Independent Peer Review of River Temperature Decision Support Tools for the Central Valley of California to Support Management of Sacramento River Winter-run Chinook Salmon

Prepared on behalf of the Center for Independent Experts (CIE)

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Executive Summary

As a result of anthropogenic alterations to watercourses and climate change, many Pacific salmon populations are imperiled. This is particularly the case in California, which is the southern extent of the range for several species including chinook salmon. In the Sacramento River system, the Sacramento River Winter-run Chinook (SRWRC) salmon populations have been blocked from accessing their historic spawning habitat since 1940, when the Shasta Dam was constructed. Spawning now occurs below the dam and the quality (e.g., water temperature) and quantity is largely controlled by releases from the dam. Various temperature compliance points have been established to help protect various life stages of SRWRC given that they are listed by the Endangered Species Act. To assist managers with determining controlled releases, efforts have been devoted to developing various river temperature decision support tools. Here, I reviewed the suite of temperature modeling tools developed for water and fisheries management in California's Central Valley. I approached the review from the perspective of the fish, in that I am an expert in fish-environment interactions. In general, the models developed appear to perform rather well (most error within 1°C); however, it is worth noting that even small temperature differences may be important for SRWRC. There may be opportunity for further refinement by collection of additional field data. Explicitly identifying these research and monitoring needs within the technical report would seem worthwhile. Some aspects that were not considered here but seem relevant include oxygen requirements (and how that interfaces with water temperature), as well as considering how different water management options may influence the olfactory cues used by migrating salmon. The web portal developed as an interface for the models is straightforward, but would benefit from more context and other refinements (e.g., more clarity on which temperature units – Celsius or Fahrenheit – are being used). Overall, I consider this to be a robust modeling framework with appropriate validation. Nonetheless, there are certainly opportunities for refinement.

Background

Across the globe, freshwater surface resources are changing. Land use change and human development associated with agriculture (irrigation), hydroelectricity generation, channelization, and urbanization have all contributed to changes in flows and thermal conditions in freshwater systems (Vörösmarty et al. 2010). In addition, climate change has further stressed these systems such that the variation in flows and thermal conditions is even more extreme (Kundzewicz et al. 2008). Not surprisingly, these collective changes to freshwater systems, along with other stressors such as invasive species, have led to dramatic changes in freshwater biodiversity (Dudgeon et al. 2006). In fact, freshwater fish are now among the most imperiled taxa on the planet (Bruton 1995; Sala et al. 2000). Although very much a global and pan North-American (See Jelks et al. 2008) issue, some regions and fish populations have been particularly impacted. For example, California has a large human population with extensive agricultural activity which have collectively put pressure on scarce water resources. When their Mediterranean-type climate is combined with climate change and episodic droughts, many freshwater fish populations in California are now threatened with extirpation (Moyle 1995; Moyle et al. 2013). Coldwater fish such as Pacific salmonids have been particularly impacted (Moyle et al. 2011). Indeed, recent reports suggest that there is an impending extinction of salmon, steelhead and trout in California (Katz et al. 2013).

Given the state of freshwater salmonid fisheries resources in California, there has been much interest and effort devoted to reversing declines and restoring wild salmonid populations. Resource management agencies rely on a variety of strategies including use of various modeling tools to inform management activities. The waters of the Central Valley are among the most impacted and heavily managed in California (Tanaka et al. 2006). When the Shasta Dam was built in the 1940s, it blocked Sacramento River Winter-run Chinook (SRWRC) salmon from accessing the cold waters of their native spawning habitat (Yoshiyama et al. 1998). The quality (water flow and temperature) of their current habitat below the dam is now entirely controlled by releases from the dam, and because SRWRC are listed under the Endangered Species Act, dam operations must take into account the impacts on their spawning and rearing habitat. Various temperature compliance points have been established to help protect various life stages of SRWRC.

To aid in the water and fisheries management decisions, the SWFSC has developed linked temperature models for the Shasta Reservoir and the Sacramento River to model how operations will impact water temperatures within the SRWRC spawning habitat. Such modeling approaches with thermal compliance points are common in fisheries protection given the manifold effects of water temperature on fish (Fry 1971). The SWFSC then developed a thermal tolerance model for SRWRC eggs (the most temperature sensitive life stage) and linked it to the temperature model. The combined suite of models allows for water and fisheries managers to evaluate how proposed seasonal water operations impact SRWRC eggs in a spatiotemporally explicit manner. In 2017, the SWFSC Fisheries Ecology Division (FED) of the National Marine Fisheries Service requested an independent peer review of the suite of temperature modeling tools they have developed for water and fisheries management in California's Central Valley. Here, I contribute to the peer review of this model and associated documents.

Reviewer Context

To contextualize my review, I briefly outline my relevant training and expertise. I also comment on my approach to conducting the review.

I currently serve as a tenured professor and Canada Research Chair at Carleton University in Ottawa, Canada. I am the Director of the Fish Ecology and Conservation Physiology Laboratory (team of ~35 students and post docs – see www.FECPL.ca) and Director of the Canadian Centre for Evidence-Based Conservation and Environmental Management. I completed my undergraduate studies in Environment and Resource Studies at the University of Waterloo. I then stayed at Waterloo for my M.Sc. in Biology before moving to the University of Illinois. For my Ph.D. dissertation, I worked with Dr. David Philipp and Dr. David Wahl at the Illinois Natural History Survey to study the applied physiology and behaviour of wild fish. I then held NSERC and Izaak Walton Killam post doctoral fellowships at the University of British Columbia between 2002 and 2005 where I worked with Drs. Scott Hinch, Tony Farrell and Mike Healey on Pacific salmon migration biology. In 2005, I accepted a tenure track faculty position at Carleton University in the Institute for Environmental Science and Department of Biology. I have over 600 peer reviewed publications in leading fisheries, ecology, conservation, and physiology journals, which have been cited more than 19,000 times.

Our lab maintains broad interests in all aspects of aquatic ecology, conservation biology, physiological ecology, animal behaviour and environmental science. Freshwater and marine fishes are used as research models for experiments conducted in laboratory tanks, experimental ponds, and most commonly, field sites. Specific interests are (1) determining the energetic, fitness, and potential evolutionary consequences of a variety of natural (e.g., winter, reproduction) and anthropogenic (e.g., angling, environmental pollution) stressors and, (2) understanding the diversity of energetic, physiological, and behavioural responses of fish to stress at the individual, population, and species level. The lab then applies the fundamental knowledge derived from these basic research activities to aid in the conservation and management of aquatic resources. I have particular expertise in the study of free-swimming fish in the wild using biotelemetry. I have applied these approaches to a variety of issues, most recently to address issues related to fish passage (including the development of the CanFishPass database for DFO), entrainment and hydropower impacts.

Relevant here is that I have knowledge of the fundamental environmental relationships for Pacific salmonids. I have spent 15+ years studying how thermal conditions and flows influence the fitness, health and condition of wild Pacific salmon. I am regarded as a leader in the topic of Pacific salmon migration biology, with particular expertise in physiological ecology, energetics, and behaviour, all from an applied perspective. Our lab routinely generates data that is fed into various management models. I am not a modeler per se, so I approach my review as someone who can really focus on the biological assumptions underpinning the model and less so on the mechanics of the model. This expertise is well complemented by the other referees who themselves develop models on a regular basis and are less empirically oriented.

To conduct my review, I first read the background materials provided (including web links) and listed in Appendix 1. I then conducted my review to align with the terms of reference outlined in statement of work (see Appendix 2). I focus on the strengths and weaknesses while also considering aspects of uncertainty. Beyond simply pointing out weaknesses, I identify opportunity for refinement and improvement.

Summary of Findings for Review of River Temperature Decision Support Tools

1. Evaluation of the strength and weaknesses of the individual water temperature models as well as the process of linking the models, bringing attention to those weaknesses not adequately addressed in technical memorandum

The authors state that "The calibration and validation of RAFT confirms its utility as a tool to assess water temperature impacts downstream from Shasta Reservoir… with error typically being less than 1°C over the model domain when using known boundary conditions and assessing daily average water temperatures…. however, temperatures were often overestimated during June-July across sites and years, which have been a peak time for SRWRC spawning…". To me this is the most salient take home message from this entire report. The authors are sufficiently self-aware that they recognize the context in which the model is applicable and reliable. They also recognize that the temperatures are often overestimated during a critical period of SRWRC life history. This candor is important and makes the entire document quite believable. It also serves as a template for future research/science needed to refine the model. To that end, it would have been useful to see a specific list of key information/research needs. Many of the "holes" that need to be filled are not ones to be filled by modelers but by empiricists. Don't make the empiricists have to dig for those needs – put them in a clear list (perhaps a table or box). For example, key messages are hidden in the text ("empirical data collected in field studies on reservoir and TCD dynamics may also be needed to better resolve reasons for discrepancies between years." Maybe you could even prioritize the list of gaps that need to be addressed.

I found the linking of the models to be adequately described and done in a way that is intuitive. The authors do not explicitly state where they would invest more effort in model refinement (the reservoir or the river) but there seems to be opportunity for refinements in both.

What about dissolved oxygen? There are obviously direct links between the thermal properties of water and its ability to hold oxygen. We also know that dams have the potential to generate total dissolved gasses to levels that exceed saturation and have the potential to contribute to gas bubble trauma. A quick Google search did not reveal any specific reports on gas bubble trauma for this system (although it was a cursory search). I also searched for the word "oxygen" in the technical report and failed to find a single mention of the word. Given that lack of oxygen (which seems to be a potential problem in the reservoir based on a quick read of Bartholow et al. 2001), or alternatively supersaturation, are both of major concern to fish. Indeed, although temperature is often what we use when thinking about thresholds for fish it is how temperature influences the ability of an organism (including adult chinook salmon; Clark et al. 2008 – but see Poletto et al. 2017 for somewhat divergent data from juveniles) to extract oxygen from the water that we think ultimately influences whether salmon will be able to migrate and survive (Farrell 2009).

2. Evaluation of the methods used to incorporate uncertainty into predicting water temperature in Shasta Reservoir and Sacramento River down to Red Bluff, such as the use of variable meteorology and model parameters

I will preface this section by noting that I found that the attempts to integrate uncertainty into the model to be impressive. Before I dug into the report, I constructed a list of potential factors that I thought were worthy of consideration. All but a few of these were well represented in the report. The exception related to the biology of the animals that live in the system. For example, we are told that "RAFT is well suited to simulate the thermal dynamics of well-mixed systems and has previously been applied to the Sacramento River." Even in well-mixed systems there can be opportunities for fish to behaviourally thermoregulate. I appreciate that this may not be the case here, but the authors need to convince us of that. More specifically, I would like to see stronger justification for the 2 km spatial scale. Why not 5 km? Why not 500 m? There may be a good reason, but I was looking for more justification. The evidence for behavioural thermoregulation is mixed… For adult sockeye salmon in the mainstem Fraser River of BC there was limited evidence of behavioural thermoregulation during upstream spawning migration (Donaldson et al. 2009). Similarly, Hasler et al. (2012) found that the body temperature of adult chinook salmon in the Puntledge River (on Vancouver Island) was very similar to river temperatures. Yet in the Columbia River, adult fall chinook salmon did use thermal refugia in an "abnormally" high temperature year (Goniea et al. 2006). The extent to which refuge presence and refuge use varies spatially and temporally (across years and seasons) remains unclear. This issue is largely addressed by referring us to the earlier work by Pike and Danner rather than provide us with the necessary details. I understand that there have been some telemetry studies on various life-stages of SRWRC, but found little evidence of how these data have been used to enhance or otherwise validate the model. I could not find evidence of any biologging studies (where fish body temperatures are recorded during migration) on SRWRC, but I may have missed something in the literature (grey or peer reviewed). Recall that fish have the ability to differentiate between temperatures as small as 0.03°C (Bull 1936). As such, "well mixed" may still be irrelevant to a fish with the sensory capabilities to identify and select paths that are cooler. Fortunately, this would benefit the fish in that it would potentially provide them with a thermal buffer, but this would need to be determined empirically. I will add that we know little about thermal refuge use by juvenile Pacific salmon during the freshwater phase of their early life history, so this represents a major knowledge gap.

3. Evaluation of the water temperature model calibration and validation procedure outlined in the technical memorandum and its ability to properly parameterize each water temperature model

The level of error noted during the calibration and validation of the W2 and RAFT models were typically within 1°C. This of course is impressive, but we can't forget that for fish living on the edge (very near their thermal maxima) a 1°C temperature difference could mean the difference between life and death (or contributing genes to the next generation or not). This is not necessarily a problem with the model itself but more of a reality check for those using it in that it would be necessary to include an appropriate safety buffer which should at least equal that of the error.

Moving forward, I wonder the extent to which expanding the thermal monitoring in the river will be enhanced? I understand there is already extensive infrastructure in place to measure water temperature in real time or near real time. I could not determine if there is need for more such monitoring or not, but if it would help with ongoing refinement then it would seem to be necessary to enhance the real time river temperature measurement system.

It is unclear how stable the river geometry is… Some aspects of geometry are inherently more stable than others. After high water years is there appreciable change in geometry or river features that would alter the model outputs in a meaningful way?

4. Evaluation of the implication of this work as decision support tools, bringing attention to the any potential for mis-use or mis-interpretation of this information to aid in fisheries and water management in California's Central Valley

Tools are tools. And it is well known that tools (and science, numbers, statistics, knowledge of any sort, etc.) can be mis-used. As with anything, knowing the limitations of a tool or data-set is critical to the appropriate use of modeling support tools. I can't pretend to understand the regional content in terms of culture, stakeholders, or institutions. Nonetheless, there are some lessons that can be taken from research on knowledge mobilization and the science-action "gap". For example, it is important to recognize that managers and stakeholders may view science (included models) through different lenses. Recent work related to Pacific salmon management in the Fraser Basin (i.e., Young et al. 2016a,b) suggests that different knowledge users view new knowledge (such as this new model) differently. Young et al. (2016a) suggest that potential users make judgements about the reliability of science based on three broad criteria: (1) the perceived merits of the claim, (2) perceptions of the character and motivation of the claimant, and (3) considerations of the social and political context of the claim. In the Fraser Basin, government employees preferred knowledge that was quantitative and stripped of unnecessary interpretation (leaving the interpretation to the end users themselves). Stakeholders care about bias and are most willing to accept new science when they have respect for the knowledge claimant. That is, what does the stakeholder community think about the character of the authors of the report? I have no knowledge of this, but am simply sharing this perspective because it has important implications for how the model will be viewed and used.

The biggest potential threat I see with this model is the potential for there to be disparities between how fish actually use and move through the system relative to the assumptions regarding the conditions experienced by fish. The upshot is that there will presumably be inherent bias towards a conservative perspective given that the current model fails to incorporate refugia or other subtle aspects of fish behavioural thermoregulation. In that sense, there is little risk with the mis-application of the model in a manner that would unduly harm fish. The exception would be that the biological assumptions are independent of multiple stressors (see Miller et al. 2014). For example, will the thermal conditions experienced by a fish (say 18°C) be moot if the fish are "clean" yet if fish have parasite A, B or C they will die? Or if they are encountered as bycatch yet released will they survive or die, and how is that modulated by small differences in water temperature? To determine such relationships there is a need for experimental science (e.g., manipulating water temperature and other factors such as pathogen load/community, fish condition, fisheries interactions, etc.; e.g., see Teffer et al. 2017).

One thing I noted was that the report was in degrees Celsius (although in the text it never says that… one has to infer from the figure labels – that should be added), yet the web interface defaults are in degrees Fahrenheit. I could not find an easy way to change this… It needs to be abundantly clear to users of the websites and the various reports what units are being used. If someone were to be confused by this, it could have negative consequences for fish given the disparity between these units of measurement.

5. Evaluation of the content made available in the CVTEMP website, bringing attention to content that was unclear and that could be improved

I approached this task by thinking about who might be the logical "users" of the website. In doing so, I presumed the primary users would be regulators, environmental managers, and hydropower or irrigation utilities. It is conceivable that the model would also be used by various public interest groups (e.g., NGOS), environmental consultants (hired by various parties), or academics (engaged in research or advocacy), but those groups would be comparatively small in terms of users. I presumed that the primary target audience would want a web interface that is simple to navigate with appropriate "help" files. Another key feature would be the ability of the user to "capture" the various parameters they manipulated (or held constant), and to log the version of the model they used (recognizing that refinements are possible). I did not "run" any models, so I am unsure the extent to which these issues are already addressed. In general, the website is reasonably "friendly". Including a section detailing its "peer review" and the process that led to its creation may be useful and help to elevate the credibility (and thus usability) of the model.

A few other thoughts on the website…

- The "about" page (http://oceanview.pfeg.noaa.gov/CVTEMP/) has nothing useful for the user/explorer… Need to provide a brief overview of what this is all about – why it was created, who it is for, who created it, etc. There is decent info on the models themselves on the specific tabs, but the "splash" page has nearly zero context. I know this could be used for MANY purposes beyond SRWRC conservation, but I feel that there is lost opportunity if the reason for the model genesis is not presented. Including such info will improve the ability of users to "find" the tool when doing Google searches… If no one can find this, it has little value.

- Not sure what requirements are to provide at least the "about" page in a language other than English (Spanish being the logical one…).

- Does the website meet current standards for accessibility by peoples with disabilities? https://www.w3.org/standards/webdesign/accessibility. Not sure about US law, but in Ontario we have to meet certain standards with government websites.

- What is the plan for long-term support for the website? Is there benefit in giving this to a 3rd party link, such as an NGO or academic institution (e.g., library), to house so that it is immune to changes in political priorities?

- The reference page (http://oceanview.pfeg.noaa.gov/CVTEMP/reference) is good but would be nice to have more direct links… At a minimum, each reference should link back to the publisher website. Ideally, these would all be open access such that the PDFs can be linked directly, but assuming that is not the case then needs to be easy path to purchasing or download through institutional repositories.

6. Provide a brief description on other aspects of the model not described above

I have little to add here… The documentation is quite thorough. What is missing for me is the biological justification for various aspects of the model. There is much thought about the hydraulic aspects of the model, but much less thought about the biology of the animals (especially the SRWRC). These issues are described elsewhere.

The text around line 988 has me thinking about the extent to which there is the need to also think about historical contributions from the various tributaries. With current engineering, it is possible to change the ratio of water coming from different sources. This is relevant inasmuch as that salmon "smell their way home" during spawning migrations to natal spawning sites (see Bett and Hinch 2016). There has been much work done on this in the Bridge-Seton-Cayoosh system of British Columbia (work going back decades by Mike Fretwell and more recently by Scott Hinch and his team at UBC) which may be informative. I understand the importance of adequate flows and meeting thermal targets, but if doing so means modifying the relative ratio of water from different sources it may be that the olfactory bouquet has been so modified that fish will be unable to smell their way home. It is up to biologists to determine the ratios that attract/repel the SRWRC, and the modelers to identify historical levels and compare them to current or future scenarios.

Conclusions and Recommendations

The team has created a tool to support water resource managers and other users interested in understanding how various factors (e.g., reservoir operation, meteorology) influence the thermal conditions in the Sacramento River downstream of Shasta Reservoir. The hope is that this tool will enable the protection of SRWRC such that populations are not further impacted and can be restored (ideally to historical levels). As with any model, the quality and diversity of information sources used to parameterize the model are critical for determining its validity and utility. From my perspective (that of a fish eco-physiologist who studies and models how fish respond to heterogeneity in environmental conditions), the most obvious omission is data on how fish actually use the river. The assumption that the river is well mixed is naïve in the sense that fish have exceptional abilities for detecting minute thermal variation. The tools exist for looking at river use (thermal habitats) from the perspective of the fish and such information could be used to test the validity of the model and refine it as appropriate.

Another missing element is dissolved oxygen. Dissolved oxygen (hypoxic or super-saturated) may not be an "issue" in this system, but it is never mentioned and deserves some consideration. Similarly, when one modified dam operations at the hydro-system level to achieve a thermal benchmark, one may alter the water ratios that come from different systems. This is highly relevant to Pacific salmon which are known to use the olfactory bouquet to smell their way home. I appreciate how the platform has been developed such that it can be used online with a point and click interface. My concern is that those who stumble upon it will be unsure why the model was created and its potential use given the paucity of background material. Moreover, I worry about it being difficult to find if it is not optimized for search engines. There are also disparities between the units used for most of the technical reports (i.e., degrees Celsius) and the online tool (i.e., degrees Fahrenheit) which is inherently confusing.

Overall, I consider this to be a robust modeling framework with appropriate validation. Nonetheless, there are certainly opportunities for refinement as described above.

I recommend the following actions be considered:

- Hold workshops for potential users of the model to help them understand the ways in which the model can be used while also being transparent regarding limitations.
- Provide information on how river geometry might change through time (e.g., after major flood events that re-arrange river features) and what this means for model performance and refinement.
- Provide a list of the knowledge gaps that need to be addressed by empirical science.
- Conduct field biotelemetry/biologging studies (with thermal sensors on tags) to understand how fish "view" and experience the thermal environment during river residency (see Donaldson et al. 2009 and Hasler et al. 2012 for examples).
- Consider incorporating information on "olfactory thresholds" related to maintaining adequate olfactory bouquet needed for SRWRC to home to their spawning grounds into the model.
- Consider means of incorporating dissolved oxygen into models to understand how different dam operations may contribute to oxygen levels that are either below or above thresholds known to impair chinook salmon fitness.

- Be more transparent and obvious about the units of temperature measurement (i.e., Celsius vs Fahrenheit) given that there are disparities between the technical reports and the web interface.
- Enhance the website to ensure it can be found, accessed, and used by diverse stakeholders.
- Provide information on the website splash page that describes the context for the tool which will also enhance the ability for it to be located by search engines.
- Consider how stakeholders and managers will view the model (e.g., will they have issues with how it was created, who created it, how it was peer reviewed) and use that to inform how you roll this out, so it can have maximum benefit for the users.

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Appendix 1: Bibliography of materials provided for review

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Martin, B. T., A. Pike, S. N. John, N. Hamda, J. Roberts, S. T. Lindley, and E. M. Danner. 2017. Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters. DOI: 10.1111/ele.12705

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The Central Valley Temperature Mapping and Prediction (CVTEMP) website: http://oceanview.pfeg.noaa.gov/CVTEMP/

Appendix 2: A copy of the CIE Statement of Work

Statement of Work

National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

River Temperature Decision Support Tools

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf). Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The SWFSC Fisheries Ecology Division (FED) requests an independent review of the suite of temperature modeling tools they have developed for water and fisheries management in California's Central Valley. When Shasta Dam was built in the 1940s it blocked Sacramento River Winter-run Chinook (SRWRC) salmon from accessing the cold waters of their native spawning habitat. The quality (water flow and temperature) of their current habitat below the dam is now entirely controlled by releases from the dam, and because SRWRC are listed under the Endangered Species Act, dam operations must take into account the impacts on their spawning and rearing habitat. As a result, temperature compliance points have been established:

> From Reclamation's 2008 OCAP Biological Assessment, Chapter 2, pg. 2- 38 (http://www.usbr.gov/mp/cvo/ocap_page.html):
>
> "In 1990 and 1991, SWRCB issued Water Rights Orders 90-05 and 91-01 modifying Reclamation's water rights for the Sacramento River. The orders stated that Reclamation shall operate Keswick and Shasta Dams and the Spring Creek Power Plant to meet a daily average water temperature of 56°F as far downstream in the Sacramento River as practicable during periods when higher temperature would be harmful to fisheries. The optimal control point is the Red Bluff Pumping Plant. Under the orders, the water temperature compliance point may be modified when the objective cannot be met at Red Bluff Pumping Plant."
>
> Page 590 of the 2009 OCAP Biological Opinion starts off with RPA Action Requirements:
>
> http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/ocap.html

To aid in the water and fisheries management decisions, SWFSC has developed linked temperature models for the Shasta Reservoir and the Sacramento River to model how operations will impact water temperatures within the SRWRC spawning habitat. The SWFSC then developed a thermal tolerance model for SRWRC eggs (the most temperature sensitive life stage) and linked it to the temperature model. The combined suite of models allows for water and fisheries managers to evaluate how proposed seasonal water operations impact SRWRC eggs in a spatiotemporally explicit manner.

Requirements
NMFS requires three reviewers to conduct an impartial and independent peer review in accordance with the Statement of Work SoW, OMB Guidelines, and the Terms of Reference (ToR) below. The reviewers shall have working knowledge and recent experience in temperature modeling, with specific emphasis on water temperature modeling in both lentic and lotic fresh water systems (i.e. river and reservoirs), thermal performance modeling of ectothermic organisms with an emphasis on early life stage development in relation to temperature exposure, and experience linking physical and biological models. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

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

<u>Pre-review Background Documents</u>: Review the following background materials and reports prior to the review. The contractor will provide these documents (via electronic mail or made available at an FTP site) to the CIE reviewers.

M. Daniels, E. Danner. 2017. Technical Memorandum: Calibration and Validation of Water Temperature Models for the Shasta/Sacramento System.

Martin, B. T., A. Pike, S. N. John, N. Hamda, J. Roberts, S. T. Lindley, and E. M. Danner. 2017. Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters. DOI: 10.1111/ele.12705

Pike, A., E. Danner, D. Boughton, F. Melton, R. Nemani, B. Rajagopalan, and S. Lindley. 2013. Forecasting river temperatures in real time using a stochastic dynamics approach. Water Resources Research 49(9):5168-5182. DOI: 10.1002/wrcr.20389

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<u>Desk Review</u>: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the Contracting Officer's Representative (COR) and the CIE contractor.

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

Place of Performance
Each CIE reviewer shall conduct an independent peer review as a desk review, therefore no travel is required.

Period of Performance
The period of performance shall be from the time of award through November 2017. Each reviewer's duties shall not exceed 10 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
Within four weeks of award	Contractor provides the pre-review documents to the reviewers
October 2017	Each reviewer conducts an independent peer review as a desk review
Within two weeks after review	Contractor receives draft reports
Within two weeks of receiving draft reports	Contractor submits final reports to the Government

Applicable Performance Standards
The acceptance of the contract deliverables shall be based on three performance standards:
(1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel
Since this is a desk review travel is neither required nor authorized for this contract.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

Annex 1: Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

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

3. The reviewer report shall include the following appendices:
    a. Appendix 1: Bibliography of materials provided for review
    b. Appendix 2: A copy of the CIE Statement of Work

Annex 2: Terms of Reference for the Peer Review

River Temperature Decision Support Tools

1. Evaluation of the strength and weaknesses of the individual water temperature models as well as the process of linking the models, bringing attention to those weaknesses not adequately addressed in technical memorandum.

2. Evaluation of the methods used to incorporate uncertainty into predicting water temperature in Shasta Reservoir and Sacramento River down to Red Bluff, such as the use of variable meteorology and model parameters.

3. Evaluation of the water temperature model calibration and validation procedure outlined in the technical memorandum and its ability to properly parameterize each water temperature model.

4. Evaluation of the implication of this work as decision support tools, bringing attention to the any potential for miss-use or miss-interpretation of this information to aid in fisheries and water management in California's Central Valley

5. Evaluation of the content made available in the CVTEMP website, bringing attention to content that was unclear and that could be improved.

6. Provide a brief description on other aspects of the model not described above.

7.