Independent Peer Review Report to the Center for Independent Experts on the Central Valley Chinook Life Cycle Model Panel Review held November 5-6, 2015, in Santa Cruz, California.

Prepared for:

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Executive Summary

This document forms my independent reviewer report of review activities and findings for the Central Valley Chinook Life Cycle Model Panel Review, centered about a review workshop held in Santa Cruz, California, November 5-6, 2015. The review focused on a new salmonid life cycle modeling framework that will be used to analyze the effects of water management scenarios on fish survival in the current development of the Bay-Delta Conservation Plan, and on a specific application of the framework (currently in an advanced stage of development) for winter-run Chinook salmon. The core of the model consists of a time- and stage-structured life cycle model. The model is linked to management goals and constraints via the effects of project operations on water flows that determine habitat characteristics (quality and quantity of habitat, water velocity, temperature, etc.), which in turn determine the distribution, survival and movement of salmon within the river system. This direct linking of project operations to the population dynamics model enables the evaluation of how water management decisions would be expected to affect the abundance, distribution and survival of specific life stages in the river system, and ultimately to predict the effects at a population level.

Because the model framework is designed explicitly for evaluating the effects of water management scenarios on salmonids, the model framework is highly appropriate for evaluating the effects of water operations on salmon at different life stages and at the population level; and on both short-term and longer-term time scales. Additionally, because the framework is very flexible, the framework presented for winter-run Chinook appears readily adaptable to other management questions and for other salmonid species.

The specific application for winter-run Chinook was still under development at the time of the peer review. Although some technical aspects remain to be addressed, including the estimation or selection of parameter values for the model, model checking and testing, further development of the methods for doing the population simulations, and developing effective methods of summarizing and communicating model results, based on the development of this application to the time of the review, I believe the likelihood that these aspects can be addressed is high. Conditional on an appropriate formulation for the final model, I believe the model results should be highly informative about the relative risk evaluations associated with status quo conditions and various Reasonable and Prudent Alternative (RPA) action scenarios, for evaluating how flow alterations would be expected to affect the abundance, survival and distribution of early life stages of winter-run Chinook, for evaluating how these alterations would be expected to impact the number of spawners produced by the affected cohort or cohorts, and for evaluating the effects on the overall productivity of the population. As such, the developed life cycle model for winter-run Chinook should fit very well within a relevant decision-making framework.

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1.0. Background

This document forms my independent review report of review activities and findings for the Central Valley Chinook Life Cycle Model Panel Review, centered about a review workshop held in Santa Cruz, California, November 5-6, 2015. The purpose of this process was to review a new salmonid life cycle modeling framework that will be used to analyze the effects of water management scenarios on fish survival in the current development of the Bay-Delta Conservation Plan. The development of this modeling framework follows a recommendation from an independent review of existing salmonid life cycle models (Rose et al. 2011) that the National Marine Fisheries Service (NMFS) create a salmonid life cycle model tailored specifically for their purposes. The framework links together a salmon population dynamics model with supporting hydrological, hydraulic, water quality and habitat models in a way that the effects of complex water management, habitat restoration, fishing mortality and climate change scenarios on a salmon population can be evaluated. The review material focused primarily on an application of the life cycle modeling framework being developed for Sacramento River Winter-Run Chinook Salmon, a population listed as “endangered” under the U.S. Endangered Species Act (NMFS 1994).

2.0. Individual Reviewer Activities

Prior to the review meeting, the review panel (Appendix 3) was provided with a Statement of Work (Appendix 2), including the Terms of Reference (TORs) for the assessment and for the review panel. I received URL’s for background material for the review (Appendix 1) by email on October 28, 2015, which provided sufficient time to review this material. The background material consisted of the independent panel report from the Salmonid Integrated Life Cycle Models Workshop (Rose et al. 2011), intended as a guide for reviewing the new modeling framework, and a NOAA Technical Memorandum describing the life cycle model framework for Sacramento River Winter-Run Chinook Salmon produced in July 2014 (Hendrix et al. 2014). NMFS has made an impressive amount of progress in the development of the model within the framework since the writing of the background material. Detailed descriptions of the model, the management and legal context under which it is being developed, and its various components were provided via PowerPoint presentations during the review meeting. I found these to be sufficient for review, particularly given that this review occurred during the transition from the development of the overall model framework and the development of a specific model within the framework. This approach provided a very current presentation of the specific model development to date. Further information to facilitate the review, including information about the specific Reasonable and Prudent Alternative (RPA) actions that would be evaluated using the model, was provided after the review meeting.

I reviewed the background material provided for the workshop prior to the meeting. I participated in the review meeting in Santa Cruz, California, on November 5-6, 2015. During this meeting, I actively participated as member of the review panel, and questioned and discussed many aspects of the model framework and the winter-run Chinook Salmon model. The meeting was fairly informal with a lot of lively discussion during presentations, which worked particularly well given the objective of reviewing the framework while examining a specific application of the modelling framework. While reviewing the background material and listening to the presentations, I noted a few inconsistencies between the model descriptions and model equations (these are not unexpected while a model is being developed), and had some suggestions that could potentially help with model fitting to obtain parameter estimates (if needed), and an alternate formulation for modelling density dependence in the fry rearing stage. These comments and suggestions are intended to help with further model development, its application and its communication, and should not be considered as a criticism of the overall modelling framework, which I consider to be very impressive.

After the review meeting, I prepared this individual, independent report and provided comments on the Review Workshop Report. As outlined in Appendix 2, this independent report is intended to summarize review activities during the panel review meeting, including providing a summary of findings, conclusions, and recommendations for each TOR. The following sections in this document contain my personal perspectives about this model framework for salmonids in general, as well as comments about the specific application of the framework being developed for winter-run Chinook salmon.

3.0. Summary of Findings in Accordance with the TOR's

1) Is the model useful for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level?

Conditional on its appropriate application for specific species and/or populations, and management questions, I expect that the model framework presented to the review panel (updated from Hendrix et al. 2014) will be very useful for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level. At the core of the model is a time- and stage-structured life cycle model. The model is linked to management goals and constrains via the effects of project operations on water flows that determine habitat characteristics (quality and quantity of habitat, water velocity, temperature, etc.) which in turn determine the abundance, survival and movement of salmon within the river. This direct linking of project operations to the life cycle model parameters enables the evaluation of how RPA actions would be expected to alter the abundance, distribution and survival of specific life stages in the river. Additionally, because the entire life cycle is modelled, the life cycle model can be used to integrate over all the predicted changes in life cycle parameters associated with a proposed management action to predict the effects at a population level.

The review panel was presented with a detailed description of a specific application of the model framework currently being developed for Sacramento River Winter-Run Chinook Salmon. The overall goal is to develop a simulation model capable of evaluating alternate scenarios on a relative basis. This model included the developmental stages: eggs, fry, smolts, ocean sub-adults and mature adults, and the geographic states of the mainstem river, the floodplain, the delta, the bay and the ocean. The model includes a monthly time step. State transitions include the processes of survival, migration, maturation and reproduction, some of which are density dependent. Linking of the life cycle model to water and habitat management scenarios occurs via a suite of sub-models (Figure 1). For each management scenario, flow and water velocity are determined using CALSIM II and DSM2, the results of which feed into HEC-RAS (which provides input to river and floodplain habitat capacity model), a water temperature model (SRWQM), a particle tracking model (ePTM), and a delta habitat capacity model. An ocean climate and fisheries model component governs survival in the ocean. This approach of sequentially linking the physical changes associated with a water management scenario (flow and velocity) to the available habitat, survival and movement of salmon, to the fish population's life cycle allows explicit evaluation of both the life-stage-specific and population-level changes in abundance and distribution. As such, the approach is very appropriate for evaluating the effects of water and habitat scenarios on the Winter-Run Chinook Salmon population in the Sacramento River.

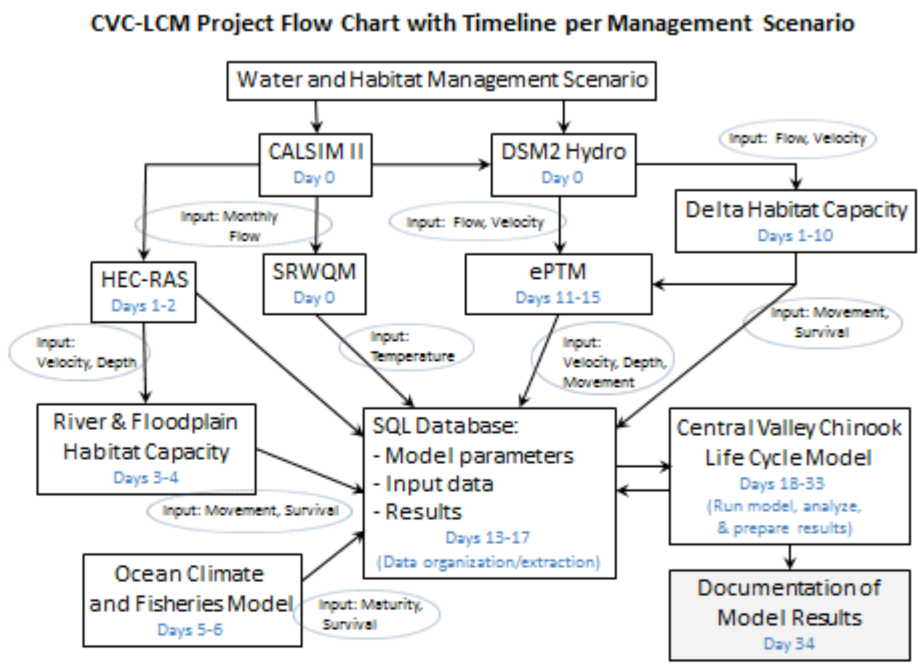

Figure 1. Schematic of the model framework with the associated timeline for each model component (from Lindley: Central Valley Chinook Life Cycle Model Project Overview – PowerPoint presentation to the review panel Nov. 5th, 2015).

a) What are the strengths and weaknesses of the model?

Rose et al. (2011) provided 16 general recommendations for developing integrated life cycle models for salmonids. Although not all of the recommendations are applicable to the winter-run Chinook application at its present developmental stage, their recommendations do provide a basis for discussing the various strengths and weaknesses of the model framework. In general, the model framework development does closely align with their recommendations. Their recommendations are:

"Philosophical:
1. Models should be developed and scaled for the questions to be addressed.
2. The resolution of the model results must be clearly stated.
3. The model should be designed from the ground-up, rather than trying to use an off the shelf model.
Communication:
4. A standard glossary should be prepared and updated daily.
5. Presentations and written documentation should be prepared and tailored to the audience.
6. The difference between precision and accuracy should be maintained and audiences reminded of it.
7. A peer review panel should be established to provide periodic feedback and advice.
Technical:
8. Development of a new model should proceed as a series of iterative steps from the questions to the formulation of the new model.
9. A transparent strategy that utilizes available data should be developed for calibration and validation.
10. Sensitivity and uncertainty analysis integral to the model is not the last step in model analysis.
11. Careful use of linked models is necessary to minimize propagation of unknown biases and uncertainties into final predictions.
12. A parallel effort of data synthesis should be started with the initiation of the modelling effort.
13. Critical aspects of the developed model will be: density-dependence, time-stepping, spatial grid, routing into and through the Delta, and ocean growth and survival.
14. Consideration of life history variation and spatial distribution, in addition to usual focus on population abundance, is needed in order to address the VSP criteria.
Ownership
15. An important consideration for a NMFS service model is that NMFS must have complete ownership of the model.
16. Manpower and resources." (adapted from Rose et al. 2011).

The major strength of the model framework is that it has been designed from the ground-up to address specific management questions (recommendations 1 and 3). The overall model framework is being developed as a series of iterative steps from the questions to the formulation of the new model (recommendation 8). In this instance, the questions arise from RPA actions, the effects of which are ultimately linked to the dynamics of the salmonid species via the model framework. Although the framework is being developed from the ground-up, another strength of the framework is that it does take advantage of several existing models as submodels (e.g. CALSIM II, HEC-RAS, DSM2, SRWQM) for linking water management decisions to the dynamics of the population, whereas other submodels are being developed specifically for this application (e.g. ePTM). The model does contain aspects addressing: density-dependence (but see comments below), time-stepping, spatial grid, routing into and through the Delta, and ocean growth and survival (recommendation 13), and the temporal (monthly) and spatial resolution (mainstem, floodplain, delta, bay and ocean) are clearly stated (recommendation 2). Although an evaluation of the existing data was not a part of this review, it is clear that a data synthesis has occurred and the data are being used to derive parameter estimates for the model using state-of-the-art statistical methods (recommendations 9 and 11), as discussed below. Where there evidence that parameter values likely could not be derived using population-specific data (e.g. habitat carrying capacity for a population at very low abundance), information from other populations is being used. This approach is appropriate, although caution is warranted given that meta-analyses of habitat carrying capacity suggest it can be highly variable among populations (e.g. Barrowman et al. 2003, Gibson 2006). Sensitivity and uncertainty analyses (recommendation 10) are proceeding as the model is being developed, as evidenced by the model variants developed for parameter estimation. Additionally, for scenario analyses, the model framework is sufficiently flexible to allow for alterations to the relationships (between flow and survival, as an example) to evaluate the effects of stronger or weaker relationships as sensitivity analyses. Although the difference between accuracy and precision (recommendation 6) are important to maintain, model assumptions and formulations (model structure), model parameter values, and, during scenario evaluation, assumptions about (unknown) future conditions ultimately determine model accuracy, the uncertainty is expected to be large relative to the precision of the estimates. The model framework does appear sufficient to address a broad suite of alternate formulations and assumptions. Because the specific application is being developed, communication (recommendation 5) of the model and results (presentations and written documents) are also being developed and improved (e.g. the model framework shown here as Figure 1 is an improved version of the same figure in Noble et al. 2014). While the present application of the framework does focus on the survival and abundance of winter-run Chinook as a single population, the overall approach of linking water management decisions to population dynamics via their effects on habitat quality and quantity, survival and migration, could, in the future, be extended to address VSP concerns related to life history variation and spatial distribution (recommendation 14) via the addition of sub-population components that are effected differently. In summary, the model framework does align well with the recommendations of Rose et al. (2011).

Although it is not really a weakness of the framework, the complexity of the situation coupled with uncertainties in the model and parameters would be expected to lead to a very large number of scenarios to be analyzed, which may make communication of the results fairly difficult. Models are simplifications of real systems and finding an appropriate level of complexity can be tricky. While this model framework is very complex, it is not overly so given the complexity of this ecosystem, the complexity of the life cycle and the multiple pathways through which water management decisions can affect the dynamics of a population. However, given the complexity, there are many inter-related assumptions and decisions that are being made during model development that can affect the model output and resulting conclusions. While these assumptions can be documented together with a set of sensitivity analyses to address the resulting uncertainty, the number of model runs to evaluate the sensitivity to combinations of these assumptions together with the RPA scenarios could be very large, potentially compounding communication issues.

Population viability, as typically determined using population models, is based on the cumulative effects of growth, survival and reproduction across all life stages, age classes and habitats. As such, the effectiveness of an RPA action in reducing jeopardy to a population would be expected to be conditional on these other rates and on other recovery activities. For example, in the case of inner Bay of Fundy Atlantic Salmon in Canada, at-sea survival is low enough that addressing threats in freshwater environments is not expected to markedly reduce extinction risk (Gibson et al. 2008). Similarly, for Atlantic Salmon in the Tobique River (a population that is not viable without supportive rearing), with threats divided into just three broad categories (habitat productivity, survival migrating past hydroelectric generating stations) the magnitude of the effect in each category is large enough that addressing a single threat is not expected to create a viable population (Gibson et al. 2009). In both of these examples, more than one recovery action is required, and the magnitude of the intervention required in one life stage is conditional on the magnitude of the interventions for other life stages. In the case of winter-run Chinook salmon, statements about effectiveness of an RPA action will be conditional on other rates (e.g. the effectiveness of flow alterations in reducing jeopardy may be conditional on predation rate or predator density assumptions in the delta), and if more than one action is required to effectively reduce extinction risk, then there may be many inter-related scenarios that would need to be evaluated, also making communication more difficult. However, while the number of scenarios required and communication can become problematic given the complexity of both the model and the system being modelled, a major strength of the model is that it contains enough detail to allow all of the various permutations to be evaluated and prioritized.

b) Are key parameters and performance measures captured in the model? If not, what other parameters and performance measures should be included?

Overall, I believe the life cycle model and associated parameters for winter-run Chinook are appropriate for this application, although as discussed under TOR 2, I would like to see the model generalized slightly in order that scenarios incorporating density-dependent survival of fry can be explored. With respect to parameter estimation using the statistical variation of the model, the methods being used to fit are appropriate, and the performance measures to evaluate the model fitting procedure, including evaluation of fits to the data, precision of the parameter estimates, and MCMC diagnostics to evaluate convergence (autocorrelation in the chains, acceptance rate criteria) are also appropriate and sufficient.

In its current iteration, the parameter estimation model is set up as an observation error model. However, when the model is used to simulate future abundance, in addition to the life history parameter estimates and their associated uncertainty, process variability, non-stationarity, parameter autocorrelation, and the frequency and magnitude of extreme events are all expected to affect abundance predictions and estimates of the time to extinction or recovery. Additionally, the relative importance of demographic stochasticity as opposed to environmental stochasticity increases as abundance decreases (Lande et al. 2003). These aspects of a population's true dynamics are not fully captured in the current model (and rarely are in any model, unless values are assumed). With respect to the life history aspects directly related to flow, variability, autocorrelation, and frequency extreme events can be incorporated into the abundance projections using the historical flow and precipitation records. For other aspects of the life history, such as predation rates and natural and human-induced impacts in the marine environment, process variability may be more difficult to incorporate. Demographic stochasticity could be incorporated in the projection model by including a quasi-extinction threshold that is high enough that the effects of demographic stochasticity can be ignored.

Although ideally process uncertainty would be incorporated in the projection model, as discussed under TOR 4, the model output would still be expected to be informative even if parts of the model are projected forward deterministically. For example, uncertainty in the long-term abundance projections would be expected to be under represented, but the productivity changes associated with RPA actions as characterized by the projections are likely to be highly informative about the effectiveness of these actions relative to the current situation or other scenarios.

The viable salmon population (VSP) concept identifies four parameters that form the key to evaluating population viability status: abundance, population growth rate, population spatial structure, and diversity (McElany et al. 2000). The background material, presentations, and discussion at the review panel meeting focused primarily on abundance prediction, although these other aspects were discussed. Extending the model to predict the population growth rate under current conditions or associated with RPA actions using average rates should be relatively straight forward, although results could also be presented as a function of flow for each scenario. An appropriate metric for the population growth rate is the maximum lifetime reproductive rate (Myers et al. 1999). This rate can be calculated by integrating over the age-specific survivals, stage transition probabilities, maturation and fecundities. Examples are available in Winship et al. (2014) and Gibson and Bowlby (2013). Equilibrium population sizes associated with each scenario is another potential performance metric that could be used to compare among RPA scenarios without the need for population projections (examples in Gibson et al. 2009, Gibson and Bowlby 2013).

Given that winter-run Chinook are considered a single population, metrics related to spatial structure and diversity may be less applicable at this time. However, if introductions into unutilized habitat are considered, adaptation of the model to include more than one sub-population could be achieved with appropriate modifications of the spatial grid and (possibly) concurrently running a separate life cycle model driven by the same or similar sub-models. Overall, the model framework as presented is very flexible and can be adapted to many situations.

Habitat quality and quantity, and subsequently survival and migration, are modelled based on the conditions experienced in a specific month. In reality, these variables might not be expected to be independent of conditions in previous time periods. In my opinion, the additional complexity that would be required to model these inter-relationships would likely be impractical and extremely difficult to parameterize. However, if there are several scenarios that produce similar results, developing a set of guidelines that extend beyond what can reasonably be modeled (in this instance, scenarios where monthly survival is highly variable are less preferred than those where conditions are more stable, for example), may help prioritize among scenarios.

c) Can the model be applied to address the multiple timescales associated with RPA decisions and operations?

As a result of its structure, consisting of a set of sub-models linked to a life cycle model, the model framework can readily be applied to address questions at the multiple time scales associated with RPA decisions and operations. On short time scales, the effects of water management decisions on the survival and distribution of early life stages of winter-run Chinook can be evaluated and on the number of returning salmon from the affected cohort or cohorts can also be determined. On medium time scales, the effectiveness of RPA actions (potentially involving some sort of water availability – flow release decision rules) can be evaluated via simulations on the time scales of 1-2 decades using the existing hydrological record. This approach would be expected to be most useful for medium term planning decisions. On longer time scales, the model could be used to evaluate RPA actions in the context of climate change scenarios allowing for planning on long time scales.

d) What are the technical constraints to the implementation of the model and the feasibility to address them (e.g., transparency of the model, data sets availability, model parameter uncertainties and sensitivities, etc.)?

In my opinion, the primary technical constraints to the implementation of the winter-run Chinook model are: estimation or selection of parameter estimates for the model, model checking, further development of the methods for doing the population simulations, and developing effective methods of communicating the results of a very complex model and the many potential scenarios resulting from both (discussed above).

Model development can be viewed as an iterative process involving a series of steps proceeding from the development of a model structure, to the development of model coefficient estimates used in making predictions with the model, to using the model for scenario evaluation (Figure 2). Model evaluation occurs throughout the process potentially leading to model revision. At the time of the panel review, the Sacramento River winter-run Chinook salmon model was in what I would call an advanced stage of model development, although it was not finalized. The model development process was demonstrated by presenting an iteration of the model being used as a statistical model for parameter estimation, as well as a revision to the model being used for the same purpose. This approach is highly appropriate for balancing a complex simulation model with an estimation model from which the parameter values are estimated from the available data. The presentation of the model as progress-to-date also afforded the review panel the opportunity to comment on specific details of the current iteration as well as the framework in general.

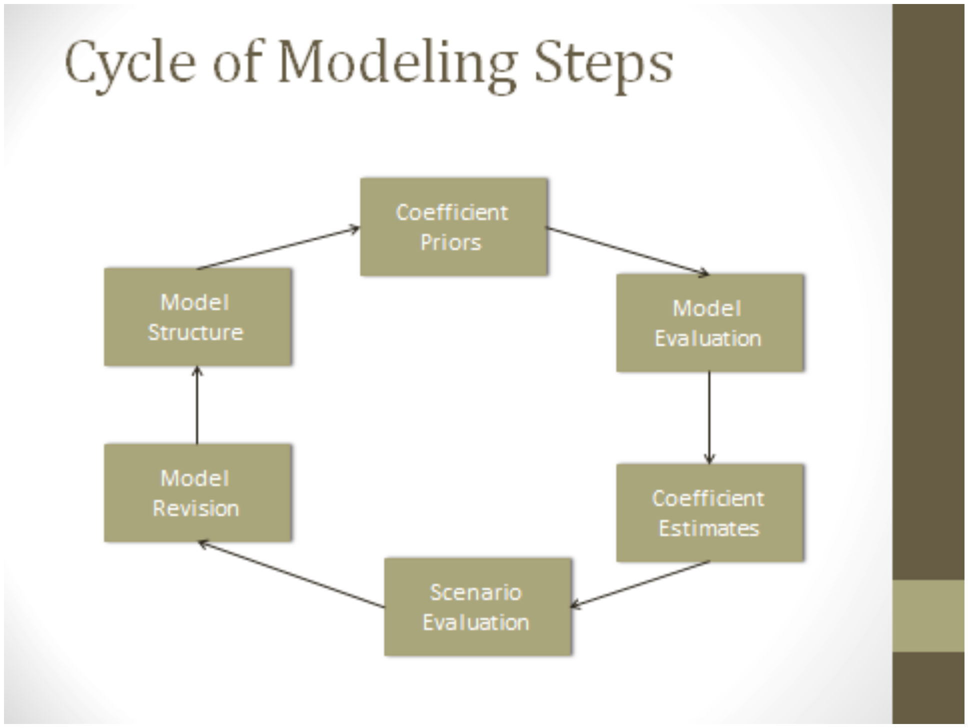

Figure 2. Schematic of the steps in the model development (from Hendrix et al.: CIE Review of the life cycle modelling framework for Sacramento River winter-run Chinook salmon – PowerPoint presentation to the review panel Nov. 5th, 2015).

At the time of the review panel meeting, parameter values were being estimated or otherwise derived for the winter-run Chinook model. Priors for model parameters were developed from a combination of existing studies and expert opinion, and these priors were being used as a starting point for a statistical analysis to derive posterior distributions for the parameter estimates that incorporate information from existing studies, expert opinion, as well as from the available data, in a Bayesian framework. Two versions of the model were presented to demonstrate progress to date. I agree with the presenters that the second version, for which parameters were estimated using a robust adaptive Metropolis Hastings Markov Chain Monte Carlo (MCMC algorithm) showed the greater promise. MCMC methods are highly appropriate for parameter estimation for simulation models, because sets of parameter estimates are accepted or rejected as a block. For this reason, if the simulations are carried out using the MCMC output, parameter covariance is preserved and carried forward to the simulations. I consider the statistical methods being used to be state-of-the-art. This said, a final version of the model was available for the review, so this specific application cannot yet be evaluated.

At the time of the review, the second version of the model was able to capture the general pattern in some of the data series, but uncertainty appeared underestimated by the model (e.g. Figure 3). It was unclear whether the proposal function (multivariate normal) was sufficiently flat enough to allow full exploration of the parameter space, a possibility that was being evaluated around the time that the model was being presented. Personally, I thought the modes of the annual abundance estimates shown in Figure 3 looked promising, because they captured the general pattern in the data. This iteration of the model projects abundance forward from time step to time step from a starting abundance without any adjustment for process variability or error from year to year. In my experience fitting similar (but simpler) models for Atlantic Salmon, the addition of annual deviates can improve the overall fit of these types of models. These can be introduced either as deviates around a fitted relationship (often influencing abundance of a very early life stage) in a model in which the life cycle is closed (e.g. Gibson et al. 2015), or else by breaking the life cycle at an appropriate stage and analyzing the dynamics of each cohort individually, but simultaneously. For example, for Southern Upland Atlantic Salmon in Canada, each cohort began with an estimated egg deposition, and all survival and stage transition probabilities were estimated assuming they were constant over years, but the life cycle was split at the adult escapement phase (Gibson et al. 2013). This could be considered the equivalent of fitting a statistical-catch-at-age model to marine fisheries data (Quinn and Deriso 1999) in which the annual abundances of the first age class are estimated parameters unconstrained by a stock-recruitment relationship. As mentioned, the statistical fitting of the model was presented as a work in progress so, at this time, it is not known whether or not the current approach will be sufficient to obtain plausible parameter values. These examples are provided as suggestions for exploration in the event that obtaining plausible parameter estimates becomes a greater technical constraint.

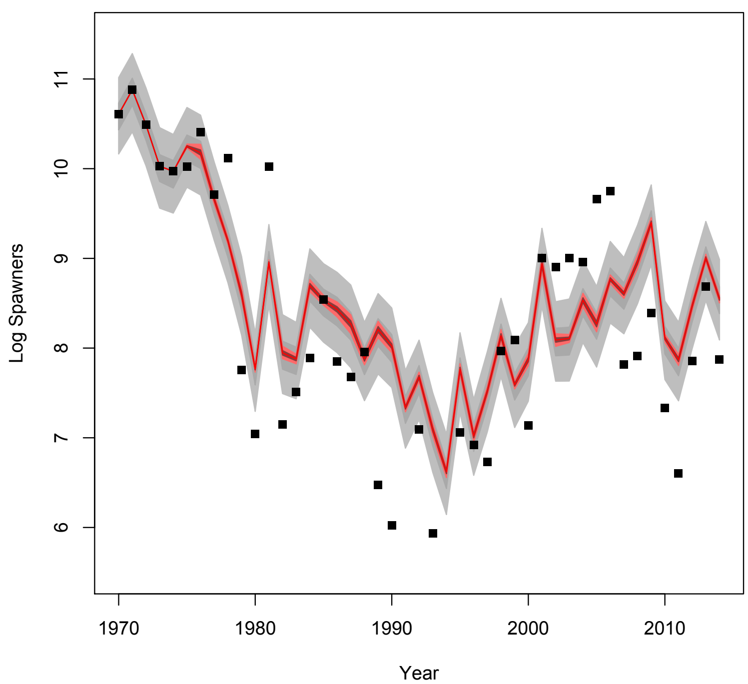

Figure 3. Model fits to the log of escapement (presented for illustrative purposes – this is not a final result). (from Hendrix et al.: CIE Review of the life cycle modelling framework for Sacramento River winter-run Chinook salmon – PowerPoint presentation to the review panel Nov. 5th, 2015)

Methods of conducting the simulations for scenario analyses were under development at the time of the peer review, although these should not pose a significant technical constraint. The use of deterministic projections based of the MCMC output to evaluate RPA actions was discussed as a possible method during the review. This method addresses the issue of parameter estimation uncertainty and covariance, but does not deal with process variability and parameter autocorrelation, both of which can affect extinction risk. Autocorrelation is often difficult to measure given the length of the time series typically available. The approach of using deterministic projections for comparative purposes is likely more appropriate on shorter time scales than longer ones. As discussed by the presenters, river flow is a key determinant of survival and migration for early life stages, and for this reason the historical hydrological record could be used to model variability in flow regimes from year to year. This could be accomplished either by modelling the flow as an autoregressive process and generating random values using that model, or else by using the existing record itself. If the existing record is used, randomizing the start year (possibly using a different randomly chosen start year for each saved iteration of the Markov Chain) while using the same set of random values for each RPA scenario being compared, might be one way of reducing the effects of having a series of good or poor years at the start of the simulation.

Identification of climate factors that determine survival and ultimately dynamics of populations can be a technical constraint when evaluating climate-change scenarios. Although I do not have specific concerns with the marine component of the model as implemented, ratio methods, a variation of the Murphy (1952) method, have been used with Atlantic Salmon to address the issue of separating out the confounding effects of annual survival from maturation probabilities leading to identification of climate-survival relationships. For example, using a Bayesian application of the method, a decreasing trend in survival during the first year at sea, and a correlation between the survival in the second year at sea and the North Atlantic Oscillation Index for adult salmon between spawning events was identified for a Southern Upland salmon population (Hubley and Gibson 2011). While the applicability of these methods to the smolt-to-adult survival of winter-run Chinook salmon is unknown, I'm providing this example as a potential avenue for future research with respect to oceanic conditions and climate change, not as a specific need for this model.

In summary, I think that the feasibility of both addressing the technical constraints in the model in its current form, and of developing appropriate communication mechanisms to address any transparency issues, is high.

2) Has NMFS effectively linked multiple specific models to represent the whole life cycle to inform NMFS in determining the effects of water operations and prescribed RPA actions on salmonids at the population level?

Overall, I do believe that NMFS has effectively linked multiple specific models to represent the whole life cycle to inform NMFS in determining the effects of water operations and prescribed RPA actions on salmonids at the population level. The life cycle model is a stage-structured model including developmental stages: eggs, fry, smolts, ocean sub-adults, and mature adults, and the geographic states of the mainstem river, the floodplain, the delta, the bays and ocean. The model includes a monthly time step. This level of detail appears appropriate to capture the tradeoff associated with differing growth prospects among habitats and the extent to which habitat alterations effect patterns of rearing, migration and size at ocean entry. The sub-models linking water operations to a population's dynamics appear sufficient. While I do believe the overall framework is very appropriate for this application, I do have some suggestions with respect to its current formulation. Additionally, the current iteration of the winter-run Chinook model is not set up to address all RPA actions, although I agree with the presenters that the framework can be readily adapted to address actions related to re-introductions, fish passage and stocking.

The application of the framework to winter-run Chinook salmon was still under development at the time of the review. When reviewing the background description of the model (Hendrix et al. 2014), I found that the formulation of the Beverton-Holt equation used to model fry rearing, survival and migration (page 15) was not consistent with the definitions of the model parameters (described below), an issue that had been carried forward in the presentation of the current version of the model. This issue also appeared as inconsistencies between the formulations used in the background material and the presentation material for the number of eggs produced per spawner (page 22 – I think it is correct in the text). Additionally, under transition 9 (page 17), the number of smolts from each habitat and month is calculated from the number of residents, but there isn't a corresponding equation decrementing the number of residents prior to the rearing calculations (transitions 2-5). The extent to which these were model description issues versus coding issues was investigated during the review panel meeting. Towards ensuring that the model code is correct, and that the code and model description match precisely, running sets of fixed values through the code while doing the calculations concurrently by hand should help ensure the model is working as expected and the documentation is correct. Using extreme values can help to identify places where there are potential issues (e.g. using an extremely high number of residents to see if the number of residents remaining approaches the asymptote), if any.

The timing and nature of density-dependence processes are very important components of a life cycle model, and I do question whether the model is sufficiently flexible with respect to how density dependence is modeled in the fry rearing stage. In the model, fry rear among river, floodplain, delta, and bay habitats according to density dependent movement functions, as described by Hendrix et al. (2014, page 15):

"The number of residents in the month (time subscript suppressed) is calculated from the following equation (Figure 9):

$$\text{Residents}_i = S_i(1-m)N_i/(1+N_i/K_i),$$

Where S_i is the survival rate, N_i is the pre-transition abundance, and K_i is the capacity for habitat type i = River, Floodplain, Delta, Bay, and m is the migration rate in the absence of density dependence. The number of migrants in the month is calculated from the following equation (Figure 7):

$$\text{Migrants}_i = S_i N_i - \text{Residents}_i.$$" (Hendrix et al. 2014).

As described during the meeting, N_i is the number of fry remaining in habitat i after smoltification, a process assumed to occur prior to mortality and migration each month and mortality occurs prior to migration.

As written, survival is density independent, whereas the realized migration rate is density dependent. To me, this appears to be a strong assumption given that the survival of fry in a given habitat would not be expected to change as abundance increases or decreases, an assumption that may not hold under all conditions. For example, under low flow conditions, migration could potentially be impeded, leading to increasing mortality rates with increasing densities. The equations above could be generalized to allow for sensitivity analyses with respect to this assumption.

Correcting the formulation of the Beverton-Holt equation above to match the definition of the model parameters (the equation in Hendrix et al. is only correct if K is defined as the half saturation constant rather than an asymptotic level), and defining both S_i and $(1-m_i)$ as the maximum survival and retention rates at low abundance in the absence of density dependence, the number of residents remaining can be modelled as:

$$Residents_i = \frac{S_i(1-m_i)N_i}{1+\frac{S_i(1-m_i)N_i}{K_i}}$$

where K_i is the carrying capacity of habitat i, now defined as the asymptotic level consistent with Figure 7 of Hendrix et al. (2014). The number of migrants could then be calculated a few ways to examine different scenarios. For example, if both density dependent mortality and migration are occurring, the number of migrants can be calculated as:

$Migrants_i=(N_i-Residents_i)p_i$,

where p_i is the proportion of the fry lost from the population in habitat i that are lost via migration to another habitat (p_i could potentially be flow dependent). This formulation could allow for the exploration of the relative effects of density dependent survival and migration.

If the migration rate is density independent and survival is density-dependent, a situation that contrasts the approach of Hendrix et al. (2014), and migration occurs prior to mortality, the number of migrants is simply:

$Migrants_i=m_iN_i$.

Similarly, if density independent migration occurs after density dependent mortality, the number of migrants can be calculated as:

$$Migrants_i = \frac{S_iN_i}{1+\frac{S_iN_i}{K_i}}m_i$$

These suggestions are not intended as an exhaustive list, but are suggested as some alternative formulations that could be used to explore the implications of the assumption that density dependence in the fry stage results only in density dependent migration, and that the survival rate of fry is density independent, as currently modeled.

The application of the framework under development for winter-run Chinook is highly appropriate for evaluating RPA actions related to water management, but will need modification to address RPA actions such as reintroductions above Shasta Dam and restoration of Battle Creek, including adaptation of the model to include more than one sub-population, appropriate modifications of the spatial grid, and potentially the addition of a hatchery component. As described to the review panel during the meeting, future versions of the model to evaluate these scenarios are anticipated.

With respect to the hatchery component, incorporation of the removals of broodstock from the population and inputs of hatchery fish into the population can be relatively straightforward (e.g. Gibson et al. 2008, Winship et al. 2014), but extending the model to incorporate fitness changes associated with captive rearing is more difficult. A relatively simple approach is the application of the breeder's equation (e.g. Bowlby and Gibson 2011) to explore scenarios based on different assumed values for the selection differential, the selection intensity, the response to selection, and the heritability. Although the approach has limitations (e.g. fitness recovery in subsequent generations in wild wasn't included in this example), it does provide a mechanism for bracketing the potential effects, and for evaluating the timelines over which population-level fitness changes might accrue based on the magnitude of a hatchery program.

3) Is the model framework suitable for winter-run, spring-run, and fall-run and can the framework be adapted for other species of Pacific salmonids?

The model framework is very flexible and, based on progress up to the review meeting, can be suitably applied for winter-run Chinook. The framework should also be adaptable for spring-run and fall-run Chinook by appropriately modifying the life cycle model to address differences in life history and timing of life history events; by modifying the spatial grid; and by modifying the model subcomponents linking water operations to survival and migration (via habitat quality and quantity, velocity, and temperature) to appropriately match the life stages, habitats being used and the time steps. Where subpopulations are included within the model, depending on the differences among the subpopulations, they could be included either by adding another dimension to the numbers-at-age arrays for each life stage, or, if the differences are large, by using separate models for each subpopulation (potentially linked if there are interactions between the subpopulations). Similarly, the framework should be adaptable for other Pacific salmon species.

4) Can the model fit into a decision-making framework for using life cycle models (at appropriate temporal and spatial scales) to adapt water operations and prescribed RPA actions on individual and multiple species?

Note: At the start of the review meeting, this TOR was changed to read: "Is there evidence that the developed life cycle models can be placed within a relevant decision-making framework? What are the key strengths? What is this telling us more broadly?"

5) Is there evidence that the developed life cycle models can be placed within a relevant decision-making framework?

Very generally, the developed life cycle model of winter-run Chinook uses a population model to project abundance forward through time to evaluate the effectiveness of the RPA actions, and is therefore a form of population viability analysis (PVA). PVA's are used extensively in conservation biology to predict the risk of extinction for populations, recovery probabilities and to evaluate management strategies to recover populations (Beissinger and McCullough 2002). Models are necessary for these types of evaluations, particularly when the proposed actions are complex, as is the case with winter-run Chinook. The models are useful for identifying threats to populations, bottlenecks in the life cycle that can be limiting recovery, and for evaluating how future management actions and/or environmental changes may influence the probabilities of extinction or of achieving recovery goals (Reed et al. 2002). Although, as discussed below, the utility of PVAs has been subject to debate (McCarthy et al. 1996, Reed et al. 2002), it is generally accepted that, appropriately used, PVA is a powerful tool to explore current conditions, assess risks, and simulate how future management actions or environmental changes could influence the abundance of a population in decline. As such, the developed life cycle model for winter-run Chinook is consistent with the approaches being used broadly in conservation biology.

Additionally, the developed life cycle model is tailored specifically to many of the management scenarios and RPA actions, and therefore is highly relevant for the decision making framework. As discussed below, its best use is for evaluating relative risk associated with the current conditions and for alternative management scenarios.

The consistency of the model framework with common practices in conservation biology, together with the degree to which the model has been developed to address these specific management questions, provide evidence that the model can effectively be placed within the decision-making framework.

a) What are the key strengths?

The key strengths are discussed primarily under TOR 1. The two major strengths are that the model directly links water management actions to the dynamics of the population via their effects on habitat quality, habitat quantity, survival and migration; and that the model framework is very flexible and can be adapted to model a very broad range of scenarios.

b) What is this telling us more broadly?"

A major criticism of PVAs is that their longer-term abundance predictions, as well as predictions of time to extinction, are highly uncertain (e.g. Taylor 1995; McCarthy et al. 1996; Ludwig 1999). For this reason, some authors have suggested that the best use of PVAs is to assess relative risk among a set of possible management actions (Akçakaya and Raphael 1998; Beissinger and Westphal 1998; Lindenmayer and Possingham 1996, McCarthy et al. 2001). For example, McCarthy et al. (2003) used a simulation study to test preferred management strategies and found that they were able to identify the better of two management strategies 67–74% of the time using 10 years of data, and 92–93% of the time with 100 years of data. Generally, models which track abundance at multiple life stages are preferred when adequate data are available and uncertainties can be accounted for (Holt and Peterman 2008, McCarthy et al. 2001).

As discussed under TOR 1b, with the exception of variability in hydrology, process variability is not fully incorporated in the model. Appropriately characterizing process in all aspects of the life cycle is generally problematic for the majority of PVAs, and can have the effect of increasing the uncertainty of the abundance projections under future (unknown) conditions, and can also lead to projections that are overly precise if all sources of variability are not accounted for. However, model output can be interpreted along the lines described above for PVAs generally. Although the actual long-term abundance projections will be uncertain, the productivity changes characterized by the projections are expected to be highly informative about the effectiveness of RPA actions relative to the current situation. The model is expected to be more informative for relative risk evaluations among status quo conditions and various RPA action scenarios than it is for actual long-term abundance predictions. Additionally, short-term predictions are expected to be more accurate than longer-term ones.

Based on the above, the application for winter-run Chinook should be very useful for evaluating how flow alterations would be expected to affect the abundance, survival and distribution of early life stages of winter-run Chinook, and the model should also be useful for evaluating how these alterations would be expected to impact the number of spawners produced by the cohort or cohorts affected by the flow alterations. As such, changes to the overall productivity can be evaluated. Although the actual long-term abundance projections will be uncertain, the productivity changes characterized by either the projections or population growth rate calculations are likely to be highly informative about the effectiveness of RPA scenarios relative to the current situation or other scenarios. Results will be conditional on the full suite of model inputs, but this conditionality provides a background for interpreting these results. The model can also be used to evaluate the tradeoffs among changes (flow-related or not) that might deleteriously affect survival of one life stage and alterations that might positively affect survival in another life stage. Finally, in situations where interventions expected to sufficiently increase survival are not known, the model can be informative of the magnitude of the change in survival that is required, which can guide discussions and research about potential interventions.

4.0. Conclusions and Recommendations in Accordance with the TOR's

Overall, I believe that NMFS has developed an excellent model framework for explicitly evaluating the effects of water management scenarios on winter-run Chinook, and, due to its flexibility, that this framework is readily adaptable to other management questions, as well as for other populations and other salmonid species. By linking water management decisions to their effects on the quality and quantity of habitat, and those effects to the abundance, survival and migration of different life stages occupying different habitats, I believe the model is appropriate for informing management on multiple time scales. Although the specific application of the framework for winter-run Chinook was still under development at the time of this peer review, I think that the remaining technical aspects can be addressed to complete the application. In general, I consider the framework and model to be quite impressive.

1) Is the model useful for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level?

The model framework appears highly appropriate for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level. The direct linking of project operations to the life cycle model parameters enables the evaluation of how RPA actions would be expected to alter the abundance, distribution and survival of specific life stages in the river, and because the entire life cycle is modelled, the life cycle model can be used to integrate over all the predicted changes in life cycle parameters to predict the effects at a population level.

a) What are the strengths and weaknesses of the model?

The major strengths of the model framework are that it has been designed from the ground-up to address specific management questions, and it has been designed in a way that is very flexible and can therefore be adapted to address additional questions or used for other species. The model is very complex, but not overly so, given the complexity of this ecosystem, the complexity of the life cycle and the multiple pathways through which water management decisions can affect the dynamics of a population. Given the complexity, the number of model runs to evaluate the sensitivity to combinations of model assumptions and RPA scenarios could become very large, making communication of the model and results difficult.

b) Are key parameters and performance measures captured in the model? If not, what other parameters and performance measures should be included?

Overall, I believe the life cycle model and associated parameters for winter-run Chinook are appropriate for this application. The performance measures to evaluate the model fitting procedure appear appropriate and sufficient. In the current iteration, process variability is not being estimated, although even without fully incorporating process variability, the model output should still be expected to be informative about changes in productivity associated with RPA actions, even if parts of the model are projected forward deterministically.

The viable salmon population (VSP) concept identifies four parameters that form the key to evaluating population viability status: abundance, population growth rate, population spatial structure, and diversity. In the current iteration of the model, the emphasis in the scenario analysis is primarily on abundance. Population growth rates, using maximum lifetime reproductive rates as a metric, can readily be calculated from the model output and could be included as a performance measure. Given the flexibility of the model framework, it should be readily adaptable to include population spatial structure and diversity, as appropriate for future applications.

c) Can the model be applied to address the multiple timescales associated with RPA decisions and operations?

Through the use of a set of sub-models linked to a life cycle model, the model framework can readily be applied to address questions at the multiple time scales associated with RPA decisions and operations. On short time scales, the effects of water management decisions on the survival, abundance and distribution of early life stages of winter-run Chinook can be evaluated. On longer time scales, the model could be used to evaluate RPA actions in the context of climate change scenarios allowing for long-term planning.

d) What are the technical constraints to the implementation of the model and the feasibility to address them (e.g., transparency of the model, data sets availability, model parameter uncertainties and sensitivities, etc.)?

In my opinion, the primary technical constraints to the implementation of the model are: estimation or selection of parameter estimates for the model, model checking, further development of the methods for doing the population simulations, and developing effective methods of communicating model results. Overall, I think that the feasibility of both addressing the technical constraints in the model in its current form, and of developing appropriate communication mechanisms to address any transparency issues, is high.

2) Has NMFS effectively linked multiple specific models to represent the whole life cycle to inform NMFS in determining the effects of water operations and prescribed RPA actions on salmonids at the population level?

Overall, I believe that NMFS has effectively linked multiple specific models to represent the whole life cycle to inform NMFS in determining the effects of water operations and prescribed RPA actions on salmonids at the population level. The level of detail appears appropriate. Although the current iteration of the model is not set up to address RPA actions associated re-introductions and hatchery supplementation, it is expected that future versions of the model could be set up to address these questions as required. The overall framework is very appropriate for these types of applications.

Although the multiple specific models are appropriately linked, I think that generalizing the density-dependent fry rearing component of the model would allow for further exploration of model assumptions, and that the model equations and associated code should be checked for consistency and to ensure they are projecting abundance forward as intended (the presented model was still being developed - some inconsistencies are to be expected at this stage).

3) Is the model framework suitable for winter-run, spring-run, and fall-run and can the framework be adapted for other species of Pacific salmonids?

With appropriate adaptations, the model framework is suitable for winter-run, spring-run, and fall-run and the framework can be adapted for other species of Pacific salmonids .The model framework is very flexible and should be adaptable by modifying the life cycle model to address differences in life history and timing of events; by modifying the spatial grid; and by modifying model subcomponents linking water operations to habitat quality and quantity, to river temperature, and to survival and migration, in order to appropriately match life stages, habitats used and the time steps appropriate for other species.

4. Is there evidence that the developed life cycle models can be placed within a relevant decision-making framework?

Ultimately, the model will be used as a form of population viability analysis, a tool that is well established in conservation biology. Additionally, the life cycle model is tailored specifically to investigate many of the management scenarios and RPA actions. As such, the developed life cycle model should fit well within a relevant decision-making framework.

a) What are the key strengths?

The key strengths are discussed under TOR 1.

b) What is this telling us more broadly?

As is the case with most models used for long-term abundance projections, the abundance projections are likely to be highly uncertain. The model results should be to be highly informative about the relative risk evaluations associated with status quo conditions and various RPA action scenarios, for evaluating how flow alterations would be expected to affect the abundance, survival and distribution of early life stages of winter-run Chinook, for evaluating how these alterations would be expected to affect the number of spawners produced by the cohort or cohorts affected by the flow alterations, and for evaluating effects on the overall productivity of the population.

5.0. References

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6.0. Appendices

Appendix 1: Bibliography of Materials Provided for Review
Appendix 2: CIE Statement of Work
Appendix 3: Panel Membership

Appendix 1: Bibliography of Materials Provided for Review.

Central Valley Chinook Life Cycle Model Panel Review Document List

Hendrix, N., Criss, A., Danner, E. Greene, C.M., Imaki, H., Pike, A., and S.T. Lindley, 2014. Life Cycle Modeling Framework for Sacramento River Winter-run Chinook Salmon, NOAA-TM-NMFS-SWFSC-530.

Rose, K., Anderson, J., McClure, M. and G. Ruggerone. 2011. Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel. Organized by the Delta Science Panel.

Appendix 2: CIE Statement of Work.

Statement of Work

External Independent Peer Review by the Center for Independent Experts

Central Valley Chinook Life Cycle Model Panel Review

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description:

In April 2011, at the request of NMFS, the Delta Science Panel (DSP) convened an independent review panel to provide recommendations on how the agency should proceed with incorporating life cycle modeling of Chinook salmon into the ongoing analyses related to the Operations Criteria and Plan (OCAP), Biological Opinion (BiOp), and Reasonable Prudent Alternatives (RPA). The review panel reviewed existing models and considered four questions on model development. In June 2011, the review panel produced a report, *Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel,* detailing their recommendations. One recommendation was that NMFS create a salmonid life cycle model tailored expressly for their purposes.

The Southwest Fisheries Science Center (SWFSC) has developed a new salmonid life cycle modeling framework which will be used to analyze water management scenarios on fish survival in the current development of the Biological Assessment (BA) for the Bay-Delta Conservation Plan. SWFSC is now requesting that a similar panel review the newly developed life cycle modeling framework. An independent panel review of the model will add credibility in its use in the BA scheduled to be completed in March 2016.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Appendix 2: CIE Statement of Work.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers should have expertise in water, habitat and fisheries management and coupled physical-biological models of freshwater or estuarine fish populations; landscape ecology; and knowledge of Pacific salmonid life history and ecology.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in **Santa Cruz, CA at the Southwest Fisheries Science Center's Fisheries Ecology Division** during November 5-6, 2015.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/
http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Hendrix, N., Criss, A., Danner, E. Greene, C.M., Imaki, H., Pike, A., and S.T. Lindley, 2014. Life Cycle Modeling Framework for Sacramento River Winter-run Chinook Salmon, NOAA-TM-NMFS-SWFSC-530. (26 pages)

Rose, K., Anderson, J., McClure, M. and G. Ruggerone. 2011. Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel. Organized by the Delta Science Panel. (28 pages)

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs cannot be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

The role of the panel is to review the framework for the Central Valley winter-run Chinook life cycle model developed by NOAA Fisheries SWFSC FED to determine whether NOAA Fisheries has fulfilled the recommendations given by Rose et al in the report, Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel. The panel will appoint a chair and will use the Terms of Reference outlined in this document to guide their review. The chair will run the meeting and lead the development of a summary report on the second day of the review.

The specific responsibilities of the panel are to:
1. Review the technical documents listed above prior to the panel review.
2. Listen to presentations by project scientists describing the model framework.
3. Develop a summary report detailing whether NMFS has met the recommendations outlined in the report Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel developed by Rose et al.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting in Santa Cruz, CA from 5-6 November 2015.
3) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than 20 November 2015, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to *mshivlani@ntvifederal.com*, and Dr. David Die, the CIE Regional Coordinator, via email to *ddie@rsmas.miami.edu*. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

October 9, 2015	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
October 22, 2015	NMFS Project Contact sends the CIE Reviewers the pre-review documents
November 5-6 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
November 20, 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
December 4, 2015	CIE submits CIE independent peer review reports to the COTR
December 8, 2015	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) The CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) The CIE report shall address each ToR as specified in **Annex 2**,
(3) The CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Appendix 2: CIE Statement of Work.

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Appendix 2: CIE Statement of Work.

Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Appendix 2: CIE Statement of Work.

Annex 2: Terms of Reference for the Peer Review

Central Valley Chinook Life Cycle Model Panel Review

1) Is the model useful for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level?
   a) What are the strengths and weaknesses of the model?
   b) Are key parameters and performance measures captured in the model? If not, what other parameters and performance measures should be included?
   c) Can the model be applied to address the multiple timescales associated with RPA decisions and operations?
   d) What are the technical constraints to the implementation of the model and the feasibility to address them (e.g., transparency of the model, data sets availability, model parameter uncertainties and sensitivities, etc.)?

2) Has NMFS effectively linked multiple specific models to represent the whole life cycle to inform NMFS in determining the effects of water operations and prescribed RPA actions on salmonids at the population level?

3) Is the model framework suitable for winter-run, spring-run, and fall-run and can the framework be adapted for other species of Pacific salmonids?

4) Can the model fit into a decision-making framework for using life cycle models (at appropriate temporal and spatial scales) to adapt water operations and prescribed RPA actions on individual and multiple species?

Appendix 2: CIE Statement of Work.

Annex 3: Tentative Agenda

Central Valley Chinook Life Cycle Model Panel Review
Southwest Fisheries Science Center, 110 Shaffer Road, Santa Cruz, CA 95062
November 5-6, 2015, 8:30 am – 5:00 pm

First day

8:30 am Arrival and coffee	
9:00 am Welcome and introductions	Steve Lindley
9:10 am Legal and Regulatory Context	Rea, McClain, or Yip (NMFS-CVO office)
9:30 am Project Overview	Steve Lindley
9:45 am Winter-run Life Cycle Model Framework Part 1	Noble Hendrix
10:45 am Break	
11:00 am Winter-run Life Cycle Model Framework Part 2	Noble Hendrix
12:00 pm Lunch	
1:15 pm Habitat Capacity	Correigh Greene
1:45 pm Enhanced Particle Tracking Model	Steve Lindley
2:15 pm Break	
2:30 pm Panel and Presenter Discussion	
4:30 pm Public Comment and Concluding Remarks	Steve Lindley
5:00 pm Adjourn	

Second Day

9:00 Panel Report Preparation

Point of contact for reviewer security & check-in

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Appendix 3: Panel Membership

Review Panel Membership

David Hankin	Reviewer	CIE
Jamie Gibson	Reviewer	CIE
John G Williams	Reviewer	CIE

Review Meeting Chair

Anne Criss	NOAA