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Subject: Personal comments on the Science Basis of EWA Salmon Studies

During the 2004 EWA review the interpretation and "science" in support of the salmon management was singled out by the EWA review Panel and often contrasted with the work to date with Delta smelt. Clearly, the work on salmon is noteworthy and valuable to the EWA program. However, the scope of the problem of understanding salmon recruitment in a complex system is substantial and I believe that the analysis and interpretation of the data could be improved. In this letter I provide, from my prospective, details on the issues related to salmon alluded to in the EWA report. I emphasize that these are my views derived from my participation in four EWA panel reviews. I have not discussed the details in a panel meeting or individually with any panel member.

The EWA identifies three primary actions for salmon:

- SWP/CVP pumping curtailments to minimize take of salmon at the pumps.
- River flow augmentation to increase Delta survival of migrating smolts.
- Modification of hydropower operations for water temperature management to increase salmon production upstream.

Accompanying these actions, research has focused on quantifying the impact of the actions, and in some cases, exploring the causal mechanisms. The three actions are discussed here, with some attempt to synthesize the findings in a larger context.

Take at the Pumps and Take Limits

Take at the pump remains the most quantifiable measure; the actions to mitigate take amount to a reduction in pumping during the juvenile migrations, when high takes are possible. The two stage (yellow and red light) take levels have been identified:

- Winter chinook run take levels = 1% and 2% of the Juvenile Production Estimate (JPE)
- Spring chinook run take levels = 0.5% and 1% of the surrogate releases
- Steelhead take levels = 3000 for the season.

Benefits of EWA Water to Salmon

EWA actions have had measurable impacts on take of salmonids at the pumps. With a redefinition of the juvenile production estimate, take at the pumps is a factor of 7 below the authorized take level for winter chinook. Across years and seasons, the loss of spring chinook surrogates (a measure of the wild spring chinook which are not monitored) has been below the 1% authorized take in 2/3 of the monitoring periods; in the three periods take was exceeded (ranging between 1.21% and 1.36%). Steelhead salvage was below the authorized incidental take in the four years monitored. Taken together, the EWA has successfully limited pump take and, based on take limits, the EWA program is a success.

A question remains as to the significance of the pump actions. That is, what if the EWA actions had not been implemented? What would be the take, and how significant would it have been? Here significance might be assessed in terms of economic and biological terms. In either case, the most meaningful measure is not juvenile counts but additional adults. In economic terms, consider the number of adult salmon produced per thousand-acre feet (TAF) of water. The estimate of winter chinook saved by EWA actions in 2001 was in 6000 juveniles (White and Brandes 2004). In that year, 86 TAF of EWA water were deployed specifically for salmon and steelhead, and 23 TAF were deployed prior to March 15 for salmon and delta smelt. In 2002 and 2003, EWA actions saved 183 and 445 juveniles respectively and the water allocations over the period were 67 and 121 TAF. Adjusted to adult survivals, which is expected to be about 2 % of the juvenile outmigration based on the recovery rates of marked fish in the ocean fishery, the number of adults saved by EWA pump curtailments actions are 120, 4 and 9 adults in 2001, 2002 and 2003 respectively. Attributing the EWA water entirely to pump curtailment, each TAF of EWA water yielded between 0.05 and 1.4 additional adult salmon. Although these efficiencies seem small, in comparison to other water allocation programs, they are comparable.

For example, in the Snake River, up to 2000 (TAF) are allocated yearly to assist juvenile migrations. This added water increases flow by about 10 thousand cubic feet per second (10 kcfs) over a two-month period, and migration survival changes from about 30 to 33%. On a base migration release of 10 million Snake River smolts, of which 10% migrate in river while the others are barged, the adult population will increase by about 400, which results in the yield of 0.2 adult/TAF. Minimum flow criteria have been established for rivers emptying into Puget Sound, but no estimates are available of the impact of the flows in these rivers. Thus, with the information available across systems, the efficiency of water allocations to fish may range between 0.05 to 1 additional adult/TAF of water. Furthermore, the efficiency of the water allocations is not linear. The impact of additional flow is likely greater when flows are low and may, in fact, be negative at higher flows depending on the life stage affected. For example, in Puget Sound rivers late autumn floods can disrupt eggs in the redds. However, the mechanisms through which flow affects juvenile salmon in the Delta and the resulting flow survival relationship are unknown. In summary, the effects of EWA water allocations to salmon are relatively small from an economic cost-benefit perspective, but appear to be as effective as water allocations in other systems.

Assessing the biological significance of the pump curtailments is problematic. Although the ROD identified allowable takes on the order of 1% of the JPE or its surrogate, the significance of these levels on population extinction cannot be estimated because the impacts are small compared to the major factors that determine population survival. Harvest of winter chinook, which exceeded 60% prior to 1995, is now on the order of 20% (Kimmerer and Brown 2004) so harvest takes 20 to 60 times more than the pumps. Kimmerer and Brown (2004) found strong effects of temperature and harvest on winter chinook survival.

Thus, in terms of salmon, which are listed as endangered species and are harvested commercially, their sustained management involves a balance of biological and societal factors. Both water users and harvesters take salmon, and share responsibility for its management. While some ecosystem actions may contribute significantly to stock productivity, the studies to date suggest the actions of EWA have small impacts on fish populations. However, the compounded effect of improved water management over decades may have tangible benefits. Unfortunately commercial harvest can have immediate negative impacts on populations; in a single season, overharvesting could deplete the cumulative benefits of years of water management. On top of these factors, both year and decadal scale changes in ocean productivity and climate can have major effects on the stock productivity. In essence, we have no quantitative way of identifying the overall effect of EWA actions on stocks and the effect of actions to reduce loss at the pumps is very small relative to other factors that affect salmon abundance. The efficiency in terms of water volumes is small but on the same level of efficiency as in other systems.

Migration Survival

The studies exploring the difference in survival in interior Delta vs. mainstem-Sacramento release points provided valuable information on the possible benefits of fish residence in the inner Delta. The interior Delta-mainstem survival ratios were compared using recaptures at Chipps Island and the ocean fishery (Brandes 2004). Both measures indicated survivals of fall and late-fall chinook released in the Sacramento River mainstem were about 2.5 times higher than for fish released in the Delta. The results were highly significant: they appear to answer the question of the efficacy of Delta residence relative to mainstem passage.

Although the mainstem passage routes have higher survival than interior passage routes, the evidence presented in the 2004 review now suggests that migration survival may in fact be lower than previously thought. Revisions of the Juvenile Production Estimate for Winter Chinook resulted in the survival being adjusted from 75% to 11%. Similar low migration survivals have also been found for San Joaquin fish (Brandes 2004) and fish that migrate through the river appear to survive better than fish that enter the interior of the Delta. Correlation of water operations with these migration survivals has had mixed success. Hypotheses for why fish survive poorly in the Delta should be explored and current thinking reconsidered. For example, is residence time longer, and are the fish exposed to more predators, or do the fish wander into dead end channels and exceed a window of smoltification?

Studies in both the Sacramento and San Joaquin rivers indicate fish passing through the mainstem of these rivers have higher survival to Chipps Island than fish passing through the inner Delta. EWA and the ERP have focused on assessing the impacts of the water operations on the survival of salmon and steelhead through the Sacramento and San Joaquin rivers and the Delta. Combinations of actions to improve survival are being evaluated, including closure of the Delta Cross Channel during fish migration, flow augmentation in the San Joaquin and the impacts of pump curtailment. The status of the research to evaluate and quantify the impact of each action is discussed below.

Pump Curtailment and Migration Survival

Four models were developed to explore the impacts of pump curtailment on juvenile migrant survival through Sacramento River to Chipps Island (White 2004). The models use varying degrees of formalism and reach different conclusions. Models 1 and 2 correlate a ratio of interior Delta to mainstem survivals to pump exports. Model 3 correlates a measure of survival between Sacramento and Chipps Island to direct loss at the pumps. Model 4 correlates survival to Chipps Island with river flow, turbidity, salinity, export flow and Delta Cross Channel gate position. The percent change in survival estimated from the models varies from -2.8 % to + 29%. Models 1 through 3 are single variable models, which may be useful to explore whether pump operations have any relationship to migration survival. However, it is inappropriate to infer cause using single variable models. If a relationship is found, it is inappropriate to quantify the effect, if any, of pump curtailments on survival. These models have low statistical power, do not account for uncertainty in the survival estimates and the correlations were highly influenced by a few outlier points. Model 1, based on late fall chinook migrants only, excluded outliers for 1999. The single high survival estimate drives the slope of the relationship in the opposite direction, in which survival increases with increased exports. In addition, with increasing pump curtailments, fall chinook survival increases for the inner Delta route relative to the mainstem route. Models 2 and 3 have similar problems and, again, are not statistically significant. In models 1, 2 and 3 the effect of any actions, or environmental covariates, that happen to coincide with pump curtailments are attributed to the curtailments. Only model 4 explores the impacts of multiple water operations on survival. In this model, the estimated impact of pump curtailments is very small. In summary, models 1, 2 and 3 are inappropriate to characterize the impacts of pumping on survival. The fact that three models produce a trend that agrees with the hypothesis on the impact of pump curtailments is not evidence of the validity of the hypothesis.

Although model 4 (Newman 2002) was designed to disentangle the multiple effects of water operations and covariates, the data available were limited and the effects of time varying factors could not be explored. Flow and river properties, pump exports, gate operations, and fish migration patterns are all variable in time. Identifying the significance of each factor requires a significant temporal resolution of the covariates as well as appropriate models. The existing tagging protocols and experiments that have been used for the past 25 years in the Delta are unlikely to provide the resolution needed to identify the multiple factors affecting migration survival. CALFED is studying the feasibility and value of a PIT tag monitoring program for the Central Valley.

Delta Cross Channel Gate Operations and Migration Survival

The studies of fish behavior in the DCC gates offer compelling evidence of the importance of gate operations on excluding fish from the Delta interior (Brandes 2004). In particular, the fish tracking experiments show the importance of tidal flows on fish entrainment into the Delta. Unfortunately, many of these studies are not yet published, and the results to date are incomplete. It is valuable to complete these studies, and explore the possible application of the work to limit fish entrainment into the inner Delta. The discussions should also include issues with Georgiana Slough, which is a secondary route by which fish reach the inner Delta.

Vernalis Experiment and Migration Survival

A number of studies are exploring the hypothesis that San Joaquin flow and the associated flow/export ratio can affect salmon migration survival through San Joaquin River and the Delta. The studies reviewed suggest trends that agree with the hypothesis, but the studies also display uncertainties.

Regressions of spring flow, and flow/export to San Joaquin escapement 2.5 years later reveal interesting and significant $p < 0.01$ linear relationships. However, escapement depends on many factors other than spring flow, such as the size of the out-migration, ocean survival and

harvest. A correlation between ocean condition and annual rainfall could create a relationship with a mechanism that involves the ocean and not the spring flow. Single variable, correlation analyses, such as flow vs. survival or escapement, are valuable to suggest further exploration, but they are not evidence for the significance of a variable's impact without a more extensive analysis that includes other possible factors. At the least, the analysis should relate flow variables to stock productivity expressed as recruits per spawner ratios, or smolts per adult.
It is not clear that the Vernalis flow/export survival hypothesis is supported with the combined differential recovery rate from Durham Ferry and Mossdale to Jersey Point. In particular, the significant outliers in 2003 and 2004, which also have lowest standard error, suggest that correlation of Delta survival with flow measures is not linear. It is recognized that the VAMP is a multiyear experiment, but the fact that 2003and 2004 outliners are far outside the standard error bounds is cause for concern; it begs the question of the adequacy of using linear models between flows and survival. What is different in these two years compared to other years? The VAMP investigators should consider how to resolve this issue.

Upstream Actions

The intent of upstream actions were to reduce prespawning temperatures and to augment flow in the American River. The actions were short-term and complimented upstream actions by other water programs, notably the b(2) program. No actions were specifically monitored and no analyses of the potential impacts were made. Further, it does not appear that the EWA staff has sufficient resources to address the upstream actions in a comprehensive manner. Although the actions are beneficial on the basis of qualitative ecological principles, it is not possible to assess the relative benefit of the actions against other uses of EWA resources, because they were not evaluated quantitatively. In terms of program efficiency, it might be desirable to combine all upstream temperature control programs into a single effort that would be responsible for research, monitoring and management of temperature control activities in the Central Valley.

Comments on Approaches Used in Salmon Analyses

Evaluating the effects of pumping curtailments, flow augmentation, and temperature management on salmon populations is difficult and challenging. Multiple factors affect fish survival and migration paths through the rivers and the Delta. The studies to date have not indicated a strong effect of any one action, with perhaps the exception of the significant mortalities incurred with inner Delta passage relative to mainstem passage. For the most part, the analyses of various flow measures on salmon survival have been based on single variable linear models. These models are inappropriate from both scientific and management perspectives. Scientifically, single variable linear regressions simply do not represent the multivariate nonlinear interactions that determine fish migration and survival. In terms of management, overly simple models can be misleading; they run the risk of misdirecting or providing erroneous justification of a management action. For example, if migration survival depends on gate operations and if the operations are inadvertently correlated with pump operations, then evaluating the data with models that only consider pump operations would establish an erroneous correlation with survival. Furthermore, such an analysis, or analyses if several variants of a flow survival model were offered, could inadvertently be used to justify ineffective pump operations.

Effective use of water to improve fish survival is not a trivial undertaking. However, studies on the effects of the EWA on salmon are incomplete and many of the analyses are inadequate. I also see the need for a comprehensive synthesis quantifying and comparing the merits of the various allocations of EWA water with other actions. For example, in our brief and cursory review it appears that actions to exclude salmon from the inner Delta are more effective than actions that minimize take at the pump. Such an assessment is needed to determine the value and size of a future the EWA program. CALFED scientists are well aware of the challenges, as noted in the 2003 summary report of the ecological effects of long-term water project operations:

"The VAMP and DCC studies offer new insights and tools for examining how physical processes affect fish survival in the Delta. For example, in river bends and channel junctions, fish move with the velocity vectors (current structure), not simply the bulk flow discharge. The implication for managers is that understanding water velocity structure within bends and junctions and the interactions with fish behavior may lead to novel solutions to minimize impacts of existing and proposed water operation facilities. Further, integrating contaminant research into multidisciplinary studies like VAMP and DCC can also help to reduce the uncertainty associated with through-Delta salmon survival through the application of innovative tools and research strategies (Honey, Hymanson, and Luoma 2003). "

While current EWA analyses are a first step on the path envisioned by CALFED, it is time to move forward.

References

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