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BEFORE THE

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

HEARING IN THE MATTER OF THE CALIFORNIA DEPARTMENT OF WATER RESOURCES AND UNITED STATES BUREAU OF RECLAMATION REQUEST FOR A CHANGE IN POINT OF DIVERSION FOR CALIFORNIA WATER FIX	**PART 2 SURREBUTTAL TESTIMONY OF ANDREW JAHN**

I. QUALIFICATIONS

I, Andrew Jahn, am a biological oceanographer with over 40 years of experience in marine, estuarine, and some freshwater ecological studies. I have a B.S. degree in biological Sciences from the University of California at Davis and a Ph.D. in Biological Oceanography from the Woods Hole Oceanographic Institution. I have designed sampling programs and experiments to analyze effects of coastal power stations, spills, and various marine industrial activities since 1976. I have published peer-reviewed papers on precision and estimation methods in the fisheries literature and served as a peer reviewer for the journals Copeia, Fishery Bulletin, Journal of Experimental Marine Biology and Ecology, Transactions of the American Fisheries Society, Estuaries and Coasts, and CalCOFI Reports. I have also reviewed proposals and reports for the Los Angeles Department of Water and Power, Southern California Edison Company, National Science Foundation, Sea Grant, California Coastal Commission, San Francisco Estuary Institute, and various water quality and energy-related projects in coastal and inland waters. My recent contributions include an analysis of statistical power and sampling strategy for the fish contaminants study segment of the San Francisco Bay Regional Monitoring Program, experimental design for a study of pile-driving effects on juvenile salmon, an analysis of salmonid migration patterns in San Francisco Bay, and the development of a method for estimating fish loss at water export facilities in the Sacramento/San Joaquin Delta. My professional resume is included as Exhibit DDJ-330.

II. INTRODUCTION

Water pumping facilities of the State Water Project ("SWP") and the federal Central Valley Project ("CVP") entrain and kill fish incident to their operations. The purpose of my testimony is to provide sur-rebuttal to the rebuttal testimony of Charles Hanson (DWR-1223 Revised) to the conclusions in the 2010 Delta Flow Criteria Report regarding the effects, and the significance thereof, of existing SWP and CVP operations on salmonid populations.

III. SUMMARY OF TESTIMONY

A. Nature of the Flow-Survival Relationship for Chinook Salmon

As Hanson notes, it has been hypothesized that alteration of flow in the delta by the CVP and SWP export facilities alters the migration routes of juvenile salmon. Hanson cites Kimmerer (2008), Windell et al. (2017), and SST (2017) as authorities for stating that changes in flow due to exports cause indirect mortality to salmonids (p. 7 at line 20-24.) Indirect losses due to changes in migration routes were not studied in Kimmerer (2008) (Exhibit CSPA-357), but were studied in another 2008 publication by Kimmerer and Nobriga (Exhibit DDJ-336.)

The 2010 Delta Flow Criteria Report cited Kimmerer and Nobriga (2008), and the reverse flow restrictions in the NMFS BiOp. (Exhibit SWRCB-25, p. 33.) The NMFS BiOp attributes entrainment effects to changes in Old and Middle River ("OMR") flow due to the exports. Kimmerer and Nobriga (2008) found entrainment effects to be due to a combination of inflow to the delta and exports, and Zeug and Cavallo (2014) found both factors to be significant predictors of salmon mortality. Therefore the hypothesis to be examined here should be restated as:

- H_1: High exports relative to delta inflow cause changes in migration routes of juvenile salmonids resulting both directly and indirectly in reduced survival.

Hanson re-analyzes US Fish and Wildlife Service ("USFWS") Coded Wire Tag ("CWT") Chinook salmon data as part of his argument to counter the hypothesis that SWP and CVP operations affect the survival of juvenile salmon. Hanson then states this hypothesis as predicting that effects on survival should be seen as due to exports alone, that is, neglecting inflow to the delta. His first-order treatments of the data reflect this over-simplification and are therefore misleading. Simple changes in the approach to the same data, though still crude, produce a roughly 10-fold reduction in uncertainty and reveal a stronger relationships between project-altered flow characteristics and salmon mortality. This simple modification shows that the USFWS data provide more support, not less, for hypothesis H_1. Salmon direct loss to exports is likely underestimated.

B. Salmon Direct Loss to Exports is Likely Underestimated

Contrary to the 2010 Delta Flow Criteria Report, Hanson concludes that population effects from direct losses due to exports are not biologically significant. It is my professional opinion that all the estimates of salmon mortality based on expanded salvage alone at the state and federal export facilities are underestimates, because predation in the approaches to the facilities has not been sufficiently studied and guidance efficiencies in the facilities are over-estimated. The true intakes of these facilities are those reaches of OMR where (and when) reverse flows begin to move the fish toward the pumps. The difference in mortality between these OMR reaches and Chipps Island of fish that go through the export facilities vs. fish taking alternate routes would be a true measure of project effects.

As acknowledged by Hanson on cross-examination, Kimmerer (2008) found that estimates of salvage loss are highly sensitive to pre-screen loss estimates. (August 30, 2018 Hearing Transcript, pages 68 at 1, to 69 at 14.) There are many sources of errors for expanded salvage. Fish counts from the salvage are expanded to adjust for sampling fraction (hours) but then expanded further for efficiency of the guidance systems (louvers) and then again by, for want of a better term, "pre-screen loss" (e.g., Kimmerer 2008, Jahn 2011, Zeug and Cavallo 2014). A further adjustment for cleaning operations is also necessary at the CVP (Jahn 2011). The problem at SWP is that the pre-screen loss estimates for salmon (and steelhead) at SWP are based on studies that begin at the entrance to Clifton Court Forebay. Jahn (2011) and Grossman et al. (2013) noted that, because of the mobility of the major predator (striped bass), high predation rates can be expected for some distance outside the forebay. For salmon, the SWP pre-screen loss estimate is based on eight experiments (Gingras 1997). And for the CVP, a stipulated value of 0.15 is used, but it is merely a placeholder number that no one has ever changed, and is not based on any data.

C. Transit Time and Survival Are Improved by Stronger Sacramento River Flows; Despite Hanson's Contrary Implication

The 2010 Delta Flow Criteria Report cites many US Fish and Wildlife Service ("USFWS") studies on flow-survival relationships, based on Coded Wire Tag ("CWT") data. (Exhibit SWRCB-25, p. 52-54.) Section 3 of Hanson's testimony, beginning on p. 19, questions the strength of the flow-survival relationship for Sacramento River Chinook Salmon, based on re-analysis of the USFWS CWT data. My examination of Hanson's data shows that a reasonable view of the USFWS CWT data provides much stronger support for the conclusions of the USFWS CWT studies than Hanson's re-analyses imply.

D. Population-Level Significance of Salmon Loss Estimates

Some of Hanson's literature citations, though not untruthful, are misleading. For example:

- In citing the high survival of salmon through the "Delta Region" reported by Michel et al. (2015), Hanson fails to clarify that the authors' definition of the delta for this purpose included the main stem of the Sacramento River between Freeport and Chipps Island. Even so, scaling their findings to the number of river miles included, the authors reported survival values per 10 km that indicate the only part of the migration route more lethal to juvenile salmon is the lower bays region.

- As a counter-argument to the expectation that high river flows should increase survival Hanson cites the report of Buchanan et al. (2018) of 2% survival of San Joaquin salmon in 2011, a wet year. However, he shows on the same page, but does not call out, the estimate of Michel et al. (2015) of relatively high survival (>15%) of Sacramento River salmon (a large majority of the outmigrants) in the same year. Proximity of the San Joaquin migratory routes to the facility intakes (discussed by Zeug and Cavallo, 2014) may well explain the difference between these results, though water quality problems in the southern delta (Grossman et al. 2013) might have contributed to the poor result for San Joaquin fish.

E. Variability and Uncertainty

Hanson uses the words uncertainty and variability 24 times. With high variability, there is of course the need to perform a large number of repeated studies to reduce uncertainty. But the thrust of his testimony is that the changes in operations recommended in the 2010 Flow Criteria Report and the Phase II Technical Basis Report should be put on hold while these studies are performed. The need for some such studies was noted a decade or more ago (e.g., of pre-screen loss of Chinook salmon: Williams 2006, Kimmerer 2008), and resource managers still await them. Moyle et al. (2017) state that winter run salmon face immediate risk of extinction. Regarding his take estimate of winter-run by the export facilities, Kimmerer (2008) wrote, "From a population maintenance standpoint, the calculated loss rate at the export facilities would be a significant component of direct anthropogenic mortality." (Exhibit CSPA-357, p. 24.)

Waiting for greater certainty in the flow-survival relationship of this ESU would stand the risk of losing this unique and valuable resource.

IV. DETAILED TESTIMONY

Hanson claims as follows:

> [new] information suggests that the 2010 Flow Criteria Report and the Phase II Technical Basis Report should not be accepted by the SWRCB as the best available science without further consideration of current science.

(Exhibit DWR-1223 Revised, p. 3:8-13.)

The 2010 Delta Flow Criteria Report (Exhibit SWRCB-25) discusses direct and indirect mortality from entrainment (Exhibit SWRCB-25, p. 34.) Hanson mentions both direct and indirect mortality caused by the pumping operations, though it is not always clear what he means by these terms. At the outset, it will be useful to define direct mortality as the estimated number of entrained fish that are not returned live to the estuary. Indirect mortality, then, refers to mortality attributable to alterations in flow patterns that influence migration routes and cause excess mortality along those routes. Many tagging studies necessarily combine these terms into total mortality (or survival) along routes that may or may not include the export facilities.

A. Nature of the Flow-Survival Relationship for Chinook Salmon

The 2010 Delta Flow Criteria Report cites the restrictions on OMR flows in Action IV.2.3 in the National Marine Fisheries Service ("NMFS") Biological Opinion ("BiOp.") (Exhibit SWRCB-25, p. 34.) The NMFS BiOp opines that reverse (negative) flows in OMR above -5,000 cfs sharply increases loss of juvenile salmon at the export facilities (Exhibit SWRCB-84, p. 361.) The NMFS BiOp cites in part graphs from DWR data on OMR flows and older juvenile loss, Figures 6-65 and 6-66 on p. 361 to 362. Figures 6-65 and 6-66 are reproduced here as Figures 1 and 2.

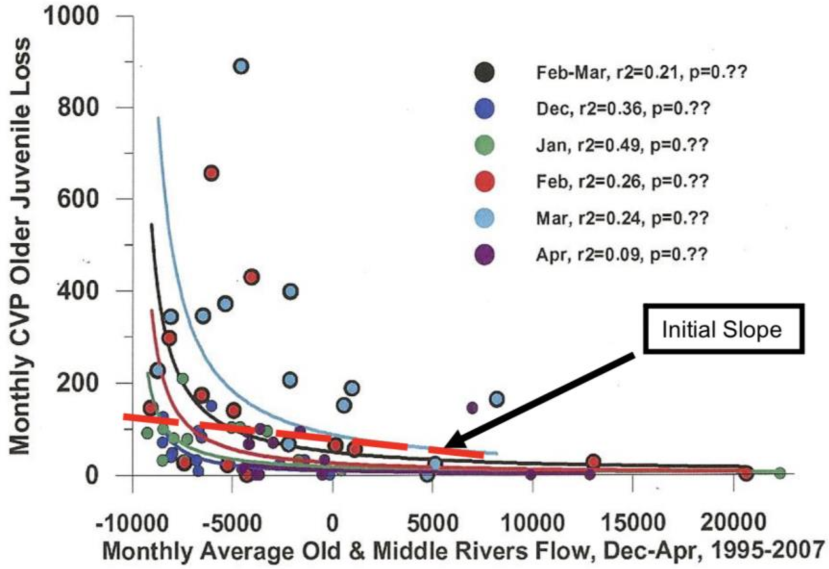

Figure 1. Relationship between OMR flows and entrainment at the CVP, 1995-1997. From Figure 6-65 in the NMFS BiOp.

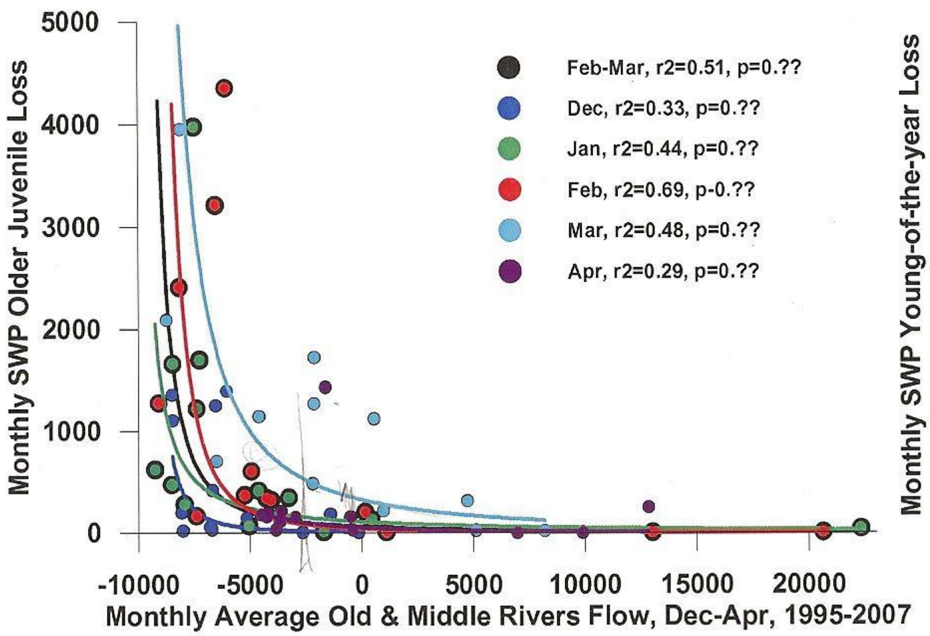

Figure 2. Relationship between older juvenile salmon loss at the SWP, 1995-1997. From Figure 6-66 in the NMFS BiOp.

The NMFS BiOp defines the OMR flows as the sum of the tidally filtered flow estimates of the U.S. Geological Survey stations, Old River at Bacon Island, and Middle River at Middle River (Exhibit SWRCB-84, p. 648, footnote 36.)

The 2010 Delta Flow Criteria Report also discusses net OMR flows, which are "calculated as half the flow of the San Joaquin River at Vernalis minus the combined SWP and CVP pumping rate." (Exhibit SWRCB-25, p. 33.) According to the 2010 Delta Flow Criteria Report:

> Net OMR reverse flows are now a regular occurrence in the Delta (Figure 8). Net OMR reverse flows are caused by the fact that the major freshwater source, the Sacramento River, enters on the northern side of the Delta while the two major pumping facilities, the SWP and CVP, are located in the south (Figure 1). This results in a net water movement across the Delta in a north-south direction along a web of channels including Old and Middle rivers instead of the more natural pattern from east to west or from land to sea."

(*Id.*)

The 2010 Delta Flow Criteria Report also cites the particle tracking model (PTM) studies by Kimmerer and Nobriga (2008) in support of entrainment effects (Exhibit SWRCB-25, p. 34.) Kimmerer and Nobriga found sharp increases in entrainment with increasing export flows, writing "The ratio of flow into the export facilities to freshwater flow into the Delta (export:inflow or E:I ratio) was a useful predictor of entrainment probability if the model were allowed to run long enough to resolve particles' ultimate fate." (Exhibit DDJ-336, p. 1.)With regard to juvenile salmon, they wrote the following:

> Salmon smolts are not particles; they have complex behaviors and are strong swimmers. We do not know what cues them to navigate downstream and out to the ocean. However, there are two reasons why PTM results may be informative with regard to salmon. First, whether the fish have strongly directed movement or not, they swim in the channels where they are subject to tidal and residual currents, and thus they will be distributed among alternative pathways during downstream migration, since it seems unlikely that they can distinguish among pathways. Although this distribution may differ from that of the water, it will still result in a dispersive movement pattern. Second, a recent unpublished report on radio tracking of larger yearling Chinook salmon concluded that the movement of the fish could not be distinguished from tidal excursions, and that any seaward-directed movement must be subtle (Vogel 2004). We do not claim that the specific results presented here represent actual movements of salmon; rather, these results indicate what factors may or may not be important in determining how salmon smolts may move through the Delta.

(Exhibit DDJ-336, p. 20.)

I concur with this opinion.

Hanson cites a more recent study by Zeug and Cavallo (2014.) (Exhibit DWR-1364.) This study contradicts his re-analysis of the CWT data. Zeug and Cavallo (2014) identified both

Delta input and export volumes as significant factors in export facility salvage of CWT hatchery salmon from both Sacramento River and San Joaquin River releases. Because high rates of export should be expected to have greater effects at times of low Delta inflow, and smaller effects at times of less inflow, and *vice versa* (Zeug and Cavallo 2014, Table 1), it makes sense to consider both variables when examining the relationships of flow and salvage or survival. Formally, then, the working hypothesis in the 2010 Delta Flow Criteria Report and more recent studies can be stated as follows:

- H_1: High exports relative to delta inflow cause changes in migration routes of juvenile salmonids resulting both directly and indirectly in reduced survival.

In his testimony, Hanson's analysis of USFWS CWT data (DWR Exhibits 1387a and 1387b) uses ordinary least squares regression to test the single-factor hypotheses that positive effects on salvage and negative effects on survival are predicted by exports alone. The spreadsheet in Exhibit DWR-1387b is clearly the source of Hanson's figures 2, 3, and 5, although the file is missing one release of approximately 50,000 fish (i.e., there are 117 releases totaling 14,153,528 fish). For comparison to the original, I reproduce Hanson's Figure 5 here (Figure 3). In this graph, and in Hanson's Figures 2 and 3, export flow serves as the horizontal axis of three scatter plots with poor-fitting regression lines. I re-analyzed Hanson's survival index, truncating two of the values >1 to =1, and incorporating Delta inflow in the ratio of exports:inflow (E:I, as in Kimmerer and Nobriga 2008). The graph is shown on the next page as Figure 4.

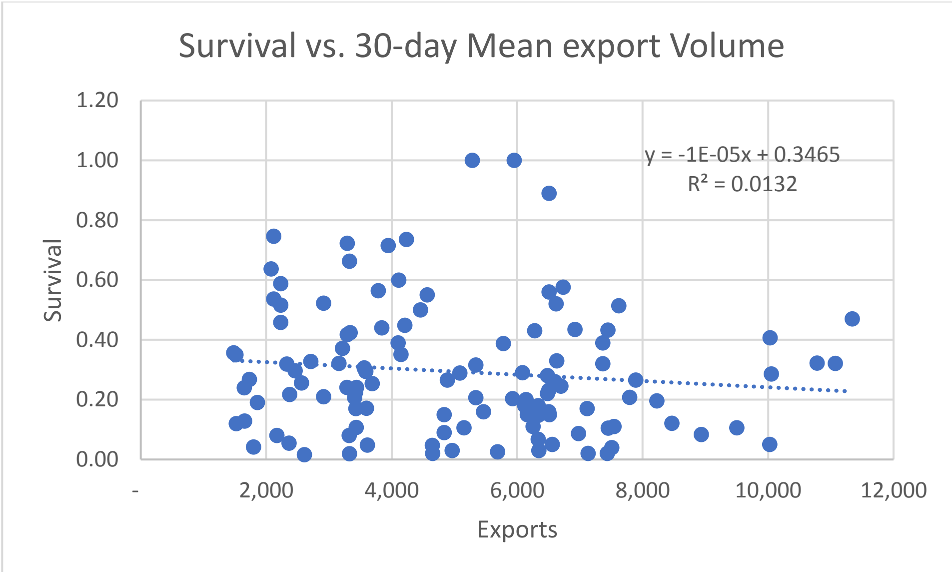

Figure 3. Near-reproduction of Hanson's regression of Survival vs. 30-day average CVP and SWP exports. The intercept and R^2 are all within rounding error of the values reported in Hanson's Figure 2, and the slope is just slightly steeper.

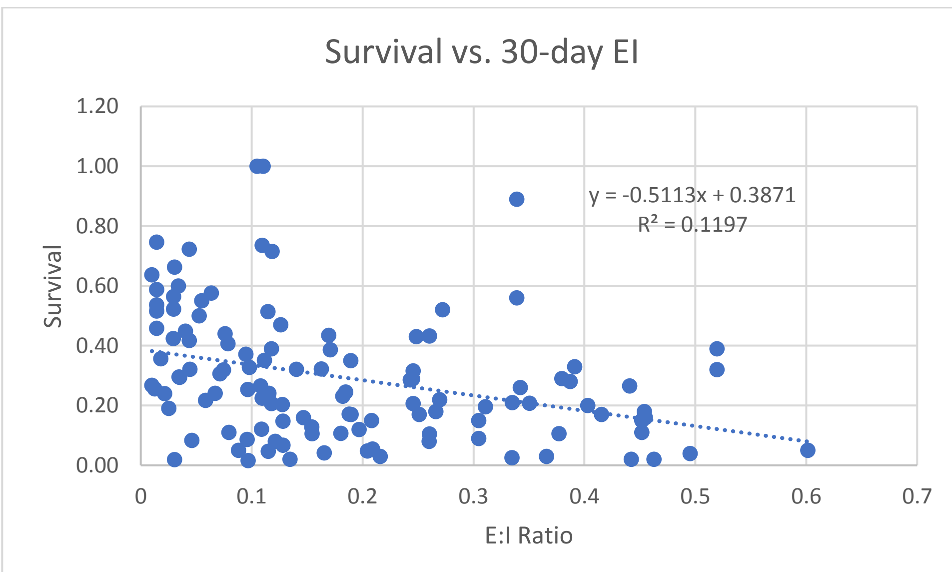

Figure 4. Re-analysis of Hanson's survival index using the ratio of 30-day average exports to 30-day average Delta inflow as the predictor variable.

The regression for survival using E:I (Figure 4) instead of exports alone (Figure 3) shows a nearly ten-fold increase in R^2 (10-fold decrease in uncertainty). I do not present Figure 4 as a recommendation for using least squares regression on these data, but simply to show that the data, approached in the context of the NMFS BiOp, provide *more* support – not less – for H_1.

The salvage data are not suitable for this sort of analysis, because most of the values are zero. Hanson's Figures 2 and 3, which show confidence bands overlapping zero and, in Figure 3, a negative intercept, should be ignored. By giving equal weight to flow data for times when few fish were in the system, Hanson introduces noise. In contrast to Hanson, Kimmerer (2008) analyzed 64 hatchery releases from 1989 to 2005 totaling about 3.5 million CWT Chinook. By weighting the export flows according to the number of fish captured at the facilities and at Chipps Island in a given time period, Kimmerer removed noise in the data caused by high export rates at times of low fish abundance.   Kimmerer's results of salvage vs. exports (Figure 9, Exhibit CSPA-357, p. 19) are reproduced below as Figure 5

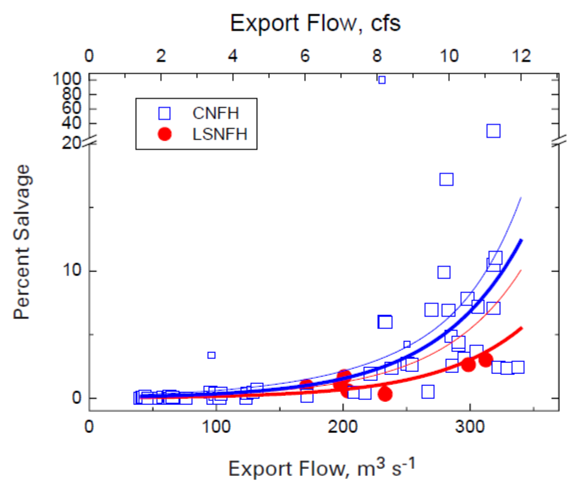

Figure 9. Chinook salmon. Relationship of estimated proportional salvage of tagged smolts at the fish facilities, P_S, to export flow. Small symbols represent data based on six or fewer fish caught, which were not used in determining the line. Lines are from a generalized linear model with log link function and variance proportional to the mean ($p < 0.0001$, 57 df), with source of fish as a categorical variable. Thick lines are predictions for fish from each hatchery; thin lines are upper 90% confidence limits of the predicted mean values.

Figure 5. Graph of percent salvage vs. export flow from Kimmerer 2008

While Hanson's analysis adds a new look at old data, his methodology reflects none of the refinements of either the NMFS BiOp, the 2008 Kimmerer analysis, or the more recent 2014 analysis by Zeug and Cavallo, which he cites.

Zeug and Cavallo analyzed data for 15 years of CWT releases (1000 releases of some 35 million fish), treating positive salvage counts separately from zero counts, for which they used a zero-inflated negative binomial model. For salmon releases in the Sacramento River, they obtained significant effects of both Delta inflow (flow: negative effect for counts, positive for zeros) and exports (diversion: positive for counts, negative for zeros) for salvage at CVP (their Table 3). At SWP, exports were significant for both models, but flow was significant only for the zero-inflation model. Other variables, especially Delta Cross Channel condition and fork length, were significant for some cases. For San Joaquin River releases, flow was significant only for zeros at CVP; exports were significant for both models at both facilities.

Despite strong relationships between salvage and flow variables, Zeug and Cavallo (2014) did not find consistent relationships between salvage and survival to Chipps Island. They note the small percentages of fish from the release groups lost to the facilities compared to ranges of mortality estimates obtained from acoustic tag (AT) studies, and uncertainties in the loss estimates (expanded salvage) as possible contributing problems. However, Zeug and Cavallo report percentages of migration mortality as high as 5% for winter-run and even higher for some releases of late-fall run and San Joaquin fall run salmon, although only Coleman releases of late-fall run showed the expected increase in relative loss with increasing diversion rate. Most of these relative loss results, if accurate, do contrast with the findings supporting H_1, as claimed by Hanson. Accuracy of the estimates is not assured, as discussed by Zeug and Cavallo (2014). I discuss accuracy of the salvage expansion into loss estimates in the next section.

B. Salmon Direct Loss to Exports is Likely Underestimated

The 2010 Delta Flow Criteria Report states:

> The export facilities have been documented to entrain most species of fish present in the upper estuary. (Brown *et al*. 1996,.) Approximately 110 million fish were salvaged at the SWP pumping facilities and returned to the Delta over a 15 year period, (Brown et al. 1996.) However, this number underestimates the actual number of fish entrained, as it does not include losses at the CVP nor does it account for fish less than 20 mm in length.

(Exhibit SWRCB-25, p. 33.)

In rebuttal, Hanson concludes from re-analysis of the CWT data that direct loss from exports does not have population-level impacts. However, he notes that the actual degree of mortality due to export activities is unknown because of uncertainties in pre-screen mortality. Winter and Spring-Run Sacramento River Chinook ESUs are listed, and so some precaution is in order. Estimates of salmon mortality at the state and federal export facilities are almost certainly underestimates, because predation in the approaches to the facilities has not been sufficiently studied and its likely spatial extent is under-appreciated (Jahn 2011.) The pre-entrapment survival and guidance system efficiency parameters used by some authors (e.g, Kimmerer 2008, Zeug and Cavallo 2014) are also too high. The paucity and insufficiency of studies has been pointed out by others, including Williams (2006), Kimmerer (2008) and Zeug and Cavallo (2014). The expansion of salvage counts into loss estimates is a multi-step process (Jahn 2011) in which fish counts from the salvage are adjusted for sampling fraction (hours) and then expanded further for efficiency of the guidance systems (louvers) and then again by, for want of a better term, "pre-screen loss." Further adjustments are made for cleaning operations, etc. The greatest source of potential error is in the pre-screen loss values used by DWR and others. Earlier (Jahn 2011), I wrote:

> Among the "action elements" analyzed by NMFS (2009), the one pertinent to the present effort is "Exports from the CVP and SWP water diversions facilities which include changes in delta hydrodynamics, direct entrainment of listed fish at the project facilities, and indirect mortality within the delta related to exports and non-export factors." Non-export factors are not within the scope of this report. However, as the foregoing mention of pre-screen loss indicates, there is no logical bright line between direct effects within the fish screening facilities and predation effects within and near them. As demonstrated by Kimmerer (2008), uncertainties and unknowns concerning these near-field predation effects rank among the leading impediments to accurate and precise fish loss estimates attributable to CVP/SWP operations. There are two main reasons given in NMFS (2009) to question the accuracy of pre-screen loss estimates: naivety of tagged hatchery experimental subjects, and potential exit of tagged fish from the study area (sometimes called "non-participation"). The fate of experimental subjects that do not end up in the salvage is unknown but generally assumed to represent loss in the experimental results. Especially under low-flow conditions, fish can leave the area in which they are introduced and swim into Old River, or even into the other project (CVP to SWP and vice versa). Clark et al. (2009) and USBR (in comments on earlier drafts of this report) have

> suggested that such non-participating fish be excluded from the loss side of the survival estimate, resulting in higher estimated survival and smaller loss estimates. However, the lack of a reasonable definition of the near-field entrainment zone, and the near absence of predation studies outside the physical boundaries of the CVP/SWP facilities, give rise to the possibility that all existing loss estimates are biased low.

One problem at SWP is that the pre-screen loss estimates for salmon (and steelhead) are based on studies that begin at the entrance to Clifton Court Forebay (CCF). Grossman et al. (2013) called CCF a "predation hot-spot" and noted that, because of the mobility of the major predator (striped bass), high predation rates can be expected for some distance outside the forebay. Experiments conducted over a wider region, including parts of OMR, would surely increase estimates on pre-screen loss and thus of direct mortality due to SWP operations. For salmon, the SWP pre-screen loss estimate is based on just eight experiments (Gingras 1997), which provide a small sample for calculating a standard error leading to an estimation of uncertainty. Moreover, none of the existing pre-screen loss estimates are independent of the estimates of efficiency of the guidance systems – one reason why I recommended new work to simplify the expansion calculation by combining the guidance efficiency with pre-screen loss (Jahn 2011).

Gingras used estimated guidance efficiencies ranging from 0.29 to 0.81, to expand the salvage of his experimental subjects (dyed Chinook salmon). At present, guidance system efficiencies are calculated using a poorly documented relationship of efficiency with fish size and water velocity through the primary louvers (Exhibit DDJ-327, modified from Jahn 2011) that generally produces values <0.75. All of the above guidance efficiencies are less than the value (0.9) used by Kimmerer (2008) and Zeug and Cavallo (2014), leading to underestimated mortality for this reason alone.

At the CVP export facilities, there is no estimate of pre-screen loss. Rather, a stipulated value of 0.15 is used, backed by no data whatsoever. (August 30, 2018 Hearing Transcript, page 72, lines 8-9) As Hanson testified, it was a placeholder number that no one has ever changed.

(*Id*.) That it continues to be used, after several decades of CVP operations, should be an embarrassment to all involved. I am reminded of a comment made by Hanson (1976):

> In addition to internal censorship and suppression of results opposing the preconceived conclusions regarding potential environmental damage, many clients retain the right to review and approve material prior to public release. In the case of such client review, tremendous pressure can be brought to bear on consultants, thus assuring suppression of undesirable results. Under such conditions detrimental environmental impacts and the cost of environmental protection for the proposed project are calculated- followed by a quiet reversion to an attitude that any technological development that has good economic payoffs should be pursued.

(Exhibit DDJ-334, p. 2)

In my view, a total loss parameter that includes in-facility loss along with predation losses in the nearfield environment should be estimated for both facilities simultaneously under a representative array of flow and other conditions. The true intakes of these facilities are those reaches of OMR where (and when) reverse flows begin to move the fish toward the pumps. In principle, the difference in mortality between these OMR reaches and Chipps Island of fish that go through the export facilities vs. fish taking alternate routes would be a true measure of project effects. Practicability will be an issue, but experts could work them out to a reasonable design. Given the track records of DWR and, especially, USBR, this will likely never happen as long as those agencies determine funding, schedule, data availability, and review. If such studies were to be done, we should not be surprised to learn that present direct loss estimates are low by a factor of two or more.

C. Transit Time and Survival Are Improved by Stronger Sacramento River Flows; Despite Hanson's Contrary Implication

The 2010 Delta Flow Criteria Report cites many USFWS studies on flow-survival relationships, based on CWT data. (Exhibit SWRCB-25, p. 52-54.) Section 3 of Hanson's testimony, beginning on p. 19, questions the strength of the flow-survival relationship for Sacramento River Chinook Salmon. In addition to his choice of literature citations, Hanson provides his re-analyses of USFWS CWT data (Exhibits DWR-1387a and DWR-1387b) to illustrate his point. Hanson's testimony regarding effects of Sacramento River flow on his index of “group survival” of juvenile CWT salmon (his Figure 7) cannot be reproduced from file DWR-1387b, because the 14-day average flow data are not in the file. The file does, however, contain a column labeled “group survival” and another labeled “30 day Sac River”. A least-squares regression analysis using these two variables produces the graph shown in Figure 4. This regression has a slightly steeper slope and double the R^2 value of Hanson’s regression, providing stronger evidence in support of the “theory that increasing river flow will result in faster migration rates through the Delta or reduced exposure to in-Delta predation mortality” (Exhibit DWR-1223 revised, p. 24, lines 3-4).

I was able to reproduce Hanson’s analysis of transit time vs. flow (his Figures 9 and 10) only by using the time to first detection at Chipps Island. In other words, his analysis uses the minimum measured transit time. Another measure of transit time, such as the mode or other measure of central tendency, would make more sense. File DWR-1387b contains only the times of first and last captures at Chipps Island for each release group, and so the best option with this data set is to use the time in days to the mid-point of the transit interval. This mid-point – labeled “Median transit time” in Figure 5 to distinguish the statistic from the mean flow labeled “average” – produces a much stronger regression with a low but significant R^2 ($p<0.01$). In presenting Figures 4 and 5, once again I do not claim that either analysis is particularly thoughtful or even proper. However, in both cases, a reasonable view of the data provides much stronger support for the “theory” than Hanson’s analyses imply.

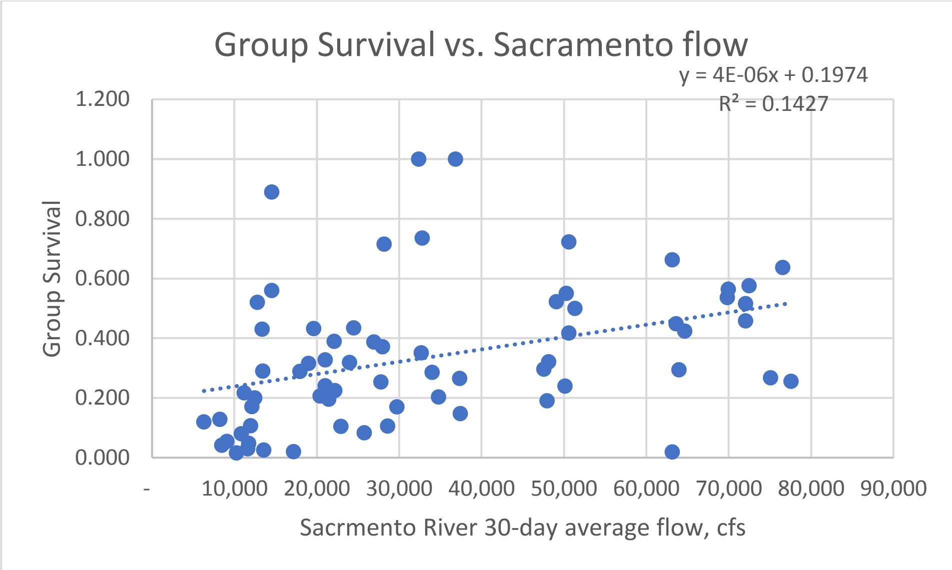

Figure 6, Re-analysis of the flow vs. group survival relationship.

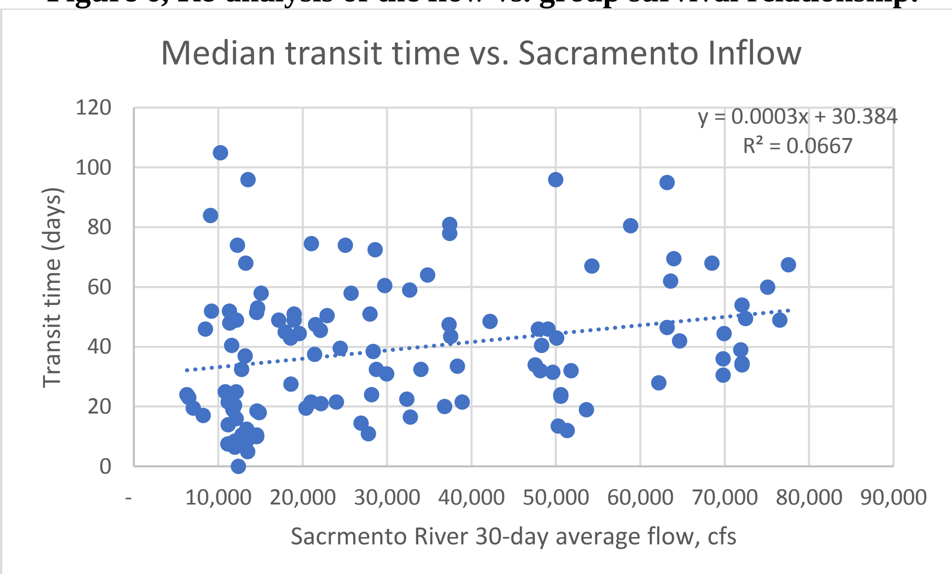

Figure 5. Mid-point of transit interval vs. 30-day average Sacramento River flow

D. Population-Level Significance of Salmon Loss Estimates

Moyle et al. (2017) state that winter run salmon face immediate risk of extinction. Regarding his take estimate of winter-run by the export facilities, Kimmerer (2008) wrote, "From a population maintenance stand- point, the calculated loss rate at the export facilities would be a significant component of direct anthropogenic mortality." If population-level mortalities estimated by Zeug and Cavallo (2014) are low even by a factor of 2, then some of them are as high as that of Kimmerer (2008).Michel et al. (2018) stated, "Our study has demonstrated remarkably low survival rates for acoustically tagged hatchery-origin late-fall-run Chinook salmon smolts in the Sacramento River. The Sacramento River is also home to three other runs of Chinook salmon that migrate at smaller sizes and later in the season (Fisher 1994), when water temperatures are higher and predators may be more active. These other runs may therefore be experiencing even lower survival." Whether preventable incremental mortalities of critically endangered (and economically valuable) fish stocks are tolerable is not a purely scientific question. In this context, I offer the following quotation from the U. S. Commission on Ocean Policy (2004, emphasis added).

> In contrast to the precautionary principle, the Commission recommends adoption of a more balanced *precautionary approach* that weighs the level of scientific uncertainty and the potential risk of damage as part of every management decision. Such an approach can be explained as follows:
>
> **Precautionary Approach:** To ensure the sustainability of ecosystems for the benefit of future as well as current generations, decision makers should follow a balanced precautionary approach, applying judicious and responsible management practices based on the best available science and on proactive, rather than reactive, policies. **Where threats of serious or irreversible damage exist, lack of full scientific certainty shall not be used as a justification for postponing action** to prevent environmental degradation. Management plans and actions based on this precautionary approach should include scientific assessments, monitoring, mitigation measures to reduce environmental risk where needed, and periodic reviews of any restrictions and their scientific bases.

E. Variability and Uncertainty

By my count, Hanson's testimony contains the words variability and uncertainty 24 times. There is certainly much variability in the environments used by migrating juvenile salmon, and there is much uncertainty attending estimates of many of the variables needed by managers to inform decision making. To his credit, parts of his testimony (e.g., p. 18, lines 4 to 10) identify studies that should help reduce uncertainty. However, in other parts of the testimony Hanson exaggerates it.

I pointed out in section IV(A) that Hanson's analysis of CWT juvenile survival uses a predictor variable that provides an incomplete measure of flow conditions in the delta, obtaining a measure of uncertainty that can be reduced nearly 10-fold by a still-crude combination of variables. (This analysis should be re-done by a competent analyst who has the time and support to do so.) And his “analysis” of the salvage data is so inadequate that its only purpose can be to emphasize uncertainty over information. In some cases, his citations of the literature also imply more uncertainty than actually exists.

For example, in his adopted role as contrarian, Hanson cites the high survival of salmon through the “Delta Region” reported by Michel et al. (2015). In doing so, Hanson fails to describe that the authors’ definition of the delta for this purpose included the main stem of the Sacramento River between Freeport and Chipps Island or that the authors’ Delta Region as was the smallest of their five regions. Scaling their findings to the number of river miles included in each region, the authors reported:

> Survival rate on a reach-by-reach basis was quite variable. During the first 4 years of the study, the upper river reaches (reaches 1 through 8; rkm 518–325) had some of the lowest survival per 10 km, and the lower reaches of the river (reaches 9–12; rkm 325– 169) had the highest. The delta was comparable to the upper river, and the San Francisco and Suisun bays (reaches 13–17; rkm 169–2) had the lowest survival rates

(Exhibit DWR-1340, Michel et al. (2015) at p. 1754.)

In other words, survival values per 10 km indicated the only part of the migration route more lethal to juvenile salmon than the Delta region was the lower bays region. (The fifth year of the study, 2011, had detection difficulties due to high flows and so was analyzed separately; in Figure 3 of Michel et al. -reproduced as figure 6 of Hanson’s testimony- the upper and lower Sacramento regions were combined into the “major region” River.

As a counter-argument to the expectation that high river flows should increase survival Hanson cites the report of Buchanan et al. (2018) of 2% survival of San Joaquin salmon in 2011, a wet year. However, he shows on the same page, but does not call out, the estimate of Michel et al. (2015) of relatively high survival (>15%) of Sacramento River salmon (a large majority of the outmigrants) in the same year. Proximity of the San Joaquin migratory routes to the facility intakes (discussed by Zeug and Cavallo, 2014) may well explain the difference between these results, though water quality problems in the southern delta (Grossman et al. 2013) might have contributed to the poor result for San Joaquin fish.

With regard to the survival of critically endangered winter-run Chinook salmon, at least two questions must be answered:

1. Will export-related take of migrating juveniles lead to better escapement of adults from the ocean fisheries?
2. Are the 2010 Delta Flow Criteria clearly over-protective of this species?

The answer to the first question is "probably not." Although certain compensation mechanisms might be argued, it would seem prudent to minimize anthropogenic mortality where economically feasible. As to the second question, I would reverse the burden of proof in the face of all the true uncertainty stressed by Hanson and say that the answer is definitely "no". If future studies, including some recommended by Hanson, provide for more informed decisions, the criteria can be revisited adaptively.

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V. CONCLUSIONS

In conclusion, Hanson's re-analyses of CWT data have serious flaws that make his graphs and re-analyses obfuscatory, and undermine his conclusions. A comparison of Hanson's analyses with the peer-reviewed studies that the 2010 Flow Criteria Report relies on shows that those studies use methods which are much better formulated. Therefore, Hanson's graphs and re-analyses do not rebut the conclusions in those studies.

An examination of Hanson's references to peer-reviewed literature also finds misleading characterizations. Contrary to Hanson's assertions, the conclusions in the 2010 Delta Flow Criteria Report are supported by more recent, peer reviewed studies.

Hanson is correct that there is variability and uncertainty in the data. While Hanson recommends studies that would reduce uncertainty, the results of such work should not be analyzed by the methods he used in his testimony.

The 2010 Flow Criteria provide reasonable and prudent measures to protect the viability of salmonids, including winter-run, a valuable resource that is considered by experts to be in immediate risk of extinction.

Some estimates of population-level incremental mortality of winter-run salmon approach estimates of mortality caused by the mixed-stock ocean fisheries. Though these estimates are uncertain, it would be shameful to witness the extinction of this species through inaction while awaiting further study.

A precautionary approach to conservation of winter-run salmon should entail a balanced, program of protective flow criteria, research and management options that give fair weight to the high risk of extinction of winter-run salmon while studies are performed to increase understanding of flow issues and reduce uncertainty of water export-caused direct and indirect mortality.

The West Coast salmon fishery has also been in decline and cannot wait for future studies. A precautionary approach would implement protective criteria to rebuild stocks to withstand the impacts of climate change.

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I declare under the penalty of perjury under the laws of the State of California that the foregoing testimony is true and correct, and represents my best professional judgment and is based on my review of the referenced documents. Executed on this 21th day of September, 2018.

Andrew E. Jahn, PhD