Technical Memorandum

To: California Department of Water Resources (DWR)

From: Marin Greenwood, Ph.D. (Aquatic Ecologist, ICF)

Date: 7/2/2018

Re: Potential Effects on Zooplankton From California WaterFix Operations

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Background

Testimony provided in Part 2 of the State Water Resources Control Board hearing for a change in point of diversion for California WaterFix (CWF) provided opinions on potential negative effects to zooplankton as a result of CWF operations. In particular, Dr. Jonathan Rosenfield's testimony (Exhibit NRDC-58; p.39, lines 15-22) suggested "…reductions in freshwater flows into, through, and out of the Delta caused by WaterFix operations are likely to reduce productivity and abundance of important zooplankton prey species in the Delta. For example, *Crangon* shrimp display a strong, persistent, and significant positive relationship with spring Delta outflows; this relationship did not change with the introduction of *Corbula* clams to this ecosystem in the mid-1980's (Jassby et al. 1995; Kimmerer 2002). Spring populations of the copepod *Eurytemora*, a key prey species for most small juvenile pelagic fish in this ecosystem, also show a significant positive relationship with Delta outflow (negative relationship with X2, Kimmerer 2002)."

In this technical memorandum I address the potential for effects to *E. affinis* and *Crangon* as a result of CWF H3+ operations in relation to the No Action Alternative (NAA).

Crangon (Bay Shrimp)

Kimmerer (2002) found statistically significant negative relationships between mean spring (March-May) X2 and the relative abundance (catch per unit effort) of *E. affinis* and *Crangon* (Bay Shrimp); Kimmerer et al. (2009) updated the latter relationship with additional years of data. As I described in my written testimony (Exhibit DWR-1012; p.52, lines 8-15), the CWF Final Environmental Impact Report/Statement (FEIR/S) demonstrated based on the application of the Kimmerer et al. (2009) Bay Shrimp X2-abundance relationship that there is little difference in predicted relative abundance between the NAA and H3/H4 scenarios; application of the same relationship to CWF H3+ X2 outputs confirms that there is little difference in predicted relative abundance between NAA and CWF H3+ (Table 1)[1].

Table 1. Bay Shrimp: Water Year Type Mean of Relative Abundance Predicted for California WaterFix H3+ and No Action Alternative Operational Scenarios, Based on Application of Kimmerer et al. (2009) X2-Relative Abundance Relationship to 1922-2003 Mean March-May X2 CalSim-II Model Outputs.

Water Year Type	NAA	CWF H3+	CWF H3+ vs. NAA
Wet	397	395	-2 (-1%)
Above Normal	320	325	5 (1%)
Below Normal	204	209	5 (2%)
Dry	209	209	1 (0%)
Critical	138	139	0 (0%)

Eurytemora affinis

For *E. affinis*, the paper by Kimmerer (2002) did not provide full regression coefficients and so for this reason, plus the fact that the paper only analyzed data from 1980 to 2000, I followed Kimmerer's (2002) methods to conduct an analysis for the period from 1980 to 2017. The main steps in preparing the data for analysis were as follows:

1. I obtained historical zooplankton data from ftp://ftp.dfg.ca.gov/IEP_Zooplankton/1972-2017CBMatrix.xlsx
    a. I subsetted to only include surveys 3, 4, and 5 (March-May).
    b. I converted specific conductance to salinity by applying Schemel's (2001) method, then selected only samples within the low salinity zone (salinity = 0.5-6).
    c. I added 10 to *E. affinis* adult catch per unit effort (number per cubic meter) in each sample, then $\log_{10}$-transformed the resulting value.
    d. I averaged the $\log_{10}$-transformed values first by month, and then by year.

[1] The data and calculations are provided in Exhibit DWR-1353.

   e. The procedure is shown in the '1. Zooplankton' tab of Exhibit DWR-1354.
2. I obtained historical X2 data from DAYFLOW (https://www.water.ca.gov/Programs/Environmental-Services/Compliance-Monitoring-And-Assessment/Dayflow-Data)
   a. For years prior to water year 1997 (which is the year DAYFLOW X2 values began to be provided), I used the DAYFLOW daily predictive equation for X2[2], based on a starting value from Anke Mueller-Solger[3].
   b. I calculated the mean March-May X2 for each year.
   c. The procedure is shown in the '2. X2' tab of Exhibit DWR-1354.

Similar to Kimmerer (2002), I then regressed with a general linear model mean annual $\log_{10}$-transformed *E. affinis* catch per unit effort against mean March-May X2, including a step change between 1987 and 1988 to reflect the *Potamocorbula amurensis* clam invasion and a step change between 2002 and 2003 to reflect the onset of the Pelagic Organism Decline (POD; Thomson et al. 2010). I included the interaction of X2 and the step change in a full model, but the interaction was not statistically significant, so I re-ran the model with only X2 and the step changes included. These analyses were conducted in SAS 9.4 software and the code and outputs are provided in the '3. SAS code – historical' and '4. SAS outputs – historical' tabs of Exhibit DWR-1354. The statistical outputs indicate that there is little difference in the coefficients for the post-*Potamocorbula* and POD step changes, whereas both coefficients were significantly less than the coefficient for the pre-*Potamocorbula* period. Regression coefficients from the model were saved for prediction of *E. affinis* relative abundance for the CWF H3+ and NAA scenarios.

CalSim-II inputs used for prediction of *E. affinis* relative abundance for the CWF H3+ and NAA scenarios are presented in the '5. CalSim inputs' tab of Exhibit DWR-1354. The stored regression coefficients from the regression of historical *E. affinis* catch per unit effort vs. X2 and step changes were then applied to these inputs using PROC PLM in SAS 9.4 software[4]. The basic regression model being applied was:

$\log_{10}$(*E. affinis* catch per unit effort) = 3.9404 – 0.0152 (mean March-May X2) – 0.7863

[2] The formula is X2(t) = 10.16 + 0.945*X2(t-1) – 1.487log(QOUT(t)); where t = a given day, t-1 = the previous day, and QOUT(t) is Delta outflow on the given day t, as provided in DAYFLOW.
[3] The starting value for October 1, 1955, is 84.3434152523116 km; see Mueller-Solger, A. 2012. Unpublished estimates of X2 presented in Excel workbook <FullDayflowAndX2WithNotes1930-2011_3-6-2012.xlsx>.
[4] The SAS code is provided in the '6. SAS code – CWF' tab of Exhibit DWR-1354.

where 3.9404 is the intercept and -0.7863 is the coefficient for the POD step change. Predictions were back-transformed to the original measurement scale (catch per unit effort, number per cubic meter) for summary of results.

There was appreciable variability in the predictions of *E. affinis* catch per unit effort for the NAA and CWF H3+ operational scenarios, with 95% prediction intervals spanning several orders of magnitude (Figure 1)[5]. This high variability was considerably greater than differences between the NAA and CWF H3+ scenarios, which tracked very closely. There was little difference (2% or less) in mean predicted *E. affinis* catch per unit effort averaged by water year type between CWF H3+ and NAA (Table 2).

[5] Detailed results are presented in the '7. CWF results' tab of Exhibit DWR-1354.

Exhibit DWR-1349

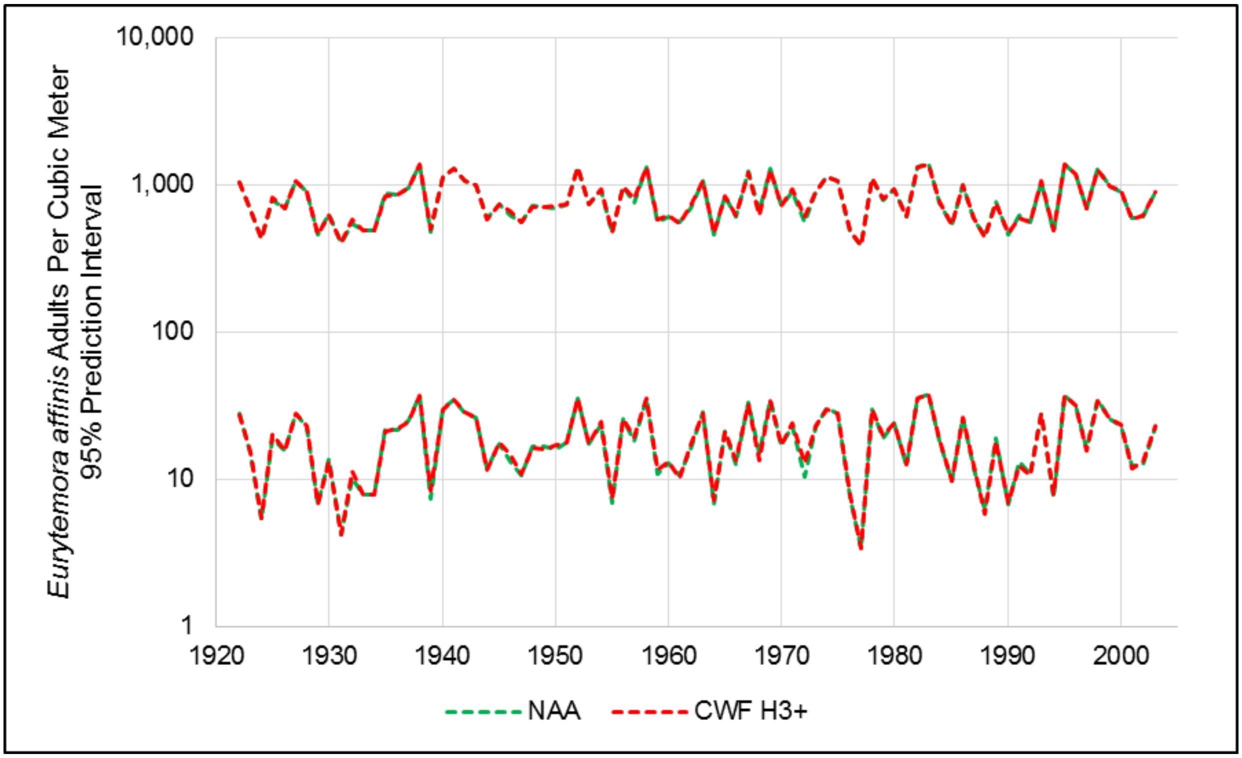

Figure 1. *Eurytemora affinis* Relative Abundance: 95% Prediction Interval for California WaterFix H3+ and No Action Alternative Operational Scenarios, Based on Regression Including Mean March-May X2 and Pelagic Organism Decline Step Change Applied to 1922-2003 CalSim-II Model Outputs.

Table 2. *Eurytemora affinis* Relative Abundance: Water Year Type Mean Predicted for California WaterFix H3+ and No Action Alternative Operational Scenarios, Based on Regression Including Mean March-May X2 and Pelagic Organism Decline Step Change Applied to 1922-2003 CalSim-II Model Outputs.

Water Year Type	**NAA**	**CWF H3+**	**CWF H3+ vs. NAA**
Wet	196	195	-1 (0%)
Above Normal	165	167	2 (1%)
Below Normal	114	117	2 (2%)
Dry	116	116	0 (0%)
Critical	83	83	0 (0%)

References

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