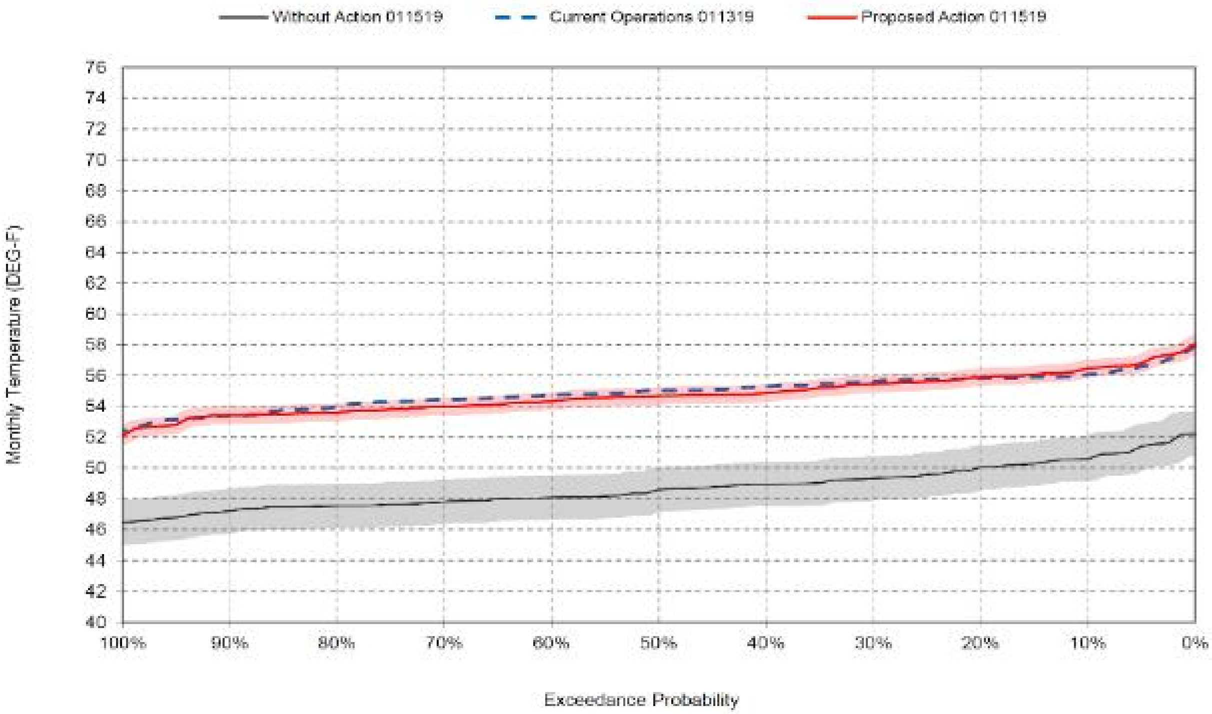

Figure 5.6-20. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, proposed action, and COS scenarios, November

While the HEC-5Q model provides 6-hour data, the results presented here are monthly averages, which should reasonably estimate daily average temperatures near the Keswick Dam because operations at Shasta and Keswick dams create relatively stable summer flow and water temperature conditions. Variable weather conditions and travel time of water result in greater fluctuations around the mean further downstream of the dam. During the June through September peak spawning and incubation period, the water temperatures at Clear Creek exceed the 53.5 degrees Fahrenheit threshold in at most 25 percent of years (50% for September). During October, when the cold water pool is especially at risk of being depleted, the water temperatures would exceed the 53.5 degrees Fahrenheit threshold in about 40 percent of years. There is little difference in water temperatures among the proposed action and COS scenarios during all months except October (Figures 5.6-13 through 5.6-20). In October, temperature modeling indicates that the proposed action has an improvement over the current operations scenario in 80% of the years, and an improvement over the WOA scenario in 90% of the years, decreasing October temperatures by 1-2 degrees Fahrenheit as compared to COS, and 4-5 degrees as compared to WOA. The proposed action conserves cold water earlier in the year and is able to extend cooler temperatures into October.

Summer water temperatures under the proposed action and COS scenarios are consistently much lower than those under the WOA scenario (Figures 5.6-15 through 5.6-18). These results indicate that the proposed action and COS, relative to the WOA, provide a clear benefit to Winter-run Chinook Salmon eggs and alevins incubating in the upper Sacramento River. In view of the improved water temperature management operations planned for the proposed action, this action is expected to benefit the Winter-run Chinook Salmon eggs and alevins relative to current operations.

Martin et al. (2017) developed an egg mortality model for Winter-run Chinook Salmon on the Upper Sacramento River and performed regression on historical data to find a critical incubation temperature for eggs of 53.6 degrees Fahrenheit below which minimal mortality due to temperature occurred. The 2017

LOBO review (Gore, 2018), stated that the Martin et al. (2017) approach represents a powerful predictive model for salmon vulnerability to temperature exposure but that the results of the oxygen diffusion model should be tested under field conditions. The model is sensitive to extremely small changes in flow velocity, and it may be problematic to apply a density dependent model that lacks mechanistic basis or site-specific information. Additionally, new laboratory studies from UC Davis (Del Rio et al. In Press) affirm earlier findings (USFWS 1999) that embryo survival is not appreciably impaired at daily mean water temperatures at or near 56 °F.

Newer models, described in Anderson (2018), are similar but include different assumptions and provide for more targeted water temperature management practices in the upper Sacramento River (Anderson 2018). Both the Martin et al. (2017), and Anderson (2018) models were used to estimate water-temperature related mortality of Winter-run Chinook Salmon eggs to fry under the WOA, proposed action, and COS. Martin et al applies mortality based on the season-long temperature. Anderson applies mortality based on just the temperature of the 5 days preceding hatch. The modeling was based on the HEC 5Q water temperature estimates at Keswick Reservoir under the three scenarios for the range for years (1922 to 2002) used for the CalSim and HEC 5Q modeling. Figure 5.6-21 gives the exceedance curves for the water-temperature related egg to fry mortalities under the WOA, COS, and proposed action scenarios. Separate results are given for the Martin et al. (2017) and Anderson 2018 modeling.

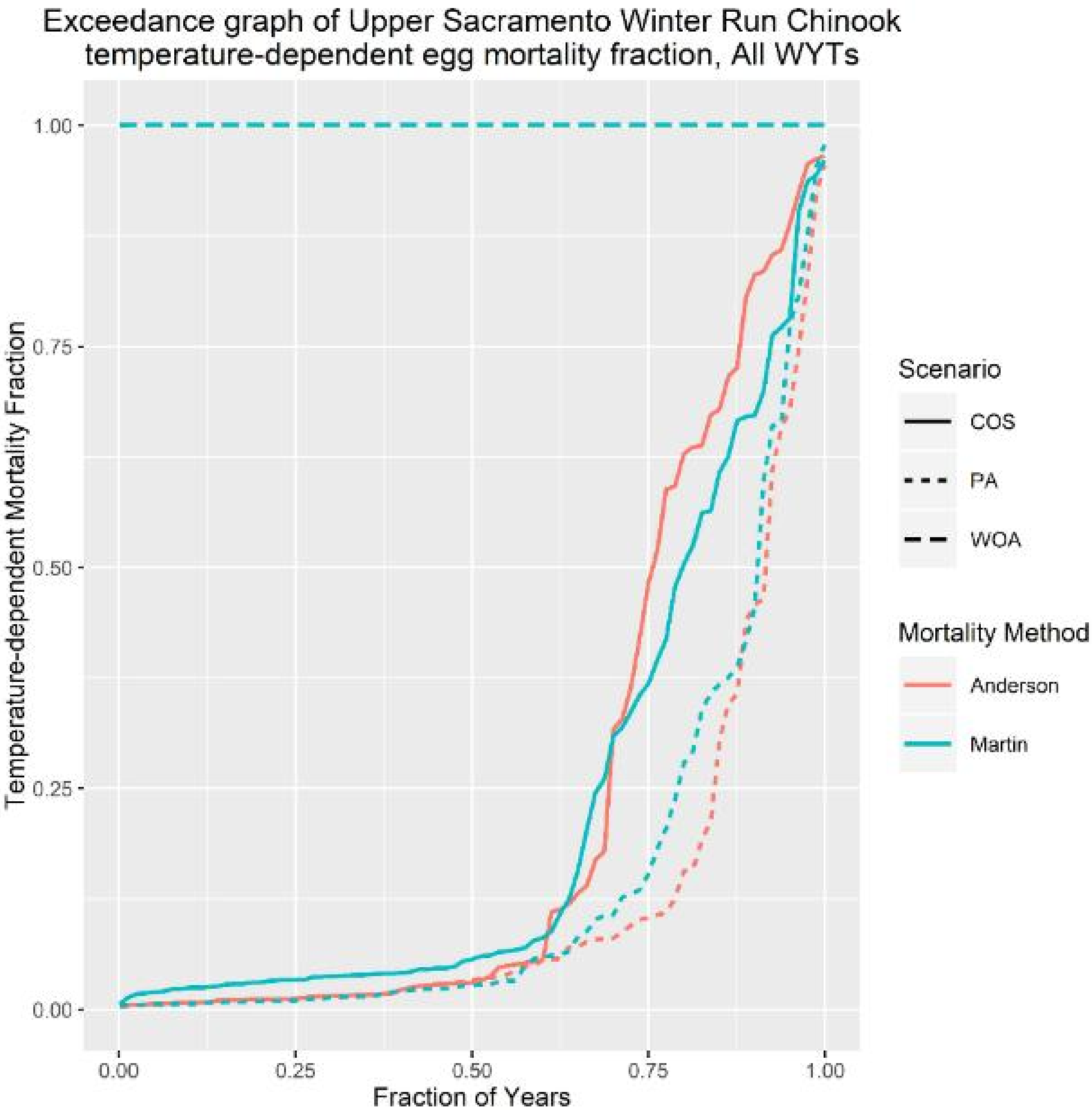

Figure 5.6-21. Exceedance curves of Upper Sacramento River Winter-run Chinook Salmon Temperature-Dependent Egg to Fry Mortality for All Water Year Types

The modeled mortality rate for the WOA scenario is 100 percent for both models used (Figure 5.6-21). This result is the same as that deduced from the HEC 5Q water temperature results presented previously in the water temperature section. Differences between the Martin and Anderson model results are generally small, but tend to show slightly higher mortalities for years with overall lower mortalities (i.e., cooler water temperatures) for the Martin model and slightly higher mortalities for years with overall high mortalities (warmer temperatures) for the Anderson model. For both models, the proposed action mortalities are less than the COS mortalities for the majority of years in all water year types, with some lower performance in some above-normal water-year types.

Figure 5.6-21 combines results for all water year types, including wet years, when there is little temperature-related mortality. This obscures the modeling results for drier years, when egg/alevin mortalities are especially high. In critically dry years, the proposed action continues to outperform current operations, with up to a 40 percent improvement in mortality above current operations in some critically dry years (Figure 5.6-22). As discussed above, the proposed action optimization of water temperatures early in the year leads to significant October improvements in temperatures driving these large improvements in temperature dependent mortality in wetter critically dry years.

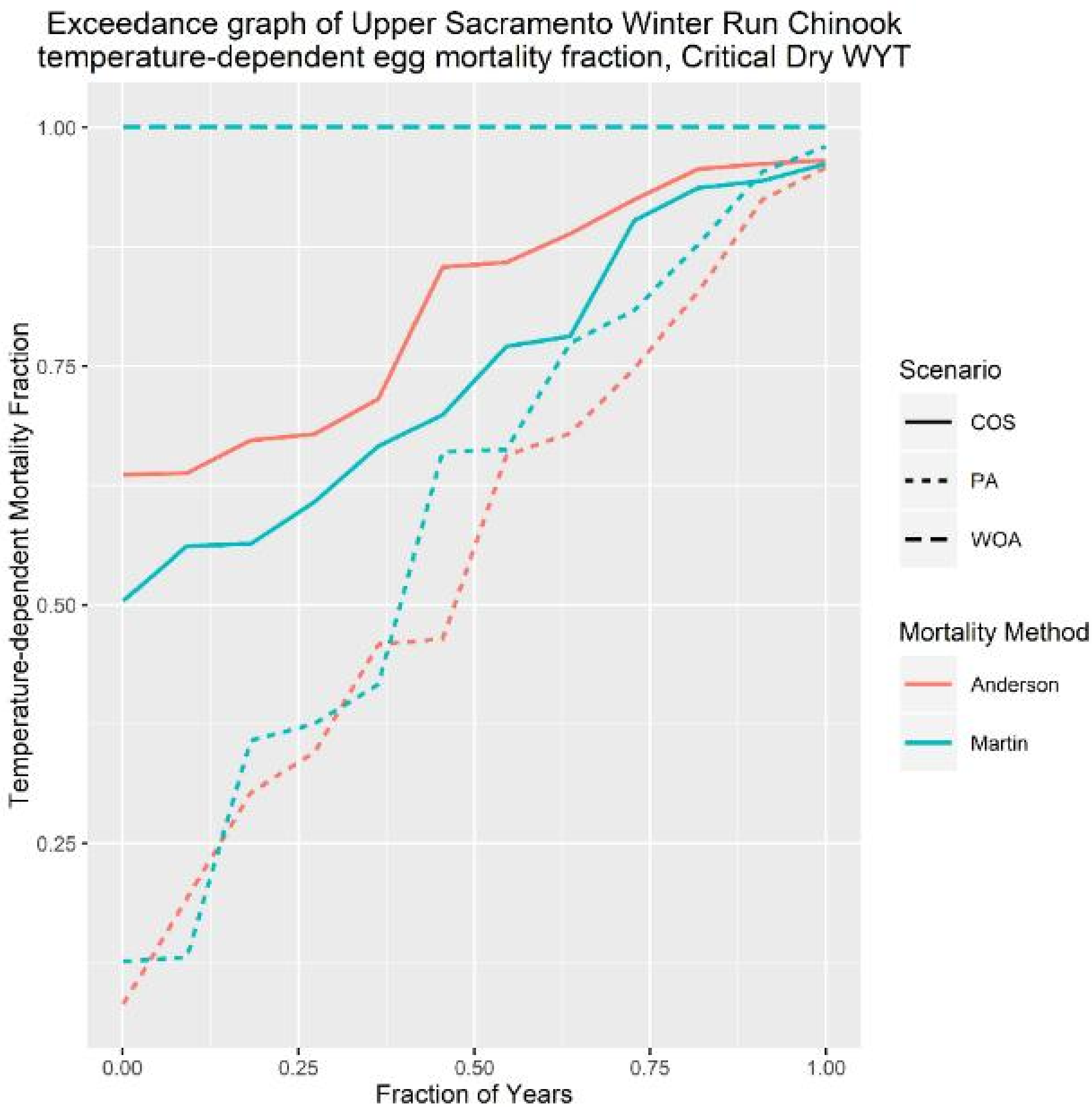

Figure 5.6-22. Exceedance curves of Upper Sacramento River Winter-run Chinook Salmon Temperature-Dependent Egg to Fry Mortality for Critically Dry Water Year Types