Independent Review Panel (IRP) Report for the 2015 Long-term Operations Biological Opinions (LOBO) Annual Science Review

A report to the
Delta Science Program

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Scope and Intent of Review: This report presents findings and opinions of the Independent Review Panel (IRP) assembled by the Delta Science Program to inform the National Marine Fisheries Service (NMFS) and the U.S. Fish & Wildlife Service (USFWS) as to the efficacy of water operations and certain regulatory actions prescribed by their respective Long-term Operations Biological Opinions' (LOBO) Reasonable and Prudent Alternative Actions (RPAs) as applied from October 1, 2014 through September 30, 2015 (Water Year 2015).

This year's annual review focused primarily on: (1) Shasta Reservoir and Sacramento River temperature monitoring, modeling, and management, (2) the River Assessment for Forecasting Temperature (RAFT) decision support tool (model), (3) an Enhanced Particle Tracking Model (E-PTM), and (4) a USFWS report on past, present, and future approaches to incidental take of Delta Smelt.

After reviewing a required set of written documents (Appendix 1), the IRP convened at a public workshop in Sacramento, CA on 5-6 November 2015. The first day of the 2-day workshop included agency presentations and provided a forum for the IRP to interact and consider information presented on water operations, temperature modeling, monitoring and RPA Actions as implemented in yet another critically dry 2015 water year. On the second day, the IRP deliberated in a private session beginning at 9:00 a.m. in order to prepare and present their initial findings at the public workshop at 2:00 p.m., after which there was an opportunity for agency representatives, members of the public, and the IRP members to comment and otherwise exchange impressions and information. Subsequent IRP communication and deliberations were conducted via email and conference calls in the course of drafting this final report.

EXECUTIVE SUMMARY

The 2015 WY was the fourth consecutive year of drought conditions in California's Central Valley and the concerns expressed in previous Independent Review Panel (IRP) reports (Anderson et al. 2010 to 2014) regarding the capacity to achieve specific Reasonable and Prudent Alternative (RPA) habitat quality targets are apparently being confirmed. The 2015 IRP (Panel) continues to remain positive about progress toward the incorporation of more direct links between the biological and physical components of the models used to guide water operations. The development of methods that explicitly link the success or failure of achieving desired temperatures, flows and other physical targets to the biological/ecological responses of the listed species is the only way that the intended goals of the RPA Actions can be assessed in a scientific context.

The first of five charge questions to the 2015 IRP concerned temperature monitoring, modeling and water management in Shasta Reservoir and the Sacramento River. The Panel has concerns and questions about the adequacy of apparently outdated data gathering methods for conditions in Shasta as well as the lack of accuracy, resolution and redundancy in the instrumentation on which data collection depends. Reliability of the data guiding water operations is especially important in critically dry years such as WY2015. Beyond the data, the operations model also may be inadequate under conditions of long-term drought and should be updated to accurately predict conditions in the reservoir when the available water resource, particularly the cold-water pool, is persistently constrained. In terms of ecosystem water requirements, the focus of Shasta operations continues to be on meeting downriver temperature targets for salmon. However, salmon habitat is not adequately described by the number of river miles that can be maintained at or below a certain temperature. Habitat quality has multiple facets best identified by areas actually used by a species. Water resources could be better conserved and allocated by allowing salmon to guide when and where those resources are required.

A second related charge to the Panel involved the River Assessment for Forecasting Temperature (RAFT) Decision Support Tool (DST). The Panel had a generally positive opinion of the RAFT DST and, in particular, found its publication in the peer-reviewed literature commendable. However there may be a number of possible sources of model errors that should be considered in future updates, including effects of ground water and hyporheic flows, evaporative cooling, shading and river-segment orientation. Overlaying salmon early life stage distributions on the temperature landscape maps provided a useful example of incorporating biological considerations into physical models. The Panel encourages more interactions with biologists in moving forward toward melding physical and biological elements needed to guide agency decisions in the future.

The Enhanced Particle Tracking Model (ePTM) was another example of movement toward incorporating biology into existing or developing physical models, which this and previous IRPs have strongly encouraged. The Panel viewed the ePTM as a potentially useful tool for testing hypotheses related to effects of water operations and environmental conditions on salmon smolt routing and survival. That said, there were concerns about linking the model's physical and biological components, as well as the interpretations of parameters used in fitting the model. The Panel considers it premature to recommend application of the ePTM for management purposes at this time, but encourages revision and further development of the model.

The U.S. Fish and Wildlife report on past and future approaches to incidental take of Delta Smelt also represented movement toward new ground. Past and present approaches to setting incidental take limits for Delta Smelt were based on historical correlations among turbidity, Old and Middle River (OMR) flows and salvage applied to smelt abundance indices derived from inadequate sampling methods. These approaches have rarely triggered a significant RPA Action intended to be protective of Delta Smelt. At the same time, smelt abundance indices have remained on a declining trajectory to an all-time low. Clearly, the current approaches are not functioning to protect, much less restore, Delta Smelt. The proposed new approach to monitoring and estimating source-specific mortality in a meta-population context (Low- and High Risk Zones) is moving in a potentially productive direction for understanding any actual relationship between water operations and jeopardy in this species. However, the Panel had certain statistical and biological reservations regarding the specifics of the new approach and also remains concerned as to whether or not any improved approach can be implemented in time to protect and restore the Delta Smelt population before it becomes unsustainable in the wild.

Regarding the effectiveness of RPA Actions under dry year conditions, the Panel found it difficult to comment given the paucity of reliable data on responses of species under protection. Four consecutive years of drought have tested the engineered limits of the Central Valley Project to meet California's co-equal goals of improving the reliability of water supply and protecting the Delta ecosystem. Current climate change predictions offer little reassurance that challenges will be less severe in the future. It may be time for all stakeholders to view their expectations in the context of a "new normal" climate pattern that constrains the availability of water resources, particularly cold-water reserves, in more years than might be expected from the historical record.

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INTRODUCTION

Over a period of four decades beginning in the late 1930s, surface water resources of California's Central Valley have been controlled through a highly-engineered storage/delivery system that was developed to meet the needs of farms, industry, and millions of people residing within and outside this watershed. Added to the complex infrastructure and landscape alterations is an equally complex suite of rules and water rights governing the distribution of water, which affect flows and water quality of riverine and deltaic ecosystems associated with California's Central Valley. These and other anthropogenic alterations over time have been accompanied by substantive changes in aquatic flora and fauna, including a persistent decline in native fishes. With the passage of the Central Valley Project Improvement Act (CVPIA) in 1992, the U.S. Congress recognized the need for water management to consider the requirements of fish and wildlife, and in the same year California's state legislature adopted the coequal goals of improving the reliability of the water supply and protecting ecosystem health, including native fishes of the Central Valley. Some of these fish species have been afforded federal protection under the Endangered Species Act (ESA) and government agencies have been charged with developing ways of protecting these populations from further jeopardy associated directly or indirectly with water operation projects in the region.

Four consecutive years of persistent drought has been a major obstacle to achieving the coequal goals of maintaining both a reliable water supply and a healthy ecosystem capable of supporting viable populations of threatened and endangered native fish species. Options for water management in this engineered system, in which most of the historical riverine wetlands have been converted to agricultural lands, are limited largely to the regulation of flows and water temperature at dams and pumping facilities. When water supplies are adequate, properly adjusting the "knobs" can provide acceptable results. However, under persistent drought conditions water reserves, especially cold-water stores, are inadequate to meet demands. This has placed increasing pressure on ground water resources to supplement dwindling surface water supplies without apparent concern for connections between surface and ground water pools.

Climate change predictions offer little relief in the foreseeable future and, even in years with normal or above-normal precipitation, there are no guarantees that the distribution of precipitation events in space and time will replenish the cold-water resources necessary to support viable populations of endangered native fishes. The time may have come to adapt to a "new normal" in terms of both water supply and ecosystem components in California's Central Valley.

***Background on the LOBO RPA review process*:** NOAA's National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) have each issued Biological Opinions (Opinions) on long-term operations of the Central Valley Project (CVP) and State Water Project (SWP) that include Reasonable and Prudent Alternatives (RPA) designed to alleviate jeopardy to listed species and adverse modification of critical habitat. NMFS' Opinion requires the U.S. Bureau of Reclamation (USBR) and NMFS to host a workshop no later than November 30 of each year to review the prior water year's operations and to determine whether any measures prescribed in the RPA should be altered in light of new information (NMFS' OCAP Opinion, section 11.2.1.2, starting on page 583). Amendments to the RPA must be consistent with the underlying analysis and conclusions of the Biological Opinions and must not limit the effectiveness of the RPA in avoiding jeopardy to the ESA listed species or result in adverse modification of critical habitat.

The purpose of this annual review of the Long-term Operations Biological Opinions is to inform NMFS and USFWS as to the effectiveness of operations and regulatory actions prescribed by their respective RPAs in the 2015 Water Year, and to make recommendations/review proposals for changes to implementation of actions consistent with the purpose of the RPA.

Since the Long-term Operations Biological Opinions were issued, NMFS, USFWS, USBR, U.S. Geological Survey (USGS), California Department of Fish and Wildlife (CDFW) and the Department of Water Resources (DWR) have been performing scientific research and monitoring in concordance with the implementation of the RPAs. Technical teams and/or working groups, including the geographic divisions specified in the NMFS' Opinion, have summarized their data and results following implementation of the RPA actions within technical reports. The data and summary of findings related to the implementation of the RPAs provide the primary context for scientific review regarding the effectiveness of the RPA Actions for minimizing the effects of water operations on ESA listed species and critical habitat related to the operations of the CVP/SWP. A subset of these technical reports was presented for consideration by the 2015 LOBO IRP (see Appendix 1).

General charge and scope for the 2015 LOBO IRP: Annual reviews prior to 2012 considered all of the RPA actions but in subsequent years, the panel's charge has focused on a subset of RPAs for water operations and fisheries management. The previous and present years' (WY 2014 & 2015) water operations and actions have been subject to Drought Contingency Plans in response to prolonged (currently four years) drought conditions in California.

This year's (2015) annual review included:

(1) Progress on Shasta Reservoir and Sacramento River temperature monitoring, modeling, and management;

(2) River Assessment for Forecasting Temperature (RAFT) decision support tool;

(3) Enhanced particle tracking modeling;

(4) USFWS report on past, present, and future approaches to incidental take of Delta Smelt; and

(5) A general consideration of RPA actions under dry year conditions based on questions and concerns expressed in prior annual science reviews.

As in previous years, the specific scope of the 2015 LOBO review was defined by questions posed to the 2015 IRP by the agencies and technical teams/task groups that presented materials for review. This IRP report addresses each of the questions posed from a scientific perspective, and provides additional observations, opinions and recommendations where, in the panel's opinion, they seemed potentially useful to agency staff for consideration, especially in regard to near real-time decision making.

Acknowledgments**:** The members of the IRP appreciate and acknowledge the efforts of the agency and technical team representatives and contractors who responded to questions and suggestions made by previous IRPs, prepared the written materials, and delivered the workshop presentations on which this report is based. Each year we are cognizant that much of the material has to be compiled, analyzed, and organized in a relatively short time. We also recognize that government agency personnel faced additional challenges resulting from yet another critically dry water year in 2015, and continuing government budget uncertainties. Despite the many competing demands on the workshop participants, the materials were presented professionally and concisely. The panel wishes to express a special thanks to Cliff Dahm (Lead Scientist), Sam Harader (Program Manager II) and the staff of the Delta Science Program for providing the organization and logistical support to facilitate our task. In particular, Jill McGee and Nicole Stern attended to a variety of technical and provisional details in support of the IRP's efforts before, during and following the workshop. Title page photo credit: www.gerhardbock.com/public/140119_ShastaLake_BridgeBay_pano4.jpg

LOBO IRP COMMENTS ON RPA ACTIONS IN WATER YEAR 2015

General comments and observations

After experiencing a sequential four years of drought, including two consecutive years of critically dry conditions, there is mounting evidence to support the need for a shift in perspective toward the expectation of a deviation from the historical climate pattern. This may mean significant adjustments in water operations and expectations for meeting water requirements for all purposes in the future. Although the 2015 El Nino (ENSO) may provide some relief to California, most of the precipitation is expected to fall in the southern portion of the State as rain and contribute little to replenishment of the depleted northern Sierra Nevada snowpack from which California derives more than 60% of its water supply during summer months and almost all of its cold-water resource pool. Ecosystem water requirements depend on the timely delivery of cold water primarily from snowmelt now captured in reservoirs. If a cycle of droughts becomes the norm for the future, with extended periods of dry years punctuated by one or two years of previously normal snowfall, then management decisions in the future may have to contemplate alternate delivery of warm water to downstream users (e.g., bypass channels or a different mixing regime) in order to preserve what little cold water will be available in the system. Even with some “predictable” snow events, it will take several years to get back to cold-water management and storage goals. This was acknowledged at the recent LOBO workshop and suggests the need for even greater interagency discussion and cooperation to describe a new set of storage and release scenarios into the future.

Questions may also arise regarding potential disconnects between limited cold-water resources and endangered species (e.g., Chinook Salmon) that depend on them for their continued existence. Dams are barriers between salmon and their historical spawning and nursery habitats. Thus far, it has been possible to engineer solutions that relocate suitable habitat by providing sufficient cold-water resources and substrates to support the continued survival of these species below reservoirs, albeit at reduced population sizes. However, when sources of cold water inflows via snowmelt or groundwater/hyporheic flows are reduced below some critical threshold, it may no longer be feasible to provide spawning and rearing habitat of sufficient quality to support some salmonids below the reservoirs, which prevent these species from accessing historical spawning and nursery habitats upriver of the dams.

The Panel continues to be impressed by efforts to improve models for the prediction of physical conditions, primarily temperatures and flows, in the water storage and conveyance channels within the Central Valley system. Furthermore, it is commendable that the agencies have heeded the Panel’s annual call for incorporating biological considerations into the development of their various predictive models. Although in comparison to the effort invested in understanding the physical components of the system, the incorporation of biology remains in its infancy. The Panel urges the agencies to continue to connect hydrologic conditions to fish and macroinvertebrate life history requirements, and to assess the adequacy of current models. If water management decisions are to be ultimately based upon predictive models, the decisions will only be as good as the weakest component of the models. In moving forward, it may be time to begin devoting more resources (time, money and effort) to improving the integration of biological components rather than expending those resources on further alterations of the physical models.

Other comments

Comment on 2015 Clear Creek Technical Team (CCTT) Report:

On p. 6-7 of the CCTT report, two-sample t-tests are used to compare the mean number of fish per day passing a video sampling station before, during, and after controlled pulse flows. Each mean passage count is calculated over a sequence of 6 or 9 successive days. However, the passage rates on successive days are almost surely correlated. However t-tests require that the daily counts be statistically independent, and hence the reported P-values are highly questionable. Unfortunately, the sampling periods are too short to adjust the t-tests for temporal correlation. Perhaps it would be more appropriate to replace the t-tests with time-series plots of the counts along with the mean count in each period.

Progress on Shasta Reservoir and Sacramento River Temperature Monitoring, Modeling, and Management

"The purpose of the Sacramento River Temperature Task Group (SRTTG) is to provide advice to Reclamation on managing water temperatures downstream of Central Valley Project (CVP) reservoirs in the Sacramento River, Trinity River and Clear Creek." Their stated objective this year was to "…manage the cold water storage within Shasta Reservoir and make cold water releases from Shasta Reservoir to provide suitable habitat temperatures…" The 2015 water year presented some unique and extreme challenges and it is difficult to say how successfully these were met, particularly as the data were not all at hand at the time of the Workshop.

However, the extreme nature of the conditions, combined with the dire consequences that may emerge as a result of actions taken and not taken, serve to highlight some important structural deficiencies with the way in which the Shasta Reservoir – Sacramento River system is managed. These deficiencies relate to the fundamental data gathering infrastructure that is available to inform managers and operators, and to the modeling tools that are used to base operational decisions.

With regard to data gathering, from the information presented it appears that the practices and equipment used at Shasta Dam are decades out of date. Statements to the effect that uncertainty levels were increased because of doubts about the accuracy of a single temperature probe highlight the problem. Even though it was never fully ascertained whether the probe was in error or not, the fact that decisions with the financial and ecological magnitude of those surrounding the operations of Shasta reservoir rest on a single measurement is disturbing. Such a lack of redundancy and backup/confirmation data should not exist. Similarly, the absolute accuracy and resolution of the instruments used should be to the highest practical standards.

For many decades, the practice in lakes and reservoirs has been to deploy real-time “thermistor chains”, a vertical array of thermistors that have an accuracy and resolution approaching 0.001 °C. Data from the chain are often telemetered back to a data center/scientists/engineers and the state of the reservoir temperature, stratification etc. can be determined immediately. Equally important, as stratified reservoirs are highly dynamic systems that respond to operations (withdrawal levels and rates), weather (wind) and river inflows, the continuous nature of the measurements (frequency as much as 1 sec^{-1}) allows operators to know how the water column is changing over time scales of hours, days, weeks, etc. It was reported by a different research team that a vertical Distributed Temperature System (DTS) was recently installed at Shasta. While these instruments provide valuable data on the temporal and spatial variability of temperature, they do not as yet have the accuracy on which to base water release decisions. Typically their accuracy is on the order of 1 °C, a value that could have substantial impacts on salmonid spawning success.

Another concern related to the current vertical profiling of the reservoir was that the probe used for this purpose was believed to be in error. While no details were supplied on the type of probe used, the Panel assumed that it was the same general type used at Whiskeytown Reservoir (see Fig. 14 in Clear Creek Working group report). That probe is lowered to a particular depth, left at that depth for a period of time (minutes) to allow the instrument to equilibrate, and then moved down to the next depth. As seen in the above referenced figure, that depth interval is approximately 25 ft. Linear interpolation was applied to fill in temperatures between the measurement depths. As a consequence, there is an inherent uncertainty in the temperature profile of up to 50 ft, and where the temperature changes markedly, the uncertainty in the temperature reading could be up to 5 ºF. This uncertainty is purely the result of the discrete measurement depths, and is independent of the manufacturer’s stated instrument accuracy.

Again, the technology currently used is decades old and imposes a totally unnecessary level of uncertainty and absolute error on operations. Instruments (probes) are available that can equilibrate and measure instantaneously and allow spatial discretization on the order of centimeters (an inch). Temperature accuracy is on the order of 0.001 ºC.

Equally important, such instruments can accommodate a large number of auxiliary sensors that would provide information that is absolutely critical to (1) improve the modeling of the reservoirs, and (2) to provide information that will alert operators to other changing conditions in the reservoir that may influence operations. Examples include light attenuation (which directly influences the temperature of the water), dissolved oxygen concentrations, pigments associated with cyanobacteria, turbidity and pH.

Thermistor chains (for high accuracy and temporal resolution) and profiling instruments (for high accuracy and spatial resolution) should be used together to provide a new operating protocol. The data obtained should be applied to: (1) make more informed decisions when actual release temperatures deviate from the operation model guidelines or unplanned events arise; (2) provide input for improved models (both initial and boundary conditions, as well as data to calibrate and validate the models); and (3) accumulate new real-time knowledge of how the Shasta Reservoir thermal structure responds to operations and environmental fluctuations.

The operations model described appears to be inadequate, particularly in years when it is most needed. In other words, when there is plenty of cold water, large uncertainties and mismatches in the model can be tolerated as there may be many ways to compensate. However, when water - especially cold water - is in extremely limited supply, a model that can better match reservoir conditions (including the effects of gate operations) is an absolute necessity.

While operation models typically provide guidance for monthly operations, it is still necessary for the model to match measured conditions at shorter time scales (e.g. daily). There are numerous lake and reservoir models that provide this type of temporal resolution. Whether a 1-D, 2-D or 3-D model best suits the needs is a matter for consideration and experimentation. Hopefully, for many of the most critical questions, a 1-D or 2-D model would be sufficient. But even so, there is a case to be made that 3-D modeling should also be conducted in order to better understand areas where the model results may vary from the measured results (measured here refers to the new type of measurement described above because the current measurements are inadequate).

A new operations model should be based on a monthly (or any preferred interval) output from a model run at a sub-daily time-step (hourly or shorter). The model should be carefully calibrated and validated before it is put into operation. As part of continuing operations, daily model predictions need to be compared with actual reservoir conditions, so that operators have both the information and the time to respond. Events where model and data diverge should not be viewed as failures, but rather as opportunities to improve the model and in that way improve operations. Model improvements may be needed in many areas – for example, the representation of withdrawals from the stratified water column, input of groundwater, and meteorological data (especially wind) that is not uniform over such a large area as Shasta reservoir.

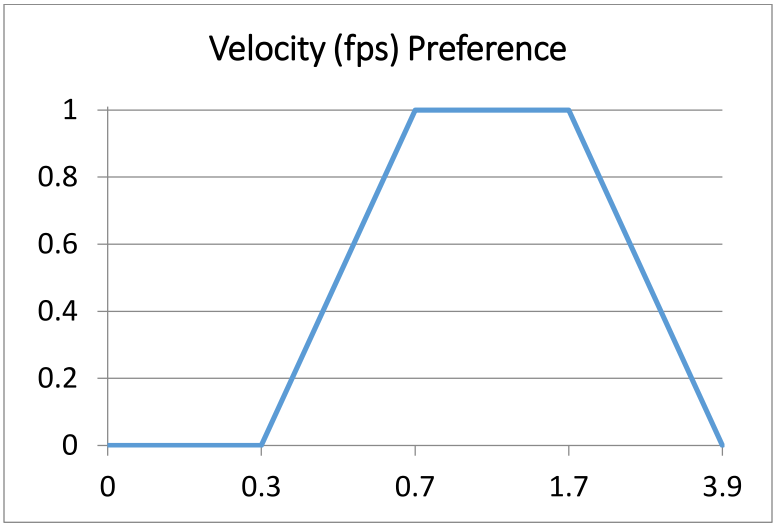
Interpretation of both the data and the model results need input from limnologists or others who are experts in the processes that occur within lakes. The goal is for the operators to better understand the reservoir and to anticipate the consequences of future conditions before they occur. While WY 2015 was extreme, operators only had to deal with two variables – the quantity of water and the temperature of the releases. It is easy to conceive of other variables emerging in the future that would compound the difficulties faced by water operations. These might include upstream chemical spills (as occurred in the 1990s at Dunsmuir), toxic cyanobacterial blooms (as have been known to occur in other locations during extremely warm years), anoxic conditions in the hypolimnion, etc. Better data-based understanding of trends in the reservoir, combined with modeling studies on plausible future scenarios would help operators know both how to plan for such occurrences and how best to respond to them.

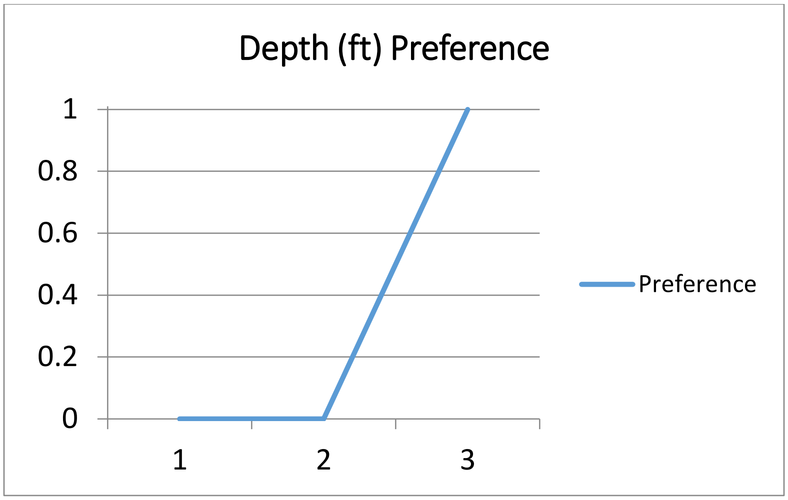
Shifting from a physical monitoring perspective to a biological one, the Panel had a general concern about the way “habitat” is apparently perceived in linking the biological requirements of salmon with water operations. A recurring theme through the reports and presentations was the description of “available habitat” as the number of river miles maintained at a given target temperature. However, the ecological term ‘habitat’ is the place where a species normally lives (e.g., see Calow 1998). Habitat is defined as the sum total of physical and chemical characteristics that allow a species - or life-stage - to survive, grow and reproduce in an area. Secondarily, this also includes intra- and inter-specific interactions which further restrict access to certain “preferred” physical and chemical conditions. Temperature is only one component of habitat quality, and thus cannot be used alone as a surrogate for all habitat conditions essential for a species’ survival and persistence.

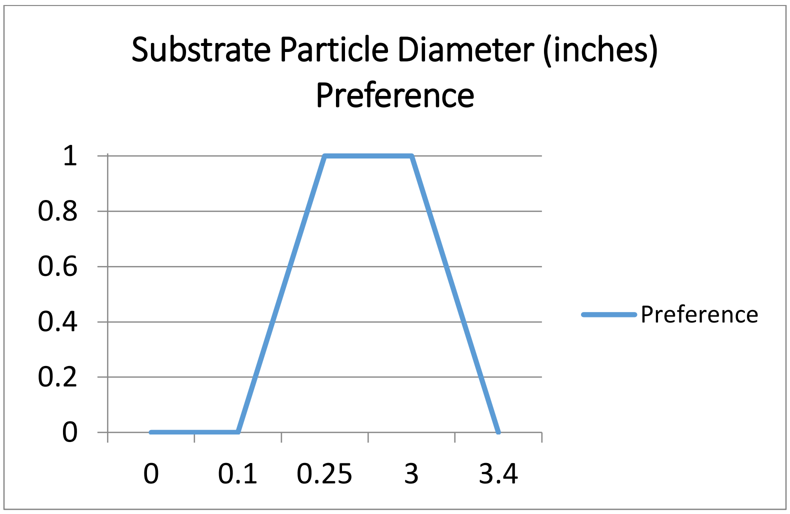
In 2014, the IRP (Anderson et al. 2014) recommended flexibility in the amount of riverine space (habitat) below Keswick Dam that should be targeted for minimally required temperature conditions, with presence of salmon defining the extent of habitat in use. The purpose of this recommendation was to conserve cold water resources for subsequent use in times of shortage by providing suitable temperatures during the times and places that different life stages required them. However, in WY2015, it became apparent that the cold water resource pool was inadequate to maintain target temperatures even within the restricted reaches containing salmon redds. Subsequently, and in the name of “flexibility”, the decision was made to increase the maximum target temperature of water released from Shasta Reservoir, which may have exposed early life stages of winter-run Chinook Salmon to suboptimal habitat quality and consequently reduced survival rates.

Even in years when cold water reserves are sufficient to maintain optimal temperatures, the distribution and success of winter-run salmon redds in the Sacramento River will also depend on other essential habitat qualities such as substrate type, critical water velocity, sediment accumulation and depth. Wetted area as an index of habitat availability, even over redds, fails to describe the many combinations of complex hydraulics that could potentially affect emergence success (e.g., Statzner et al. 1988, and Bovee et al.1998).As an example, salmonids can use gravel sizes from 0.3 to 10 cm in construction of redds, but 1.0 to 7.0 cm are most often used; ultimately, this is usually determined by the size of the spawning female (Reiser and Wesche 1977, Bovee 1978). This underscores the need to understand the biology of the fish, the distribution of sizes within the population, as well as the physical size of the substrate material in order to assess available spawning habitat. The suitability of the gravel environment for hatching embryos and successful emergence of fry depends upon both sufficient water velocity to clean redds of sediment and sufficient levels of dissolved oxygen to support developing embryos. The embryo optima are, in essence, chosen by spawning adults. Thus, careful records of adult preferences for combinations of velocity and depth may be a better index of habitat suitability/quality/distribution than wetted area or temperature alone. There should be a more analytical means of describing the extent or location of "habitat" for salmonids in river reaches immediately below Shasta.

For example, the following charts show preferences for salmonid spawning and incubation conditions from Bovee (1978):







According to the criteria depicted in the three graphs above, a 100% suitable habitat (highest quality) is defined by velocities between 0.7 and 1.7 fps, depths greater than three feet, and substrate dominated by particles between 0.25 and 3 inches. Outside this relatively narrow range of optimal conditions, habitat quality is very low. For example, an area characterized as 2.5 ft in depth, with a velocity of 0.5 fps, and gravels of 3.2 inches would yield a habitat suitability index of only 12% (the product of 0.5, 0.4, and 0.6).

It is important to note that, although the preferences are based upon the greatest number of individuals utilizing certain conditions, the converse is not a practical output of the model; that is, the amount of available quality habitat cannot be used to predict density or productivity. “Quality” is a far better “currency” to evaluate in management decisions than an approximation of density or productivity (Gore and Nestler 1988).

The set of redd conditions described as physical and biological conditions suggests that management of cold water should be focused upon the location of the fish rather than extending the temperature compensation to a point where no redds have been located. In other words, let the fish utilization describe the conditions to be optimized.

River Forecasting and Temperature (RAFT) Decision Support Tool (DST)

The RAFT DST represents a large step in a good direction. It is predicated on getting the physical processes correct, and then using that physically correct representation of the river temperatures as a tool to support decision making. The fact that the model results were published in the peer-reviewed literature is particularly noteworthy and to be commended. At the end of the day, actions need to be taken and decisions need to be made and, if they are based on what has been accepted in the peer-reviewed literature, then that goes a long way toward making a convincing argument that they are being driven by the best scientific information available.

A number of substantive questions remain about the model that the developers should address going forward. The first relates to water balance. This is an issue that has dogged previous modeling efforts from the 1990s. Is there a water balance? Obviously the main inputs are the flow from Keswick and the flow from the major tributaries; the agencies and technical teams surely have those data in hand. The evidence that suggests there is not a water balance in the current model is the result from Red Bluff Diversion Dam (see Figure 3a in Pike et al. 2013). There is an apparently large mismatch between the data and the model. The model is showing evidence of a temperature node at RBDD, whereas the actual measured data shows that location is far from a node because it has a large diurnal temperature range. If the incorrect flow is used in the model, by not taking proper account of groundwater or withdrawals for example, then the node position will shift. It will move downstream if the flow is overestimated or move upstream if the flow is underestimated.

Figure 4a in Pike et al. (2013) shows another aspect of the model that may need to be corrected but could, in part, be related to the lack of correct water balance. This figure shows the temperature variance between measured and modeled values increasing downstream. While it is not clear whether this variance is randomly distributed about a mean, or whether the model consistently under-predicts or over-predicts, the fact that at Bend the variance is 0.5 ºC implies that the standard deviation is actually closer to 0.7 ºC, or about 1.5 ºF. Currently, it is unclear whether or not this is a large difference in the context of ecological impacts. The proposed method of using data assimilation to correct the error may not always be a good option. However, while the model includes most of the important physics, it would appear that calibration/validation may still be needed, especially if the model is used to make long-term temperature forecasts, in which case no data would be available to correct for the accumulation of downstream errors.

A list of possible sources of model errors that should be addressed in future updates are:

(1) *Groundwater flows*. These can be both sources (gaining reaches) and sinks (losing reaches). Large amounts of groundwater pumping occurred in WY2015, suggesting that the whole balance between riverine surface flow and groundwater may be changing on different time scales than the simple meteorological timescale. There were suggestions at the Workshop that Battle Creek (a largely spring fed system) had greatly reduced flows in 2015. This suggests that applying corrections for groundwater inflow may in the long-term need a separate model rather than just assuming fixed amounts of groundwater in or out along specific river reaches. This also has potentially important impacts for the water balance and for existence of thermal refugia for salmonids.

(2) *Hyporheic flow*. This is distinct from groundwater inflows, and represents the water travelling through the subsurface and periodically reconnecting to the actual river flow. The temperature characteristics of the hyporheic flow component is different in that it has little, if any, diurnal component. These flows may also change water chemistry and play an important role in the size and location of thermal refugia.

(3) *Meteorological data and evaporative cooling*. The meteorological inputs to RAFT came from a model/forecast that applied to the Sacramento Valley. Was any allowance/offset made for the difference between the broad valley floor and the actual current, incised flow channel? Wind effects would likely be very different. As wind blows across the incised river channel, there would be boundary layer separation and so any estimate of evaporation - and associated cooling - would likely be an overestimate. Temperature would likely be in error too.

(4) *Shading and river orientation*. Riparian vegetation can block direct sunlight from impacting part of the river for the early and late parts of the day. This varies with river orientation (N-S or E-W). Neglect of this could result in the model over-predicting water temperature, and not identifying potential thermal refugia.

The Workshop presentation on RAFT suggested the use of HEC-RAS as a means to determine water velocity distributions. However, HEC-RAS is too coarse-grained to provide the necessary information to estimate velocity distributions over the target area to be evaluated. Transect intervals tended to be about 20ft and, in most cases, only five or so velocity, depth, substrate conditions might be measured and recorded. Such a small sample size can yield an error of greater than 7.5% while 20 equidistant measurements of velocity and depth within the wetted channel (the recommendation for most surveys) yields an error of 2.5% or less (Gore and Banning 2016).

Despite these concerns, the RAFT model seems to be working well for extrapolating measured temperatures in time and space in many areas of interest. The temperature landscape maps (e.g., Figure 4 in the report on Temperature Decision Support for the Sacramento River) provide a useful picture of how the location of salmonid early life stages can be superimposed on the modeled temperature regime.

The Panel also appreciated the effort to incorporate more realistic biological considerations in the future, and encourages more interactions with biologists to continue this trend of melding physical and biological considerations of habitat quality in the Sacramento River.

Report on Enhanced Particle Tracking Modeling

The enhanced particle tracking model (ePTM) attempts to include fish migration behavior and survival in a physical particle tracking model. When development is complete, with calibration and validation, the model should be a useful tool for testing hypotheses on the effects of water management and environmental conditions on smolt routing and survival through river system and Delta.

The document submitted for Panel review included mathematical details of the calibration approach and a basic description of the behavioral submodels on movement and survival. Several different configurations of the behavioral models were explored with different combinations of parameters being held constant or variable on region (riverine, transitional, tidal) and reach (2-10) levels.

The model moves fish through the river and Delta with four processes:

1. The PTM defines the movement of water through reaches and partitions flow at the junctions. The model simulates the tidal and subtidal (residual river flow) components of neutrally buoyant particles with both components affecting fish.
2. A movement submodel adds fish behavior in response to changes in flow. Ten behavior models were tested. The most viable model, the selective tidal stream transport model (STST) (Table 4 in the ePTM Report), includes downstream swimming and probability of confusing upstream for downstream. This model contains 6 independent factors. The submodel output is a probability distribution of the travel time through each reach. The distribution of travel times was compared to measured travel times of acoustically tagged fish expressed as an inverse Gaussian reverse normal distribution (IGRN) (Gurarie et al. 2009).
3. The third component is a routing model that partitions fish to different junctions according to the percent of flow through each junction.
4. The fourth submodel describes survival and based on the XT model which characterizes fish survival as a function of distance traveled and mean travel time (Anderson et al. 2005).

The model was calibrated using state-of-the art Bayesian methods. Eight model parameters were fit to the data. Of these, five parameters were calibrated by fitting the model to survival and travel time data and three parameters were fixed. Three calibrated parameters characterize the movement of fish relative to the movement of neutrally buoyant particles: *swimSpeed* characterizes the downstream swimming velocity of the fish in meters s^{-1} when it is not holding position, *holdThr*, in meters s^{-1}, characterizes water velocity at which the fish begins active downstream swimming, *ConstProbConfusion*, characterizes mistakes in swimming downstream. Two calibrated parameters characterized survival as a function of distance traveled in a reach and the time of travel: λ characterizes the mean free path length to encounter a predator and ω characterizes the random movement speed.

Data: The model was calibrated with acoustic tagging studies of juvenile late fall Chinook Salmon released near Sacramento and tracked through the Delta.

Fit of Model to Data: To calibrate the model combinations of parameters were grouped according to region and reach. For example, λ could be the same in all reaches, different in each reach, or held constant in each region. These combinations, designated as modeling methodologies A-F in Table 3 of the ePTM Report, represented a small subset of all possible combinations.

Fitted Travel Time: Ten different movement models were evaluated describing different behaviors with the tides. The travel time of each model was fit to each of the modeling methodologies and it was found that the model predicted faster travel times than were observed. The current comparison method (KS statistic for travel time distributions) is inadequate for understanding how well the model fits the detailed observed travel times. There appear to be possible inconsistencies or misunderstandings regarding how travel time is interpreted in the XT model for survival.

Fitted Survival: Model predictions were shown for CWT and acoustic tagged juvenile salmon. The fit to the CWT data was poor (ePTM Report, Figure 9) and the predictions from acoustic tagged survival studies were also problematic. When all reaches are plotted together the model exhibits a general correspondence with the data for all fitting methodologies (Figure 14 in the ePTM Report reproduced with additions as Figure 1 below). The model fits (represented by the 1-to-1 straight lines in Figure 1) through the clusters of points for each reach suggests that the fit may capture the effect of the mean flow over the data set. This is not surprising because, for the higher dimension methodologies, the parameters are different for each reach or for each region. Thus, the fitting routine adjusted the parameters to capture the average survival in each spatial grouping over the data set. This fitting however does not characterize the effect of flow variations on survival within a reach. To understand this effect requires looking at modeled and observed survival within reaches. To emphasize these relationship lines were placed through clusters of like-colored (e.g. reach specific) points in Figure 1.

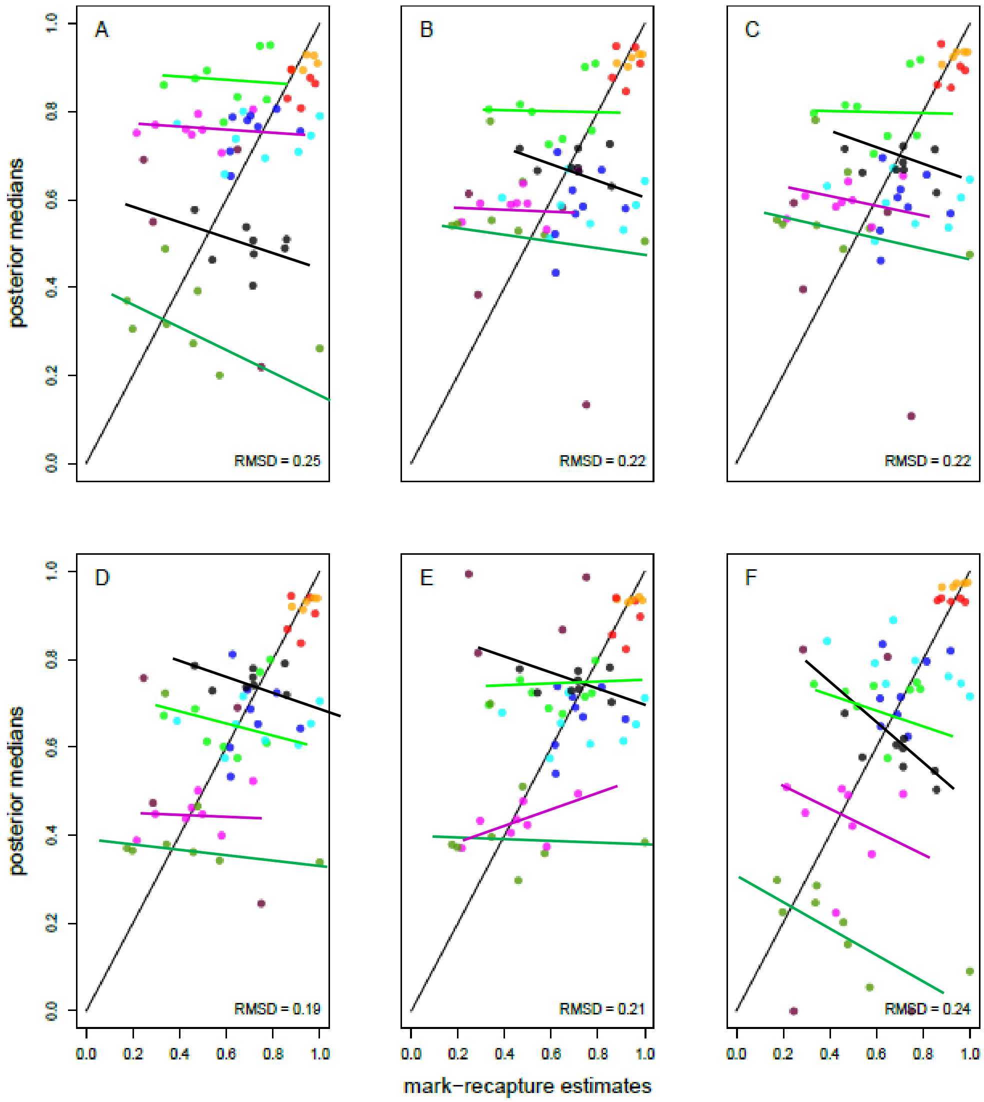


Figure. 1. Revised from Figure 14 in the ePTM Report. Survival posteriors (model predictions) vs. mark-recapture estimates (data). RMSD: root mean squared deviation (smaller is better); color codes indicate reach colors specified in Figure 7. The clusters of points representing all reaches generally pass through the black one-to-one line. The colored lines illustrate the relationship of modeled to observed survivals for specific reaches. Note the lack of a relationship within a reach.

Strikingly, model predictions have little correspondence with observed survivals or vary *inversely* with observed survival on a reach-specific basis. This suggest the possibility that the existing model may fit average flow conditions, but survival predictions when flows change are unreliable and may be opposite to actual responses. It is possible that the ePTM in its present form is less reliable at predicting reach survivals than a model without water flow information.

Routing at Junctions: The model predicts routing of fish according to the net presence of water flowing into arms of a junction. The routing was independent of the relationship between the tidal and subtidal velocities.

Fitting Parameters: The fitting parameters for the methodologies A-E are given in Fig 10 of the ePTM document.

- *Swim speed* ranged between near zero in the riverine reaches and 40 cm s^{-1} in the tidal and transition reaches. The average size of the tagged fish (Perry et al. 2010) was 16 cm which - assuming a natural swimming velocity of 1 to 2 body length per second (Lacroix and McCurdy 1996) - would indicate the model fish swimming velocity might be about 1.3 to 2 times the expected swimming velocity in the tidal reaches and considerably below the swimming velocity in the riverine reaches.

- The validity of the *holdThr* and *constProbConfusion* terms cannot be easily evaluated. In particular, these terms are likely to be entangled with the *swim speed* parameter. The Panel was concerned that the travel time elements of the model might contain interdependent parameters making the effect of travel time parameters opaque.

- The mean-free path length characterizes the travel distance across the ground a smolt travels before experiencing predation mortality. In the XT model this is a net distance traveled. Calibrated estimates ranged from 100 km to 500 km. In method D (selected as the best parameter set) λ ranged from 100 to about 240 km. In comparison, an application of the XT model to survival of acoustic tagged juvenile fall chinook salmon in a 73 km reach of the lower Sacramento River gave $\lambda = 344 \pm \sim 20$ km (A. Steel personal communication).

The random encounter velocity was held constant in all reaches and varied by data grouping from ω = ~0 to 4.5 cm s^{-1} with ω = 1 cm/s in the best calibration (method D). For the Sacramento River study (A. Steel personal communication) ω = 12 ± 2 cm s^{-1}. This difference on encounter velocities between the two studies needs further evaluation. In methodologies A-E, encounter velocity was fixed to the same value in the riverine, transition and tidal reaches. This assumption appears to violate the XT model theory which suggests that random encounters of predator and prey would be greater in a tidal environment than in a riverine environment. It is of concern that Steel's estimate of ω for a riverine environment was a factor of ten higher than that estimated from the ePTM model for a tidal environment.

The Panel also had some concern about how a suite of predators, ranging from striped bass to the pike minnow, would be incorporated into the model. It appears that a "generic predator" is used in the current model, with little regard for how the effects of different predators might vary from that of the generic one. This could be of importance in the likely event that there are shifts in the abundance of different predator species over time. Perhaps the model will be unable to accommodate this level of detail in any practical way, but the Workshop presentation identified a number of predator species that were being considered as potentially important sources of salmon smolt mortality.

While the Panel commends the ePTM developers for attempting to enhance the passive PTM with some biological realism, it would be premature to apply the current ePTM to specific management scenarios of the type presented at the Workshop (Nov. 5-6).

USFWS Report on Past, Present, and Future Approaches to Incidental Take of Delta Smelt

The incidental take of endangered species, such as Delta Smelt, is allowable under provisions of the U.S. Endangered Species Act as long as it does not "jeopardize" the persistence of the species in the wild. From a quantitative perspective there is a difficulty with the jeopardy criterion because it has no universal, quantitative definition (McGown and Ryan 2009). There has to be a way to relate allowable take to population size in order to determine jeopardy. The 2014 LOBO Panel (Anderson et al. 2014) recognized that approaches taken to setting incidental take of Delta Smelt lack a direct and reliable connection to Delta Smelt population size. How is it possible to set a level of incidental take that will not jeopardize the persistence of Delta Smelt without relating take to the actual population size?

The USFWS Report proposed a plan intended to protect and restore the Delta Smelt population, with the specific objectives to: (1) manage water operations to control Delta Smelt entrainment, (2) estimate Delta Smelt abundance and distribution in low-risk and high-risk zones (i.e., two meta-populations), (3) establish a new Delta Smelt monitoring program for entrainment (DSEM), and (4) conduct a population viability analysis to assess long-term effects of different management operation scenarios under different levels of smelt population abundance within zones of low and high entrainment risk. Until reliable data are available to relate take to population size of Delta Smelt, incidental take limits will continue to be set by some modification of the current method that relies on an inferior assessment of smelt abundance (Fall Mid-Water Trawl program) coupled with a questionable estimate of take based on a historical correlation with OMR flows and turbidity. This approach has rarely, if ever, triggered a significant RPA Action for Delta Smelt while, at the same time, smelt abundance indices continue to suggest that the population size has remained on a declining trajectory to an all-time low. Consequently, it is impossible to conclude that the current method is doing anything to protect, much less restore, Delta Smelt.

With certain statistical and biological reservations regarding the specifics of the approach, the Panel believes that the USFWS is moving in a productive direction for setting levels of incidental take in the future. A major concern is whether or not improved methods can be implemented in time to meet the stated fundamental objective of protecting and restoring the Delta Smelt population before it becomes unsustainable.

Estimating incidental take for Delta Smelt

The USFWS proposed method for estimating future incidental take is a slight variation of the regression method proposed to the 2014 panel by the Metropolitan Water District (MWD). Rather than using a linear regression to predict a cumulative salvage index (proposed in 2014) from turbidity and OMR flow, the 2015 proposal would predict the ratio of smelt salvage to a December smelt abundance estimate.

The 2014 Panel was skeptical of that year's proposed regression approach because its predictions are highly uncertain. The current proposed approach does adopt the 2014 panel's suggestion for Monte Carlo sampling of likely future values of turbidity and OMR, to use as predictive inputs to the regression model, thus generating a distribution of possible future values for the salvage/abundance ratio. A quantile of this distribution, when multiplied by a December abundance estimate, then yields an estimate of future smelt salvage, which is used as the projected incidental take. The Monte Carlo strategy accounts for the first of two major sources of uncertainty in the regression approach, namely, the unknown turbidity and OMR levels that smelt will encounter in a future year.

The Panel believes that the proposed estimation method for 2016 needs more consideration on two issues: 1) the distribution of turbidity and OMR values used for predictions, and 2) uncertainty in the regression approach.

1) The current USFWS approach would use all historical data for turbidity and OMR to construct a joint distribution of their historically likely values. However, Monte Carlo sampling would be done only within the subspace of this distribution that is compliant with the future values of turbidity and OMR that would be allowed under RPA rules

(Figure 1, USFWS Past, Present, Future... report, hereafter PPF). In a presentation to the 2015 Panel, the MWD argued that historical (turbidity, OMR) values lying outside the RPA-compliant subspace were not at all relevant for determining a probability distribution of future values, because such historical values could never occur in the future, as long as RPA compliance continues to be enforced.

The MWD argument has some merit and perhaps the USFWS could devise an alternative estimate of an RPA-compliant distribution of probable future values of (turbidity, OMR).

The MWD used their "compliance model" to project the (turbidity, OMR) values that would have resulted, had the RPA rules been applied to shift any noncompliant, historical (turbidity, OMR) values into RPA compliance. For example, this compliance model would increase any highly-negative OMR values up to, or greater than, the lower limit for OMR compliance, while maintaining a fixed value of turbidity (Figure 5, "Comments on the USFWS WY2016...", MWD). Likewise, a turbidity level that is below the compliance limit would be increased up to that limit by RPA actions, without making any change to a corresponding OMR that is already in compliance (Figure 5, ibid.).

However, these compliance-model projections are likely unrealistic. It seems highly unlikely that RPA actions could substantially alter OMR without also changing turbidity values, and vice versa, because of hydrodynamic processes linking flow and turbidity. The Panel also noted the apparent nonlinear relationship between turbidity and OMR observed by K. Newman in the 18-year historical record (Newman, K. 2014. "Draft comments on a proposal for a revised ITL and expected take for adult Delta smelt").

In the USFWS Report section on Future Analyses and Refinements (Table 4) “Hypothetical proportional entrainment $\tilde{n}_t$ as a function of mean OMR ($cf^3\ s^{-1}$) over the sampling period and CCFB turbidity (NTU) indicates that turbidity affects entrainment much more than negative flows (especially at lower negative flows). If so, controlling turbidity would be more effective than controlling negative flows as a means of reducing Delta Smelt entrainment/salvage, but there is no RPA Action that involves controlling turbidity – and there may be no practical way of doing so. Given the swimming ability of Delta Smelt, it seems unlikely that turbidity would have a greater effect than OMR flows on smelt salvage.

There is also the issue of whether any historical correlation between incidental take and flow/turbidity values will continue to hold in the future. In an extreme scenario, as the Delta Smelt population approaches zero, neither turbidity nor OMR flows will predict take at the pumping stations. Any use of historical take based on these variables could be meaningless in the future. The size of the population at risk is the most important variable needed here, and it is missing. Over what range of low population sizes will measureable take effectively become zero?

An improved compliance model may be able to shift out-of-compliance (turbidity, OMR) values to the boundary of the compliance subspace in a more realistic fashion (Fig. 1, USFWS PPF, and Fig. 5, MWD report). It will still be a statistical challenge to infer a joint (turbidity, OMR) distribution in part from such boundary values, and the issue of whether or not the projected estimates of take relate to Delta Smelt population size remain.

2) The second major source of uncertainty.

As the 2014 Panel argued, any regression-model prediction of the salvage/abundance ratio, denoted by *y*, will have high uncertainty for any given values of turbidity and OMR. This is because the regression model has been fitted to a very small data set (n=11, reduced from n=18 in the 2014 MWD proposal), and especially because the model does not fit the data perfectly ($R^2 < 1$). As demonstrated in Anderson et al. (2014), even a small residual standard error (RSE) in the fitted regression model translates into large uncertainty in a predicted y-value, because the RSE pertains to log(*y*), and it has a multiplicative, not additive, impact on back-transformed predicted values. This impact was illustrated by plotting confidence intervals on historical predicted values of *y*.

The current (2015) regression proposal still does not account for this second source of uncertainty. To reinforce our concern, the Panel will again demonstrate its approximate impact on an incidental take estimate. Ignoring the uncertainty in the fitted regression coefficients, the true predicted value of log(*y*), for a given (turbidity, OMR), is a Normally-distributed variate with mean equal to the point prediction of log(*y*) from the regression model, and standard deviation equal to the RSE. Thus, an approximate 95% confidence interval around any point prediction will span at least ± 2RSE. The regression model was refitted to the data in Newman et al. (2015, Appendix A) to estimate the RSE by fitting the regression using leave-one-out cross-validation. This approach was taken because the high risk of overfitting with n=11 likely yields an in-sample RSE that seriously understates the uncertainty of novel predictions. Using cross-validation, with $\log_{10}(y)$ as the response variable yielded RSE = 0.47, and $10^{2*0.47} = 8.7$, while $10^{-2*0.47} = 0.11$. Thus, any single prediction, y_0, will have a 95% confidence interval spanning at least from $0.11y_0$ to $8.7y_0$, that is, over nearly two orders of magnitude. Since the 11 observed values of the salvage/abundance ratio vary over about 2.5 orders of magnitude, this prediction uncertainty is relatively large.

This model uncertainty should be propagated into the distribution of salvage/abundance ratios that is generated by Monte Carlo sampling. This can be achieved by choosing a random value, ε, of the model error from the Normal distribution mentioned above, during each Monte Carlo trial, and multiplying the corresponding predicted value of *y* by the factor 10^{ε}. The end result will be a broader, and hence more realistic, probability distribution of future salvage/abundance ratios.

Delta Smelt monitoring strategy.

It is rare and refreshing to see a proposed sampling design that is developed from such a detailed conceptual and mathematical model, and with such precisely articulated goals. However, it is possible that monitoring results will ultimately lead to changes in the model. The Panel suggests considering such possibilities, to maximize the robustness of the sampling design.

For example, the proposed plan would model the mortality rate as *M* within a Low Risk Zone, and as *(M+E)* within a High Risk Zone, where *E* is the added mortality rate due to entrainment loss. "Disentangling" natural mortality from entrainment mortality in the High Risk Zone is problematic because it may be impossible to determine how much of the predation that occurs in the southeastern portion of the Delta is "natural" and independent of water operations. Assuming that natural mortality in the High Risk Zone is similar to that in the Low Risk Zone might be more believable if the High Risk Zone did not encompass the entire portion of the Delta most directly affected by exports. Prior to the Central Valley Project, this portion of the Delta was higher quality habitat for Delta Smelt. If the export facilities had been located where they are because Delta Smelt and other fish populations were already at low levels in these areas prior to water export pumping, one might be able to argue that natural mortality was always greater in this portion of the Delta. However, it seems more likely that entrainment now enhances "unnatural" mortality by providing a reliable prey source for predators or an environment (e.g., Clifton Forebay) that collects predators and forms a sink for prey populations. It is unlikely that a good case could be made for separate natural vs entrainment mortalities as independent factors in the High Risk zone. However, it may be possible to estimate natural and entrainment mortality as separate risks in the Low Risk zone if the number of individuals moving from Low to High Risk meta-populations (i.e., source to sink populations) can be estimated and assumed to be lost to entrainment.

The proposed monitoring plan (DSEM), as comprehensive as it seems to appear, still includes a number of assumptions that could prove problematic in practice and may need to be considered:

(1) The DSEM sampling would start in early December and then timing of subsequent samples would be at some set interval (2 weeks was given as an example): Two weeks would keep sampling at approximately the same point in the lunar tidal cycle. If there is a relationship between the catchability of Delta Smelt and the lunar tidal cycle, this could create bias in the data (e.g., missing cycles in catch per unit effort if smelt movements are cued by some feature of the lunar tidal cycle such as synchronized spawning activity or other movements on new or full moons).

(2) In the formula used to estimate abundance from DSEM data, there is a value for gear (Kodiak Trawl) efficiency that will be assumed to be “1” initially. But in reality, no gear type is 100% efficient. Gear efficiency is almost always less than assumed. Also, although the Kodiak Trawl is more effective than the Fall Mid-Water Trawl in collecting Delta Smelt, but the current sampling plan will collect only in water that is at least four meters in depth; the greatest density of Delta Smelt is believed to occur at around two meters depth, with density declining toward both the surface and the bottom. However, nothing prevents them from occupying shallower water, where sampling for Delta Smelt rarely occurs. By failing to sample waters that are less than four meters depth, the sampling plan could be missing a substantial portion of the population. For example, L. Grimaldo, F. Feyer, J. Burns and D. Maniscalco gave a recent (November 2015) presentation at the Biennial Meeting of the Coastal and Estuarine Research Federation entitled “Sampling uncharted waters: examining Longfin Smelt rearing habitat in marshes of the San Francisco Estuary”. They reported finding that shallow waters in and around low salinity tidal marshes – which are not sampled by routine monitoring programs - contained densities of Longfin Smelt yolk-sac larvae as great or greater than those found in the deeper channels sampled by traditional monitoring programs; they suggested that marshes may be a key spawning/rearing habitat for Longfin Smelt. It is not unreasonable, especially given the general lack of knowledge regarding where Delta Smelt spawn, that both smelt species may be using shallow water habitats more than expected.

(3) The proposed DSEM program still seems to depend on assessing abundance in a relative sense in Low and High Risk Zones and does not necessarily account for the relationship between relative abundance and actual population size. The abundance indices (number per trawl) have not been calibrated to the absolute size of the population (e.g., Aubry et al. 2012, Siddig et al. 2015), but the implication is that the allowable incidental take (i.e., an absolute number of smelt) will not jeopardize the existence of the species. Even if it can be assumed (doubtful) that there is some close statistical relationship between actual population size and the abundance measure, what does a change of any given percentage in “abundance” actually mean in terms of the survival of the species? For example, suppose there are 100,000 smelt in the population and 90% are in the Low Risk Zone and 10% in the High Risk Zone, so 10,000 are at risk of entrainment. Now, suppose the same distribution scenario occurs but the total smelt population is only 10,000 and 1,000 are at risk. Without an estimate of how total population size relates to relative abundance, how can one reasonably set a numerical take limit based on abundance if the abundance measure (i.e. catch per unit effort) is 10:1 in both cases? If population size is very low, the loss of every individual may become critically important to the sustainability of the

population. Suppose a population size of 10,000 is required to sustain the species in the wild, the loss of 10,000 out of 100,000 individuals may not be a threat to future survival, but the loss of 1,000 out of a total population of 10,000 (the same 10% in relative terms) crosses a biological threshold and leads to extinction.

Consideration of RPA Actions Under Dry Year Conditions Based On Prior Science Reviews' Questions About RPA Implementation

The continuing drought emphasizes the potential that weather patterns in California may be transitioning to a "new normal"; that is, prolonged droughts in a cycle punctuated by few years of recharge from historically "average" snowfall. Large-scale predictions of impending climate change suggest the likelihood of declining snow water availability over the next 100 years (Table 1).

Table 1. Projected April 1 Snow Water Equivalents for the combined San Joaquin, Sacramento, and Trinity Rivers (derived from Cayan et al. 2008)

Elevation	2005-2034	2035-2064	2070-2099
1000-2000m	-13 to -48 %	-26 to -68 %	-60 to -93%
2000-3000m	+12 to -33 %	-08 to -36 %	-25 to -79 %
3000-4000m	+19 to -13 %	-02 to -16 %	-02 to -55 %
All Elevations	+06 to -29 %	+.12 to -42 %	-32 to -79 %

Depending on the assumptions made regarding carbon emissions over the coming decade, as well as the potential changes in the impacts of various climatic oscillations (see, for example, Stenseth et al. 2003, Kelly and Gore 2008, Mantua et al 1997), the projected potential loss of snowmelt water over the coming century is staggering.

As has been pointed out in previous reviews (e.g., Anderson et al. 2013, 2014), this recent series of drought years offers a unique opportunity to begin to develop a new set of strategies to address dry water periods and the effective management of releases to address the need to protect target species of concern. Relief from the current drought will require about 193% of historical precipitation. This may necessitate some corrective measures which might include flood management that does not rely upon a 50-year running average but focuses upon the possibility of a different flood storage decision. In addition, the development of models to predict the probability of filling cold-water pools and projections of accessible cold-water pool capacity will be effective tools for determining where and when warm-water releases can be most effective.

IRP RESPONSES TO QUESTIONS DEFININGTHE SCOPE OF THE 2015 LOBO ANNUAL REVIEW

Responses of 2015 IRP to questions regarding Shasta Reservoir and Sacramento River temperature monitoring, modeling, and management

1) **What additional approaches, methods, or studies would you recommend to improve the accuracy and effectiveness of Sacramento River temperature management?**

Management of the cold water pool resource in Shasta Reservoir is critical during extended periods of drought. The tools, both numerical models and field equipment, currently used to manage temperature releases need to be supplemented and ultimately replaced.

The Panel encourages development of a model that can predict the timing and depth of stratification within Lake Shasta. The goal would be to predict this event with acceptable accuracy, some weeks before its occurrence, in order to advance the timeline for the lake's dry-season water management planning. Current practice is to wait until stratification occurs before the plan can be finalized.

The field temperature sampling approach in Shasta Reservoir requires significant improvement. At very minimum, there should be at least two sampling probes on the sampling boat during every field study. Both probes should be used every time to sample the water column and their data compared for accuracy. This sampling approach should be implemented immediately.

The field monitoring program should be expanded significantly to support ongoing use of the current Reclamation model (US Bureau of Reclamation, 2015), real time operations of the reservoir independently of the model, and the development of a stratification model for Shasta reservoir to understand the basic physics of Shasta reservoir.

As a long term sampling plan, multiple conventional thermistor chains can provide the necessary accuracy as well as spatial variability (by placing thermistors sufficiently close together). Additional sensors (especially DO sensors) also may be a worthwhile addition, as they would provide fundamental data pertinent to real-time water operations. Installing two or three thermistor chains along the dam face will yield high-resolution vertical temperature profiles and provide redundancy to the sampling program in case of equipment failure. Also consider installing instruments with real-time data access. Vertical profiles of temperature should also be collected on the Shasta, McCloud, and Pit River arms of Shasta to support future model development.

NOAA's Southwest Fisheries Science Center (SWFSC) showed promising fieldwork and model development (CE-QUAL-W2 (RAFT Report, pg. 4)). SWFSC and Reclamation need to collaborate, create mechanisms to share field data, and spend time in meeting, preferably in an off-site forum, to learn from each other.

From the presentations, it was unclear how much basic limnology is known about Shasta reservoir. However, based on a quick literature review through Google Scholar, Bartholow et al. (2001) have done an extensive modeling study of the effects of the temperature control gates on limnological parameters in Shasta Reservoir. This work was conducted by the Bureau of Reclamation in Denver, Colorado with support from Colorado State University (Ft. Collins) and used the CE-QUAL-W2 model. Reclamation staff should use these published findings to guide operations during drought conditions. In addition, this initial research done in 2000 could be a starting point for a cold pool management model in the future.

2) **How effectively has the temperature management process linked spatial-temporal-life-stage specific fish distributions with spatial-temporal temperature distributions?**

The Matlab generated temperature profiles that plotted emergence, etc. (RAFT report for 2015 Annual Review, Figure 4) were well received by the Panel. It is this type of data presentation that will allow researchers to work together to identify testable hypotheses about how temperature is affecting salmon survival and growth during the spawning and out migration process.

The high resolution spatial-temporal temperature distributions between Keswick and Red Bluff Diversion Dam provides critical information for understanding and predicting the relationship between spawning and smolt passage at RBDD. However, it appears that this detailed information is not being used for tracking the fate of juvenile fish. The SRTTG annual report indicated that the impact of temperature on egg and fry development is currently based on cumulate thermal units expressed through mean temperatures according to Zaug et al. (2012). The Panel suggests that inaccurate predictions of incubation time, and fry growth result from the use of mean temperatures to predict life stage transition movement and survival. However, models are available, or can be developed, to improve predictions of the impact of temperature on fish development. More accurate predictions of life stage transitions would have immediate benefits to water operations aimed at minimizing redd dewatering and juvenile stranding. Furthermore, better predictions of growth and survival would provide more accurate estimates of smolt run size at RBDD. Information on available model tools are as follows:

- A manuscript nearing submission by Beer and Steel ("Temperature variability and Chinook salmon egg phenology: impacts and implications of non-linearities on emergence") indicates that variations in temperature accelerate egg development. Using this model to track the temperature history at winter Chinook Salmon redd locations would provide more accurate real-time projections of the fry emergence distribution within a brood year. Such information could provide greater precision and therefore flexibility in targeting Shasta Reservoir operations for early life stages of winter Chinook salmon.

- Studies on fry stage of Snake River fall Chinook Salmon suggest that initiation of smolt migration are driven by fish growth patterns in part controlled by temperature. Firstly, juvenile salmon encounter a thermal boundary (~ 18^{o}C or 64ºF) at which growth efficiency rapidly declines. This threshold is strongly correlated with the movement of juvenile fall Chinook Salmon from the Snake River (Widener 2012). Winter run Chinook may encounter a similar threshold prior to passing RBDD. Secondly, studies indicate juvenile salmon also migrate prior to reaching a growth-limiting thermal threshold (Widener 2012) and studies have demonstrated shifts in migration timing of salmon correlated with climate warming (e.g. Kennedy and Crozier 2010) Some references that may be of use for developing a timing initiation model are Hinrichsen (1994), Marine and Cech (2004) and Jager (2014).

<u>Responses of 2015 IRP to questions regarding the RAFT decision support tool</u>

1) What additional calibration and validation is recommended for the RAFT model?

A useful extension of RAFT would be the ability to focus the temperature predictions and landscape maps to the short river section containing the salmon redds, to get a clearer picture of the temperatures that they experience. This may require a recalibrated version of the model, with greater accuracy being demanded relative to temperature data from the redd-containing river reaches.

RAFT may need another calibration focused on the river reaches immediately below Keswick Dam. The RAFT report and its embedded journal article had little or no information about how calibration was done.

2) **Coupling of the reservoir model with the river model requires modeling the intermediate 17 km of the Keswick "river-reservoir". Does the panel recommend extension of the RAFT model upstream or the CE-Qual-W2 model downstream?**

Given that this section of the Keswick "river-reservoir" exhibits both horizontal and vertical temperature stratification as well as other characteristics of a reservoir, the CE-Qual-W2 model seems a more appropriate choice.

3) **What additional information or capabilities should be added to the DST to improve its usefulness to management?**

The DST is a state of the art river temperature prediction model, which provides high resolution spatial temporal data. However, the model needs to be coupled to biological models to forecast egg emergence timing survival and fry growth and migration initiation. Suggested capabilities are listed below.

- Real-time forecasts of emergence from redds: The desired capability is a probabilistic forecast of emergence date and fry weight from identified redds in the spawning region below Keswick Dam. When a redd is identified in a spawning survey, RAFT would produce daily forecasts of emergence date and fry weight. See Beer and Anderson (1997, 2013) for examples of prediction methods. When a redd location and creation date is first identified by the survey the forecast would have large uncertainty but as the season progresses and RAFT hindcasts update the temperature exposure the prediction uncertainty would decrease. The Panel envisions that for a functional tool the RAFT forecast would need to be significantly extended beyond the current 72 hours. Ideally, reliable egg emergence dates would be forecast for at least a week ahead, to coincide with the SRTTG meeting schedule. The Panel postulates that even a short projection could enhance water operation efficiency and, in particular, reserve cold water for juvenile and smolt stages.

    - Fry growth and migration date: the Panel was not able to identify a need for high resolution temperature predictions for post-egg stages. However, the general temperature tool and graphic abilities may be of use for coupling temperature with fry stages.

    - The website graphical user interface provides a 72 hour snapshot of temperature conditions between Keswick and RBDD. The information contained in this snapshot would be of more use if the data were output to flat files that could be used by biological models.

- The most useful capability of RAFT would be its integration with the Shasta Reservoir model so that long term forecasts of temperature and flow were available.

Responses of 2015 IRP to questions regarding the enhanced particle tracking model

1) **Does the panel have any suggestions on if and how model calibration could be improved?**

This model is in a preliminary development stage and important issues related to the integration of biology and underlying hydrodynamics need to be addressed before it is ready for management applications.

The model calibration approach comparing observed distributions to modeled predictions in a Bayesian framework is commendable. The model fitting compared emulation of the data E_{DATA} and the model E_{ePTM} was interesting but the description was insufficient to evaluate if this technique could be improved or was appropriate. The Panel cautions that fitting model parameters according to statistical measures (e.g. conditional predictive ordinate (CPO) and Watanabe-Akaike information criterion (WAIC)) does not guarantee that the model is biologically meaningful or suitable for management actions. Outside the formal parameter estimate process, which seems powerful, the Panel recommends a number of calibration steps that are more in line with validation and confidence building of the model.

- Compare fitted model parameters to estimates from independent methods. For example, the swim speed estimate was higher than what is expected from observations of fish swimming. Additionally, the random movement speed was an order of magnitude lower than what was estimated in comparable study (A. Steel personal communication to J. Anderson).

- Test the movement model against continuous tracks of smolts in a flow field. The model needs to characterize the general response of fish to changes in the flow field. For example, see Figure 4 in Goodwin et al. (2014). In this paper the movement model captured observed patterns of fish movement in response to changes in water velocity and acceleration. The ePTM should capture the movements of fish at junctions and the relationship of fish movement to tidal flows and cross channel variations in flow. For example, fish respond to tidal velocities (see Fried et al. 1978, Moser et al. 1991, Levy and Cadenhead 1995, Lacroix and McCurdy 1996, Hering et al. 2010, Bennett and Burau 2014).

- Calibrations should be conducted on each reach individually. See section on fitted survival and Figure 1 above.

The sensitivity of each model parameter to reach survival and travel time needs to be determined to identify which parameters drive model properties. For example, see Figure S2 in Goodwin et al. (2014). The model structure suggests several of the parameters may covary so that unique model parameters cannot be resolved. In these cases, the functional relationship of model parameters needs to be identified and quantified. If functional relationships are found, e.g. a relationship between *swim speed* and *holdThr*, then consider revising the model functions to eliminate covarying parameters. If this is not plausible then reasons for covariations should be identified.

From the management of the modeling program perspective, the biggest model development support issue is that the model development problem is much larger than can be handled by only one person. This is a multi-disciplinary problem that needs a multi-disciplinary team working on it. The modeling is trying to do too many things, too quickly without testing and documenting along the way.

Hydrodynamics and the DSM2 Model:

The modeler mentioned that he thought some of the hydrodynamics in the DSM2 model needed improvement, but these items were glossed over in the presentations to the Panel. There are three significant issues of concern regarding the DSM2 hydrodynamic model simulations that were presented to the Panel.

First, the most important issue is the time step that was used to drive the DSM2-HYDRO hydrodynamic model. In many other modeling studies by other modeling groups, the DSM2 model has been calibrated and shown that it can match tides and flows in the channels well throughout the Delta if DSM2-HYDRO is run with a short enough calculation time step to resolve the tides. However, according to the Enhanced Particle Tracking Model Report (see p. 32) provided to the Panel, "It is to be noted that the short term studies with ePTM, the Hydro time step size of 1 hour, and the ePTM time step size of 15 minutes are not sufficient to resolve the effects of tides in the Delta."

This time step should be much more refined. Since the Hydro portion of the model is run separately from the particle tracking model, this should not be an issue. The report continues in that same paragraph to say that "the errors due to the coarse temporal resolution are absorbed into the emulator, thereby producing potentially erroneous behavior parameter values." There is no "potentially" about it. If the hydrodynamics are not resolved, the calculated behavior parameters will not be reliable. For example, "the ePTM uses only flow as it is the cue most directly affected by water management decisions." (2015 e-PTM Report, p. 11) The user specified upstream flow velocity, *holdThr*, parameter that specifies when fish will hold in their position can only be calculated if the model is driven with a hydrodynamic model time step that resolves the tides.

The second major issue related to hydrodynamics is the representation of mixing at junctions. The application of the mixing at the junctions still uses the standard distribution based on flow split rather than utilizing physical information about the junction bathymetry. The report indicates that this is an issue for future development. (2015 e-PTM Report, p. 38) "The validation of the ePTM has indicate modalities in the travel time distributions that it is not able to replicate. Moreover, the ePTM incorporates errors due to the flow based routing of particles through the junctions of the Delta into the behavior parameters and hence ascribes values of the behavior parameters to the modeled smolt that may not be realistic. Hence, future calibrations would include the more complex and realistic streamline following rule at junctions." (Item 8, p. 38) This change in approach should be pursued.

The third major hydrodynamic issue is the range of management questions that the DSM2 model is capable of addressing. The use of the DSM2-HYDRO model to assess alternate configurations, such as intake pipelines and Forebay for the California Water-fix proposed operations (see Figure 20 in 2015 e-PTM Report), should not be done because the DSM2-HYDRO model is limited to present-day configurations. DSM2-HYDRO has tuning parameters for every junction that must be tuned to observed values.

Statistics issues in creating the Emulator: Using Hydrodynamics as an assumed "Steady State" condition:

The DSM2-Hydro model is being used to determine "steady state" conditions in order to estimate parameters (emulator) that drive the fish elements. The main problem with that approach is that the Delta system is never in a steady state. Every time there is a change (e.g., a gate is changed, a barrier is placed, a pulse flow goes through the system, the pumps stop operating for a short period of time), the whole system adjusts to that change. Depending on what is changed, the region of influence of that operation is different. Therefore, every parameter created with this method needs to come with a caveat about the configuration of the system under which that parameter was calculated.

2) **How much does the spatial and temporal resolution of the model affect its application to physical and biological questions?**

Use of this model for these purposes may be premature. Although a good step forward, the Panel would like to see further development of the model with more rigorous testing and validation. When immature models are used for management applications, they can too easily become prematurely institutionalized.

The Panel suggests that in general the spatial and temporal resolution of a model must describe, at some level, the spatial and temporal resolution at which the fish perceive and respond to their environments. This does not mean that a model needs to capture the small scale temporal spatial fluctuations the fish perceives. Because migrating fish move across the flow field they can experience temporal variations in flow as integrated spatial variations along their swim path. For example, in (Goodwin et al. 2014) fish behavior was successfully modeled with a steady state 3-D computational fluid dynamic model. Note that while temporal variation in flows was not required in that study, it is clearly important for Delta tidal flows.

It is unclear to the Panel how many dimensions are sufficient to model movement of migrating salmon in the tidal environment. More studies will be required to gain confidence on the needed scales of resolution. Studies on effects of flow and tides on fish should be separated from survival. Successful modeling of movement can be characterized in both Lagrangian and Eulerian frameworks. For example, in an Eulerian framework model validity might be measured in the partition of fish through different passage routes, while in a Lagrangian framework validity might be measured by the trajectory of fish relative to flow stream lines and acceleration isopleths.

From a hydrologic perspective, the DSM2 model is represented by a series of link-node-channels with a few representations of open water regions (i.e. Frank’s Tract, Mildred Island, Clifton Court Forebay) using a Continuously Stirred Tank Reactor (instantaneous mixing model). There are many assumptions in the representation of the hydrology (such as mixing at the junctions and open water bodies) that cause particle tracking models to fall short of representing reality.

As a final note, DSM2 has tuning factors for every junction node. It did not appear to the Panel that these could be altered to different configurations. Therefore, it is not recommended that the model be applied in potential future configurations of the Delta.

3) How useful is the current model as a basis for real-time operations decisions for assessing effects on listed salmonids?

The current model is not useful for making water operations decisions because of the poor fit to data, biologically implausibility of some model coefficients, the immeasurability of other model coefficients and questionable interpretation of the relationship between fish movement and survival. Nonetheless, the Panel strongly encourages the continued development, calibration and validation of the model and believes that it eventually can be useful for assisting in real-time decisions on river/Delta operations.

4) **Does the panel have any recommendations for additional work that will increase confidence in model output such as accounting for and reporting uncertainty?**

Focus on biologically-interpretable measures of model performance.

Recommendations for Travel Time – The travel time equations have multiple terms that may be interrelated as was discussed above. The behavior model has a number of assumptions that need to be evaluated by comparing the travel time function against movements of fish (Lagrangian frame) or net movements (Eulerian frame) over a tidal cycle. The functions should be explored against data in riverine, transitional and tidal reaches independently. Currently the model over-predicts fish velocity through segments. However, insufficient information is given in the report to determine the significance of the predictions.

A second issue of travel time involves the relationship of the Inverse Gaussian Reciprocal Normal (IGRN) distribution with travel time expressed in the XT model. The documentation had insufficient detail for the Panel so the following issues are identified for further clarification.

1. The IGRN model for travel time assumes each fish has a fixed positive velocity and a random element that may be positive or negative. The fish mean velocity exceeds the random element so all fish velocities are positive and fish move downstream. This may not be the appropriate model for tidal reaches in which fish have significant negative velocity in parts of the tidal cycle. The Panel could not judge if this violation was significant to the model calibration.

2. If appeared to the Panel that the observed fish travel time distribution was characterized by the IGRN and this distribution was then compared against the modeled distribution in the calibration of the ePTM movement parameters. This may be valid for estimating the movement parameters but not for estimating the random movement parameter ω. In the current model ω was fixed. The Panel cautions that if the results of the IGRN were to be used to estimate ω there is a potential conceptual mismatch between the two IGRN and XT theories. The IGRN characterizes two variances; σ_v^2, which describes differences in the mean fish velocity of each fish and σ_w^2, which characterizes the variance of an individual fish. In the XT model ω^2, characterizes the relative variance between the predator and prey, and quantifies the probability of multiple predator-prey encounters as a prey pass through a reach. It is not immediately clear how terms are to be related. The point here is that coupling these models together is not trivial and the details need to be understood.

3. It is important to understand that variations in fish travel time resulting from fluctuating velocity should contribute to the encounter velocity ω in the survival model. This connection is not apparent in the model documentation and could be at the heart of why the current model does not capture the survival patterns within reaches.

A final issue involving the travel time function in the ePTM model is the possibility of over-parameterization in which the contributions of some parameters cannot be disentangled. The ePTM modelers might consider an alternative, more empirical formulation, which represents the effect of tidal velocities on migration by a single parameter. See Appendix A in the IRP 2012 report for a discussion of this approach (Anderson et al. 2012).

Recommendations for Survival functions – The ePTM documentation of the XT survival function has several issues that the Panel recommends be considered.

1. The term ω in the documentation was designated the random component of prey speed. This is not how the term is used in the XT model (Anderson et al. 2005). The term represents the relative root-mean-squared speed between the predator and prey; $\omega = \sqrt{E\left[\left(v_{pred} - v_{prey}\right)^2\right]}$. The difference between the predator and prey speeds depends on the migration strategy of prey to exit the river system while avoiding predators and the strategy of predators to encounter prey while retaining residence within the river system. The current ePTM model fixes ω as constant over all reaches (riverine, transitional, tidal). In making this assumption the model violates the underlying theory of the XT model and does not reflect the important hypothesis that predator-prey encounters are more frequent in a tidally oscillating system than in a riverine environment where prey are expected to migrate downstream. In tidal systems a stationary or resident predator would have multiple chances to encounter a given prey, while in a riverine environment once the prey has passed the predator's chance of further encounters are greatly diminished. Appendix A in (Anderson et al. 2012) outlined a possible approach to characterize ω from the tidal elements of a PTM model. This approach also relates fish travel time to mean encounter velocity.

2. Interpretation of *x* and *t* in the XT model (equation 1) needs to be reviewed. The implementation of the XT model in the ePTM involves "recording the x and t for the multiple channels that a fish traverses within a given time step". This definition is unclear and may be inconsistent with the XT model as initially developed. In the statement it is unclear what is variable and what is fixed. Time would seem to be defined by the time step and it may be interpreted that x is the

distance traveled over the time step. If this is the case, then the meaning is different from that in the XT model in which survival is computed over a distance X and the time T to travel the distance is a dependent variable defined by migration velocity U such that T = U*X. The important point here is that in the XT framework U represents the mean velocity through a reach and ω represents the relative random velocity resulting from hydraulic variations and predator prey swimming behaviors. It appeared to the Panel that the ePTM model does not represent this framework.

3. The Panel emphasizes that the XT model was developed to provide a mechanistic explanation for why survival of salmon smolts traveling through the upper Snake River was related to migration distance, but not migration travel time. The relationship is explained in terms of mean-free path length in which smolts move quickly through resident, largely stationary predators, such that once an individual predator is passed it will not be encountered again. In this concept fish swim a gauntlet of predators and their survival depends on the length of the gauntlet, not the time taken to traverse it. However, when predators and prey both move about, multiple encounters are possible and survival becomes more a function of duration of passage. In principle, the ePTM model represents an advancement of the XT theory in that it could explicitly address the issue of predator and prey interactions in a tidal system. However, ePTM modelers need to determine what levels of additional complexity is appropriate. Currently, the model ignores predator strategy and incorporates a potentially over-complex fish movement model that seems to be incorrectly coupled to the XT survival component. Importantly, the Panel believes the relationship of ω with tides is central to the model development.

Recommendations for routing model – The routing of fish from the river mainstems into the smaller channels of the Delta is important and it is here the ePTM may have its greatest contribution. In particular, the model would be immediately valuable if it can identify the effect of water exports on the routing of smolts into the Delta as a function of conditions including river flow, tidal strength, turbidity, salinity and river geometry. Currently, the ePTM routes fish at junctions according to the percent of flow entering each junction. This simple routing should be considered the null model on which other models are compared. At the least, the model needs to be reconfigured to include information presented in Cavallo et al. (2015). In this paper the percent of entrainment into the distributary is a nonlinear function of flow and tidal environment. The Cavallo model appears to be superior and better calibrated than the current linear model in the ePTM.

The Panel also emphasizes that the partitions of fish at junctions is an important and challenging area of research. If fish can be diverted from entering the inner Delta and irrigation intakes the impact of water operations on fish mortality risk could be greatly reduced. However, to date no suitable diversion system has been demonstrated other than screening at small water intakes. Furthermore, a better understanding of fish routing behavior will be essential for evaluating future modifications of the Delta system. The ePTM should have a significant role in evaluating such future plans. How should a routing model be developed? As a first step the Panel recommends incorporating the Cavallo routing model into the ePTM. Furthermore, the model will need to be calibrated with the available acoustic tag fish data. As a second step, the Panel recommends embarking on a modeling development that builds on the work of Goodwin et al. (2014), which is currently the most successful and mechanistically based model for predicting the movement of juvenile salmon through hydroelectric dams. However, predicting fish movements at tidally influenced junctions will present a unique set of challenges, both in terms of theory and observations. Junctions are known predator hot spots in which the behavioral strategies of predators and prey both come into play. See tracking studies at the head of Old River for information. As a long-term goal the ePTM should have the ability to predict movement of fish based on predator and prey strategies and the influences of small scale hydrodynamic properties of the local environment.

The model quality of fit has already been assessed and compared for many choices of modeling "methodologies" (Table 3, ePTM Report) and fish behavior assumptions (Table 4, ePTM report). (By the way, it is unclear if models were calibrated for every combination of scenarios from Tables 3 and 4). However, doing a more fundamental assessment of the increased predictive value provided, separately and jointly, by the two major biological components (mortality and swimming) may be useful. This could be done by comparing the best-fitting null model (passive PTM) to the "best" ePTMs that include a) swimming only, b) mortality only, and c) mortality + swimming.

The Panel also suggests comparing the predictive values of these (and other) models primarily in meaningful and absolute biological terms, rather than only in the abstract and relative units of loglikelihood (Table 5), WAIC and CPO (see also "footnote" comments on Table 5 and WAIC). The ePTM is not useful if it is only the "best" of a set of terrible models. And the few understandable comparisons between ePTM predictions and observations that are given in the report (Figures 9, 14, 15) are not encouraging. In Figure 9, predicted and observed survival fractions appear to be completely unrelated. The scatterplots in Figure 14 are difficult to assess visually because of their unequal x-y scaling. In Figure 14, we suggest reporting x-y correlations rather than RMSD because the latter is difficult to interpret. What, for example, would be the RMSD for two totally unrelated variables? The KS statistics in Figure 15 are also quantitatively uninterpretable in biological terms. Figure 15 only tells us that, in the great majority of cases, predicted travel times exceed the observed travel times. But how great is this exceedance in time units? And what is a similar comparison for the null PTM? To answer this crucial question, comparisons could be made between predicted versus observed, mean or median travel times, along with SD's, for both the PTM and ePTM. A detailed comparison of ePTM versus PTM simulations (p. 43 and Appendix C) showed fairly minor differences between their behaviors, but there did not appear to be a comparison of the two models' predictions versus real data in biologically meaningful units.

Finally, the greater biological realism of ePTM, relative to that of PTM, should eventually make ePTM the preferred model for management applications. However, model users should consider model complexity, transparency to non-modelers, and ease of use, when choosing between the two models. For example, the elaborate calibration procedure (Bayesian, MCMC, GP emulator) used for ePTM will be opaque to all but a few specialists and may require substantially greater effort in coding, setup, and run-time, relative to that of PTM.

Footnotes: a) The differences in log likelihood among the three models of Table 5 appear unrealistically large. Verify that the three models were all fit to the exact same subset of response-variable data. If they were not, then their log likelihoods are differently scaled and hence not comparable. b) The effective number of fitted model parameters is not evident in the pWAIC formulae (Equations 7 and 8).

Responses of 2015 IPR to questions regarding the USFWS report on past, present, and future approaches to incidental take of Delta Smelt

1) **How could the revised interim approach that the Service expects to use for Water Year 2016 be improved?**

Propagate the regression model uncertainty into the predicted probability distribution of future values of the salvage/abundance ratio. Also, develop a more accurate model of the joint distribution of likely future values of OMR and Secchi that would be seen under RPA-controlled conditions. See text for details.

2) **What suggestions does the panel have for improvement of the proportional entrainment approach?**

[Proportional entrainment can be estimated from absolute abundance and entrainment estimates. The Panel is unclear about the USFWS meaning of a proportional entrainment “approach”, and hence cannot address this question with confidence. However, there may be a better way to approach the entire issue of setting allowable take limits by using a quantitative framework similar to that developed by McGowan and Ryan (2009). Although the endangered species of interest in their case was Piping

Plover in the Great Plains, the methods are applicable to populations of any species as a way of quantitatively linking take and jeopardy. In a more recent consideration, McGowan et al. (2014) extended the model to develop recovery criteria for endangered species based on a conceptual model of meta-population dynamics that seem directly applicable to the Low-Risk/High-Risk zone populations proposed for Delta Smelt. The Panel encourages the USFWS to consider such an approach for estimating extinction risk of Delta Smelt under different scenarios, which may even include hypothetical risks independent of water operations. The ability to link the poorly-developed concept of "jeopardy" to a quantitative measure of extinction risk would go a long way to resolving concerns about an objective basis for setting incidental take limits for Delta Smelt.

Responses of 2015 IPR to questions regarding implementation of the RPA Actions under dry year conditions based on prior science reviews' questions about RPA implementation

1) **Were the scientific indicators, study designs, methods, and implementation procedures used appropriate for evaluating the effectiveness of the RPA actions under dry conditions? Are there other approaches that may be more appropriate under dry conditions?**

Although the prolonged drought has provided a unique opportunity to consider adjustments to implementation of RPA Actions, there does not appear to be a research effort to test or validate any such actual or potential alternatives in terms of their effects on endangered species populations. As stated in the main body of this report, it is time to let the fish tell the researchers and managers where conditions continue to be preferred under a stressful scenario and to learn what makes these portions of habitat so desirable as refugia and spawning areas.

2) **How can implementation of RPA actions be adjusted to more effectively meet their objectives under dry conditions?**

A utilized-habitat approach could be the most effective in implementing the RPA Actions. That is, rather than arbitrarily setting areal goals (i.e., river miles) in which to meet preset physical or chemical targets, base the RPA Actions on the observed responses of fish to the changes in the physical or chemical conditions. For example, if an area has the potential to support spawning but has never been used for spawning, even under "normal" conditions, there is little value in creating a release schedule that provides appropriate water quality conditions for spawning at that location. Something undetected or unmeasured may be restricting the use of that area for spawning. In which case, it would be reasonable under critically dry conditions to reserve essential resources (e.g., cold-water pool) for areas known to be used for spawning.

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APPENDIX 1 – Materials for 2015 IRP Review

Review Materials Available to the 2015 LOBO Independent Review Panel

I. The following documents were provided in electronic format as required reading by the IRP prior to the 2-day workshop in Sacramento, CA on 5-6 November 2015:

1) USFWS report – "Past, Present and Future Approaches to Incidental Take"
2) Sacramento River Temperature Task Group (SRTTG) Annual Report of Activities
3) Clear Creek Technical Team (CCTT) Annual Report of Activities
4) American River Group (ARG) Annual Report of Activities
5) Stanislaus Operations Group (SOG) Annual Report of Activities
6) Delta Operations for Salmonids and Sturgeon Group (DOSS) Annual Report of Activities
7) RAFT decision support tool report
8) Enhanced particle tracking model report

II. The following additional reports were made available in electronic format for supplemental use in providing historical context for the IRP:

1) Interagency Fish Passage Steering Committee (IFPSC) Annual Report of Activities
2) The Smelt Working Group (SWG) Annual Report of Activities
3) RPA Summary Matrix of the NMFS and USFWS Long-term Operations BiOps RPAs
4) Central Valley Project and State Water Project Drought Contingency Plan, January 15, 2015 - September 30, 2015

III. ***The following additional materials were made available following the Workshop in Sacramento at the request of the IRP for supplemental use of the IRP***:

- Public Comments on the USFWS report - Past, present and future approaches to incidental take of Delta Smelt (from David Fullerton, Metropolitan Water District of Southern California, November 5, 2015)

Additional background information from the Science Program website was also available, including reports from previous IRPs.