the Delta. This set up a scenario where adult delta smelt were entrained into the south and central Delta, and ultimately salvaged at the Projects. The Service has concluded that Action 1 was successful in slowing the rate of entrainment and delta smelt salvage, and the Projects did not exceed their ITL for adults in WY 2013.

Retrospective analysis, WY 2013

The Service has engaged its partners and stakeholders to evaluate the BiOp's RPA in order to determine if there are opportunities to provide greater or equal protection to delta smelt, while affording the Projects the ability to better manage water operations and possibly increase water deliveries. The Service is evaluating several tools and approaches to explore this question.

One approach is an investigation of the Action 1onset criteria. For this effort, the Service and DCT are employing a turbidity simulation model to evaluate if additional reductions in OMR flows prior to the implementation of Action 1 on December 19, 2012 might have resulted in the reduction of delta smelt movement into the south and central Delta during the first flush period. If there is evidence that different water operations during December 2012 would have resulted in a different degree and persistence of the intrusion of Sacramento River turbidity into the south and central Delta, then the Service plans to continue this investigation to evaluate how delta smelt behavioral assumptions interact with the physical processes being studied to determine effects on adult smelt distribution following a first flush-influenced migration.

Turbidity Simulation Model

The turbidity simulation model is supported by DSM2, a river, estuary and land modeling system. A general description of DSM2 can be found at http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2v6/dsm2.cfm. DSM2 can calculate river stage, flow, and velocity; as well as many mass transport processes, including salts, multiple non-conservative constituents, temperature, trihalomethane formation potential, and individual particles.

Model output locations were selected to evaluate the movement of the first flush of turbidity from the Sacramento River (as indicated by the Hood and Rio Vista locations) into the central Delta (Jersey Point, Prisoners Point, and Holland Cut) and then into the south Delta (Victoria Canal, and Vernalis) (Figure 6). Five scenarios were simulated, including modeled turbidity given actual river flow data, modeled turbidity assuming OMR target flows of -2000 cfs

and -5000 cfs. Turbidity at threshold levels above 12NTUs at adjacent locations in the central Delta could provide a "turbidity pathway" from delta smelt rearing areas in the Sacramento-San Joaquin confluence to the central Delta and ultimately the south Delta (Grimaldo et al. 2009), and were of interest in the analysis. The turbidity pathway (also referred to as a turbidity bridge) is a phrase that captures the idea of turbid water dispersing south through Old and Middle rivers to the Projects' pumps (see Table 3 for description of turbidity criteria).

Scenario Simulated

1. Scenario A: Historical delta conditions
2. Scenario B: OMR of -2000 cfs for December 1 to 14
3. Scenario C: OMR of -5000 cfs for December 1 to 14
4. Scenario D: OMR of -2000 cfs for December 4 to 17
5. Scenario E: OMR of -5000 cfs for December 10 to 14

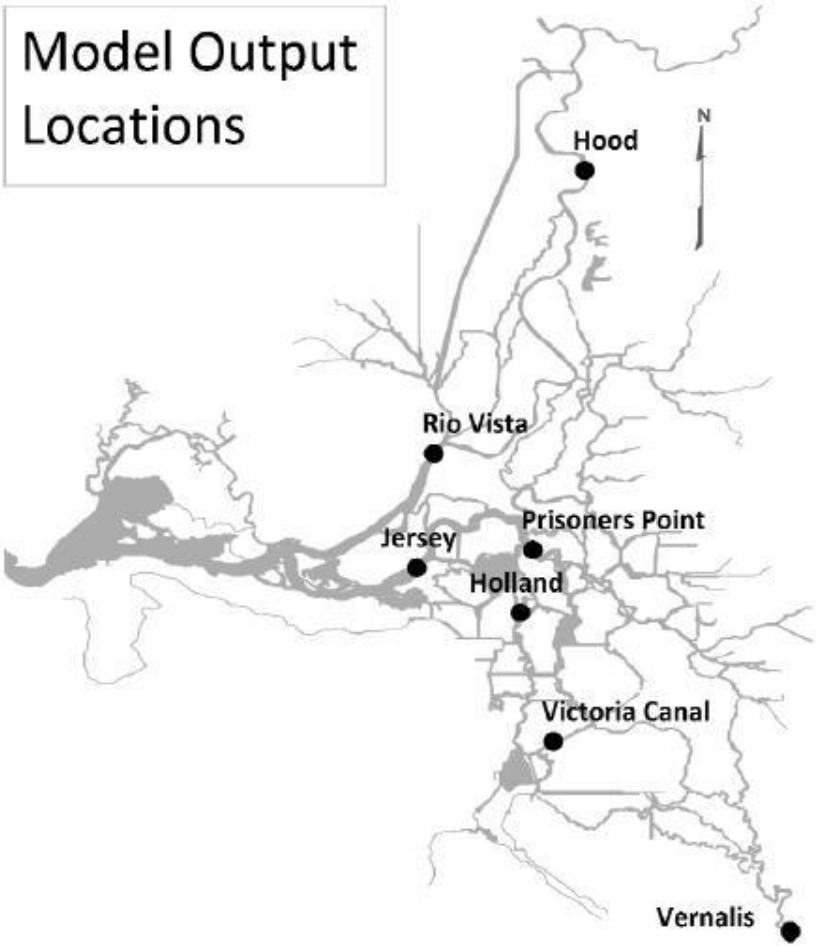

Figure 6. Turbidity simulation scenarios and output locations.

Summary of Turbidity Simulation

For the last two WYs, the Service has reviewed the results of the DSM2 turbidity simulation model as one source in the suite of information used to assess delta smelt entrainment risk in near-real time. The Service is currently working collaboratively with its partners and stakeholders to determine if this model can be used in retrospect to identify efficiencies in our protective actions such that we provide equal or greater protection to delta smelt and potentially increase and better manage water deliveries through the remainder of the WY. Preliminary results indicate that the turbidity forecasting model predicted Sacramento River turbidity with reasonable accuracy, though it was less accurate in portraying the dispersion of turbidity into the south Delta. At this time the Service finds that the turbidity simulation model, alone, is not adequate to answer the question of whether modifications to Action 1 could provide greater or equal protection to delta smelt, while potentially affording the Projects increased flexibility in management of water operations.

Conclusions

The Service is seeking feedback on implementation of Action 1 in December of 2012. In addition, the Service has been asked by its partners and stakeholders to consider adjustments to the Action. The Service is working collaboratively to answer the following questions:

1. How well did implementation of RPA Action 1 meet the intended purpose of the Action?
2. How can implementation of RPA Action 1 be adjusted to more effectively meet its objectives?

The Service has concluded that Action 1 was successful in slowing the rate of entrainment and delta smelt salvage. However, continued delta smelt salvage in January and February contributed to subsequent determination of delta smelt protective actions by the Service throughout the remainder of the delta smelt entrainment season. The actions were successful in keeping the Projects under their ITL, though they also resulted in a reduction in the Projects' ability to export water.

The Service is reviewing potential modifications to Action 1 that could provide greater or equal protection to delta smelt, while potentially affording the Projects increased flexibility in management of water operations and possibly increased water deliveries. To analyze this question, the Service and our partners and stakeholders are working in partnership to evaluate Action 1. One of our assessments is an evaluation of DSM2 turbidity simulation model given a more proactive implementation of Action 1. The Service has concluded that further development of the model or development of a new model may have the potential to provide valuable information regarding proactive protective delta smelt actions early in a similar water year to that of WY 2013.

The Service expects this collaborative investigation will make considerable progress during the coming year, and requests feedback from the IRP on our evaluation of a more aggressive and preemptive implementation of Action 1. The Service plans to continue in this effort, and will likely provide the IRP with a more comprehensive analysis next year.

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