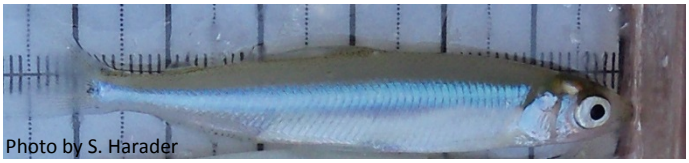
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Independent Review Panel (IRP) Report of the Collaborative Adaptive Management Team (CAMT) Proposed Investigations on Characterization of Relations between Autumn Outflow and Survival, Recruitment, and Habitat Quality for Delta smelt (*Hypomesus transpacificus*) Collaborative Adaptive Management Team Work Element 3-1-3

A report to the

Delta Science Program

Prepared by

Dr. James J. Anderson, (Lead Author), University of Washington

Dr. James A. Gore, University of Tampa

Dr. Robert T. Leaf, University of Southern Mississippi

Dr. Mary C. Fabrizio, Virginia Institute of Marine Science

Dr. Charles Yackulic, U.S. Geological Survey

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Delta Stewardship Council
Delta Science Program

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Executive Summary

The Independent Review Panel (IRP) reviewed the proposed "Characterization of relations between autumn outflow and survival, recruitment, and habitat quality for delta smelt (*Hypomesus transpacificus*)".

The proposed work is to estimate survival of Delta smelt during autumn (fall), conduct a stock-recruitment analysis, and assess occupancy and habitat quality for Delta smelt in the autumn. A secondary goal is to account for effects of imperfect detection on inferences about the relationship among population dynamics of Delta smelt and environmental covariates. The Scoping Document, which identified goals the proposal was to address, outlines a staged structure in which estimates of survival and recruitment would be linked to covariates in several ways: correlations with all suggested covariates, correlations with fall outflow only, correlations with covariates except fall outflow, and correlations of fall outflow to the other covariates. It appeared to the Panel the plan of proposal was in part disconnected from the Scoping Document goals. However, the Panel believes that the research can provide meaningful, but incremental, information on the effects of covariates on survival and recruitment of Delta smelt.

Strong points of the proposal included a comprehensive statistical framework to estimate abundance and survival as well as a simulation component to generate simulated data that would then be fit to the statistical model to evaluate the biases resulting from inferences of population variables and environmental covariates. The expert elicitation component of the proposal to identify covariates for including in the statistical and simulation models is also commendable. These strengths indicate to the Panel that the analysis will produce valuable information.

The weak points of the proposal include potential mismatch between the spatial/temporal scales of the models and the smaller scales that likely control Delta smelt movement and survival, imprecise descriptions of habitat quality measures and overly simplified statistical and simulation models of Delta smelt movement and survival. Descriptions of how simulation and statistical models will be linked and how biases will be evaluated are not articulated in the proposal. Finally, the mismatch between the coarse scales of the survey data compared to the small scale that recent research indicates controls Delta smelt detection and movement may limit inferences from the proposed work.

The Panel suggests the research plan could be improved if the proposal goals were prioritized to better align with the Scoping Document and to better assess the effects of data limitations and model assumptions on estimates of survival and abundance and their relationships to covariates.

The Panel suggests the basis framework of modeling survival and abundance of Delta smelt as defined by equations 1-10 in the proposal are for the most part useful, with the exception of the movement model which currently assumes that regional scale signaling of habitat quality

drives movements between regions. The Panel suggests consideration of movement in terms of tidal "surfing" processes that are controlled by local environmental conditions. This is a challenging endeavor that is likely to involve considerable effort and input from the Delta smelt research community. Spatial and temporal scales relevant to Delta smelt will need to be identified and appropriate covariates developed. For example, instead of correlating region-scale abundance of Delta smelt with regional seasonal flows averaged across seasons, the patterns of catch probabilities at individual stations may need to be related to the value of covariates at the time of the trawls. The panel understands that such an examination of abiotic values at this level of temporal and spatial resolution would likely require significant additional work. The panel believes that such an approach would expand the utility of the regional-scale model.

Besides suggesting an evaluation of the appropriate scales and functional forms of the statistical model, the Panel suggests expanding the simulation modeling to explore effects of modeling different scales and functional forms for survival movement and recruitment. The Panel sees a comparison of statistical and simulation models with different dimensions and scales as a potential way to evaluate the statistical model biases. For example, fitting a lower dimension statistical model to simulated data generated by higher dimension individual based model of Delta smelt (e.g. Rose et al 2013) would provide information on bias resulting from misspecification and simplification of the statistical model. Currently the research plan includes a limited comparison of the statistical model to simulated data. The Panel suggests the project would benefit from an expansion of this type of comparison. Furthermore, the Panel suggests the work be expanded in consultation with regional experts studying the biology and behavior of Delta smelt as well as with experts on Delta smelt modeling.

The Panel suggests the occupancy modeling be given low priority. It was not made clear how this work would lead to characterizing Delta smelt abundance or the relationship of abundance with environmental covariates related to fall outflow.

The Panel suggests the Investigator Team evaluates the value of including predators in the study due to the scarcity of Delta smelt in diets of predators.

Brief summaries of responses to the 5 Panel charge questions are listed below.

1. **Are goals and objectives presented in the proposal clearly articulated, internally consistent, and are they adequate to address the questions outlined in the Scoping Document?**

   The Panel agrees the goals and objectives of the proposal are relatively well articulated and internally consistent but deviate somewhat from the questions outlined in the scoping document.

   The Scoping Document emphasizes the interconnectedness of fall outflow, other environmental covariates, and survival/recruitment of Delta smelt, whereas the proposal focuses on a few other processes (movement, occupancy, colonization/extinction), but

with much less development of how environmental conditions, X2 and especially fall outflow, are correlated with survival and abundance. The Panel suggests that neither the data nor the analysis outlined may be adequate to answer the questions in the Scoping Document and emphasis of parts of the proposal should be revaluated.

2. **Does the proposed work have strong potential to contribute to an improved understanding of Delta smelt survival through the fall and winter-spring recruitment?**

   The Panel was in agreement that the approach outlined by the investigators is sensible and fairly general regarding treatment of the count data. However, there were doubts about whether the data are sufficient to model accurate and reasonably precise survival estimates. However, the multifaceted effort proposed by the authors is likely to make a meaningful contribution in identifying the limitations of the data for understanding survival and recruitment.

3. **Does the proposed work using zero-inflated models, region designation, and occupancy modeling represent a feasible and robust approach to addressing questions such as detection probability, occupancy, and collinearity among covariates?**

   The proposed methods all appear adequate and represent well accepted modeling techniques for the most part, however, there are some concerns based on mismatch between modeling assumptions and this particular study system. The Panel has questions about the utility of the occupancy modeling in relating the fall outflow with Delta smelt recruitment and survival.

4. **Is the proposed expert elicitation approach precedented, sound, feasible and realistic; and does it have the potential to contribute to understanding of the Delta smelt population?**

   The method proposed is a modified version of the roundtable discussion combined with the anonymity (presumably) of the Delphi Technique. The proposed method does take advantage of expert opinion; however, it is possible that a strong personality in the discussion can affect the outcome so it will be up to the organizer to assure that no single opinion outweighs the "minority" opinions. The elicitation needs to include members of other research groups studying Delta smelt. These should include those developing life cycle models and those studying the behavior and movement of Delta smelt in their local environment.

5. **Is the proposal explicit in what data will be used and how limitations of the data will be addressed in relation to the questions being asked?**

   In consideration of the objectives stated in the scoping document, the proposal is clear in what data will be used; those data which are provided over the historical period from 1990 to 2014, collected in conjunction with trawls. However, there seems to be little *a priori* consideration of the limitations of the data and their ability to account for the majority of the variation observed in the existing data. Indeed, there appears to be little allocated time in the proposal budget to investigate the limitations of the data or

development of covariates for inclusion in the analyses. The work allocation should be modified to allow for such analysis.

Background

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.

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 and objectives presented in the proposal clearly articulated, internally consistent, and are they adequate to address the questions outlined in the Scoping Document?
2. Does the proposed work have strong potential to contribute to an improved understanding of Delta smelt survival through the fall and winter-spring recruitment?

3. Does the proposed work using zero-inflated models, region designation, and occupancy modeling represent a feasible and robust approach to addressing questions such as detection probability, occupancy, and collinearity among covariates?
4. Is the proposed expert elicitation approach precedented, sound, feasible and realistic; and does it have the potential to contribute to understanding of the Delta smelt population?
5. Is the proposal explicit in what data will be used and how limitations of the data will be addressed in relation to the questions being asked?

Review process

The Independent Review Panel (IRP) reviewed the proposed "Characterization of relations between autumn outflow and survival, recruitment, and habitat quality for Delta smelt (*Hypomesus transpacificus*)" and a set of associated documents (Appendix 1). As instructed by the charge to the Panel we addressed the 5 questions. Individual panel members focused on at least two specific questions and provided comments on all questions. The lead author integrated the responses for the final review document. 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, representatives of the CAMT and the Delta Smelt Scoping Team and the proposal Investigator Team was conducted as teleconference meeting on September 8. The Panel called into the meeting from their respective institutions. The proposal Investigator Team either was in attendance or joined by teleconference. The meeting schedule was as follows:

Public Session: 10:00 a.m. – 12:00 p.m. PDT

1. Welcome and Review Panel Members Introductions (10 min)
   Rainer Hoenicke, Delta Science Program
2. CAMT Background and Context (10 min)
   Frances Brewster, CAMT Co-chair, Public Water Agencies
   Leo Winternitz, CAMT Co-chair, GEI Consultants (representing the NGOs)
3. Delta Smelt Scoping Team Context (10 min)
   Steve Culberson, DSST Co-chair, USFWS
   Scott Hamilton, DSST Co-chair, Coalition for Sustainable Delta
4. Review Panel/Investigator Team Q&A (90 min)

Internal Session: **1:00 – 3:00 p.m. PDT**

Panel deliberations and planning for the Review Panel Report

The morning Public Session was recorded and notes were distributed to the Panel by the Delta Science Program. Drafts were prepared with comments and exchanges amongst panel members for each draft. A second teleconference between Panel members was held Monday, September 21 to discuss the first draft. A third teleconference between Panel members was

held on September 28. The final draft report was delivered to the Delta Science Program on September 28.

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 below.

Acknowledgments

The members of the Independent Review Panel appreciate and acknowledge the efforts of the Delta Science Program for their assistance in preparation of this review.

Responses to questions

1. *Are goals, objectives, hypotheses and questions clearly articulated and internally consistent and are they adequate to address the questions outlined in the Scoping Document?*

General comments

The Panel agrees the goals and objectives of the proposal are clearly articulated and internally consistent but deviate somewhat from the questions outlined in the scoping document.

The scoping document (SD) emphasizes the interconnectedness of fall outflow, other environmental covariates, and survival/recruitment of Delta smelt, whereas the proposal focus on a few other processes (movement, occupancy, colonization/extinction), but with much less development of how environmental conditions, X2 and especially fall outflow, are correlated.

The Panel notes the Scoping Document requesting that the proposal provide information to infer how covariates strongly correlated with survival and recruitment. Four specific correlation analyses identified as questions:

Scoping Document question 1) correlations of all variables with survival and recruitment,

Scoping Document question 2) correlation of fall outflow with survival and recruitment,

Scoping Document question 3) correlations of variables except fall outflow with survival and recruitment,

Scoping Document question 4) correlations of fall outflow and the other variables. Survival and recruitment will be estimated using catch data using the three seasonal fish surveys (summer townet, fall midwater trawl and spring kodiak trawl surveys).

The Panel had doubts that the available data are adequate to make the predictions and correlations needed to identify which environmental variables are strongly correlated with annual changes in fall survival and recruitment. A number of issues were raised concerning adequacy.

Spatial coverage and temporal variability of data

To understand the survival and recruitment dynamics and their environmental covariates, the authors propose to use a suite of local and global (regional) covariates as potential predictors of variation in various state (occupancy and abundance) and process parameters (survival, movement, colonization and extinction). Inferences about survival will come mainly from a model that combines elements of state-space and Dail-Madsen modeling. Recruitment will be assessed primarily through a stock-assessment approach. One concern of the Panel is the potential mismatch between the underlying scale-dependent dynamics controlling Delta smelt survival and recruitment and the spatial and temporal scales of the data. Given the substantial data needs that are required by the models, the Panel felt that they were not sufficiently informed about the types and structure of the available data. This was a problem because there was a sense that the data were not of sufficient quality or quantity to perform the modeling exercise. It was not clear from the conference call whether these data were "in hand" by the authors – a discussion of the ability of the model to handle the existing data would have been valuable (see simulation issues). The relevance of this is that the data and modeling will necessarily limit the inferences that can be made. Some outstanding issues then are to what extent the data are capable of informing the model and to what extent the data structure will limit inference.

Simulations

The proposed simulation study is an excellent idea, and can shed light on the ability of the current data to address questions of concern to the Delta Smelt Scoping Team. The purpose of the simulation is to determine how accurately the model can estimate coefficients relating environmental covariates to survival and movement given different probabilities of detection and sample sizes. A number of issues were raised regarding the simulations and their applications.

Selection of flows – Ultimately, the simulation will rely upon historical flow / outflow records to predict the distribution and abundance of Delta smelt. This may be appropriate to "test" the simulation. However, the appropriateness of the simulation going forward, considering the effects of climate change and associated impacts on flow, may not make it an appropriate model without adjustments to the predictive protocols. Recent research suggests that large-scale climate oscillations (AMO, PDO, and ENSO) do not influence continental weather patterns in the manner that has been recorded over the past one hundred years. In some areas, additional flooding might be expected. However, it appears that historically low and high flow patterns will now be much reduced. As a result, the low

outflow simulation may not be appropriate to predict the distribution of Delta smelt. The assumption of a continuous connection between high quality habitat patches may not be valid under lower than "historical low" flows. The Panel suggests that the proposal Investigator Team considers an even lower flow scenario that reflects this potential flow regime in the Delta. The flow regime is dependent upon releases from upstream reservoirs but these are likely to become impoverished as agricultural demands increase and as low flow / drought conditions continue or become the new "historical" condition. The discontinuity in patch connections may dramatically alter predictions of the model. This comment is emphasized by a large number of simulations (for example, Maurer 2007 and Xenopoulos et al. 2005) which predict dramatic reductions in flow and loss of freshwater fish species (up to 37% losses from the Sacramento, in some scenarios) by 2070 if climate-change induced changes in river flow patterns in the Sierra Nevada continue. An alternative would be to run simulations with varying degrees of connectivity between habitat patches.

Movement models

The goal of this simulation is to assess the bias in assumptions of capture probability. The Panel suggests that it is equally important is to assess biases in the movement model. In this regard the Panel has concerns for the adequacy of the movement model.

Recent studies suggest movements are driven by local (channel width and tidal cycle) scales of asymmetry in turbidity that induces intermittent "tidal surfing" (Bennett and Burau 2014). The occurrence and strength of this movement mechanism varies within the Delta and is likely to vary over the season (Feyrer 2013). Tidal surfing may concentrate Delta smelt in the X2 region in the summer (Kimmerer et al. 2014) but allow upstream migration in the fall. The Panel does not see how the wide-scale horizontal attraction model of movement equations (5) and (6) can be related to this emerging understanding of the effect of local process on movement. Note that equation (6) is incomplete: W_{rt} and $kappa_{rt}$ are not defined.

The Panel believes that development of a movement model that reflect the local scale dynamics is beyond the scope of the study; the Panel recommends consideration of some revision of the model that takes into account the recent studies of Delta smelt movement dynamics. The challenge is to revise the current movement model to capture some issues affecting fall flows on fish survival and recruitment.

The Delta is an interconnected system with major inputs flows from the Sacramento and San Joaquin rivers and exports through the pumps in the southern Delta. While these flows set the mean water movement, the Delta is dominated by tidal flow which, coupled with the complex geometry, creates tidally varying regimes of velocity, turbidity and salinity. For example during the fall flush, the rate of movement of turbidity from the Sacramento River depends on the rate of export of water from the sound Delta pumps. Delta smelt

movement is influenced by the tidally varying distributions of turbidity gradients over scales of a few meters (Bennett and Bauer 2014). The Panel believes that to understand the effects of fall flows on Delta smelt populations, details of the interactions of these flow elements will need to be addressed.

The proposed movement model assumes that movement is driven by the horizontal differential of region-wide measures of habitat quality and distance of separation. In the model, dispersal probability is proportional to the Euclidean distance between regions (centroid-to-centroid distances) (equation 7). This approach may be adequate for modeling movement in a relatively linear system, such as the Hudson River. Euclidean distance between regional centroids is unlikely to accurately represent true distances (i.e., the distance 'as the fish swims'). Are regional centroids defined geographically without regard to sampling intensity, or will a weighting scheme be applied (e.g., number and location of stations in the region)? In particular, dispersal probabilities from the North and South regions may not be adequately represented by Euclidean distances between their centroids. The distance between the Northern and Southern centroids is likely to underestimate the actual distance that a fish would need to swim to move between these two regions. If the bias is constant among regions, than the effect would not be concerning. However, the bias in the use of Euclidean distances between regional centroids is likely to be inconsistent among regions. A more direct approach would be to estimate distances between all adjacent sampling stations (e.g., using their GPS coordinates) and combining these to estimate dispersal probabilities from any given station in a particular region to the nearest station in the adjacent region. Other similar approaches could be considered.

Another approach to improve estimation of dispersal probabilities is to model the relationship between dispersal probability and time. Such an approach would acknowledge the biology of the Delta smelt and would lend additional realism to the model. For example, fish may be more likely to move prior to or around the time of spawning (spring); thus, dispersal probabilities in December should be higher than those in September. This type of response may be modeled as time- (month) dependent or age- (fish size) dependent.

The Panel encourages the Investigator Team to consult with groups doing this work and incorporate suitable functional models and identify relevant spatial scales for their simulation to explore the bias in abundance and survival estimates. The Panel sees this as critical to address the Scoping Document questions because fall flows affect the turbidity distribution and tidal dynamics. Ideally the work could be facilitated by collaboration with the other research teams being funded as part of CAMT Delta smelt research.

To assess whether the movement model is adequate to estimate survival, the Panel recommends a model comparison exercise where pseudo-data generated with a more complex individual based model, e.g. Rose et al. (2013), is analyzed with the abundance

model outlined in the proposal. In this way ability of the analysis framework and selections of spatial/temporal scales are able to recover meaningful scale adjusted estimates of the underlying movement and survival processes used to generate the IBM data.

Linking model outcomes to Scoping Document

It is not clear how the Investigator Team proposes to integrate the individual model outcomes (abundance, movement, survival, occupancy, detectability, and expert elicitation) to address questions in the Scoping Document. Equation 4 will be used to determine factors affecting survival in fall (SD question 1), and equations 11 and 13 (page 17) will be used to characterize habitat quality for Delta smelt in the fall (SD question 3). However, it is unclear how SD question 2 concerning the relationship between abundance of Delta smelt in December and larval production in the spring (recruitment) will be addressed.

The proposal spends very little time addressing the recruitment analysis (mainly on pages 15 and 16). However, this appears to be an important part of the Scoping Document (questions 2 and 3). Although an understanding of correlations between predictors is a large part of the Scoping Document (questions 1 and 4) it is barely covered in the proposal.

Objective 4 (page 4) implies that the team will 'compare model-based estimates of abundance in December with recruitment in the spring', but the proposal does not describe in detail how recruitment in the spring will be measured or modeled. The text on page 20 suggests that occupancy model outputs for December will be compared with distribution of recruits in April; however, the output from occupancy models includes detection probabilities and estimates of the proportion of sites occupied, not abundances. It is unclear how occupancy model outputs will be used to estimate "abundance."

2. *Does the proposed work have strong potential to contribute to an improved understanding of Delta smelt survival through the fall and winter-spring recruitment?*

General comments

The Panel was in agreement that the approach outlined by the investigators is sensible and fairly general regarding treatment of the count data. However, there were doubts about whether the data will allow for a complex model that leads to believable and reasonably precise survival estimates.

Very little is known about the environmental drivers that contribute to survivorship in Delta smelt. Indeed, based on the literature presented, the stock exhibits a wide degree of phenotypic variation in demographic and behavioral characteristics. Previous work has indicated that regional (spatial) designation has little predictive power in understanding

the likelihood of capturing Delta smelt. Modeling studies suggest that survivorship and recruitment are affected by multiple factors, working at small scales (Rose et al 2013). However, the Panel believes that the multifaceted effort proposed by the proposal authors is likely to make a meaningful contribution to understanding the mortality dynamics of the Delta smelt stock. The major contribution may be in identifying the limitations of the data to make such inferences and make substantial management recommendations to improve sampling efforts, such that the mortality estimates can be improved in the future.

The value of the approach will be contingent on the power of covariates to describe survival and the statistical power to detect meaningfully variations. At a minimum, the Investigator Team efforts to understand how sensitive mortality is to each covariate will be informative and the simulations will hopefully illustrate the power (or lack of power) based on current sampling design. An understanding of the relative sensitivity of state variables to environmental drivers and the functional forms of the linkages will provide valuable information to help guide monitoring practices. This represents a valuable contribution to the management of Delta smelt, especially given the many ambiguities in understanding the behavior and demographic characteristics of the species.

In particular, the modelers may need to constrain the movement model based on recent information on fish movement (see movement models above). In addition, the degree to which capture probability in the model conflates use and detection processes in the real world, as well as the implications of this, is unclear. Simulations and use of posterior predictive checks may help in identifying this and other issues associated with the goodness of fit.

The proposed work will likely contribute to an improved understanding of Delta smelt dynamics particularly given that the Delta Smelt Scoping Team requested that the researchers use currently existing data only. This directly affects the level of uncertainty in the outcome of the proposed modeling work. The Investigator Team proposes to apply new modeling approaches and as such, this represents a positive, important step forward.

The idea of consulting and working with the members of the Delta Smelt Scoping Team and the Collaborative Adaptive Management Team to frame hypotheses about attributes of habitat quality is excellent and should be pursued.

As an aside, the Panel had an internal discussion on definitions of detectability and catchability which are included here. To detect a species, at least one individual must occur at the site, and, as expected, the probability of detection increases when a greater number of individuals are present. Thus, detectability is a function of the number of organisms that are vulnerable to capture and the probability of capture. For a given level of abundance, researchers can maximize detectability by ensuring high catchability which entails the deployment of efficient sampling gear during times and in locations where the species is available (Bayley and Peterson 2001). Catchability, or the proportion of a fish stock

captured with a single unit of effort (Gulland 1983), is the product of availability and gear efficiency (Kimura and Somerton 2006). Availability refers to the proportion of the fish stock that occurs in locations where the gear is deployed, and gear efficiency is the proportion of fish captured from those that occurred within the sampled area (Kimura and Somerton 2006). Although often assumed constant, catchability is temporally and spatially variable because availability and efficiency vary. For example, gear efficiency may be affected by environmental factors that alter gear performance and by fish behavior, as well as, by the selectivity of the gear and the vulnerability of individual fish. It is important to clearly differentiate detectability, availability, catchability, and gear efficiency when discussing sampling concerns for Delta smelt (Williams and Fabrizio 2011).

Abundance modeling

The research team will model Delta smelt abundance and survival during fall using catch data from a time series of fishery-independent surveys. Two surveys provide such information: the summer townet (STN) survey (August), and the fall midwater trawl survey (FMWT, September through December). In addition to using different gears, the two surveys sample at different fixed stations, and the number of stations sampled varies: the FMWT survey samples 100 stations annually compared with 31 stations in the STN survey. How will abundance data (catch per effort) from the STN and the FMWT surveys be used in the same analysis? For example, the STN data will be used to initialize the abundance model (p. 10), but the two surveys are characterized by differences in the spatial intensity of sampling.

In the observation process model, the number of individuals observed is modeled as a binomial random variable, with regional abundances estimated from the FMWT survey and the probability of capture estimated as a function of covariates. In this model, in addition to consideration of the main effect of each covariate (which were not specified here, but presumably include flow, temperature, salinity, turbidity, etc.), the Panel recommends consideration of the interactions between covariates. For example, the probability of capture may increase with increasing temperature in low turbidity, but may not change with temperature at high turbidity. This will allow for more nuanced understanding of covariate effects.

The section on 'Modeling multiple cohorts with the abundance model' proposes to estimate overall cohort survival using regional estimates of abundances in December and September ($N_{r, Dec}$ and $N_{r, Sep}$). In the previous section, monthly regional abundances ($N_{r, Dec}$ and $N_{r, Sep}$) were said to be derived from the FMWT survey. These estimates rely strongly on the assumptions that all fish in a given region are available during each survey in a region (one assumption in N-mixture models). Clearly, estimates of detection probability will be dependent on both use and detection, and what is unclear is how well the N-mixture approach will work in this setting, both because of additional heterogeneity and because the product of the probability of use and detection is likely to be exceedingly

small. Given the potential sparseness of the data, it is also unclear how much power there will be to detect variation in detection probability.

Regarding the estimation of annual recruitment of Delta smelt (page 14), the 'stock-recruitment analysis' proposed by the Investigator Team is quite vague. Which models will be considered for this analysis? The traditional stock-recruitment models such as those due to Ricker or Beverton and Holt may not be useful to address stock-recruitment dynamics in Delta smelt. These models, which describe compensatory mortality of pre-recruits, often account for only a small portion (5-15%) of the total variation in recruitment of fishes (see recent papers by Cury et al. 2014 and Szuwalski et al. 2014). The assumptions and limitations of the Ricker and Beverton-Holt models should be fully considered prior to their application. In particular, the assumption that 'stock' and 'recruitment' are appropriately measured using FMWT abundances in winter (stock) and the number of potential spawners in the spring trawl survey (recruitment) requires careful consideration. Examination of these two abundance estimates appears to provide a good estimate of survival, but it is not clear how the stock-recruitment relationship would be described. The panel recommends using the abundance of larvae in the spring from the 20 mm survey as an index of 'recruitment'. The measure of 'stock' size in stock-recruitment models should represent reproductive output (total number of eggs produced is best, but failing this, other estimates such as spawning stock biomass or mature female biomass have been used). Finally, fitting the stock-recruitment models of Beverton-Holt and Ricker to fisheries data requires an adequate range of values for 'stock' size. Given the declining abundance of Delta smelt, it is not likely that a sufficiently broad range of values for stock size will be available. Due to low abundances of Delta smelt in recent decades, simpler models (e.g., a linear model) may be sufficient to describe the relationship between spawners and recruits. At these lower 'stock' sizes, recruitment may, indeed, depend on stock size (Szuwalski et al. 2014). Unfortunately, at low population sizes (such as those observed for Delta smelt), depensatory mortality may need to be considered, assuming depensation mechanisms can be described for this species.

3. *Does the proposed work using zero-inflated models, region designation, and occupancy modeling represent a feasible and robust approach to addressing questions such as detection probability, occupancy, and collinearity among covariates?*

General comments

The proposed methods all appear adequate and represent well accepted modeling techniques for the most part, however, there are some concerns based on mismatch between modeling assumptions and this particular study system. The Panel has questions about the utility of the occupancy modeling in relating the fall outflow with Delta smelt recruitment and survival.

Regional designations

The region designation is based on previously established regions within the Delta and the authors' plan, because of constraints in the spatial distribution of the samples, to delineate only four regions. The regions were delineated based on previous work but it is not clear how consistent the spatial covariates (at local or regional scales) are within each region. We understand that the authors do not have the abundance data for Delta smelt at the time of writing this proposal, but it is difficult to justify the regional designations without a discussion about the coherence of the catch-per-unit effort or some metric of abundance of Delta smelt or the coherence of the habitat or environmental covariates. This raises the question "to what extent will the results of modeling work be sensitive to these designations?". The Panel recommends that the Investigator Team performs a *post hoc* sensitivity analysis to address the issue of regional designations.

One outstanding issue is how the covariates (local and regional) will be synthesized. The Investigator Team mentions the range in spatial and temporal scale that the covariates exhibit. For example, some covariates exhibit high-frequency and fine spatial-scale variability (salinity, turbidity, water temperature) and others perhaps less so (volume of tidal marsh, habitat quality). It is not clear to what extent a covariate that exhibits high-frequency and fine spatial-scale variability is representative of a large spatial region. These are not insurmountable or novel issues but it would be informative to understand how the Investigator Team intends to deal with these.

On page 6, the Investigator Team states that the data are not likely to be sufficient to delineate more than 4 regions for models of abundance. Yet, for estimation of habitat quality (using occupancy models), more than 4 regions may be considered. In terms of abundance estimation, because the STN estimates will be used to initiate the abundance model, the spatial resolution will be limited to that which is supported by the 31 survey sites; 4 regions seems reasonable here. The spatial resolution of the data for occupancy modeling will allow delineation of more than 4 regions because the FMWT survey comprises 100 (index) sampling sites. Given the likelihood that detection probabilities will be low, and the fact that spatial replicates will be used for occupancy sampling, the Panel recommends that 'patches' include no less than three sampling sites. Delineation of these patches on the basis of hydrology seems reasonable and may result in 'patches' with more than three sampling sites. It would be helpful to know how sampling sites from the FMWT survey align with different regional delineations being considered.

Collinearity among covariates:

The issues of collinearity among candidate covariates were discussed on the conference call and will be treated in two alternative ways – one of which was a departure from the methods averred in the proposal: covariates will be treated outside of the model to inspect for collinearity and only those that are considered to add to the explanatory power of

models would be included into candidate models. Collinear factors were to be treated in a data reduction statistical treatment using non-metric multidimensional scaling and incorporated into models.

The Investigator Team will consider the effect of multiple covariates on occupancy and detectability. During the review Panel's interaction with the Investigator Team, one of the researchers indicated that centering and standardizing of covariates will be considered. Although useful, the inclusion of multiple covariates and especially inclusion of interaction terms, will likely cause collinearity of candidate predictor variables, regardless of whether the variable is re-scaled. Collinearity can be addressed in three ways, the first is to assess the pairwise correlation of predictor variables and the second is to examine variance inflation factor, *post hoc*. If necessary, the Investigator Team will use a multivariate analysis for data reduction. Such reduction includes using a Principal Component Analysis (PCA) or Non-metric multidimensional scaling (NMS), whereby multiple covariates are transformed into a single factor.

The Panel recommends the following steps:

1. Focus on a parsimonious set of management-related covariates.
2. If data reduction is necessary, the collinear variables should be limited to sets of variables that are interpretable (e.g., a PC vector based on multiple covariates that measure an overall regional climate signal, or an overall signal for 'flow').
3. If these approaches fail, the Panel recommends elimination of covariates because interpretation of the effect of the derived covariate (e.g. the 1st principal component) will be difficult.

The Panel also recommends thinking about correlated covariates (especially when correlation is between fall outflow and some other covariate of less management concern) in a decision support context and multimodal inference context. What would happen if the response was driven solely by one covariate vs. the other or at intermediate levels?

Occupancy modeling and detection probability:

The proposed study will use spatial replicates to estimate probability of detection and occupancy; presumably, the spatial replicates are the multiple stations sampled within each patch. Application of occupancy models requires the assumption of closure at the patch level which spatially encompasses multiple stations. Although a recent paper by Kendall and others relaxes the closure assumption, "the power to detect the violation of closure is high if detection probability is reasonably high" (Kendall et al. 2013). Detection probabilities for Delta smelt are unknown, but are not likely to be high, thus, it may be difficult to know if the closure assumption will be acceptable for these data. The relaxation of the closure assumption allows organisms to move seasonally between patches, which could describe Delta smelt movements in the Delta. However, spatial replication will need to be fairly high (a minimum of 3 possibly more sampling stations per 'patch') to provide

useful estimates of occupancy and detectability (see Table 6.1 in MacKenzie et al. 2006). How the stations are assigned to a patch is a critical step in the modeling process. That is, how are the 'patches' operationally defined in this study? The Panel recommends discussions with the agencies/scientists that collected the survey data to determine the best possible assignment of stations to patches, and patches to regions. The level of resolution of the patches appears to be a critical question that will affect interpretation of results as well as the selection and use of covariates.

Time-of-day of sampling is a relevant factor for occupancy models because Delta smelt may avoid areas with high light levels. Given this behavior, Delta smelt are not likely to be present in areas when light levels are high (sunny afternoons, clear water); therefore, time of day is a potentially important covariate for detectability. However, because the effect of 'time of day' may vary depending on cloud cover, the Panel recommends consideration of other covariates such as the interaction of depth and turbidity, which may be more informative.

On page 18, the research team describes the use of the summer townet data (August sampling) to determine initial occupancy states. However, there are only 31 stations sampled by the STN survey, so the level of resolution will be different from that of the FMWT, which samples at 100 stations. The 'patches' for the STN survey data will be geographically larger than those for the FMWT. It is not clear how the less spatially-intensive STN can be used to initialize occupancy states for the FMWT data. It is unlikely that colonization/extinction rates will be able to be estimated at the station level – particularly because 'stations' will be used as the spatial replicates (of the 'patch').

The proposed use of cross-validation of the occupancy model parameters may not be viable – the samples appear to be too limited.

Multi-state occupancy models may be worth considering to better understand detectability and occupancy of Delta smelt. Although multi-state occupancy models are discussed, it is not clear if the research team intends to apply such models. One difficulty will be determining the abundance 'bins' (low, medium, high abundance) to describe the multiple states. It may be useful to consider non-linear thresholds for the bins – for example, low (0-1 fish/tow), medium (2-10 fish/tow); high (greater than 10 fish/tow).

As mentioned above, the Panel is concerned about patterns of use within regions and how this process will interact with underlying variation in detection rates. These concerns result from the use of spatial replicates for both occupancy and abundance models. In the occupancy modeling, it may be possible to define regions at smaller spatial scales, potentially removing some of the heterogeneity in use that may occur in the larger regions. However, this may also lead to only a few replicates per region. In addition, both the use of the spatial replicates (Kendall & White, 2009) and the low number of regions and replicates

(Mckann, Gray and Thogmartin 2013) raise concerns about bias in estimates of occupancy, colonization and extinction.

Abundance distributions

Multiple options were considered for modeling abundance (p. 10) including the Poisson, negative binomial, zero-inflated, and mixture models. One type of model that is commonly used in fisheries is the delta-lognormal model (as well as other delta models). The approach of the delta model seems to be described on page 15, but is not identified as such. It is important to recognize the multiple approaches that can be used in modeling abundance data from survey data, but there is no indication of which approach will be applied by the research team. In the section titled 'Research Challenges', the discussion in the text appears to favor use of the negative binomial and zero-inflated negative binomial models for estimating abundance. Will each of these approaches be used or will the determination of approach be made using an objective criterion or some other method? The Investigator Team highlights the trade-off between methods that account for over-dispersion versus those that model processes that can lead to over-dispersion (e.g., the two-component Poisson). However, the team does not specify which approach will be used. Questions concerning the number of parameters and the principle of parsimony could be addressed here, as well as the expected limitations concerning the ability to generalize results from two-component Poisson models to survey data collected in future years. The Panel recommends exploring the sensitivity of model outputs to different assumptions of abundance.

4. *Is the proposed expert elicitation approach precedented, sound, feasible and realistic; and does it have the potential to contribute to understanding of the Delta smelt population?*

General comments

When it is not possible to obtain more field data to create habitat or response models of specific organisms, experts are consulted and, through a process of joint or independent conversation, create habitat or response models based upon a combined expert opinion. This is called the Delphi technique [presumably for the Oracle at Delphi who was consulted about the future] (Zuboy 1981). Of course, credibility can always be questioned since the ultimate response is based upon expert opinion and experience rather than a data-intensive study. The best outcomes are derived from a panel of experts who can remain neutral and objective with respect to the criteria involved. This technique is commonly used by instream flow modelers when minimum flows and levels must be created without the ability to conduct a data-intensive study [which can take a year or more].

The method proposed here is a modified version of the roundtable discussion combined with the anonymity (presumably) of the Delphi technique. The proposed method does take

advantage of expert opinion; however, it is possible that a strong personality in the discussion can affect the outcome so it will be up to the organizer to assure that no single opinion outweighs the "minority" opinions. At a minimum, some of the participants should include members of Ken Newman's group who are most familiar with recent models of movement with the Fall turbidity plume members of the research team studying the response of Delta smelt to tidal processes (e.g. Bennett).

Specific suggestions

Although the proposal does not indicate the exact procedure, the first round of questionnaires is critical to obtaining the information needed for the model. In this case, the assumption is that the experts will be given either (1) a suite of conditions for which they must create some indication of "preference" by the target organism or, preferably, (2) a "free-hand" set of questions is created in which the experts are asked about the habitat criteria that most likely affect the distribution of the potential predator. In an ideal Delphi technique, (with mean and interquartile ranges being recalculated each time) the process is repeated until a relatively stable level of responses is achieved. To neutralize any problems with the choices, the group opinion should be summarized as median and interquartile range, announced to the group, and a second round of questions answered with ability to modify response based upon knowledge of the first summary. In some cases, a third or fourth round may occur.

Using option (1) may be the best choice for this study but this suffers the possibility that the covariates given (even according to the experts questioned) may not account for a great percentage of the variability. Option (2) is fraught with the danger that the primary covariates chosen have not been measured in the existing data set. For example, the striped bass adult habitat criteria that have been shown to predict about 75% of the distribution in *riverine systems* are:

Velocity: no known preferences

Depth: Mean:	2.82 ft
Lower Quartile:	1.27 ft
Upper Quartile:	7 ft

Substrate: equal preference

Sand
Gravel
Cobble
Boulder
Bedrock

No known instream or overhead cover criteria.

Mean Daily Water Temperature:	21° C
Lower Quartile:	16° C
Upper Quartile:	26° C

These values shift with life stage (spawning, incubation, larvae, juveniles) (Crance 1984).

For coastal stocks, the critical criteria are slightly different and the success of the species is more dependent upon percent original salt marsh in the coastal estuary, percent of original freshwater input to the estuary during late winter, water temperature, and salinity during spawning and egg development, while adult habitat requirements remain approximately the same as the riverine populations (Bain and Bain 1982). This suggests that spawning and larval success under various environmental conditions also has a strong influence on the ultimate density and success of adult predators. These do not appear to have been accounted for in the proposal.

Some of these criteria are listed as potential covariates in the proposal. Although local experts may create some statements on the preferences or influence or location of striped bass for salinity gradients, toxic substances, turbidity, etc., in the Delta there is the possibility that the predictive ability might be low.

Although the list is not complete, there does appear to be an error in the suggested list of predators to model. The proposal suggests that a Delphi evaluation will be created for *Ptychocheilus oregonensis* (northern pikeminnow) which, unless new records exist, is not likely to appear in this particular drainage. That species is found in the Columbia River drainage. Perhaps the authors meant *P. grandis* (Sacramento pikeminnow)? This suggests a fundamental misunderstanding of the fish community in the system.

More importantly, the Panel questions whether this is an appropriate exercise as part of the study? The gut-contents data that have been published or presented to Panel reviewing the Long-term Operations Biological Opinions (LOBO) seem to indicate that predator pressure on Delta smelt is quite small. Unless there are other data that indicate greater predator pressure, the model of predator-prey interactions would have a small impact on the outcomes of the ultimate simulation modeling. Considering that several iterations of opinions will be required to obtain a working model of predator impact (100+ person hours) (Crance 1987, for example), the Panel is not convinced that the effort will improve the predictive ability of the proposed models.

<u>Functional forms</u>

While the expert elicitation approach may provide information on covariates and their ranges, it is not clear how the process can be applied to evaluate and potentially revise the model functional forms according to input from experts. For example, the movement model is very different from models that focus on movement through tidal surfing. It

appears the research team does not have a formal mechanism to elicit opinion and input on the specific functional forms for the model.

5. *Is the proposal explicit in what data will be used and how limitations of the data will be addressed in relation to the questions being asked?*

General comments

In consideration of the objectives stated in the Scoping Document, the proposal is clear in what data will be used; those data which are provided over the historical period from 1990 to 2014, collected in conjunction with mid-water trawls. However, there seems to be little a priori consideration of the limitations of the data and their ability to account for the majority of the variation observed in the existing data. Indeed, there appears to be little allocated time in the proposal budget to investigate the limitations of the data or development of covariates for inclusion in the analyses. The budget should be modified to allow for such analysis.

Descriptions of covariates

The description of covariates was limited, particularly for the station-specific covariates measured by the fisheries surveys (STN, FMWT). The spatial scale of the covariates is also not described. For example, do the single-point-in-time measures of salinity represent conditions at the sampling site only or will salinity measures be averaged at the patch level? How is 'flow' measured and considered in the models and at which spatial scale? Additional covariates (e.g., habitat type such as river, channel, etc.) may apply to multiple adjacent patches, but the scales of measurement and application need clarification. Studies have indicated that Delta smelt distributions and abundance are correlated with turbidity but not with annualized covariates of water quality or flow (Latour 2015).

Data for abundance and occupancy modeling

The proposal states which data sources will be considered and suggests the use of simulations to determine the efficacy of abundance modeling (a sound suggestion). The Investigator Team may want to consider a similar approach for the occupancy modeling to establish whether parameters may be potentially biased. The team may want to develop a backup modeling approach if neither abundance nor occupancy modeling can be undertaken with the available data.

The proposal indicates that if the assumptions that accompany use of spatial replicates for occupancy modeling are not met, then estimates of abundance may be biased (page 24). However, it is not clear how estimates of abundance will be derived from application of

occupancy models. The proposal lacks a discussion of the necessary assumptions of occupancy models and how these may affect inferences from the proposed application.

The STN survey, which will provide catch data from which to estimate abundance of Delta smelt in August of each year, is characterized by inconsistent sampling frequencies since its inception. Prior to 2003, 2 to 5 surveys were completed each year, whereas, 6 surveys were completed from 2003 to 2014. What is the effect of variable sample sizes and how might this affect understanding of annual survival of Delta smelt across 'wet' and 'dry' years? Perhaps a simulation study using the 2003-2014 data can provide information on the utility of reduced sampling for estimation of Delta smelt abundance in August.

The information provided about the 20 mm survey is insufficient, but it appears that the duration of this survey will limit the analysis of stock and recruitment to the period during which this survey was operational, 1995 – 2014. Information regarding the number of stations, the type of sampling design (fixed station survey, random stratified survey, or other), and the spatial distribution of stations would help to understand how this survey can be used to inform the recruitment analysis. The 20 mm survey includes replicate tows, but it is not clear if these are independent replicates, or how the catch and other data from replicate tows will be treated (whether they are independent or not).

Several references are made to the use of Bayesian estimation, but these references are not clearly linked with a specific model. Also not clear is how the N-mixture models will be used and which questions these models will address. The section on 'other models of dependence between abundance and detection' is not well integrated with the remainder of the proposal.

One of the limitations that should be acknowledged is that occupancy models may not be able to detect a relationship between occupancy (the proportion of sites occupied) and a given environmental covariate if the range of the measured covariate is narrow. For example, the full salinity or temperature gradient of the Delta may not be sampled by the STN or FMWT surveys. In any given year, the range of the 'flow' covariate(s) may also be restricted. The temporal scales of analyses (monthly flow vs annual flow) require further clarification.

Flow data in occupancy models

How will global covariates (outflow, e.g.) be considered in occupancy models? Does outflow affect occupancy, detectability, or both? If both, how will outflow be characterized/measured? The temporal/spatial measurement scale of the covariate depends on how it is used in the occupancy model. For instance, the outflow covariate for detectability within a given patch (an area encompassing multiple stations) may be represented by the mean flow estimated at each station within the patch. The outflow covariate for occupancy may be represented by the mean flow across patches. Are station-specific estimates of 'flow' available for these calculations or will hydrodynamic model-

based estimates of flow be used? Another concern with the outflow covariate for occupancy is that outflow may be confounded with year and cohort of Delta smelt; that is, a single outflow measure is available for each year (or group of months, say, September to December or September to April). Perhaps categories of outflow such as low/med/high, may be useful in modeling occupancy. Alternatively, annual estimates of occupancy (proportion of area used by Delta smelt) can then be compared with annual patterns in outflow conditions in the Delta. The recent work of Latour (2015) is highly relevant to identifying how flow will be represented in the analysis. This work indicated little support for the importance of flow.

Tidal data in observation process

The proposal indicates the observation process will be modeled as a binomial process (equations 8, 9, 10) which is highly desirable. In selecting the covariates to employ in this exercise the Panel recommends specific attention to formulating the effects of the tidal-scale environment about the sampling stations. Feyrer et al (2013) demonstrated the catch is strongly correlated with tidal cycle in specific areas but not in others. The differences are likely to depend on the details of the environment. Discussions with researchers studying tidal surfing is critical to identify these covariates. The Panel suspects that both tidal stage during each fish survey and the geomorphological characteristics of the station, e.g. channel area (depth, width), tow length of sampling, channel and tidal volume excursion, may be informative covariates in identifying catchability.

These covariates will also be important to include in the occupancy modeling. One of the covariates proposed for consideration is 'surface area or volume of tidal marsh'; during the review Panel's discussion with the Investigator Team, one of the PIs indicated that area and volume will be determined from areas adjacent to the patches sampled for Delta smelt. Will area or volume be considered as a covariate for occupancy, detectability, or both?

Allocation of time to prepare data

The Investigator Team expects to update the currently available survey catches for Delta smelt with information collected through 2014, implying that the team has access to some portion of the time series of survey catches (and accompanying covariates). Presumably, the more recent data will be made available to the Investigator Team, but no time has been allocated for quality-assurance testing or quality control (p.25). We recommend allocation of sufficient time for these important tasks. In particular, the issues with the data are potentially voluminous. It is not clear to the Panel how onerous the data quality control and quality assurance process may be. This is time that needs to be budgeted in the proposal.

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APPENDIX 1 – Materials Reviewed

Review Materials Available to the Independent Review Panel

1. Charge Questions – specific requests for panelists to consider in developing their report
2. CAMT Fall Outflow Scoping Document. Version 1-29-2015 – criteria and needs addressed by the proposer
3. CAMT Background and Context Information, August 2014.
4. Progress Report to the Collaborative Science Policy Group, February 14, 2014. Prepared by the Collaborative Adaptive Management Team (CAMT).
5. Annual Progress Report to the Collaborative Science Policy Group, February 14, 2015. Prepared by the Collaborative Adaptive Management Team (CAMT).