TECHNICAL MEMORANDUM

Prepared for: Sacramento River Settlement Contractors

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Re: SWFSC Interstitial flow proposal

Date: January 25, 2018

We reviewed the NMFS Southwest Fishery Science Center (SWFSC) proposal "The biophysical ecology of salmon redds" and identified three major issues.

1. The proposal is premised upon unfounded conclusions reported by Martin et al. (2017)
In early 2017, Dr. Martin and others from the NMFS Southwest Fishery Science Center published "Phenomenological vs. biophysical models of thermal stress in aquatic eggs" in the journal *Ecology Letters*. The paper fit field and laboratory parameterized statistical models to estimates of winter run Chinook salmon egg-to-fry/post-fry survival. Based on the superior fit of the field parameterized model (relative to the laboratory parameterized model), Martin et al. concluded temperature tolerance of eggs in the field is lower than estimates derived from lab studies. We have carefully reviewed this paper and found Martin et al. have reported management-related conclusions that are simply not supported by their analysis.

Egg-to-fry survival of salmonid embryos is a topic of considerable research with a well-understood, accepted methodology. The variable defined by Martin et al. as "egg-to-fry survival" is inconsistent with this standard. Typically, a known number of eggs are buried in incubation containers so fry can be captured as they emerge (Rubin 1995). This approach allows focus on only eggs and emergent fry. Martin et al.'s response variable comprises four life stages that could all effect observed variation including, 1) spawning adults, 2) eggs, 3) fry and 4) post-fry migrants. Standard methods allow fry to be captured as they emerge from the gravel, whereas fry/post-fry in the Martin et al. study migrate ~90 km before they are available for capture. Fish captured weeks later as parr or smolts are converted to hypothetical "fry equivalents"; another source of uncertainty. Isolating temperature effects on eggs requires either a controlled field observation of incubation success (e.g. Dumas and Marty 2006, Roni et al. 2015) or statistical accounting for the documented influences on survival between life stages. Martin et al. did neither.

Dissolved oxygen (D.O.) limitation mediated by poor intergravel velocities are identified by Martin et al. as the explanatory mechanism, but no relevant field measures of either intergravel velocity or D.O. are presented. The interactive effect of D.O. and temperature on Chinook salmon egg survival was evaluated by Geist et al. (2006) who found results consistent with lab studies. Yet, these results are not discussed in Martin et al. (2017) or in the SWFSC proposal despite Geist et al.'s focus on the exact mechanism Martin et al. hypothesize control temperature tolerance. As a surrogate for D.O., Martin et al. compared "typical" field and lab water

velocities, but evidence for "typical" field velocities were drawn from a single paper (Zimmerman and LaPointe 2005) utilizing non-standard methods in a stream with "relatively high silt-loadings". Again, no data from the Sacramento River were considered. A broader review of the scientific literature demonstrates intergravel flows in salmon redds (e.g. Sear et al. 2014; Utz et al. 2013) appear to be consistent with laboratory flow studies cited by Martin et al. (2017).

Most of these issues have been raised previously with *Ecology Letters* and directly with Dr. Martin. Dr. Martin articulated no disagreements, responses or rebuttals to the detailed claims we provided. *Ecology Letters* affirmed the validity of our criticisms, but felt "refinements" to data and conclusions reported by Martin et al. lacked novelty to warrant a reply publication[1].

Important criticisms of the Martin et al. model were also provided by Dr. James Anderson at the 2017 Long-term Operations Biological Opinions (LOBO) Biennial Science Review. Dr. Anderson concluded that the model over-estimates mortality by ignoring life-stage specific temperature sensitivities and by making unrealistic assumptions about mortality originating from other sources.

While the findings reported by Martin et al. (2017) are interesting, the SWFSC intergravel flow proposal is predicated upon the weakest and most problematic aspects of that work (that low intergravel flows drove patterns of poor survival to fry recruitment). More direct, less costly approaches to test assumptions of Martin et al. (2017) are needed before complex laboratory studies of intergravel flows and D.O. are considered.

2. The proposed work will not effectively address critical management questions

The authors propose to use a laboratory flume, fluid dynamics modeling and high-resolution D.O. mapping to "see" how water moves through redds. The resulting hydrodynamic model is expected to accurately predict interstitial flows in the artificial environment of the laboratory flume, but this result would seem to have little applicability to salmon spawning areas of the Sacramento River. Factors influencing intergravel flows in salmon redds are understood to occur over multiple spatial scales (Tonina and Buffington 2009; Schindler-Wildhaber et al. 2014; Zimmermann and Lapointe 2005). A two-dimensional laboratory flume cannot adequately represent important variation in natural features including bedform-induced flow, redd surface hydraulics, bed materials, redd size and morphology resulting from redds constructed by fish capable of detecting and shaping key water quality attributes (e.g. Baxter and Hauer 2000). While the proposal does acknowledge these scaling and natural variability problems, the proposal describes neither field sampling nor analytical methods that might allow the resulting model to usefully translate to real-world management challenges.

3. More direct, less costly study options are available

As described previously, the SWFSC proposal is predicated upon the conclusion from Martin et al. (2017) that low interstitial flows are driving patterns of apparent poor survival from adult spawning to fry emigration at the Red Bluff Diversion Dam (RBDD). In fact, this conclusion

[1] Copies of correspondence with *Ecology Letters* and Dr. Martin are available upon request.

remains a hypothesis; no interstitial flow or D.O. data from the Sacramento River were presented in Martin et al. (2017). The validity of this hypothesis could easily be assessed by directly measuring interstitial flows in spawning gravels utilized by winter run Chinook salmon. If observed interstitial flows are not as predicted by Martin et al, then more sophisticated studies of flow-embryo survival are probably not warranted. Instead, investigative efforts could be redirected to evaluating alternative mechanisms for observed poor survival to RBDD; for example: inadequate fry food supply relative to bioenergetic demands, predation on emergent fry, disease effects on fry or other factors that might be identified as part of a collaborative science working group.

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