Review of proposal: Evaluation of key assumptions underlying analyses of delta smelt survey data

Reviewer #1

1. **Are goals, objectives, hypotheses and questions clearly articulated and internally consistent?**
   The first goal is to test the assumption that catchability in the FMWT and KST are constant. Given that catchability is not constant a second step is to quantify factors that influence catchability in the surveys. The approach will be to look at catch per unit effort (CPUE) over periods and spatial areas too small for population size to change such that changes in CPUE reflect changes in catchability. The second goal is to identify spatiotemporal correlation of CPUE data and then integrate this information into the assessment of catchability.

   The first goal is clear and consistent. Details for improvements are discussed below in Answer 4. The goal of temporal/spatial autocorrelation among surveys is less clear to me. Correlations will be identified by studying the residuals of the analysis for catchability. Autocorrelation was stated to lower the effective sampling size but the implications of this is not clear. If autocorrelation is found then "then models will be extended to formally incorporate temporally/spatially correlated residuals." I assume by models the author means the zero-inflated catchability models, but this is not clear. The CPUE data would be partitioned into covariates and temporal/spatial correlated residuals (eq. 4). But the hypotheses are too vague to understand the value of this analysis and how it affects the issue of catchability. I do not have sufficient information to determine if the second objective is internally consistent with the first.

2. **Will the proposed work contribute to our overall understanding of Delta Smelt abundance and distribution?**
   The proposal will extend a recent publication (Latour 2015) in which a 46 year set of Fall mid-water Trawl (FMWT) data was analyzed with a zero-inflated model. This modelling approach is valuable in analyzing CPUE data containing frequent zeros as a result of sampling non-habitat areas (where fish are never found) vs. habitat areas (where catch depends on population size). Using annualized measures of environmental variable, the article concluded that Total Suspended Solids (TSS) was the environmental property most associated with the decline of Delta pelagic species including Delta Smelt. The work will extend this analysis by seeking to identify the effect of catchability on

changing the CPUE in the FMTS and Spring Kodiak Trawl (SKT). Secondly, using the improved estimate of CPUE, the study will look for evidence of temporal/spatial autocorrelation from the two survey methods. The goals and objectives of the second task are less clear but it seems it could be of value to better understanding the movement and isolation of delta smelt into distinct habitats.

The zero-inflated population estimation approaches should provide a better resolution of delta smelt habitats as it states to develop "… a more informed understanding of spatiotemporal patterns in delta smelt relative abundance, relationships with ecosystem attributes, and potential biases." The value of the research will depend on identification of ecologically meaningful functional forms and covariates that inform on the habitats, migratory movements and entrainment of delta smelt.

3. **Are the budget and the schedule reasonable and adequate for the work proposed?**
   The project is divided into three segments: 1) Four weeks to acquire data and conduct catchability analysis, 2) Six weeks to conduct correlation analysis, 3) Two weeks to prepare a report and present finding.

   The total project cost is reasonable. The amount of time for segment 1 seems inadequate. My estimate is collecting data and developing covariates based on the physical and hydrologic properties of the sampling stations will require two weeks. Developing functional forms of models and meeting with biologists will require two weeks. Conducting analysis will require two weeks. The six weeks for correlation analysis (segment 2) appears to involve computer analysis only. Although I am sure the second segment could easily consume six weeks, I don't see the value of this goal compared to the first goal. Two weeks to complete the report is adequate.

   I suggest the majority of time might be better spent on the first goal (catchability), and the second goal (autocorrelation) be reduced. Also, consultation should occur during scoping phases of project when the model structure and covariate are developed.

4. **Does the proposed work take a feasible approach to addressing questions such as spatial autocorrelation in the data, correction factors for covariates affecting catchability and uncertainties concerning abundance indices? Are there other approaches that could be used in the analysis?**
   The approaches proposed have not been applied to the existing survey data, except Latour (2015), but the general approach has been used in several fish population studies, in particular studies characterizing the migration of fish (e.g. Burke et al. 2013).

Being able to partition zero catch samples into habitat and non-habitat categories and then use the covariates to adjust catchability will be extremely useful and hopefully will become a standard analysis technique for future analyses of the delta pelagic species.

The current deficiency in the proposal is that the analysis is not well motivated by delta smelt ecology and the Latour (2015) paper on which it is based, does not address the recent and highly relevant studies on delta smelt behavior (see references below). The proposal would benefit greatly by integrating this recent work. In particular, the zero contribution to the catch is likely to be related to the interaction of tidal stage and location of sampling gear relative to the tidal interface boundary which potentially drives small scale distribution of fish habitat over the tidal cycle and therefore potentially drives catchability on station and time specific basis (Bennett and Burau 2014).

The approach proposed will use zero-inflated generalized linear models to characterize CUPE and if these are deemed not sufficient the analysis would be expanded to generalized additive model. The proposal states:

> "Once final model structures are identified for both data sets, a suite of covariates hypothesized to influence catchability will be examined. Diagnostics associated with fits of those models and other parameterizations will then be evaluated for the presence of temporal/spatial correlation among survey samples."

The process for identifying suitable models and covariates is not articulated other than the combinations of covariates will be evaluated by model diagnostics and (AIC, BIC) selection criteria. Nor are the details of the model structures and covariates described or set in an ecological context. The proposal and analysis would be improved if a list of structures and covariates were developed and supported in terms of the recent literature (2012-2015) on spatial/temporal movements and correlations of delta smelt to environmental properties. It would be useful for the investigator to develop one or more model forms and covariates that will identify the partition of sampling in habitat and non-habitat regimes. These models would then be provided to the Delta research community (biologists and hydrologists) for discussion and refinement. It is possible that new covariates will need to be developed with the help of the Delta research community.

Example covariates that potentially impact the probability of false zeros (samples from tows that do not reflect population abundance) were identified as:

> Temporal variables (Year, Month, Time-of-Day), spatial variables (Area, Latitude, Longitude), physical variable (tidal cycle), and environmental conditions (temperature, salinity, Secchi depth).

What is missing from the approach is how these, or other covariates, mechanistically contribute to the false zeros. Some of these covariates are too removed from ecological processes to providing meaningful information for selecting the model structure and covariates. Again, the project needs to reconsider this important stage of the analysis based on ecological insights and mechanisms that determine CPUE. Currently the model selection process seems somewhat ad hoc.

The paper (Bennett and Burau 2014) is particularly germane to developing covariates. The paper shows that delta smelt use selective tidal movement behavior in which

> "The presence/absence of fish at the shoal-channel interface and near the shoreline was quantified hourly over complete tidal cycles. Delta smelt were caught consistently at the shoal-channel interface during flood tides and near the shoreline during ebb tides in the turbid Sacramento River, but were rare in the clearer San Joaquin River."

This behavior suggests that the false-zeros in the analysis might be identified by the specific phase of the tide in which tows were conducted, the turbidity and the location of the tow relative to the shoal-channel interface. These properties and the interface in particular may depend on the bathymetric and hydraulic conditions at sampling stations: e.g. linear tidal excursion, changes in channel width and confluences over the excursion, ratio of residual to tidal velocities. The point here is that the susceptibility of delta smelt to a particular sampling gear depends on factors that have differing relationship from station to station and time of year. The correlations of patterns might be different for the Sacramento and San Joaquin rivers and Suisun Bay. For example, the behavior of estuarine fish do vary by hydraulic regime. The presumption is that estuary retention behavior will vary according to position. Downstream of X2 a fish might have a strategy that moves it upstream on the flood tide but above X2 the tidal surfing dissipates resulting in the fish moving back down stream. The different behaviors would concentrate fish within the X2 boundary (Bennett et al. 2002, Bennett and Burau 2014). Additionally, these behaviors are expected to change when fish begin their spawning migration (Sommer et al. 2011), and the behaviors may be independent or only weakly related to the fall flush (Anderson et al. 2013).

The division of the region into 17 standard polygons presented in (Latour 2015) is a first step in this analysis, but covariates that describe the hydraulic and ecological details of the sampling sites might better be prescribed for each station instead of grouping stations in polygons. These details might require using outputs from the delta hydraulic models.

The partition between habitat and non-habitat regions will change in complex but predictable ways as the water moves from narrow deep channels to open shallow bays (Bennett et al. 2002, Kimmerer et al. 2013, Kimmerer et al. 2014). These changes will affect the lateral distribution of delta smelt relative to the trawl locations. It has been strongly recommended that these properties be established with 3-D models.

> "We conclude that the vertical distributions observed in the field studies were a result of active patterns of movement, that these patterns can result in retention, and that retention in a bathymetrically complex estuary can be understood only in the context of the full time varying three-dimensional flow field (Kimmerer et al. 2014)."

Thus, it should be possible to improve the design of the analysis by drawing on the ecological literature and relevant hydraulic models to develop the equations and covariates of the analysis. This development should be conducted in the early stages of the project with close collaboration with CAMT researchers and others in the delta smelt research community.

5. **Will the results from this proposal add value to other work that uses these survey data, and if so, how much confidence can be added from the analyses?**
   The proposal did not specifically identify projects that will benefit from the analysis. However, developing station-specific measures of catchability is of value to studies identifying delta smelt habitats, migration routes and population sizes. The study could have value in identifying index stations for assessing delta smelt population and migration timing and have value for siting further studies of selective tidal transport.

6. **Are the proposed analyses suited to constructively inform management actions, such as those associated with the existing biological opinions?**
   A central action of the export operations is triggered by the cumulative salvage of delta smelt at the pumps. The threshold level is set using an estimate of the population size from the December-March FMWT index from the previous year. By calculating the population using station-specific catchability and CPUE, a new population index would be developed to compare to the index currently used in the Biological Opinion.

Furthermore, the spatiotemporal autocorrelation of CPUE from surveys (goal 2) might provide useful information for assessing the potential of entrainment. Exactly how this would be done is beyond the scope of the proposed analysis.

If the analyses are able to develop improved estimates of the historical population trend by partitioning CPUE into abundance and catchability trends, the information would be essential for the development of the planned delta smelt life cycle model.

7. **Does the proposal address the most important potential data limitations relevant to questions about Delta Smelt entrainment and Fall outflow?**
   The proposal addresses an important data limitation, the assumption of constant catchability. Because multiple studies indicate that the fall spawning migration is triggered by changes in flow and turbidity, it is reasonable to believe that catchability also changes as fish switch from estuary retention behavior to upstream migration behavior. To the resolution available from the existing survey data, the proposed study has a reasonable chance of developing a model to describe seasonal and station-specific changes in catchability resulting from tidal/water quality mediated behaviors. A new catchability function should make the existing surveys more informative in determining delta smelt distributions and movement.

   However, an equal or more important data limitation is the inability of the present surveys to characterize the abundance of delta smelt in the shoal-channel interface. The current survey methods essentially measure mid-channel distributions of delta-smelt, and so it is reasonable to assume that the current methods only measure the edges of the fish habitat during a small fraction of the day. Developing a new survey to measure fish nearshore would appear to be a high priority for answering questions related to entrainment and fall flow. Because such a survey would likely require intensive sampling and considerable resources, selecting stations for a new survey program will require additional analysis and consideration. The proposed work could be of great value in this task, by identifying areas of high delta smelt abundances for specific estuary retention and migration phases of the fish life cycle.

References

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