Independent Review Panel (IRP) Report of the Collaborative Adaptive Management Team (CAMT) Proposed Investigations on Understanding Population Effects and Factors that Affect Entrainment of Delta Smelt at State Water Project and Central Valley Project

A report to the

Delta Science Program

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EXECUTIVE SUMMARY

The Independent Review Panel (IRP) reviewed the proposed ”Investigations on Understanding Population Effects and Factors that Affect Entrainment of Delta Smelt at State Water Project and Central Valley Project.” The investigations were partitioned into four independent but linked proposals concerning factors affecting entrainment and population consequences of entrainment. The goal of the investigations is to support a more confident assessment of Delta Smelt entrainment and, stemming from that greater understanding, to assess the efficacy of management actions used to operate the water projects in a manner consistent with the ESA. The investigations are to be directed at adult stages of Delta Smelt with the understanding that studies of larval and juvenile stages would be developed later.

The IRP was charged with responding to 10 questions. Each proposal was reviewed independently and then the proposals were considered as an integrated study. In general, the IRP believes the investigations will increase the understanding of processes controlling Delta Smelt entrainment and strongly supports the collaborative and integrated nature of the project. The investigations are linked in which Proposal I studies factors of entrainment at Delta-wide scale, Proposal II studies factors at the fish centric scale, Proposal III uses results from I and II to expand salvage sampling to entrainment estimates and Proposal IV studies the effects of entrainment on the Delta Smelt population. Proposals I, III and IV essentially revisit previous analysis using recent data sets. Proposal II is new in that it will model detailed movement of Delta Smelts based on how hydrodynamics and turbidity fields interact with fish behavior. The proposals are ambitious and the degree of success of the outcome in providing useful information for management is uncertain given the limitations of data, the lack of definition in movement models and project scheduling. The goal of the IRP is to illuminate critical weaknesses and in places suggests alternative perspectives that may strengthen the project.

Scaling across Data and Models: The IRP identified two scale-related issues, one concerned with data collection and the other with modeling. In both cases, the activity (data collection, data analysis, or modeling) must take place at the same scale as the underlying process or relationship operates. For example, if a process operates on individuals, then data collection, analysis, and modeling should also occur at an individual level. If a process operates on a local spatial or temporal scale, then relevant data is also on a local scale. The IRP understands that sometimes that can be very difficult or impossible to accomplish. However, there is a risk that apparent relationships may be quite different for individual or local information and aggregated information. For example, the relationship between the temporal and spatial average temperature, turbidity, or salinity and average population density may be quite different than the relationship between local (in time and space) measurements and fish occurrence.

Linked Conceptual Frameworks: While each proposal has merits on its own, how they are linked is not well described, and the contributions of each to improving management varies. Proposal I, studying the delta wide distribution of Delta Smelt, is limited by data. The Panel highlights problems that are expected but offers little in way of improving the analyses. However the results of Proposal I are likely to provide useful information, especially to Proposal II. Proposal II, modeling the individual movements of fish by tidal surfing, is the most challenging and central element of the investigation. The Panel believes that this work will be useful to understanding factors controlling entrainment. The Panel analyzes a simplified tidal surfing model to illustrate challenges and perspectives that may be useful in the development and application of the model. Proposal III offers clarity in the controversy of the relationship of salvage and entrainment. The Panel evaluates the approach and offers recommendations on how to improve the analysis of entrainment. The Panel notes that the entrainment partitioning term to be developed from the surfing model of Proposal II will be highly uncertain and may be of limited use for estimating entrainment. Proposal IV, re-examining an existing life cycle model with updated assumptions and data, is largely independent of the other proposals. The Panel is not convinced that a limited revision of the life cycle model will substantially add to what has been done in the past. However, the Panel sees that collaboration of the four working groups offers a unique opportunity to integrate differing temporal spatial scales of data and theoretical constructs to form a newer perspective of the life history of Delta Smelt.

Scheduling: The schedule is the weakest aspect of the project but fortunately is the most easily corrected. In the current schedule, projects work largely independently for the first 6 months and results are not available to other project until the second or third 6-month period. This scheduling virtually guarantees the projects will not be linked in a meaningful manner. The Panel strongly encourages the groups to revisit the schedule and plan in a workshop (~ week) in which the goals and products are clearly defined and linked and unlinked elements are discarded. For example: 1) Proposal I analysis of Delta Smelt distribution and habitat characteristics should be based on information from the Proposal II conceptual model of how physical and environmental processes interact, 2) habitat volume work in Proposal III should use definitions developed by Proposals I and II, and 3) the value of revising the life cycle model of Proposal IV at this time should be reconsidered. It might be more effective to move this work into the next round of studies in which larval and juvenile life stages are also considered.

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Introduction

Background on the CAMT review process:

The Collaborative Science and Adaptive Management Program (CSAMP) was launched following a decision made on April 9, 2013 by the United States District Court for the Eastern District of California (Court) to extend a court-ordered remand schedule for completing revisions to the salmon (NMFS 2009) and Delta Smelt (FWS 2008) Biological Opinions (BiOps).

Following the issuance of the Court Order, a two-tiered organizational structure was established to implement CSAMP comprised of: (1) a Policy Group made up of agency directors and top-level executives from the entities involved in the litigation, and (2) the Collaborative Adaptive Management Team (CAMT) including designated managers and scientists representing state and federal agencies, water contractors and non-governmental organizations to serve as a working group functioning under the direction of the Policy Group.

The CAMT was established to work with a sense of urgency and to develop a robust science and adaptive management program to inform both the implementation of the current BiOps and the development of revised BiOps. It was formed shortly after the April 2013 court order and was charged with preparing a workplan for the Court that identifies topic areas where significant disagreement exists between parties and describes how the topics will be addressed through a collaborative science process. The CAMT prepared a workplan and submitted it to the Court in February, 2014. The Court accepted the workplan and directed CAMT to conduct its work as described in the workplan with periodic reporting.

To assist with implementing the workplan elements, the CAMT formed two scoping teams comprised of scientists from representative organizations to develop a methodology and science process for addressing the disagreements identified in the CAMT process. One scoping team is covering Delta Smelt workplan elements (Table 3-1 Fall Outflow and Table 3-2 Old and Middle River (OMR)/Entrainment) and the other is covering south Delta salmonid workplan elements (Table 3-3 South Delta salmonid survival).

The Delta Smelt Scoping Team (DSST) develops scoping outlines for directed research and calls on teams of experts (Investigator Teams) to develop and submit a research proposal and to conduct the research. The project Investigations on Understanding Population Effects and Factors that Affect Entrainment of Delta Smelt at State Water Project and Central Valley Project (Delta Smelt Entrainment) consists of a research proposal and the research draft report, both will be subjected to an independent science review. The Delta Smelt Entrainment project will 1) use new tools to determine factors affecting entrainment of Delta Smelt under variable hydrodynamic conditions and long-term population 1) consequences of entrainment; 2) determine model sensitivity of multi-stage life cycle models; and 3) determine the best method to calculate proportional losses of adult Delta Smelt.

The Delta Science Program (DSP), consistent with its mission to provide best available scientific information to assist decision making in the Delta, is employing the services of independent reviewers to provide comment and advice on the scientific quality of the Delta Smelt Entrainment proposal. The role of the Independent Science Reviewer (reviewer) is to provide the investigative team with a balanced, considered and constructive review of the Delta Smelt Entrainment Proposal.

General charge and scope for the review:

The Panel was to review the background material (Appendix 1) and respond to the following questions.

1. Are goals, objectives, hypotheses and questions clearly articulated and internally consistent?

2. Are key questions, hypotheses and the conceptual model well stated and reasoned? Do they explain the underlying basis for the proposed work?
3. Is the approach well designed and appropriate for meeting the objectives of the project? Does the proposal fully address the questions in the scoping outline?
4. Are the budget and the schedule reasonable and adequate for the work proposed?
5. Are products likely to advance our knowledge of processes influencing entrainment and implications of entrainment?
6. Will the proposal help close gaps and address uncertainties in the science of entrainment identified by the CAMT?
7. Are there additional questions or aspects of the problem that might be addressed during the proposed work? If so give examples.
8. Does the proposal take an integrated approach across all relevant disciplines?
9. Will the analyses described in the proposal help inform the type of management actions referenced in the scoping outline?
10. Is the proposal explicit in what data it will use and how it will address limitations of the data in relation to the questions being asked? Does the proposed investigation appropriately incorporate the existing data, based on identified limitations?

Review process

The Independent Review Panel (IRP) reviewed the proposed "Investigations on Understanding Population Effects and Factors that Affect Entrainment of Delta Smelt at State Water Project and Central Valley Project" and a set of associated documents (Appendix 1). Each of four separate proposals was considered individually and then together as an integrated proposal. As instructed by the charge to the Panel we address the 10 questions for each proposal and the integrated project. Individual panel members took the leads on specific proposals, which were then integrated by the lead author. There were three stages to the review. Prior to the meeting, panel members read the proposal and background material (Appendix 1). A workshop including the Panel and CAMT group representing the Delta Smelt Investigator Teams was held in Sacramento on November 14. The Panel and CAMT group had a vigorous discussion of each proposal. This was followed by a meeting of the Panel to prepare initial findings. In the afternoon, the Panel reconvened with the CAMT group to present findings. In the first week of December, drafts of the reviews were delivered to the lead author who integrated the material and prepared a draft of the report which was then returned to the Panel on December 5. A conference call on December 8 was held to review this draft, develop consensus and clarify detailed opinions. Following the conference call, revised sections were distributed to Panel members. These were integrated into a draft report, and with an executive summary the draft report was returned to the Panel on December 14 for final revisions and approval. The final draft report was delivered the Delta Stewardship Council on December 15.

To a large degree the Panel reached agreement on the proposal but differing opinions are noted. The Panel was asked to provide substantive comments where possible on analysis and development of conceptual elements of the proposals. These comments are included as Appendices 2-5.

Acknowledgments

The members of the Independent Review Panel appreciate and acknowledge the efforts of the Delta Stewardship Counsel for their assistance preparation of this review the representatives of the Scoping Team Investigator Teams for the help the review process.

COMMENTS AND OBSERVATIONS

The overall goal of the proposed work is to support a more confident assessment of Delta Smelt entrainment and, stemming from that greater understanding, to assess the efficacy of management actions used to operate the water projects in a manner consistent with the Biological Opinion. To develop this greater understanding, the project divides into two areas. The goals of proposals I and II are to increase the understanding on the factors affecting entrainment, and the goals of proposals III and IV are to improve the estimation of population consequences of entrainment.

As is noted in the executive summary of the proposal, juvenile life stages were specifically not considered, and therefore the results of the study cannot address true population consequences of the water projects. Proposals on early the early life stages are anticipated in later years.

The Panel notes studies of Delta pelagic organisms, and in particular Delta Smelt and zooplankton fall into two categories: correlative and mechanistic. The majority of studies conducted up through the last decade have sought to statistically characterize large-scale relationships of water properties and mean Delta flows to Delta Smelt distributions over the Delta and salvage at the State Water Project and Central Valley Water Project. More recent studies, up through August 2014, have focused on characterizing their small-scale environment and delta organism (smelt and zooplankton) behavior over tidal-scales with the goal of understanding the mechanisms controlling the movement patterns. The reviewed CAMT proposal seeks to apply both correlative and mechanistic approaches in an integrated manner with the goal of developing a greater understanding of the effects of the environment and operations of the State Water Project and Central Valley Water Project on Delta Smelt entrainment and population viability. Proposals I, III and IV intend to apply statistical approaches to investigate the relationships of fish salvage and entrainment with Delta Smelt distributions. Proposal II intends to apply a mechanistic individual-based modeling approach to investigate the interaction between Delta Smelt behaviors and environmental factors that lead to adult movement and entrainment.

The structure of the overall project seeks to integrate the individual proposals with the goal of linking the large-scale distributions of Delta Smelt and environmental properties to salvage through the small-scale behavioral mechanisms.

The overall project is ambitious, and the Panel holds varied opinions as to value of the project and its viability. As to whether *the products of this project advance our knowledge of the processes influencing entrainment and it implications* (Question 4 to the Panel) our opinions range from an *emphatic no*, because the study is not different than preceding studies, to an *enthusiastic yes*, because the study moves the science into a new and mechanistic paradigm. Underlying these opinions, are a common understanding by the Panel of the challenges and limitations faced by the research team.

The review comments are aimed to address two important scientific challenges of the proposed work: poor data and incomplete theory. We also acknowledge that the Investigator Teams had limited time to prepare and coordinate the proposals and therefore a number of our comments were prepared in the hope they will provide useful information to the Investigator Teams in further development of the work plan.

General comments on the proposals as an integrated product

1. *Are goals, objectives, hypotheses and questions clearly articulated and internally consistent?*

   Yes, but it is not clear how the combined results will be synthesized to create a tool to inform management on a time scale that is relevant to the need of informed decisions by the managers.

2. *Are key questions, hypotheses and the conceptual model well stated and reasoned? Do they explain the underlying basis for the proposed work?*

   Some questions were too vague and general; in particular Proposals II and IV required additional detail.

3. *Is the approach well designed and appropriate for meeting the objectives of the project? Does the proposal fully address the questions in the scoping outline?*

   The Panel expressed different opinions for each of the proposals. Some proposals are straightforward, but it is unclear how the results will be quantitatively linked to other proposals

   The Panel notes that the overall program is not able to address population dynamics as is the goal of Proposal IV.

4. *Are the budget and the schedule reasonable and adequate for the work proposed?*

   Information is insufficient to evaluate the budget in detail. However, applying typical university factors for overhead and salary the entire project would allocate about 30 person/months over the first 6 month period resulting in about five full time equivalents (FTE). Considering there are about 10 named investigators, each would be required to commit one-half a FTE to the project. For some of the proposals this seems a generous allocation of time for the work specified.

The Panel is concerned with the schedule of the projects. The proposals are designed to sequentially provide information, Proposal I inputs to Proposal II etc. However, activities are scheduled concurrently so there is the potential for disconnect of output of one project as input to the next in line. The Panel realizes the each project has a lead time in development, however the total support is partitioned 60-30-10 across the three half year segments of the project. It might make more sense to distribute the activities more evenly across the segments.

The most critical scheduling issues involve Proposal II, which receives input from Proposal I and provides information for Proposals III and IV. Proposal II indicates that the first 6 month will mostly address 2D physical modeling, and the next 6 months address 3D physical modeling. The development of behavior models is delayed a full year to the last 6 months of the project. Linking Delta Smelt behavior to physical elements of the system is the crux of the entire project and is key ingredient in developing entrainment efficiency coefficients for Proposals III and IV. It appears to the Panel that with the current scheduling, Proposals III and IV are planned to be essentially completed and published before any meaningful results are provided from Proposal II. This appears to be a serious problem with the successful completion of the project.

5. *Are products likely to advance our knowledge of processes influencing entrainment and implications of entrainment?*

The results will lead to incremental advances in our knowledge, but may not resolve many entrainment issues. Proposal II has the potential of yielding the largest advance. Proposals I, III, IV aim at updating previous analysis with new data and potentially with results from the other proposals.

The most useful product may be an example of successful collaborative science.

6. *Will the proposal help close gaps and address uncertainties in the science of entrainment identified by the CAMT?*

The proposals will close some gaps in knowledge, however there are large uncertainties resulting from limited data and sampling regimes. Proposal II may potentially address uncertainties in mechanisms of Delta Smelt movement. Proposal I, III and IV will largely redo previous studies and are thus constrained by the limited improvements in data and techniques.

The work may provide better articulation of disagreements more than resolves them.

7. *Are there additional questions or aspects of the problem that might be addressed during the proposed work? If so give examples.*

See comments on individual proposals.

8. *Does the proposal take an integrated approach across all relevant disciplines?*

The Proposal reflects the growing recognition that both physical and biological processes are crucial to understanding the movement and population dynamics of Delta Smelt. However, the proposal integration is not well developed. It appears the main specific integration is through the entrainment efficiency parameters that expand the adult daily salvage to daily entrainment estimates of the water projects. How this will be done is not made clear in the proposal.

9. *Will the analyses described in the proposal help inform the type of management actions referenced in the scoping outline?*

   Any improvement of understanding of the factors affecting entrainment and the processes that lead to entrainment will help to inform management actions. However, it is not clear that that the analyses will result in identifying the potential consequences of management actions.

10. *Is the proposal explicit in what data it will use and how it will address limitations of the data in relation to the questions being asked? Does the proposed investigation appropriately incorporate the existing data, based on identified limitations?*

    The proposal is explicit in identifying what data is to be used, and does specify how limitations will be addressed. However, there is concern that even the best efforts to address limitations are not adequate to overcome many of the deficiencies.

Comments on Proposal I

General Review comments on Proposal I, a retrospective analysis of historical data that aims to improve our understanding of factors that may affect entrainment risk.

The proposal has been confined to using existing historical data, specifically, Delta Smelt trawl catch data and water quality data from Fall Midwater Trawl and Spring Kodiak Trawl Survey, Delta Smelt salvage data, DAYFLOW, Old and Middle river flow data, DCC gate operations data, turbidity and water temperature data from Clifton Court Forebay. While these data sets are the best available, they have significant and substantial weaknesses, especially in the completeness of spatial and temporal coverage. Also, see the comment on the use of aggregated data in regression and model building in Appendix 3.

The proposal suggests using the Akaike Information Criterion (AIC) to compare competing models by comparing the AIC of each model variation to the base model. Burnham & Anderson (2004) state that the AIC by itself is not interpretable as it contains arbitrary constants and is strongly influenced by sample size. Instead, they recommend using $\Delta_i = AIC_i - AIC_{min}$, where AIC_{min} is the minimum AIC value of all models considered. Burnham & Anderson (2004) also recommend using a modified version of AIC given by $AIC_c = AIC + \frac{2K(K+1)}{n-K=1}$, where n is the sample size and K is the number of estimated parameters.

Responses to questions

1. *Are goals, objectives, hypotheses and questions clearly articulated and internally consistent?*

   Yes

2. *Are key questions, hypotheses and the conceptual model well stated and reasoned? Do they explain the underlying basis for the proposed work?*

   Yes

3. *Is the approach well designed and appropriate for meeting the objectives of the project? Does the proposal fully address the questions in the scoping outline?*

The approach is well designed given the limitations of the existing data. It may not be possible to "determine through multi-regression models the best suite of variables that explain historical salvage patterns" without better designed sampling studies. See the comments on aggregated data in Appendix 3.

4. *Are the budget and the schedule reasonable and adequate for the work proposed?*

The budget is reasonable. However this work should be accelerated to provide useful input to Proposal II. Extending the overall project schedule is another option.

5. *Are products likely to advance our knowledge of processes influencing entrainment and implications of entrainment?*

The products may not greatly advance knowledge, and there is some possibility the products may be misleading. The examination of factors relies heavily on aggregated data (e.g., the FMWT index for Delta Smelt is a sum of monthly CPUEs, and CVP and SWP abundance indices are analogs to the FMWT index created by summing the daily adult Delta Smelt salvage CPUEs for the period December 1 through March 31 of each water year from 1993 through 2013). The process of aggregation in itself may obscure real relationships or introduce spurious relationships. The results should be interpreted with caution.

The most useful product may be an example of successful collaborative science.

6. *Will the proposal help close gaps and address uncertainties in the science of entrainment identified by the CAMT?*

Proposal I does not directly address uncertainties.

7. *Are there additional questions or aspects of the problem that might be addressed during the proposed work? If so give examples.*

   Possibly. The major data sets, the Spring Kodiak Trawl Survey (SKTS) and the Fall Midwater Trawl Survey (FMWT), both sample a restricted part of the habitat containing Delta Smelt, and thus are not suitable for direct expansion to obtain population totals. Any such extrapolation must rely on an assumed model. The model that has been used assumes uniformity i.e., that the density in the non-sampled portion of the domain is the same as the density in the sampled domain.   The work of Bennett and Burau (2014) suggests that that during flood tides, Delta Smelt are likely in mid-channel and accessible to Kodiak trawls, whereas on ebb tides, they tended to be closer to shore and accessible to the beach seines. It might be possible to draw on this study and other similar ones to develop a better extrapolation model, especially of tidal flow at the time and place of the trawls are available.

8. *Does the proposal take an integrated approach across all relevant disciplines?*

   Yes

9. *Will the analyses described in the proposal help inform the type of management actions referenced in the scoping outline?*

   If successful, the project may identify some factors that affect entrainment, which in turn could be used to inform management actions.

10. *Is the proposal explicit in what data it will use and how it will address limitations of the data in relation to the questions being asked? Does the proposed investigation appropriately incorporate the existing data, based on identified limitations?*

Yes, the proposal describes the data and how data limitations will be addressed. The data limitations may nevertheless be insurmountable.

Comments on Proposal II

General Review comments on Proposal II, which will develop an individual-based model (IBM) linking hydrodynamic, water quality, and particle tracking models to identify adult Delta Smelt behaviors that best explain movement towards SWP and CVP and entrainment.

The Scoping Team (comments 10/23/14) identified a critical goal to better understand the conditions that lead to the level of risk of entrainment of Delta Smelt and identify actions that can reduce entrainment. The Scoping Team agreed that turbidity and other conditions influence entrainment. Food was not found to be important. There was disagreement in the Scoping Team as to whether there was sufficient information to model the entrainment, but it was noted that linking habitat and behavior is a high priority. Proposal II directly addresses this priority.

The goal of Proposal II is to model the movement and entrainment of Delta Smelt in response to hydraulics and the turbidity distribution. The proposal outlines a conceptual model largely inspired by the tidal surfing paradigm that has been significantly advanced over the last few years (e.g. see Anderson et al. 2013 for review of Delta relevant studies) and in particular the models of tidal surfing for zooplankton (Kimmerer et al. 2014) and Delta Smelt (Bennett and Burau 2014). These papers and others have contributed to a significant paradigm shift in the conceptual model of Delta organism. In the old paradigm, large-scale distribution of organisms was viewed as being controlled by large-scale and tidally averaged environmental processes. In the new paradigm, organism distributions are viewed as being controlled by small-scale organism behaviors in responses to their immediate and small-scale environment. The Panel, in general, is strongly supportive of a small-scale approach to modeling Delta Smelt movement but has concerns that the theory has not been adequately developed and that the proposal is aiming to apply the approach over scales larger than are appropriate.

The proposal, on page 20, noted that the swimming behaviors algorithms were not well defined, but the algorithms will be developed from previous work and recommendations from the Scoping Team and Science Panel. This lack of specificity is understandable, because the seminal paper by (Bennett and Burau 2014) appeared after the CAMT Progress Report (2/14/2014), the central document on which the proposal is based. However, members of the CAMPT Investigation Team have recently coauthored papers on zooplankton surfing behavior, and therefore they should be well positioned to quickly develop Delta Smelt swimming algorithms, in particular if they work closely with Delta Smelt researchers.

The Panel's concern is that even though it may be possible to model the local movement of Delta Smelt in specific environments, e.g. Suisun Bay or Old River, it might not be possible to model the cross-delta movement of fish from their summer environment in X2 to the eastern Delta and Clifton Court Forebay. In other words, the Panel believes that it is potentially feasible and important to model the small-scale tidal surfing movement proposed by the Bennett and Burau paper. However, with the limited resources and time of the project it is likely to be infeasible to model the large-scale adult movement of Delta Smelt. If a realistic and creditable model of the large-scale movement of Delta Smelt cannot be achieved, then the value of entrainment modeling (Proposal III) and lifecycle modeling (Proposal IV) will be significantly compromised.

The Panel believes that the main challenge and goal of Proposal II should be to explore and test the Bennett-Burau Delta Smelt surfacing hypothesis. Details of this hypothesis and avenues of study are discussed further in Appendix 4.

Responses to questions

1. *Are goals, objectives, hypotheses and questions clearly articulated and internally consistent?*

   The proposal goal is to develop an individual-based model that best explains the movement towards the SWP and CVP and entrainment. This goal is clear.

2. *Are key questions, hypotheses and the conceptual model well stated and reasoned? Do they explain the underlying basis for the proposed work?*

   No, the proposal is vague on the implementation of the central conceptual model in how fish behavior interacts with the physical environment on the tidal cycles. Having a well-defined quantitative and biologically based conceptual model is critical to the entire set of proposals. While the modeling team indicated their understanding of the importance of this conceptual model, it is not reflected in the scheduling activities. However, the Panel believes that the models can be further developed and encourages the modeling team to allocate time and resources to this task in the first 6 months of the project.

3. *Is the approach well designed and appropriate for meeting the objectives of the project? Does the proposal fully address the questions in the scoping outline?*

   In general, the approaches outlined for Proposal II are appropriate, but the Panel suggests modifications of the staged approach. Currently stage 1 involves the use of existing modeling tools and stage 2 involves development of new tools. The existing tools are the RMA 2D hydrodynamics model, turbidity model, and particle tracking model. The new modeling tools proposed for stage 2 are the UnTRIM 3D hydrodynamic model, suspended sediment model, and particle tracking model. While the Panel understands operational constraints might favor a staged approach, from a scientific standpoint, it is difficult to justify the use of the existing tools when more mechanistic models are available (UnTRIM), for the following reasons:

- Smelt behavior is known to be three-dimensional; thus a 3D hydrodynamic model should be used.
- The existing RMA 2D model is one-dimensional in the south Delta; thus, lateral gradients in velocity that smelt are known to use to "surf the tide" are not included in this important region.
- Turbidity modeling is subject to criticism, because turbidity is not a physical quantity subject to conservation laws. It is an optical property. Thus, defensible modeling should be based on suspended sediment mechanics and conservation of mass.

For these reasons, our recommendation is to proceed directly to the use of 3D hydrodynamics and suspended sediment transport modeling. We note that this is essentially the same recommendation of the IRP Lobo review (Anderson et al. 2013). This review was cited by authors as the reason for their stage 2 modeling, as they state on page 21 of the proposal:

> "Key areas of improvement identified in the IRP review are 1) use of a sediment transport model to improve predictions of turbidity, particularly by allowing tidal time scale re-suspension; 2) using a swimming velocity vector instead of a "velocity factor" approach described in the Background section; 3) use of a three-dimensional hydrodynamic model and three-dimensional behaviors; and 4) resolution of lateral velocity gradients to the extent feasible."

Because proposed stage 2 modeling addresses all of these concerns, we see no scientific reason to perform the stage 1 modeling analyses. While it's true that the stage 1 tools are simpler and would allow for longer periods of simulation, the stage 2 model simulation periods should be sufficient. Further, once the modeling tools have been developed, this opens the door for ongoing simulations into the future.

4. *Are the budget and the schedule reasonable and adequate for the work proposed?*

The budget is generally reasonable, but scheduling needs to be evaluated (see comments in general response to question 4).

5. *Are products likely to advance our knowledge of processes influencing entrainment and implications of entrainment?*

If the team is successful in developing an IBM based on the relevant biological and behavioral mechanism the work will clearly advance knowledge entrainment processes. However, if a model is developed on the basis that it fits distributions without a plausible biological mechanism, then the products of the work will most likely not advance knowledge. A simple model without a biological underpinning may fit one particular set of data very well based on AIC criteria, while at the same time completely fail in a different environment. For example, a model that represents migration as a velocity factor into an upstream turbidity gradient may give a reasonable adult migration velocity but will not explain how adult smelt are able to hold position in the estuarine turbidity maximum. There is no clear reason why the Delta Smelt would utilize different behavioral strategies in the two conditions, and so the challenge is to find a single mechanism that explains behavior in both environments. The modeling team appears focused on adult migration but not on behavior in other important life stages. The Panel strongly encourages the modeling team to take a broad approach when developing conceptual models of swimming. Consider how each respective model might explain a suite of behaviors and judge the models on both statistical criteria and on the basis of first principles of the animal's perceptive, cognitive and physiological capabilities.

Developing behavioral algorithms is challenging and time consuming. It took a decade to develop the salmon dam passage model (Goodwin2004, Goodwin et al. 2006, Goodwin et al. 2014), and at each stage the algorithm was significantly revised. Hopefully, it will not require a decade of research to achieve a similar understanding on Delta Smelt, and to expedite the development, the Panel encourages the modeling team to early in the project devote significant time and seek wide input in the development of the Delta Smelt swimming behavior algorithms.

6. *Will the proposal help close gaps and address uncertainties in the science of entrainment identified by the CAMT?*

Yes, the work will close knowledge gaps and uncertainties in what controls the distribution of Delta Smelt in different environmental conditions. This will provide value for understating susceptibility of the population to entrainment.

7. *Are there additional questions or aspects of the problem that might be addressed during the proposed work? If so give examples.*

The proposal needs to broaden the focus beyond the period of adult migration to include large juvenile and adult stages prior to spawning migration. An ability to fit and explain the distributions and behaviors in these stages will provide further information to challenge the model validity. In addition, an ability to model these earlier stages will provide valuable insight to the processes and rates in which populations of Delta Smelt (Cache Slough, Sacramento River, Napa River) exchange members. This information will be value for developing spatially explicitly population model of Delta Smelt.

The most important products from the hydrodynamic modeling should be to describe the physical processes driving migration and entrainment. One of the key outputs mentioned in the proposal is an entrainment value "theta" for use in Proposal III. This is only one number with lots of caveats associated with it.

While predictions of theta are likely to have large uncertainty, the model should be informative in understanding and identifying factors that affect entrainment. For example, the transport timescale in Clifton Court Forebay (CCFB) is important for estimating predation rates within CCFB. Can the transport timescale be estimated with a hydraulic residence time? Or, during the conditions when entrainment occurs, do particles short-circuit CCFB? Another part of the equation to be solved in Proposal III is a representative flow rate in the south Delta (See Appendix 2 and 5). What observations from the model can help describe an alternative representative tidal time-scale entrainment flow? Are more particles entrained on flood than ebb? Are particles more likely to be entrained on spring or neap tides? What influence do the south Delta Barriers have on circulation and entrainment? What role does the opening and closing the CCFB gates play for entrainment? Does the water year type affect entrainment? If so, what are the physical factors that are managed?

8. Does the proposal take an integrated approach across all relevant disciplines?

The proposal appears in a limited way to include relevant disciplines with the considerations of tidal cycle physics, sediment transport and behavior. Within the short time frame of the work, this is probably sufficient realistic. The work could also incorporate information from the physiology, cognitive psychology, and ecology that may clarify the ability of Delta Smelt to sense and respond to their environment. For example, the decision algorithm underlying the IBM model of juvenile salmon dam passage behavior (Goodwin et al. 2014) draws on established information processing concepts in neuroscience and cognitive psychology.

9. *Will the analyses described in the proposal help inform the type of management actions referenced in the scoping outline?*

If the model is successful characterizing fish movement from summer habitat into the alternative spawning environment, it will inform management actions such as setting smelt salvage indices.

10. *Is the proposal explicit in what data it will use and how it will address limitations of the data in relation to the questions being asked? Does the proposed investigation appropriately incorporate the existing data, based on identified limitations?*

The proposal does explicitly describe the data to be used in statistically validating the model. The modeling team appears to favor testing the model against large scale distribution data including salvage data. However, how this large scale data will be related to the underlying behaviors is not defined in the proposal. If behavior models are judged on their ability to fit salvage data or distribution of fish observed in the routine sampling programs, then the approach is inadequate. This scale of description will not resolve behavior mechanisms. The Panel recommends that the modeling team find ways to evaluate the model predictions on other scales such as the tidal cycle as revealed by the Smelt Cam (Feyrer et al. 2013).

Comments on Proposal III

Proposal III proposes using the modeling tools described in Proposal II to estimate the efficiency parameters needed to expand salvage sampling data into entrainment estimates.

1. *Are goals, objectives, hypotheses and questions clearly articulated and internally consistent?*

   Proposal III offers to add clarity to a long standing controversy regarding the take of adult Delta Smelt at the State and Federal Facilities based on the work of Kimmerer (2008), the recalculation by Miller (2011), and the subsequent rebuttal by Kimmerer (2011).

   The primary products of this work will include:

   - New estimates of sub-region volumes throughout the Delta based a recent bathymetric database.
   - New estimates of the Delta Smelt adult population based on the updated sub-region volumes for periods when SKTS was available (2002-2014).
   - Finding a relationship between SKTS and the FMWT survey data so that the dataset can be extended from 1981-2014.
   - Calculations of the adult proportional losses for the years 1981-2014.

   The main hypothesis of the proposal is that by refining the estimates of volume and using the theta values calculated from the IBM model, the estimates of adult proportional losses will be refined. As such, the Investigators will be able to use this information to extend the calculations of adult proportional losses to a much longer time period that could be used for Proposal IV.

2. *Are key questions, hypotheses and the conceptual model well stated and reasoned? Do they explain the underlying basis for the proposed work?*

The biggest weakness of this proposal is that it is did not adequately go into the details of the underlying basis for the proposed work. This weakness, in part, was caused by the very fast-track deadlines that the PIs were asked to produce the proposal. But by neglecting these underlying assumptions of the problem, key information was overlooked.

The procedure used by Kimmerer (2008, 2011) and Miller (2011) are heavily math and equation intensive with multiple assumptions along the way. There are seven calculation steps that have to be considered in order to calculate adult proportional loss at the export facilities. **Appendix 5** goes into full detail of each of the equations and the assumptions made by both Kimmerer and Miller. The changes to the procedure that are proposed in Proposal III are also discussed.

Summarized here are key Panel recommendations for some of the equations to consider in order improve the approach used in Proposal III.

Calculate sub-region volumes from hydrodynamic model (Proposal II). The PIs propose to use USGS software in order to extract volumes for the different sub-regions. However, these volumes are already available in any calibrated multi-dimensional hydrodynamic model including those used in Proposal II. These sub-region volumes should be the first product of Proposal II and could be made available to Proposal III in the first couple weeks of the project (Appendix 5, equation #1).

Determine if the full Delta population estimate is necessary from a regulatory perspective. Only the ratio of adult fish population to water volume is necessary in equation #6 (see appendix 5). Kimmerer (2011) stated on the use of South Delta stations instead of the full Delta calculation, "the remaining issue for this part of the calculation is whether the samples in the south Delta represented the population there to the same degree that sampling throughout the Delta represented the overall population. Catchability is unlikely to differ between the south Delta and elsewhere (and we have no data either way on this), so the degree of representation boils down to whether the spatial coverage of sampling is adequate to represent the population."

The Spring Kodiak Trawl may not be appropriate for calculating a representative survey of fish. Kimmerer (2008) pointed out that he made the assumption for his application of equation #1 (Appendix 5) that the Kodiak trawl survey takes a representative sample of the adult Delta Smelt population. He indicated in his discussion (2008) that this is "unlikely to be true given the fixed stations of the Kodiak survey and the concentration of stations in some areas". Second, Bennett and Burau (2014) have recently expressed major concerns with the procedure for the Spring Kodiak survey stating: "Standard monitoring surveys that sample monthly across a fixed sample grid, irrespective of the tides, may be useful for detecting trends in distribution or abundance over many years, but they are hampered by considerable observational bias due to tidal aliasing and are thus not sufficient for addressing finer-scale or process-oriented questions."

Make sure the PIs understand fully what theta represents. The proportional term "theta" (Equation 4, Appendix 5) lumps all the unknowns (efficiency of Kodiak Trawl, louver efficiency, and fraction of fish entrained that reach the louver) into one big unknown that can be back-calculated with Equation #6 (Appendix 5). It is defined as:

$$Theta = \frac{Efficiency\ of\ Kodiak\ Trawl}{(Louver\ efficiency) * (fraction\ of\ fish\ entrained\ that\ reach\ the\ louver)}$$

In the introduction to the proposal, the "Efficiency of Kodiak Trawl" portion of the equation was missing. The PIs need to understand exactly what they are calculating.

The assumptions for what flow is appropriate to apply in Equation 6 (Appendix 5) has been repeatedly overlooked by Kimmerer, Miller, and the current proposal. Determining the appropriate representation of flow should be the *keystone element* of this proposal. The export facility is located in the tidal zone of the south Delta and flows around those facilities should not be simplified to daily, tidally-averaged flows when dealing with entrainment issues. Currently, "entrainment flow in the south Delta" is characterized by both Kimmerer (2008) and Miller (2001) and in Proposal III by a daily-averaged flow value called OMR flow. Please see Appendix 2 for an additional discussion of OMR flow.

Kimmerer (2008)

$$\frac{abundancy\ in\ South\ Delta}{Volume\ of\ South\ Delta} * (entrainment\ flow\ in\ South\ Delta) = \Theta_{South\ Delta}(Daily\ Salvage_{swp} + Daily\ Salvage_{cvp})$$

Miller (2011)

$$\frac{abundancy\ in\ full\ Delta}{Volume\ of\ full\ Delta} * (entrainment\ flow\ in\ South\ Delta)$$
$$= \Theta_{South\ Delta}(Daily\ Salvage_{swp} + Daily\ Salvage_{cvp})$$

An appropriate representation of flow should consider that this is a tidal system. Some factors that should be considered in its development:

- Pumping volume, including the ratio of pump volume at Federal to State
- Spring or neap tides
- Tidal excursion on Old and Middle River
- Barrier placement
- Peak upstream velocity of Old River when CCFB gates are opened
- RMS velocity
- representative upstream velocity when the CCFB gates are open based on observations at the USGS Old River flow stations

3. *Is the approach well designed and appropriate for meeting the objectives of the project? Does the proposal fully address the questions in the scoping outline?*

Proposal III should focus on developing the new estimates of adult population based on the updated sub-region volumes for periods when the SKTS was available (2002-2014) will enhance existing knowledge. This part of the project extends what was done by both Kimmerer (2008) and Miller (2011). However, as should be deduced from the comments so far, there are many places where uncertainty exists in these calculations.

Spending time defining the error bars and improving the assumptions made in the calculations will advance the knowledge of the processes involved.

The proposal should not extend the dataset back to 1981 by trying to find a relationship between the Fall Midwater Trawl data and the Spring Kodiak Trawl data. It is evident based on the conversations both in the CAMT and the LOBO panel reviews that the FMWT was not designed to catch Delta Smelt, and a direct correlation between the FMWT and the SKT data is not obvious. Assuming that the quality of the resulting estimates of adult population from 1981-2002, based on the Fall Midwater Trawl, was the same as the quality of the estimates from 2002-2014, based on the Spring Kodiak Trawl, this would add additional errors into research that would be derived from this time series.

4. *Are the budget and the schedule reasonable and adequate for the work proposed?*

One of the major timing concerns is that time that it will take for the Proposal II theta values to be provided to the Proposal III team. The theta values appear to be one of the last things produced in the Proposal II. Proposal III should also consider assuming a constant theta for the state and federal facilities and use the procedure used by Kimmerer (2008) and Miller (2011) as a first step while they are waiting for the Proposal II analysis to be completed. See General comments for further discussion of scheduling issues

5. *Are products likely to advance our knowledge of processes influencing entrainment and implications of entrainment?*

The most valuable portion of the analysis will be the extension of the dataset to 2002-2014 so that trends in the data may become more obvious.

6. *Will the proposal help close gaps and address uncertainties in the science of entrainment identified by the CAMT?*

This proposal will help to open a dialogue about the key differences in assumptions made by Kimmerer (2008) and Miller (2011). By looking in a detailed, methodical fashion at this calculation, the PIs will most likely be able to suggest key next steps. This may include improvements in sampling locations, procedures for sampling, and estimates of representative entrainment flows.

7. *Are there additional questions or aspects of the problem that might be addressed during the proposed work? If so give examples.*

More time needs to be spent developing an alternative representation of south Delta entrainment flows. The OMR parameter is a tidally-averaged index that does not represent this tidal process well.

See response to question #2 above

8. *Does the proposal take an integrated approach across all relevant disciplines?*

The knowledge of the hydrodynamic modeling team (Proposal II) should be more fully integrated into decisions such as the designation of the sub-regions. They will not necessarily need to run more simulations, but they can use their knowledge, based on hundreds of modeling simulations, to give valuable input.

9. *Will the analyses described in the proposal help inform the type of management actions referenced in the scoping outline?*

   Some scoping questions that this Proposal can address are:

   - Workplan element 3-2-1 Question b: What is the distribution and relative abundance of Delta Smelt across seasons both in the central and south Delta and elsewhere within its range? (Side comment by mln: "How well do existing monitoring surveys characterize the distribution and relative abundance of Delta Smelt?"
   - Workplan element 3-2-2 Question b: Does the proportion of adult Delta Smelt in the south Delta, derived from the Spring Kodiak Trawl, provide a more reliable estimate of the proportion of the adults entrained than estimates derived from salvage and population estimates?

10. *Is the proposal explicit in what data it will use and how it will address limitations of the data in relation to the questions being asked? Does the proposed investigation appropriately incorporate the existing data, based on identified limitations?*

    Yes, the proposal is very explicit in what sampling data will be used. It is important to consider the limitations of this data as discussed above.

Comments on Proposal IV

Proposal IV will re-examine life cycle model results using updated data sets and assumptions. The secondary objective is to develop and test new covariates in the life cycle model based on information from Proposals I and III. Ultimately, the results can be used to determine what levels of entrainment affects the viability of the Delta Smelt population.

PANEL'S RESPONSES TO QUESTIONS

1. *Are goals, objectives, hypotheses and questions clearly articulated and internally consistent?*

   Yes, but it is not clear how the combined results will be synthesized to create a tool to inform management.

2. *Are key questions, hypotheses and the conceptual model well stated and reasoned? Do they explain the underlying basis for the proposed work?*

   Yes, but not well. The conceptual model as described in the proposal is not a model at all. Rather it is a plan to separately run four different models, with the results of one being passed to the next. The authors fail to provide a convincing argument what they are proposing is substantially different than what has been done in the past.

3. *Is the approach well designed and appropriate for meeting the objectives of the project? Does the proposal fully address the questions in the scoping outline?*

   The Panel notes that the overall program is focused on entrainment but Proposal IV addressed the impact of entrainment on population life cycle. Proposal IV is unlikely to improve estimates of population level effects of entrainment. Some issues of the problems of achieving Proposal IV goals are discussed below.

   Proposal I will be used to determine what factors define risk to smelt based upon historical data when it is clear that factors as important as spawning location and predation mortality rates remain unknown. In the absence of these data, what are the beginning and the ends of the life cycle model? Will errors made in initial assumptions based upon incomplete knowledge be allowed to propagate from one model to the next?   These two factors alone have been shown to be major drivers of dynamics of exploited populations. Given that smelt are removed from the ecosystem by entrainment is in no way different than removal by power plants, or for that matter, fishing. Under this assumption, what is needed for Delta Smelt is a stock assessment that accounts for losses beginning when the smelt are as young as the data permit. As is the case in many species, the mortality rates of pre-recruits are unknown but likely to be very high. But losses early can be compensated for more successfully than losses later in life. Unfortunately the most recent predation workshop (Grossman et al. 2013) was silent on smelt. Others have shown that direct evidence of predation on smelt has been difficult to find. This, however, should not be taken as an indication that predation is not occurring, or that it is not an important source of mortality. Smelt are small, hence easily digested, and relatively uncommon even in parts of the ecosystem in which they are considered “abundant”. Predation rate could be high on smelt as large as 60 mm but difficult to detect in fish guts, because of rapid digestion. The likelihood that predation is detected now could also have declined, because the number of smelt is lower, making them appear less frequently in predator guts, thus greatly increasing the number of guts that must be examined to determine how many and by what are smelt being consumed. Recently species identifications, formally reported in the wad of goo that is usually defined in studies of gut contents as unidentified prey, can be made by using rapid and relatively inexpensive genetic assays.

4. *Are the budget and the schedule reasonable and adequate for the work proposed?*

The budget seems very high given that no new field-work is being proposed. See General comments.

5. *Are products likely to advance our knowledge of processes influencing entrainment and implications of entrainment?*

   The reviewers do not believe that the Delta Smelt entrainment problem can be better informed enough to be useful, and or solved, by extending the life cycle model with the limited information now available on early life history.

6. *Will the proposal help close gaps and address uncertainties in the science of entrainment identified by the CAMT?*

   It does not appear that Proposal IV will, in this context, provide useful information to close gaps and address uncertainties of entrainment.

7. *Are there additional questions or aspects of the problem that might be addressed during the proposed work? If so give examples.*

   The next round of studies should also develop proposals that recognize that entrainment and predation are intertwined problems, especially in locations like Clifton Court Forebay.

8. *Does the proposal take an integrated approach across all relevant disciplines?*

   No, the issues of Delta Smelt early life history and effect of predation relevant to entrainment are not well integrated in this proposal.

9. *Will the analyses described in the proposal help inform the type of management actions referenced in the scoping outline?*

   Unlikely for Proposal IV.

10. Is the proposal explicit in what data it will use and how it will address limitations of the data in relation to the questions being asked? Does the proposed investigation appropriately incorporate the existing data, based on identified limitations?

Proposal IV is not explicit. New covariates are to be recommended by other researchers but are not identified.

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APPENDIX 1 – Materials Reviewed

Review Materials Available to CAMT Independent Review Panel

Investigations on Understanding Population Effects and Factors that Affect Entrainment of Delta Smelt at State Water Project and Central Valley Project proposal. The document is provided in an electronic format.

Supplemental Documents

1. CAMT Background and Context Information

2. Draft Outline of a Scope of Work for Factors Affecting Adult Delta Smelt Entrainment, CAMT Workplan Element 3-2-1 (to address CAMT Progress Report 2/7/14 Table 3-2, Element 1)

3. Draft Outline of a Scope of Work for Assessing Population Effects of Entrainment, Workplan Element 3-2-2 (to address CAMT Progress Report 2/7/14 Table 3-2, Element 2)

4. Progress Report to the Collaborative Science Policy Group, February 14, 2014. Prepared by the Collaborative Adaptive Management Team (CAMT). http://www.sfcwa.org/wp-content/uploads/Item_7_Attach_1_CAMT-Progress-Report-Version-6_0-_140207_0.pdf

5. Workshop on the Interior Delta Flows and Related Stressors Panel Summary Report. http://deltacThe following documents were provided in electronic format as required reading by the IRP prior to the 2-day workshop in Sacramento, CA on 6-7 November 2014:

APPENDIX 2. Monsen – What is OMR and Why Should Other Measurements of Entrainment Flow be Considered?

The DAYFLOW equations used to calculate the net Delta Outflow from the Sacramento-San Joaquin Delta at Chipps Island were originally created by the Department of Water Resources in 1978 (http://www.water.ca.gov/dayflow/docs/DF3060.pdf). To give a little perspective on that date, the most advanced tool available to study water transport in the Delta at that time was the Bay-Delta physical model in Sausalito (the Delta portion of the model was built in 1967), the Fischer 1-D Hydrodynamic Delta model was still in development (originally calibrated and published in 1982), and development of multi-dimensional hydrodynamic models or the region began in the mid-1990's.

Measuring the tidal flow across the Sacramento River at Chipps Island, the western boundary of the Delta, was not (and still is not very) technically feasible because this is a very tidally-energetic location. In addition, the managers needed an estimate of the tidally-averaged flow out of the Delta at this junction.

The DAYFLOW program is a simple flow mass-balance accounting program that assumes that the Delta has a set of uni-directional rivers as flow inputs to the river-side Delta boundaries. And, if the rate of export from the State and Federal Facilities was accounted for, the net flow out (Delta Outflow) of the Delta at Chipps Island could be calculated.

The DAYFLOW program became the mainstay for the management of the Delta because of its simplicity. However, because it has been used as a management tool for so long, the philosophy that transport in the Delta can be simplified to a simple mass balance has been embraced. As a result, there are several locations in the interior Delta where this mass balance philosophy has been applied (e.g. QWEST, a measurement of negative flow in the Western

Delta). Therefore, there is a common misconception that the tidally-averaged flow best characterizes transport through the Delta.

So, what is OMR?

There are two primary conveyance sloughs in the south Delta, Old River and Middle River, towards the State and Federal export facilities. Flow is measured at multiple locations along these sloughs. Currently, the California Data Exchange Center (cdec.water.ca.gov) reports a daily, tidally- filtered flow and an hourly flow for a fictional (i.e. is not a particular location) station called OMR. This station is a calculated flow based on the combined observed flows at an Old River station (OBI) and a Middle River station (MDM). The hourly flow reported is the sum of the OBI and MDM event flow data sampled at the top of the hour. The daily, tidally-filtered flow reported is sum of the running 24-hour average flow for OBI and MDM. Because this “OMR flow” is a summation of information from two different stations, you cannot back out of it stage or velocity information from this flow value.

Paul Hutton (Metropolitan Water District) has proposed an alternative OMR flow index (OMR index Demonstration Project) based on daily time series of: 1) prior day flows on the San Joaquin River @ Vernalis, and the 2) south Delta Diversions and Exports. The index also considers the configuration of the Grant Line Canal and Head of Old River temporary barriers. (These barriers re-route water through the south Delta (Monsen et al. 2007). On February 20, 2014, the Bureau of Reclamation Central Valley Operations Office authorized implementation of the Old and Middle River Index Demonstration Project stating that “Reclamation anticipates that the Demonstration Project will remain in place indefinitely or until further information emerges as a result of project implementation.”

(http://www.usbr.gov/mp/BayDeltaOffice/Documents/Current_Implementation/OMR_Index_Demonstration_Project/Letter_to_FWS_on_OMR_Index_Demonstration_Project_02202014.pdf)

The basic assumption of this new OMR index is the same, that the tidally-averaged flow is representative of entrainment flow at the Export Facilities.

What is missing in the discussion of entrainment at the export facilities is the recognition that the export facility is located in the tidal zone of the south Delta, and that flows around those facilities cannot be simplified to daily, tidally-average flows. In fact, the tidal velocities are approximately ten times greater than the tidally-averaged velocities in this region. There is a flow towards the export facilities on every flood tide. As such, even when the OMR index reports a POSITIVE OMR flow, there are still two periods each 24-hour day during which tidal flood flow is towards the export facilities. In addition, the Clifton Court Forebay gates are only opened during flood tides. Therefore, it is not surprising that Kimmerer (2008) observed that entrainment of Adults Delta Smelt can occur even when there was a positive OMR flow. However, because Kimmerer (2008) assumed that entrainment was proportional to negative OMR flow, he was unable to use Spring Kodiak Trawl data for periods of positive OMR flows in his regression.

APPENDIX 3. Stevens – Comments on Data Limitation

All of the proposals (and especially Proposals I and III) use the Spring Kodiak Trawl Survey (SKTS) and/or the Fall Midwater Trawl (FMWT). While these surveys are no doubt the best data available for estimating Delta Smelt population levels, they both have serious deficiencies. One of the first principles of good survey design is that the sampling encompasses the entire population domain. Neither of these surveys adheres to that principle. I was not able to locate details of the design (in particular, how the sampling sites were chosen), but the information given in the Proposals clearly indicates the deficiencies. While details of site selection were elusive, there are indications in the proposal and references that the surveys do not encompass all Delta Smelt habitat. For example, SKTS samples “mostly in mid-channel” and samples “the top 1.8 meters of the water column”; the FMWT samples pelagic habitat and also samples only the top 2 meters or so. Both surveys ignore near-shore habitat. Nevertheless, the survey results are being expanded to the entire habitat water volume of the region to a 4 meter depth. An un-testable assumption of uniformity is used to make this expansion. This assumption introduces an unknown but potentially large bias in the estimates.

It may be that gear limitations restrict both the SKTS and FMWT to mid-channel locations, but a simultaneous sample of near-shore habitat (such as used in Bennett and Burau, 2014) would make these surveys much more believable.

The proposed approach addresses some of the temporal asynchronicity of the salvage and trawl data by using data aggregated to a water year by summing monthly CPUEs for the SKTS, the FMWT and the salvage indices. While this approach does synchronize the salvage indices and abundance index, it also introduces an additional problem. The conceptual model is that entrainment is proportional to abundance, possibly tempered by environmental variables.

Entrainment operates locally, both spatially and temporally. However, the analyses will be carried out using data aggregated both spatially and temporally. The difficulty is that aggregation can change the nature of an apparent relationship. Model building and regression analyses should be performed using data as close as possible to the scale where the relationship operates, in this case, with data as simultaneous as possible and as local as possible.

The problem is most often recognized in a spatial context and characterized as an ecological fallacy (Robinson, 1950; Clark & Avery, 1976; Johnson & Chess, 2006), a change of support problem (Gotway and Young, 2002; Gotway, Crawford and Young, 2005), or a modifiable area unit problem (Openshaw and Taylor, 1979; Openshaw, 1983; Jelinski and Wu, 1996). However, the issue can also occur when data are pooled across time; for example, Schooley (1994). For a more complete discussion, see Independent Multidisciplinary Science Team (2009).

APPENDIX 4. Anderson – Conceptual Model of Surfing

This appendix develops an example of a tidal surfing model based on Bennett and Burau (2014) and then discusses potential implications and applications of the model. Bennett and Burau (2014) wrote that tidal surfing:

> …. would facilitate either maintaining position or moving upriver on flood tides, and minimizing advection down-estuary on ebb tides. These movements also may reflect responses to lateral gradients in water turbidity created by temporal lags in tidal velocities between the near-shore and mid-channel habitats.

While the explanation is succinct, understanding the details of the mechanism through which tidal hydrodynamics, turbidity and behavior interact is not trivial. What follows is a heuristic and therefore simplified model of tidal surfing and a numerical analysis of its consequences to Delta Smelt movement. The example model partitions the river cross-section into two parts: a shoal section and a channel center section. The Bennett-Burau model contains four critical elements.

E1 – Large scale turbidity: Turbidity has along-channel gradients. In summer/fall period the estuary turbidity maximum produces a negative turbidity gradient in the smelt habitat (i.e. *lower* turbidity upstream). In first-flush condition river sediment flux produces a positive gradient in smelt habitat (i.e. *higher* turbidity upstream)

E2 – Hydraulics: In the transition between ebb and flood tides water currents switch direction in the shallows before changing in the center of the river channel (by as much as about an hour). During this transition shallow and channel velocities are of opposite direction.

E3 – Local environment: The interaction of the tide transition currents in E1 and along-channel turbidity gradient in E2 results in lateral turbidity gradients near slack water.

E4 – Behavior: Fish detect lateral differences in turbidity on the scale of a meter or so and swim towards higher turbidity water. Fish do not detect along-channel turbidity gradients and do not need to swim along-channel.

Mechanism of surfing

Figures 1 and 2 illustrate how in the model the interactions of the four elements produce tidal surfing. Figure 1 illustrates the large-scale, along-channel turbidity gradient through the Delta Smelt habitat before and after a first flush (E1). The turbidity gradient is negative prior to first-flush because of freshwater flow, tidal forcing and bed dynamics produce a turbidity maximum in the Western Delta (Ganju and Schoellhamer 2008). The gradient reverses and becomes positive when autumn/winter rains flush sediments down the Sacramento River.

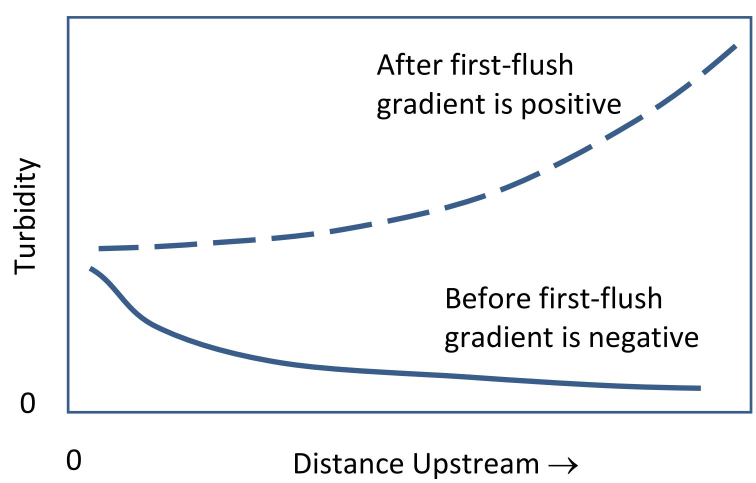
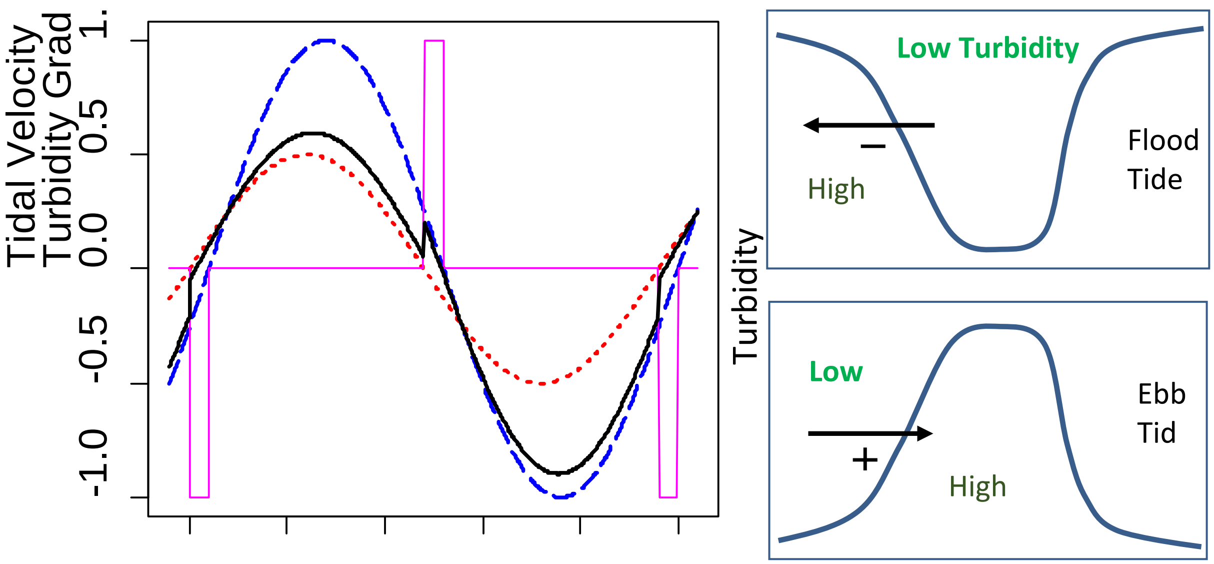


Figure 1. Along-channel turbidity gradients before and after first-flush.

The reversal in the along-channel gradient as a result of the first flush results in changes in the local lateral turbidity gradient by interactions with tidal asymmetries (Figure 2). About the transition between ebb and flood tides the shoal and channel velocities are of different signs (E2) with the shoal velocity reversing direction before the channel velocity at 0, 12 and 24 hrs. (Figure 2). During these transitions the sources of water in the shoal and channel are different. For example, beginning the flood tide the shoal current is upstream and the channel current is downstream resulting in the shoal containing more downstream water and the channel containing more upstream water. This creates a temporary lateral gradient in turbidity that reflects the along-channel turbidity gradient. After the transition the lateral gradient should tend to zero. Importantly, the ebb and flood lateral turbidity gradients reverse for positive and negative along-channel gradients (E3). When the along-channel gradient is negative, corresponding to a downstream source of turbidity, the lateral turbidity gradient is negative on the flood tide and positive on the ebb tide. The opposite conditions hold when the source of turbidity is upstream.

Because fish are attracted to higher local turbidity (E4), with a negative along-channel turbidity gradient they swim into lower velocities on the flood tide and higher velocities on the ebb tide (Figure 2). The result is a net downstream movement over a tidal cycle (Figure 3). When the along-channel gradient is positive, corresponding to the upriver turbidity source of the first-flush, the lateral gradient is positive on the flood tide and negative on the ebb tide. This puts fish in higher velocities on the flood tide and lower velocities on the ebb tide. The result is a net upstream movement over a tidal cycle during the first flush (Figure 3)

Before first-flush along-channel turbidity gradient is negative



After first-flush along-channel turbidity gradient is positive

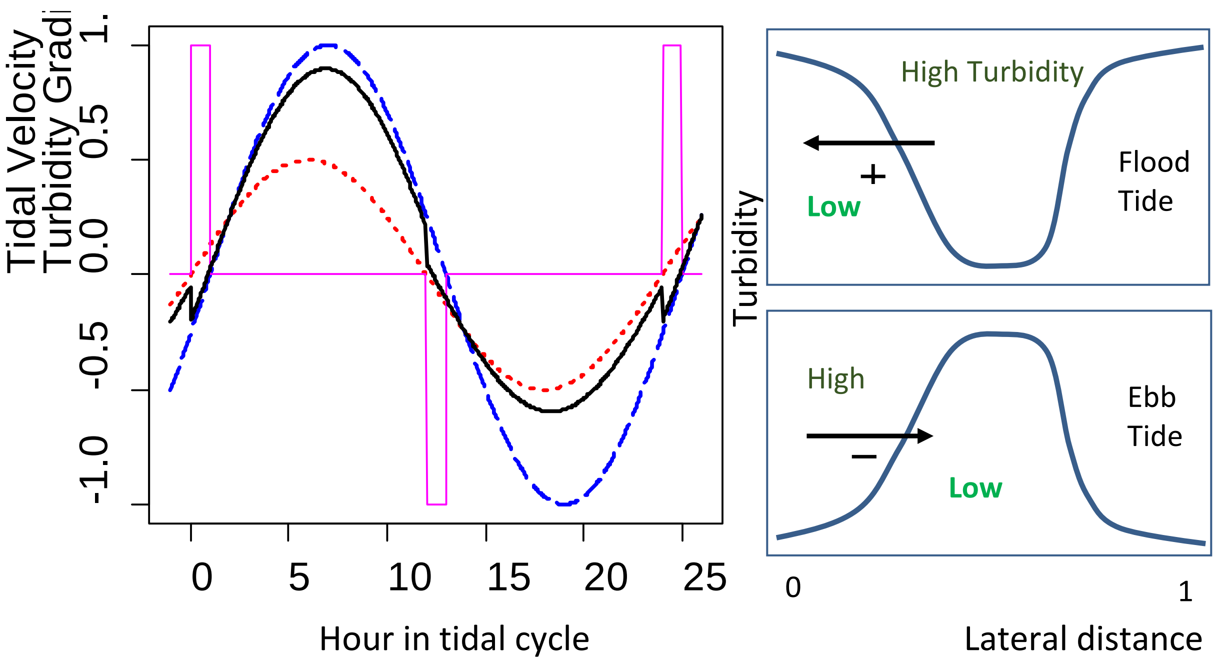


Figure 2. A heuristic model of tidal surfing. Upper rows depict conditions where the along-channel turbidity gradient is negative (turbidity decreases upstream before first-flush). Lower rows depict conditions with positive along-channel turbidity gradient (turbidity increases downstream after first-flush). Left columns depict water and fish velocities and lateral turbidity gradient. Right columns depict lateral turbidity distributions at transitions between ebb and flood tides. Channel (– –) and shoal (•••) tidal velocities are out of phase by 1 hour resulting in shoal velocity being positive and the channel velocity being negative at the beginning of the flood tide (positive velocity). Resulting lateral turbidity gradients (┌──) are negative or positive on tidal transitions. Fish velocity (—) is mixture of shoal and channel tidal velocities and depends on the lateral turbidity gradient at tidal transition which moves fish into shoal or channel region.

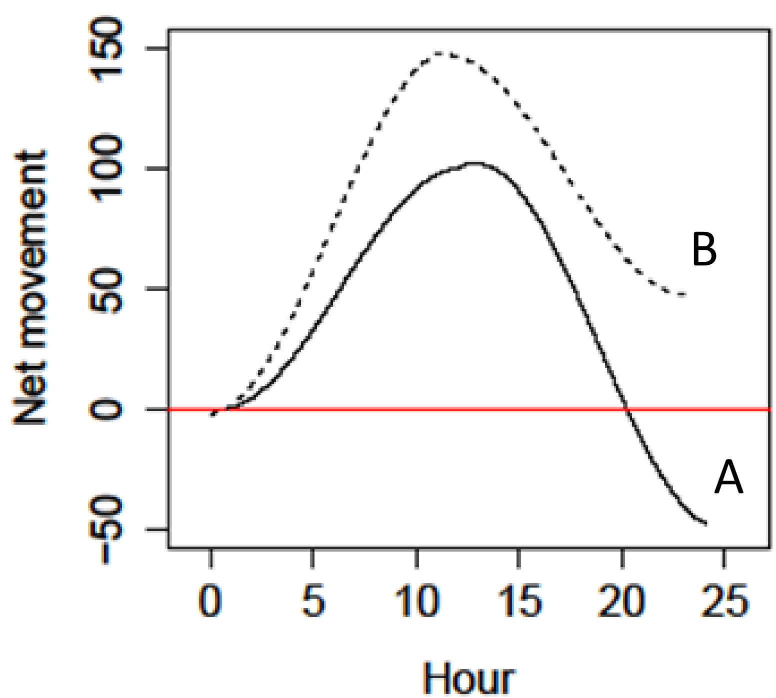


Figure 3. Net tidal cycle movement of fish corresponding to conditions depicted in Figure 1 Curve A shows net downstream movement over a tidal cycle resulting from positive along-channel turbidity gradient characteristic of conditions prior to first-flush. Curve B shows net upstream movement over a tidal cycle resulting from negative along-channel turbidity gradient characteristic of conditions after first-flush.

Implications of Tidal Surfing Mechanism

The immediate implication of the surfing mechanism is that the signal for tidal surfing depends on the along-channel distribution of turbidity and the tidal lag near slack water. Both of these properties depend on the channel depth profile and channel connections. This implies that the capacity to tidal surfing changes spatially with bathymetry of the Delta channels and the source of turbidity, either from upstream by river transport or from local resuspension which may be up or downstream depending on the fish location.

Shallow narrow area such as in Carquinez Straight are expected to be a local source of suspended sediment (i.e. estuary turbidity maximum) that might lead to a localized negative along-channel on its landward size and a positive gradient on its seaward side. Without an upstream source of turbidity, fish upstream or downstream of a local turbidity maximum could move towards the maximum through tidal surfing resulting in a localized fish density. Notably, the location of the attraction center would depend on river flow and seasonal timescales of the tides. Evaluating this hypothesis and developing an ability to identify the strength and location of the attraction zone would be critical information to assessing location of Delta Smelt prior to the first flush. Equally important, observations that correlate fish distributions with the hydraulic/turbidity factors would constitute a test of the surfing hypothesis. In particular, a model needs to explain and predict, not just the response of fish to first-flush; it also needs to predict the fish distribution prior to first-flush. The Panel notes that fish summer distributions have received minor emphasis in the proposal. A tidal surfing model offers the possibility that movement of fish over the entire adult life stages can be represented by one, possibly straightforward, tidal surfing behavior that increases and decreases in strength depending on the local spatial scales and seasonal patterns. The movement of juvenile salmon in engineered structure was reduced to three naturally evolved behavioral responses to the hydraulic environment (Goodwin et al. 2014). A similar simple set of behaviors may very plausibly explain Delta Smelt behavior.

A Tidal Surfing map from Proposal II would link to Delta Smelt distributions from Proposal I and entrainment from Proposal III.

The hydraulic-based nature of the surfing process suggests that it might be possible to characterize the potential surfing behavior strengths of different regions of the Delta. For example, using bathymetry, hydraulics and turbidity gradients, it may be possible to identify regions where fish naturally hold station, exhibit strong upstream movement, and other regions where the movement is controlled by mean flows. The spatial/temporal maps of such regions could then be compared to the distributions of Delta Smelt (a goal of Proposal I) and the relationship between OMR flows and salvage (a goal of Proposal III). In essence, a tidal surfing model might identify and classify fundamental and controlling environmental/bathymetric conditions in Delta Smelt habitats, e.g. X2 location, ship canal and Napa River, identify conditions of potential spawning habitat and regions that impact entrainment levels. From this perspective, a tidal surfing model is not used to predict the entrainment of fish but rather to map the spatial/temporal characteristics of the entrainment corridor through which Delta Smelt are transported into the south Delta. If fact a mapping exercise may provide insights to processes controlling entrainment that are not readily evident by modeling entrainment directly.

APPENDIX 5. Monsen – Steps Required to Calculate Adult Delta Smelt Entrainment Based on Kimmerer (2008, 2011) and Miller (2011)

Equation #1: Total abundance of fish (a.k.a. monthly population size)

The first calculation step determines the total abundance of the Adult Delta Smelt population. Kimmerer (2008) and Miller (2001) chose different domains for their calculations.

$$\begin{aligned} &Total\ abundance\ of\ fish \\ &\qquad = (Density\ of\ fish\ in\ sample) * Volume\ of\ habitat\ represented\ by\ sample \end{aligned}$$

Kimmerer (2008) chose to represent the population of the south Delta that could potentially be entrained in the export facilities. He estimated the mean density with 4 stations in the south Delta where fish are most vulnerable to entrainment. (902-South of Franks Tract, 906-San Joaquin near Prisoner's Point, 914-channel directly south of Mildred Island, 915-Old River USGS Flow Station) (Refer to Miller 2011; Figure 1 for station locations.)

$$\begin{aligned} &Monthly\ population\ size \\ &\qquad = [(mean\ density\ over\ all\ samples) \\ &\qquad * (Volume\ of\ habitat\ over\ which\ catches\ are\ averaged)] \\ &\qquad /(Efficiency\ of\ the\ Kodiak\ Trawl) \end{aligned}$$

Kimmerer (2008) assumption to use just the south Delta is reasonable because this is the population of fish within the region of influence of the pumps. However, is there a regulatory region that requires an estimate of the FULL population instead?

Miller (2011) chose to calculate the population of the FULL Delta (i.e., both San Joaquin and Sacramento stems of the Delta). Miller's (2011) procedure calculated the mean catch by sub-regions of the Delta. Miller's calculation was for the TOTAL abundance using ALL sampling stations including the rivers and sloughs connected to the Sacramento River stem of the Delta.

1. Define sub-regions throughout the Delta.
2. Calculate the volume of each sub-region assuming maximum depth of 4 m for Delta Smelt presence.
3. Calculate mean catch by sub-region based on the Spring Trawl sampling. Miller assumed Kodiak gear efficiency of 100%.

$$Total\ abundance\ of\ fish = (Density\ of\ fish\ in\ sample) * Volume\ of\ habitat\ represented\ by\ sample$$

4. Sum abundance values across sub-regions.

Proposal III intends to build on the approach that Miller used using improved bathymetry information to calculate the population for the FULL Delta (i.e. both San Joaquin and Sacramento connecting rivers and sloughs).

Proposed steps:

1) Divide Delta into different sub-regions based on Newman divisions. (In the next round of development of this proposal, a map of these proposed sub-divisions needs to be included.)
2) Calculate sub-region volumes based on the most recent bathymetry database assuming maximum depth of 4 m for Delta Smelt presence.
3) Calculate mean catch by sub-region based on the SKTS and then sum for full Delta population estimate.

Equation #2: Daily proportional loss rate

The daily proportional loss rate considers information about entrainment at each facility and the monthly population size. A simplified equation is stated here for clarity of the procedure.

$$Daily\ Proportional\ Loss\ Rate = \frac{(\ Daily\ Entrainment\ at\ the\ State\ Facility +\ Daily\ Entrianment\ at\ Federal\ Facility)}{(Monthly\ Population\ Size)}$$

$$Daily\ Proportional\ Loss\ Rate = \frac{(\ Equation\ \#3\ for\ State\ Facility + Equation\ \#3\ for\ Federal\ Facility)}{(Equation\ \#1)}$$

Equation #3: Entrainment at either the State or Federal Facility

$$Daily\ Salvage\ at\ a\ Pump\ Facility = \frac{Estimated\ Daily\ Salvage\ at\ Facility}{(Louver\ efficiency) * (fraction\ of\ fish\ entrained\ that\ reach\ the\ louver)}$$

Kimmerer (2008) assumed that “the efficiency of sampling by fish salvage facilities is constant.” He also stated in the paper that this assumption is probably not true, which leads to error variance in the calculation.

Equation #4: Theta: Simplify the unknowns in Equation #2

$$Theta = \frac{Efficiency\ of\ Kodiak\ Trawl}{(Louver\ efficiency) * (fraction\ of\ fish\ entrained\ that\ reach\ the\ louver)}$$

Essentially, this proportional term "theta" lumps all the unknowns (efficiency of Kodiak Trawl, louver efficiency, and fraction of fish entrained that reach the louver) into one big unknown that can be back-calculated with Equation #6.

Proposal III assumes that there is a different theta for each of the facilities. This proposal also recognizes that this value is not a constant over time. Proposal III plans to use Proposal II particle tracking to create this value.

Equation #5: Daily proportional loss rate substituting in theta (eq. #3) for unknowns efficiencies

$$Daily\ proportional\ loss\ rate = \frac{\Theta_{swp} * Daily\ Salvage_{swp} + \Theta_{cvp} * Daily\ Salvage_{cvp}}{(Density\ of\ fish\ in\ sample) * Volume\ of\ habitat\ represented\ by\ sample}$$

Equation #6: Finding "theta" based on historic take at State and Federal Facilities

There are subtle, but important differences between the Kimmerer (2008) and Miller (2011) approaches.

Kimmerer Equation (2008):

$$\frac{abundancy\ in\ South\ Delta}{Volume\ of\ South\ Delta} * (entrainment\ flow\ in\ South\ Delta) = \Theta_{South\ Delta}(Daily\ Salvage_{swp} + Daily\ Salvage_{cvp})$$

Miller Equation (2011):

$$\frac{abundancy\ in\ full\ Delta}{Volume\ of\ full\ Delta} * (entrainment\ flow\ in\ South\ Delta) = \Theta_{South\ Delta}(Daily\ Salvage_{swp} + Daily\ Salvage_{cvp})$$

Kimmerer (2008) made two major assumptions. First, he assumed that the entrainment flow in the south Delta was proportional to Old and Middle River Flow (OMR). Kimmerer (2008) stated that this assumption was “not strictly true since some adults are reported from salvage when flow is northward.”

Kimmerer also assumed that the fish arriving at the two facilities are in equal abundance per unit volume. Therefore, the louver efficiency and the fraction of fish entrained that reach the louver are the same for each facility.

$$\Theta_{South\ Delta} = \Theta_{swp} = \Theta_{cvp}$$

Review comment on this assumption: Clifton Court Forebay causes this assumption not to be valid if for no other reason than the Forebay, as designed, acts as a holding tank. Therefore, is an inherent delay in getting to the water projects. In addition, Clifton Court Forebay is known to be a predation hot spot. However, Kimmerer (2008) had no other choice but to make this assumption because he could only solve for one unknown.

Equation #7: Calculation of Adult Delta Smelt Take

Even though the form of the equation is the same for the three different approaches, there are differences between the calculations that will make a direct comparison of the results difficult.

Kimmerer Equation (2008):

$$Total\ Salvage_{State+Federal\ Facilities} \sim Poisson\left[\frac{(Volume_{South\ Delta})(\Theta)}{Representative\ Flow}\left(Annual\ Salvage_{swp} + Annual\ Salvage_{cvp}\right)\right]$$

Miller Equation (2011):

$$Total\ Salvage_{State+Federal\ Facilities} \sim zero\ inflated\ Poisson\left[\frac{(Volume_{Full\ Delta})(\Theta)}{Representative\ Flow}\left(Annual\ Salvage_{swp} + Annual\ Salvage_{cvp}\right)\right]$$

Proposal III Equation:

$$Total\ Salvage_{State+Federal\ Facilities} \sim zero\ inflated\ Poisson\left[\frac{\left(Volume_{full\ Delta}\right)}{Representative\ Flow}\left(\Theta_{swp} Annual\ Salvage_{swp} + \Theta_{cvp} Annual\ Salvage_{cvp}\right)\right]$$