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7
8 **BEFORE THE**

9 **CALIFORNIA STATE WATER RESOURCES CONTROL BOARD**

10 **HEARING IN THE MATTER OF CALIFORNIA**
11 **DEPARTMENT OF WATER RESOURCES**
12 **AND UNITED STATES BUREAU OF**
13 **RECLAMATION REQUEST FOR A CHANGE**
14 **IN POINT OF DIVERSION FOR CALIFORNIA**
WATER FIX

TESTIMONY OF CHARLES H.
HANSON

15 I, Charles H. Hanson, do hereby declare:

16 I am a fisheries biologist and Certified Fisheries Professional with over 35 years of
17 experience in freshwater, estuarine, and marine biological studies. I have a Ph.D. in
18 Ecology and Fisheries Biology from the University of California, Davis, and a M.S. and B.S.
19 in Fisheries Biology from the University of Washington. I serve as co-chair of the
20 Collaborative Adaptive Management Team (CAMT) Salmon Scoping Team (SST) and was
21 one of the co-authors of the 2017 report titled Effects of Water Project Operations on
22 Juvenile Salmonid Migration and Survival in the South Delta (See DWR Ex. 1324). I have
23 contributed to the study design, analysis, and interpretation of fisheries, stream habitat, and
24 stream flow (hydraulic) data used to develop habitat restoration strategies, Habitat
25 Conservation Plans, Endangered Species Act consultations, and environmental analyses. I
26 have directed numerous investigations and environmental impact analyses for projects
27 sited in freshwater, estuarine, and marine environments of the San Francisco Bay/Delta,
28 the central and northern California coast, Puget Sound, Hudson River, and Chesapeake

1 Bay. I have participated as an expert witness on fisheries and water quality issues in
2 numerous public hearings and state and federal court litigation regarding salmon and
3 steelhead. I have been extensively involved in incidental take monitoring and
4 investigations of endangered species, development of recovery plans, consultations, listing
5 decisions and identification of critical habitat, and preparation of aquatic Habitat
6 Conservation Plans. I served as a member of the USFWS Native Delta Fish Recovery
7 Team, Central Valley Technical Recovery Team, 2007 USFWS Delta Smelt Recovery
8 Team, numerous technical advisory committees, and as science advisor to settlement
9 negotiations. I have also participated in the development of adaptive management
10 programs including real-time monitoring, management of power plant cooling water and
11 other diversion operations, and the San Joaquin River Vernalis Adaptive Management
12 Plan. I have authored more than 125 technical and scientific reports including reports and
13 publications related to Chinook salmon, steelhead, and other estuarine fish. My
14 professional resume is included as DWR Ex. 1205 and a PowerPoint presentation of this
15 testimony is included as DWR Exhibit 1386.

16 The purpose of this rebuttal testimony is to respond to the testimony provided by
17 several parties regarding Bay-Delta fishery issues with an emphasis on Chinook salmon
18 and steelhead produced in the Sacramento River watershed. My testimony is in direct
19 response to CSPA (CSPA-202, p.2) testimony that:

20
21 In considering conditions to place on the permits for the SWP and CVP in this
22 proceeding, the Board can and must evaluate conditions for all aspects of SWP
23 and CVP operation, not just those immediately related to the new points of
24 diversion.

25 In addition, my testimony is responding to issues raised regarding impacts to existing
26 conditions, specifically, CSPA-204, pp. 7 and 31-32; CSPA-202, errata, pp. 7-8; CSPA-202,
27 errata, p. 9, CSPA-202, errata, pp. 10-11; CSPA-202, errata, pp. 11-12; NRDC-58, errata,
28 pp. 4-24; April 11, 2018, Transcript, Vol. 28, pp. 24 and 111-112; April 16, 2018, Transcript,
Vol. 29, pp. 19:9 to 20:18, p. 22:10-18 and p. 24:12-19; and PCFFA-145.

1 ~~I am also responding to several parties who's experts suggested that the SWRCB's~~
2 ~~2010 Flow Criteria Report and the SWRCB's Phase II Technical Basis Report should be~~
3 ~~accepted without modification, suggesting that there was no new relevant information that~~
4 ~~should also be considered. (See e.g., CSPA-202, errata, pp. 7-11; April 11, 2018,~~
5 ~~Transcript, Vol. 28, p. 122; April 24, 2018, Transcript, Vol. 33, pp. 110-115; PCFFA-161, p.~~
6 ~~8:7-9.) This is inaccurate.~~ Since 2010, there has been a large body of highly relevant
7 scientific investigation, and this testimony is intended to identify some of that new
8 information. This information suggests that the 2010 Flow Criteria Report and the Phase II
9 Technical Basis Report should not be accepted by the SWRCB as the best available
10 science without further consideration of current science. In further response, I am attaching
11 technical comments on the 2010 Flow Criteria Report and the Phase II Technical Basis
12 Report that provide a more detailed explanation of science that should be considered in
13 SWRCB decision-making. (DWR-Exhibit 1325)

14 **I. SUMMARY OF TESTIMONY**

- 15 • Multiple historical physical and hydrologic changes have shaped the current
16 Delta;
- 17 • The current state of the Delta is the result of multiple physical and hydrologic
18 factors operating over multiple time scales;
- 19 • There is significant uncertainty regarding the nature, extent and magnitude of
20 the effect of current SWP-CVP operations as well as other stressors on salmonid survival;
- 21 • The relationship between Sacramento River flow rates and juvenile salmonid
22 survival is weak (large changes in river flow are needed to achieve even a small change in
23 salmonid survival in the Sacramento River and Delta) with high uncertainty (low R2 values);
24 and
- 25 • Multiple authors have concluded that flow alone cannot be used to restore the
26 Delta. As stated by the NAS, "The Delta as it existed before large-scale alteration by
27 humans cannot be recreated." (NAS 2012, p. 10, DWR Exhibit 1326) Buchanan et al.
28 (2018, p. 663; DWR Exhibit 1327) also concluded that increased flow alone will not be

1 sufficient to resolve the low salmonid survival in the Delta.

2 **II. TESTIMONY**

3 **A. MULTIPLE PHYSICAL AND HYDROLOGIC CHANGES HAVE**
4 **SHAPED THE CURRENT DELTA, THE RESULTS OF WHICH HAVE**
5 **AFFECTED SALMONID ABUNDANCE AND SURVIVAL.**

6 ~~Protestants have suggested that the current state of the Delta is primarily a result of~~
7 ~~the operation of the existing SWP-CVP. (See citations, above.)~~ However, the current state
8 of the Delta should be recognized as being the result of multiple factors that have occurred
9 over varying time periods and regions of the Delta. Before European settlement began in
10 the early 1800s, the Central Valley rivers flowed through approximately 400,000 acres of
11 wetlands and other aquatic habitats in the Delta (Whipple et al. 2012, p. 83, DWR Exhibit
12 1328) as well as upstream in the Sacramento River and other tributaries to the Delta. The
13 primary landscapes in the historical Delta included flood basins in the north Delta, tidal
14 islands in the central Delta, and a complex network of channels formed by riverine
15 processes in the south Delta. Over the last 160 years, 1,335 miles of levees have been
16 constructed to drain wetlands and convert them into farmland, flood control bypass
17 channels, and for other uses. These changes are summarized in Whipple et al. (2012) and
18 illustrated in Figure 1, (DW Exhibit 1328, p. 15) below. All of these changes have impacted
19 the ecology of the Delta and the abundance and survival of its native species.
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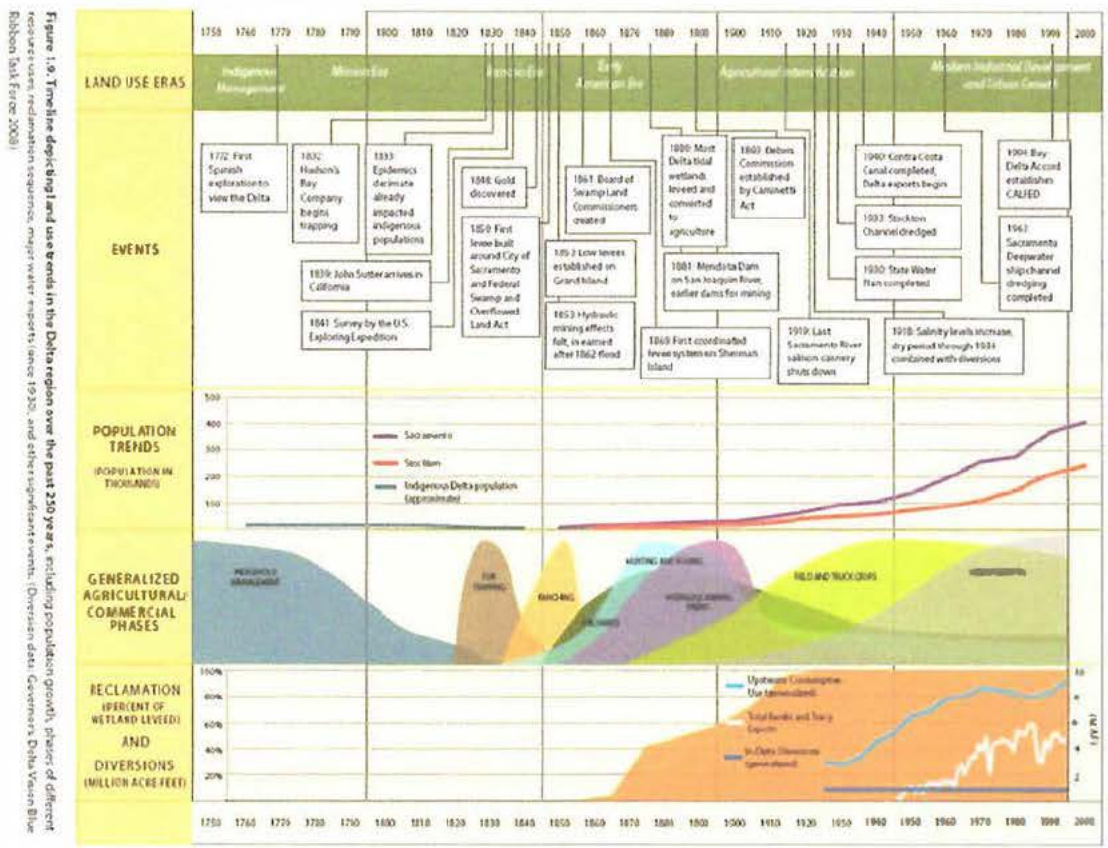


Figure 1. Timeline trends in changes within the Delta over the past 250 years (Source: DWR- Exhibit 1328 Whipple et al. 2012, p. 15)

The current state of habitat conditions in the Sacramento River and Delta, and survival and abundance of Chinook salmon and steelhead populations, is the result of these factors. This finding is consistent with the Delta Science Program panel report on the SWRCB Workshop on Interior Flows and Related Stressors (SWRCB Exhibit 56) which stated, "However, it is now generally agreed that population declines are a result of multiple stressors." (Id., p. 7.) It is also consistent with the Phase II Technical Basis Report ("Phase 2 Technical Report") which concluded, "Multiple mechanisms may be responsible for these [abundance] relationships, including effects on habitat suitability, catchability by trawl gear, and correlations with other environmental factors." (Phase 2

1 Technical Report, p. 3 9). These factors include (but are not limited to): ocean conditions,
2 contaminants, spawning gravel quality and availability, loss of historic floodplains and tidal
3 marsh, invasive species, predation, climate change, and reduced food production. (See
4 e.g., NMFS Recovery Plan for the Evolutionary Significant Unit of Sacramento River
5 Winter-Run Chinook Salmon and the Distinct Population Segment of California Central
6 Valley Steelhead Appendix B, p. 2 1 – 4 106 and 4 132 – A 137, July 2014. SWRCB
7 Exhibit-70).

8 After more than 100 years of physical and hydrologic changes in the Delta, with
9 multiple stressors acting on a multiple of time scales, the ability to restore fish abundance
10 and ecological processes using flow alone is highly uncertain. Recent science shows that
11 restoration efforts that address, and incorporate actions to improve, multiple factors are
12 more likely to yield positive results. As explained by Dr. Paul Hutton in his testimony,
13 unimpaired flow is not the same as natural flow (DWR Exhibit 1224, Sec. 4.D. citing Poff
14 and Zimmerman (2010 p. 1 and 9. DWR Exhibit 1330)). Also as explained by Dr. Hutton is
15 that in highly altered systems it is not possible to reliably predict the ecological results of a
16 new flow regime, and we cannot assume that those new flows will provide ecological
17 benefits (Id.) For example, Poff and Zimmerman (Id., p. 194 204) reviewed 165 papers
18 related to the natural flow regime. Their results revealed some sensitivity of different
19 ecological groups to alteration in flow management but robust statistical relationships were
20 not supported (Id.). Of 165 papers, 92% concluded adverse response to changed flows. In
21 largely unaltered river systems, the importance of flow in sustaining biodiversity and
22 ecological integrity is well established (Id.) However, establishing an appropriate flow in an
23 estuary is not as simple (Pierson et al. 2002, p. 7 DWR Exhibit 1331). As Poff et al. 1997,
24 p.780 (DWR- Exhibit 1332) observed, the ability to use flow as a restoration tool depends
25 on the present state of human intervention. The more altered the system, the more
26 uncertain it is that flow alone can achieve positive changes in the environment. For a more
27 detailed analysis of the extent that flow can be used to improve the ecosystem, see DWR
28 1333 (Ecosystem Change in the Bay-Delta Estuary: A technical assessment of scientific

1 information (2012).

2 **B. THERE IS SIGNIFICANT UNCERTAINTY REGARDING THE**
3 **NATURE, EXTENT AND MAGNITUDE OF THE EFFECT OF**
4 **CURRENT SWP-CVP OPERATIONS.**

5 Several Protestants definitively state that there was a high level of certainty
6 regarding the alleged negative effects of current SWP-CVP operations. (See citations,
7 above.) However, this level of alleged certainty is unwarranted. There is no clear evidence
8 that current SWP-CVP diversions in the south Delta are having a direct or indirect
9 population level effect on salmonids.

10 Juvenile Chinook salmon and Central Valley steelhead migrate from upstream
11 rearing habitat through the Delta and into coastal marine waters. Juvenile migration within
12 the Delta typically occurs during the winter and spring months. During their migration
13 through the Delta juvenile salmon and steelhead are vulnerable to direct losses (mortality)
14 from multiple sources (stressors) that include: predation by fish (e.g., striped bass,
15 largemouth bass, Sacramento pikeminnow, etc.) and birds, exposure to toxins, entrainment
16 at unscreened agricultural, municipal, and industrial water diversions, exposure to
17 seasonally elevated water temperatures, and other factors (Windell et al. 2017, p. 18-24
18 DWR Exhibit 1334).

19 **1. The USFWS CWT Studies Suggested that the Effect of**
20 **Current Entrainment in SWP-CVP Facilities is Low.**

21 It has been hypothesized (Kimmerer 2008 p. 4 and 18-20 (CSPA-Exhibit 357),
22 Windell et al. 2017, p. 19-24) that operations of the SWP and CVP export facilities indirectly
23 affect the survival of juvenile salmon and steelhead. It has been proposed that changes in
24 the direction and magnitude of tidal and current flows within the central Delta (e.g., Old and
25 Middle rivers reverse flows) as a result of water exports during the salmonid emigration
26 period leads to movement of juveniles into the central Delta which, in turn, contribute to
27 delays in downstream migration and increased salmonid mortality (SST 2017, p. 4-20
28 (DWR Exhibit 1337), Windell et al. 2017, p. 19-24). According to this hypothesis, the
survival of juvenile salmon and steelhead migrating through the Delta would be lower, and

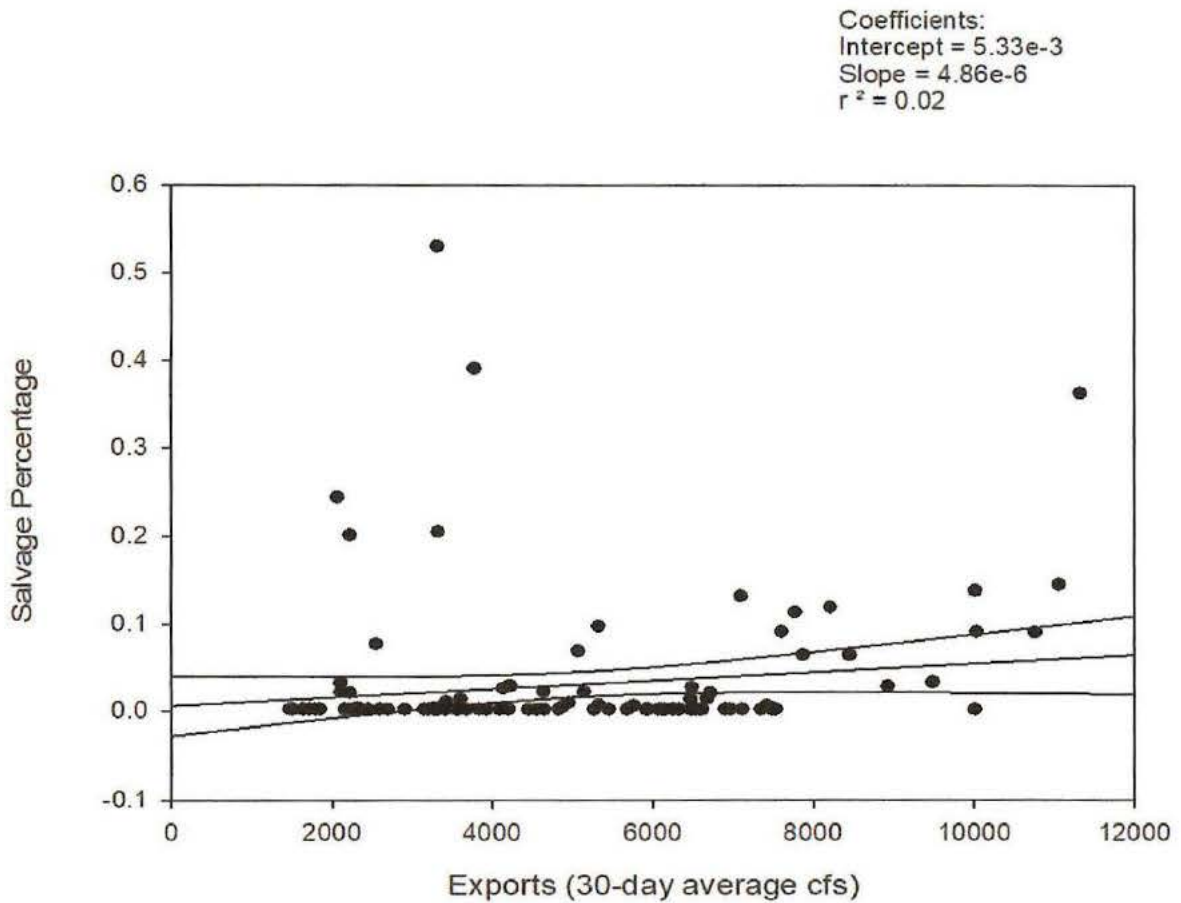
1 both direct and indirect mortality would be higher, when export rates are high, and salmonid
2 survival would be higher when exports are low. To help address these management
3 questions, I conducted a series of additional analyses using results of coded wire tag
4 (CWT) studies designed and implemented by USFWS to investigate survival relationships
5 for juvenile salmon migrating downstream through the Sacramento River and Delta. The
6 USFWS has conducted over 100 survival studies on the Sacramento River using juvenile
7 winter-run, spring-run, and fall-run Chinook salmon over the past three decades. The CWT
8 studies used in this analysis included results from 118 studies with a combined total of over
9 14,200,000 juvenile salmon released (USFWS unpubl. Data. DWR Exhibit 1387). Using
10 the USFWS' study data, I answered three management questions looking at the direct and
11 indirect effects of SWP-CVP operations, as follows:

12 ***What is the relationship, if any, between direct mortality of juvenile salmon***
13 ***and steelhead and diversion rates at the SWP and CVP export facilities?***

14 Using the USFWS CWT data, I calculated an index of direct losses as a result of
15 SWP and CVP export operations for each CWT survival test based on the percentage of
16 the number of fish released and the expanded estimate of salvage of that tag group in the
17 combined SWP and CVP fish salvage. For the study data analyzed, the percentage of
18 CWT salmon released into the upper Sacramento River subsequently collected at the
19 SWP-CVP fish salvage facilities averaged 0.03% (n=118; 95% CI = 0.0145), with a range
20 from 0 to 0.53%. The estimated percentage of each CWT group recaptured at the SWP
21 and CVP fish salvage facilities was then plotted against the average combined export rate
22 over the 30 and 60-day periods prior to the date of the last fish recaptured.

23 I hypothesized that if all other things being equal the SWP and CVP export rates
24 were an important factor affecting the percentage of salmon from the Sacramento River
25 collected in export facility salvage (direct losses), the percentage of tagged fish recaptured
26 at the salvage facilities would increase when export rates were higher. Figure 2 shows the
27 results of the analysis based on average export rates for the 30 days prior to the last
28 recapture. Results for average exports for the 60 days prior to the last recapture are shown

1 in Figure 3. Results of a linear regression model with 95% confidence intervals are also



17 depicted

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20 **Figure 2. Relationship between SWP and CVP exports (30-day average) and**
21 **percentage salvage (Data source: USFWS unpubl. data).**

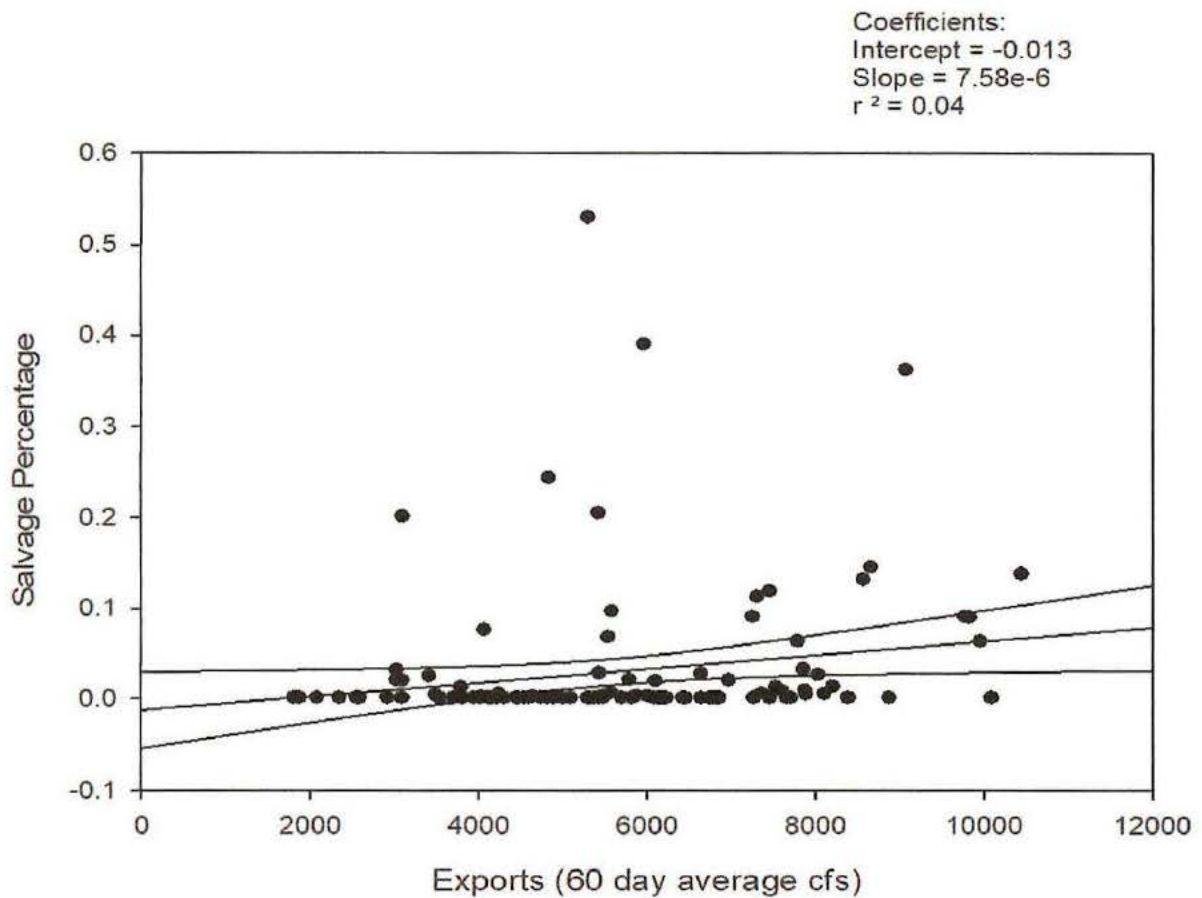


Figure 3. Relationship between SWP and CVP exports (60-day average) and percentage salvage (Data source: USFWS unpubl. data).

Overall, my analysis my analysis is consistent with that of others which showed the relationships between export rate and salmon salvage were characterized by very flat slopes (slopes < 0.0001) and low correlation coefficients ($R^2 = 0.02$ for the 30-day exports and 0.04 for the 60-day exports). The relationship between combined SWP and CVP export rates and the percentage of each tag group recaptured (direct loss) was not statistically significant for the 30-day ($p=0.12$) average export rate. The relationship between the percentage of salvage and average export rate over a 60-day period was significant ($p=0.04$); however, the relationship was extremely weak ($R^2= 0.04$). There was no evidence (i.e., one cannot conclude) based on results of these analyses that direct losses of salmon migrating downstream in the lower Sacramento River and through the

1 Delta experience greater direct losses as a result of increases in SWP or CVP export rates.
2 These surrogate salvage estimates are consistent with actual salvage of winter-run
3 Chinook salmon as a function of the Juvenile Production Estimate (JPE) developed by
4 NMFS each year, both of which are consistently low (typically less than 0.5%).

5 Results of salmon survival studies conducted by Perry (2010, p. 47-71(DWR Exhibit
6 1335)), Perry et al. (2010,14-25 (DWR Exhibit 1336)), Buchanan et al. (2018 p. 663-669
7 (DWR Exhibit 1327)) and others within the Sacramento River and Delta over the past three
8 decades have shown that (1) total survival (the overall survival estimate for a specific group
9 of tagged salmon from the point of release to Chipps Island in these analyses) has been
10 highly variable within and among years, and (2) total survival rates have been low in some
11 years. Over the 118 survival studies included in my analysis--all based on CWT salmon
12 released into the upper Sacramento River--the average survival rate to Chipps Island was
13 0.29 (n=118; 95% CI = 0.04) with a range from 0.016 to 1.0. (Studies in which no CWT
14 salmon were collected were not included in the analysis; maximum calculated survival rates
15 were truncated at 1.0). As discussed above, a number of factors affect the survival of
16 juvenile salmon during migration through the lower Sacramento River and Delta.

17 A key question to be addressed is whether SWP and CVP export rates are a factor
18 affecting (indirect effect) the survival of juvenile salmon during migration. If SWP and CVP
19 exports are a major factor affecting survival within the Delta, total salmon survival should be
20 reduced in those years when export rates are high and increased in those years when
21 export rates are low (dashed line on Figure 4). If SWP and CVP export rates are not a
22 major factor affecting Delta survival, there would be no relationship between total Delta
23 survival and combined exports during the seasonal period when juvenile salmon are
24 migrating through the lower river and Delta (solid line on Figure 4).

25 To test this hypothesis, I analyzed the estimates of total Delta survival from the CWT
26 survival studies plotted against average SWP and CVP export rates 30-days prior to the
27 date of last recapture for each CWT group of juvenile salmon. Results of the analysis are
28 shown in Figure 5 using a 30-day average for exports (results of the linear regression and

1 95% CI are shown). The slope of the regression was low (<0.0001) and characterized by a
2 high variance ($R^2= 0.01$).

3 The relationship between juvenile salmon survival in the Delta and combined SWP
4 and CVP export rates was not statistically significant for either the 30-day average export
5 rate ($p=0.27$) or the 60-day average export rate ($p=0.1$). Results of these analyses show
6 that SWP and CVP exports, overall, are a small incremental factor affecting survival of
7 juvenile salmon and that further regulation of exports would not have a strong predictive
8 effect on total survival of juvenile salmon from the Sacramento River migrating through the
9 Delta.

10 ***Conclusions regarding CWT survival study results.***

11 Results of the CWT survival studies have shown that survival of juvenile salmon
12 migrating downstream through the lower Sacramento River and Delta is highly variable
13 within and among years. Survival rates are weakly correlated with Sacramento River flow
14 and Delta inflow and outflow during the seasonal migration period. In these studies, SWP
15 and CVP export rates contributed a small incremental amount to explaining total juvenile
16 salmon survival within the lower river and Delta; however, the contribution of SWP and
17 CVP export rates were not found to be statistically significant ($p< 0.05$).

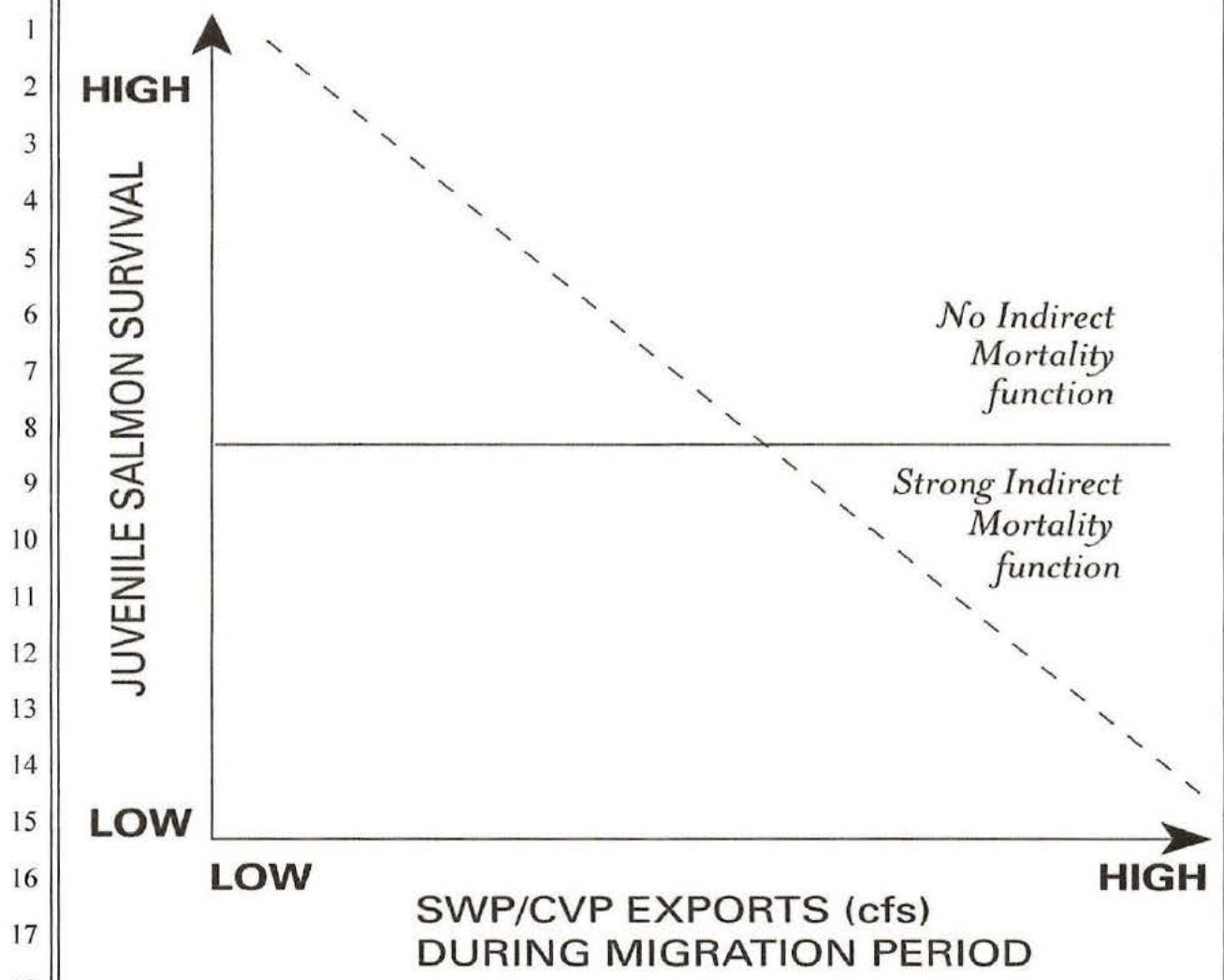


Figure 4. Hypothesis regarding the effect of SWP/CVP exports on indirect mortality of juvenile salmon.

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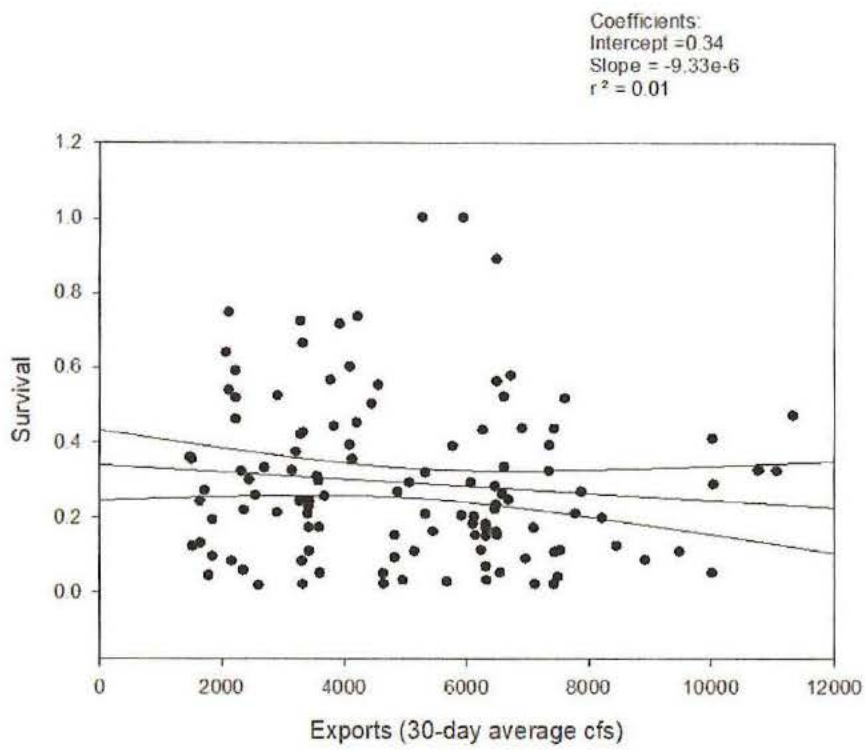


Figure 5. Relationship between SWP and CVP exports (30-day average) and Delta salmon survival (Data source: USFWS unpubl. data).

2. Multiple Agency Synthesis Reports also Conclude That There is Significant Uncertainty Regarding the Effects of Current SWP-CVP Project Operations.

In further response to Protestants' definitive statements that there was a high level of certainty regarding the alleged negative effects of current SWP-CVP operations, it is important to understand that several multiple agency investigations have strove to characterize the current state of our collective understanding of the effects of current operations of the SWP-CVP diversion in the south Delta. Their conclusions suggest that even with the significant amount of investments in monitoring and scientific research that has occurred over the past decades, the results are inconclusive and no population level effects have been identified.

This lack of certainty regarding the current effects of SWP-CVP south Delta diversions has been described in 2017 the Collaborative Adaptive Management Team's

1 Salmon Synthesis Team’s two-volume collaborative synthesis of information on juvenile
2 salmon and steelhead migration and survival in the Delta (herein “Salmon Synthesis
3 Report”) (DWR Exhibit 1337). The Salmon Synthesis Report identified key gaps,
4 uncertainties, areas of technical disagreement, and recommendations. The report presents
5 results of a collaborative scientific compilation and review of information: 1) primarily
6 related to the application of hydrodynamic simulation models used to assess local and
7 regional flow direction and water velocities in Delta channels that are affected by river
8 inflow, water project exports, and tides; 2) juvenile salmonid migration behavior including
9 migration rate and route selection based on tracking tagged juvenile Chinook salmon and
10 steelhead in the Delta and scientific literature from other basins; and 3) the survival of
11 juvenile Chinook salmon and steelhead as they migrate downstream through the Delta. The
12 assessment of information focused primarily on the effects of water project operations on
13 Delta hydrodynamics and juvenile salmon and steelhead migration and survival. Key
14 findings in the Salmon Synthesis Report regarding the Sacramento River and Delta include:

15 In regard to through-Delta survival, the Salmon Synthesis Report concluded at p.
16 ES-3:

- 17 • Many drivers for low through-Delta survival have been hypothesized, but the
18 role of each has not been quantified. Hypothesized factors contributing to the observed low
19 Delta survival include increased abundance and increased metabolic rate of predatory fish
20 such as striped bass and largemouth bass in the Delta, water project operations affecting
21 the magnitude and timing of flow resulting in increased juvenile salmonid predation
22 mortality, changes in Delta habitat including expansion of non-native submerged aquatic
23 vegetation, increased water clarity, potential exposure to contaminants, and other factors.
24 The potential contribution of these factors to salmonid mortality supports a stronger focus
25 on investigating the mechanisms underlying salmonid mortality in different regions of the
26 Delta and their link to water project operations; and
- 27 • Collection and analysis of data on migration and survival of acoustic-tagged
28 Chinook salmon is ongoing. Additional data will be compiled and analyzed to investigate

1 various hypotheses over observed conditions such as potential relationships between flows
2 and export rates and survival, as well as route selection and migration rate within various
3 regions of the lower rivers and Delta. Other analyses can also be done and support our
4 recommendation to continue studies and do additional data analyses and assessment.
5 However, because these studies were observational in nature, and were not designed to
6 test these hypotheses, the findings from such analyses will be limited and will not obviate
7 the need for future investigations.

8 In regard to the effects of the SWP-CVP, the Salmon Synthesis Report concluded at
9 p. 88:

- 10 • Despite implementing actions within the reasonable and prudent alternative
11 (RPA) intended to reduce through-Delta mortality, through-Delta survival remains low;
- 12 • Hydrodynamic monitoring and simulation modeling indicate that exports have
13 the greatest effect on flow and velocity in the region of the Delta nearest the export
14 facilities;
- 15 • Results of studies show that route selection is generally proportional to the
16 flow split at channel junctions, and the effect of exports on route selection is strongest at
17 the junction leading directly to the export facilities. Results of juvenile Chinook salmon
18 survival studies using CWT and more recently (2008, 2010, 2011, and 2012) ATs have not
19 shown a strong or consistent relationship with SWP and CVP export rates. Steelhead data
20 are limited to only 2011 and 2012; additional data through 2016 are being analyzed for both
21 salmon and steelhead. Survival rates for juvenile salmon since 2002 have been
22 consistently low independent of variation in both export rates and Delta inflows.

23 In regard to gaps in our scientific understanding, the CAMT Salmon Synthesis
24 Report concluded at p. 88-93:

- 25 • Additional analyses are needed to investigate the expected change in
26 salmonid route selection and subsequent survival from changes in export rates;
- 27 • The evidence of a relationship between exports and through-Delta survival is
28 inconclusive; the key findings are supported by medium or high basis of knowledge, but our

1 basis of knowledge on the relationship between exports and through-Delta survival is low.
2 Since 2002, juvenile fall-run Chinook salmon survival in the south Delta has been
3 consistently low despite restriction of export rates. Survival rates for acoustic-tagged
4 juvenile steelhead are currently available only for two years (2011 and 2012), which are
5 insufficient to support an analysis of the potential relationship between export rate and
6 survival. Analysis of additional acoustic tag (AT) data for 2013 through 2016 will help
7 further assess potential relationships for both salmon and steelhead;

8 • Estimates of entrainment mortality at the export facilities from salvage counts
9 depend on pre-screen mortality, but data on the magnitude and variability of pre-screen
10 mortality are unavailable at the CVP;

11 • The contribution of water project operations to the total mortality of juvenile
12 salmonids has not been quantified. Many of the mechanisms through which changes in
13 Delta hydrodynamics and other factors related to water project operations may contribute to
14 salmonid mortality (e.g., change in vulnerability to predation in Delta channels or change in
15 migration routing as a result of water project operations) are uncertain;

16 • Estimates of direct mortality (e.g., mortality resulting from pre-screen losses
17 and losses at the louver and salvage facilities, which are directly related to water project
18 export operations) have been developed from CWT data by several authors and show, in
19 general, that the magnitude of direct loss (e.g., percentage of a marked release group
20 observed in fish salvage) is typically low for juvenile Chinook salmon (typically less than
21 approximately 1%). However, such estimates do not include export-induced mortality prior
22 to entering the facilities that is indirectly related to water project operations (e.g., mortality
23 resulting from project related changes in habitat). Estimates of direct facility mortality as a
24 proportion of total migration mortality have been as high as 5.5% for winter-run Chinook
25 salmon (Zeug and Cavallo 2014 (DWR-Exhibit 1364));

26 • It is unknown whether equivocal findings regarding the existence and nature
27 of a relationship between exports and through-Delta survival is due to the lack of a
28 relationship, the concurrent and confounding influence of other variables, or the effect of

1 low overall survival in recent years. These data gaps support a recommendation for further
2 analysis of available data, as well as additional investigations to test hypotheses regarding
3 export effects on migration and survival of salmonids migrating through the Delta; and

4 • The effects of OMR reverse flows on salmonid survival and route selection in
5 the Delta (outside of the facilities) have had limited analysis. Data are available from the AT
6 migration and survival studies, as well as earlier CWT data, that might be used in analyses
7 of potential relationships between OMR reverse flows and juvenile salmonid survival.
8 Relationships between OMR reverse flows and migration route and migration rate, as well
9 as reach-specific and regional survival, could be tested using AT data from both Chinook
10 salmon and steelhead.

11 The findings of the Salmon Synthesis Report are supported by other multiple agency
12 analyses, including The Interagency Ecological Program (IEP) Salmon and Sturgeon
13 Assessment of Life Stage (SAIL) (DWR Exhibit 1334 p. ii-49), which is a program to
14 synthesize data and conceptual models to develop a framework for evaluating existing
15 information on endangered Sacramento River winter-run Chinook salmon and green and
16 white sturgeon. The SAIL assessment identified multiple uncertainties related to the
17 current operation of the SWP-CVP.

18 Based on my review of the available scientific information I identified areas of
19 scientific uncertainty related to the current operation of the SWP-CVP, including but not
20 limited to:

21 • High variability and uncertainty in predicting flow-survival relationships for
22 salmonids and the response to management and natural variability in environmental
23 conditions such as riverine and tidal hydrology;

24 • Statistical uncertainty and variability in the population level response of
25 salmonids to changes in factors such as SWP and CVP export rates, reverse flows within
26 Delta channels, habitat restoration, etc.;

27 • Population level responses to many of the stressors and management actions
28 remain uncertain: the application of lifecycle models and advanced methods for analyses

1 are starting to address uncertainty in complex relationships.

2 3. Salmonid Flow-Survival Relationships

3 ~~Protestants have alleged that current flow survival relationships explain the current~~
4 ~~status of salmonids, as well as the future effects of CWF. (See citations, above.) These~~
5 ~~relationships are not as certain or linear (meaning increased survival with every increment~~
6 ~~of additional outflow uniformly across the Delta) as has been represented.~~

7 Results of many of the flow survival studies conducted on Central Valley rivers for
8 juvenile salmonids have shown a general, but weak trend of increased juvenile survival
9 during migration through the rivers and Delta when river flows are higher. However, these
10 survival studies show: (1) high variability in the actual survival of juvenile salmonids at a
11 given flow, as reflected in the scatter of survival estimates (observations of both high and
12 low survival at a given flow); (2) low R2 values (reflecting that the relationship between
13 survival and flow is weak and flow alone does not explain a substantial proportion of the
14 observed variation in juvenile survival); and (3) based upon the low slope of the flow
15 survival relationship, that a substantial increase in flow is required to achieve a relatively
16 small predicted increase in salmonid survival. A number of experimental studies have been
17 conducted to assess the survival of juvenile Chinook salmon and steelhead migrating
18 downstream in the Sacramento River and through the Delta (Perry 2010 (DWR Exhibit
19 1335), Perry and Skalski 2010 (DWR Exhibit 1336), DWR 2012 (DWR Exhibit 1369), DWR
20 2013 (DWR Exhibit 1388), DWR 2015 (DWR Exhibit 1389), and DWR 2016 (DWR Exhibit
21 1390), Michel et al. 2015 (DWR Exhibit 1340), Kimmerer 2008 (DWR-1257), Newman and
22 Rice 2002 (DWR Exhibit 1370), Newman 2008 (DWR Exhibit 1371), Newman and Brandes
23 2009 (DWR Exhibit 1372), SJRGA 2006 (DWR Exhibit 1373), SJRGA 2008 (DWR Exhibit
24 1374), and 2011 (DWR Exhibit 1375), Perry and Skalski 2008 (DWR Exhibit 1376), Perry
25 and Skalski 2009 (DWR Exhibit 1377), and Chapman et al. 2014 (DWR-Exhibit 1378), and
26 others) using both coded wire tags (CWT) and more recently acoustic tags. Results of the
27 acoustic tag studies are currently being used to develop the NMFS Chinook salmon
28 lifecycle model (Hendrix et al. 2017, p. 11-12, 33-34, pers. comm. (DWR Exhibit 1339)), as

1 well as other life cycle models (IOS and OBAN), all of which were used to evaluate CWF.

2 There is high variability in the actual survival of juvenile salmonids at a given flow, as
3 reflected in the scatter of survival estimates (observations of both high and low survival at a
4 given flow). For example, flows in the Sacramento River during the late winter and spring
5 of 2006 were relatively high throughout the juvenile salmonid migration period and would
6 have been expected to improve juvenile survival and increase abundance of adults.

7 Average flows in the Sacramento River measured at Freeport during the 2006 juvenile
8 migration period were 68,459 cfs in January, 50,211 cfs in February, 67,873 cfs in March,
9 74,842 cfs in April, and 52,835 cfs in May (Table 1). The flows during the 2006 migration
10 season were substantially greater than in many other years. Despite these favorable
11 conditions, the escapement of adult fall-run Chinook salmon returning to the Central Valley
12 from this cohort in 2008 and 2009 (71,291 and 53,129 adults, respectively; GrandTab 2018
13 p. 2-3 (DWR-Exhibit 1379)) represented the lowest level of abundance in the last 50 years.

14 In contrast, flows in January 2009 in the Sacramento River at Freeport averaged
15 9,147 cfs, 19,977 cfs in February, 21,176 cfs in March, 11,924 cfs in April, and 15,436 cfs
16 in May which were substantially less than flows in 2006, and yet estimated adult fall-run
17 Chinook salmon abundance in 2012 was among the highest in more than a decade (adult
18 fall-run Chinook salmon abundance returning to the Central Valley was estimated by
19 CDFW to be 341,000 fish; GrandTab 2018, p. 2-3).

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1 Table 1. Sacramento River average monthly flows (cfs) at Freeport and subsequent
2 adult fall-run Chinook salmon abundance.

| 3 Month | 2006 | 2009 |
|---|----------------|-----------------|
| 4 January | 66,459 cfs | 9,147 cfs |
| 5 February | 50,211 cfs | 19,977 cfs |
| 6 March | 67,873 cfs | 21,176 cfs |
| 7 April | 74,842 cfs | 11,924 cfs |
| 8 May | 52,835 cfs | 15,436 cfs |
| 9 | | |
| 10 Estimated adult fall-run salmon abundance | 53,129 2009 | 340,819 2012 |

11
12 Source: DWR DAYFLOW and 2018 CDFW GrandTab (p. 3).

13
14 These examples illustrate the complexity of interacting factors that affect the
15 population dynamics of Central Valley salmonids and the high degree of uncertainty
16 supporting the hypothesis that simply modifying Sacramento River flows will result in a
17 desired improvement in juvenile salmon survival and adult abundance.

18 Confidence intervals for the survival estimates were relatively large in several of the
19 years (e.g., survival in the Delta in 2007 was estimated to be approximately 60% but
20 confidence intervals ranged from approximately 35 to 85%; Figure 6) suggesting high
21 variability and uncertainty in survival estimates.

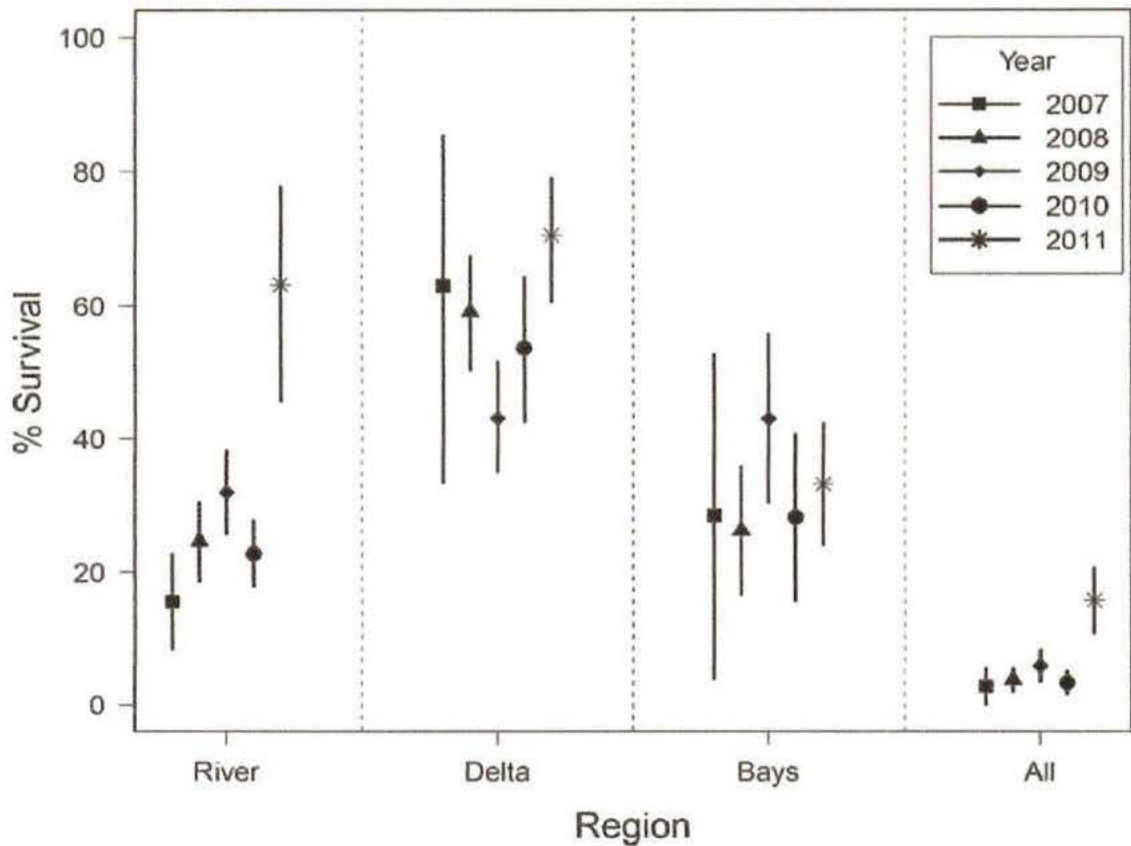


Figure 6. Percent survival per major region for all 5 study years. Regions include river, Delta, Bays, and the percent survival for the entire watershed (II). Error bars represent 95% confidence intervals. (Source: Michel et al. 2015, p. 1,757 (DWR-Exhibit XX)).

The uncertainty and variability in juvenile salmon survival in response to river flow is apparent in results of survival studies that compared survival over a wide range of hydrologic conditions in the south Delta (Buchanan et al. 2018, DWR Exhibit 1327, p. 663-669.) Survival estimates over the period from 2010 through 2015 between Mossdale and Chipps Island ranged from 0 to 5%. The survival estimate for 2011, a wet year with high spring flows was 2%, showing that increased flow alone did not result in a substantial increase in juvenile salmon survival.

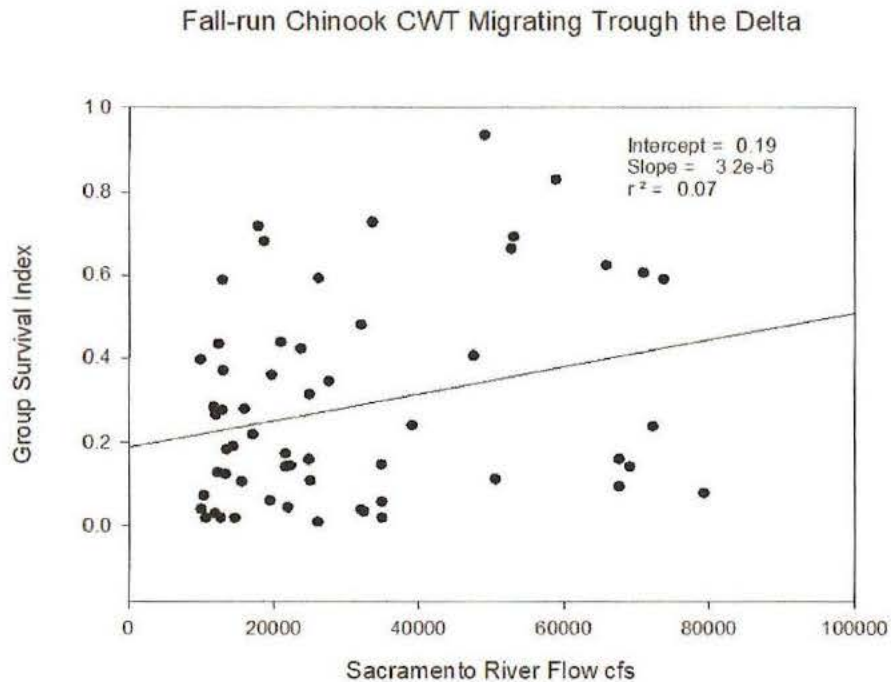
Results of the analysis I conducted using the USFWS CWT data of survival as a function of Sacramento River flow at Freeport are shown in Figure 7. Survival as a function of flow at Rio Vista is shown in Figure 8. Results of these analyses show similar trends with high variability and low R2 values (R2=0.07 for flow at Freeport and R2=0.03 for flow

1 at Rio Vista), and relatively flat slopes to the regression lines, suggesting that a large
2 change in flow would be required to achieve a relatively small change in survival (with high
3 uncertainty). These results are similar to results generated from CWT releases that
4 occurred in the upper Sacramento River, suggesting that Sacramento River flow within the
5 range evaluated (approximately 10,000 to 80,000 cfs) has only a small effect on juvenile
6 salmon survival for fish released into the upper watershed (upstream of Red Bluff Diversion
7 Dam) and for those fish released downstream in the vicinity of Sacramento.

8 The high observed variation in the flow-survival relationship for juvenile salmonids
9 (primarily based on mark-recapture results for fall-run and late fall-run Chinook salmon
10 produced in Central Valley fish hatcheries) reflects, in part, the large number of factors
11 other than river flow affect species survival. Salmonid exposure to predation is a major
12 factor affecting juvenile survival (Vogel 2011, p. iii (DWR-Exhibit 1341), Cavallo et al 2012,
13 p. 343-403 (DWR-Exhibit 1342), Grossman et al. 2013, p. 2-45 (DWR-Exhibit 1343),
14 Grossman 2016, p. 1-16 (DWR-Exhibit 1344)). Indeed, migration studies typically show
15 50% or more of migrating juvenile salmon were lost before they reach the Delta (Perry and
16 Skalski 2010, DWR-Exhibit 1336, p. 16-17, Michel et al. 2015, DWR-Exhibit 1340 p. 1,754).

17 Several theories have been advanced to support the notion that higher instream
18 flows will benefit juvenile salmonid survival. One hypothesis is that, at higher flows, the
19 downstream rate of juvenile migration would be faster and, therefore, juvenile salmonids
20 would have reduced exposure to potential predators. Results of acoustic tag studies,
21 however, indicate that juvenile downstream migration rates are faster in the upper
22 Sacramento River and migration rates decrease as the juvenile salmon pass through the
23 tidally influenced areas of the Delta and estuary (Michel 2010, p. 118 (DWR-Exhibit 1340);
24 Figure 6). The duration of migration for each release group shown in Figures 9 and 10 was
25 calculated based on the time between release and the first fish recaptured at Chipps Island
26 reflecting variability in migration rates among experimental release groups. Analysis of the
27 duration between release and recapture of CWT salmon migrating through the Delta do not
28 show a response between Sacramento River flow and migration rate (Figures 9 and 10).

1 These studies show that the relationship between river flow and migration rates (time from
2 release to recapture downstream at Chipps Island) is very weak and does not support the
3 theory that increasing river flow will result in faster migration rates through the Delta or
4 reduced exposure to in-Delta predation mortality.



18 **Figure 7. Relationship between average Sacramento River flow at Freeport**
19 **over a 14 -day period after release and juvenile fall-run salmon**
20 **survival to Chipps Island for CWT fish released in the vicinity of**
21 **Sacramento (Data source: USFWS unpubl. Data).**

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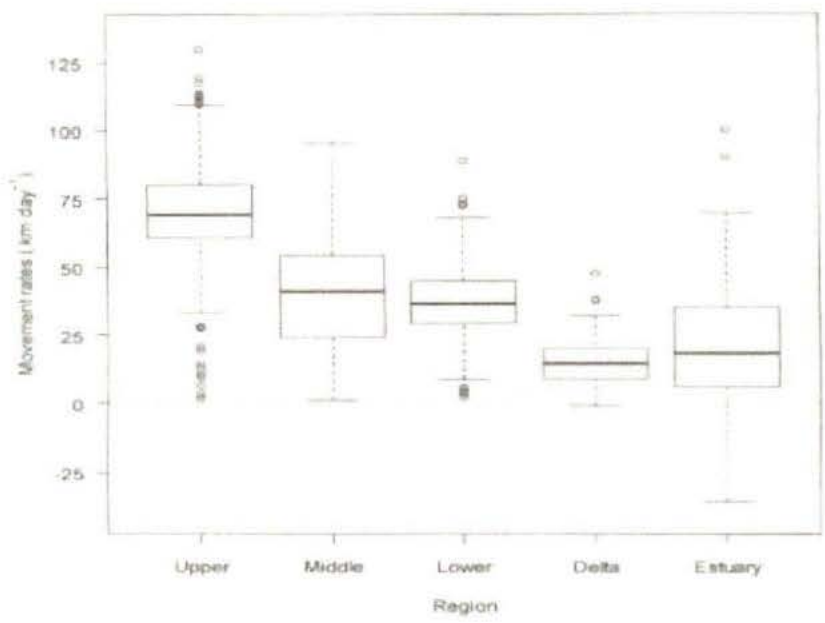


Figure 8. Reach specific migration rates for acoustically tagged late fall-run Chinook salmon in the Sacramento River, Delta, and estuary (Source: DWR-1340, Michel 2010, p. 118).

In sum, the functions and inter-relationships among flow and habitat quality and availability, growth, survival, reproductive success, and abundance of salmonids are complex. The available data show that there is high and low certainty/predictability in flow-survival relationships, although the data also show a general trend toward increased salmonid survival as flow increases during downstream migration.

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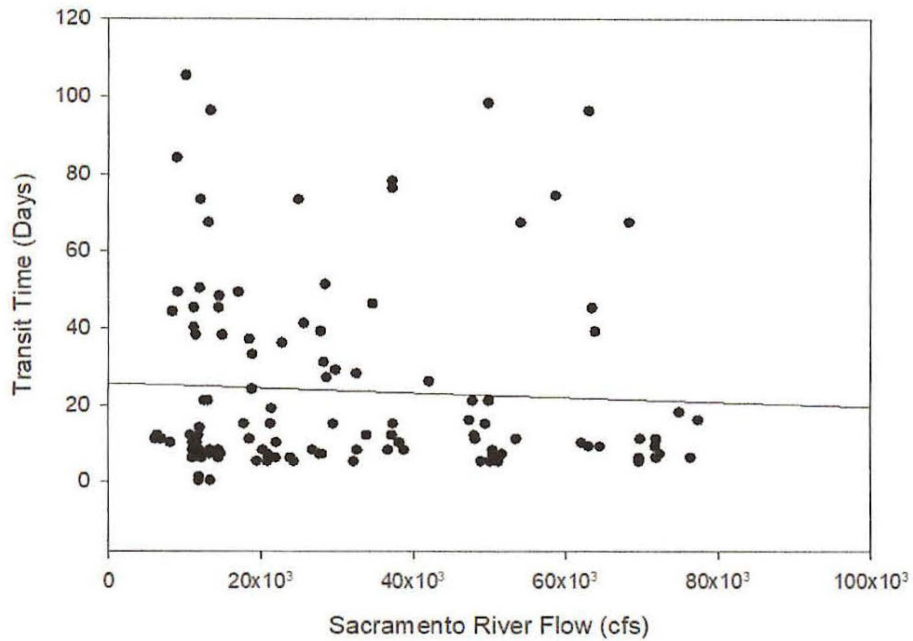


Figure 9. Relationship between Sacramento River flow (30-day average) and Delta salmon migration duration (Data source: USFWS unpubl. data).

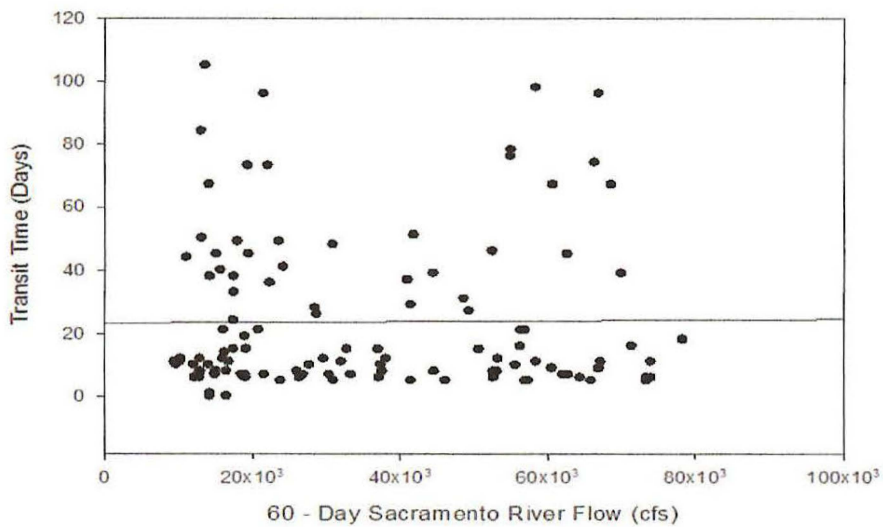


Figure 10. Relationship between Sacramento River flow (60-day average) and Delta salmon migration duration (Data source: USFWS unpubl. data).

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III. CONCLUSION

- Multiple historical physical and hydrologic changes have shaped the current Delta;
- The current state of the Delta is the result of multiple physical and hydrologic factors operating over multiple time scales;
- There is significant uncertainty regarding the nature, extent and magnitude of the effect of current SWP-CVP operations as well as other stressors on salmonid survival;
- The relationship between Sacramento River flow rates and juvenile salmonid survival is weak (large changes in river flow are needed to achieve even a small change in salmonid survival in the Sacramento River and Delta) with high uncertainty (low R2 values); and
- Multiple authors have concluded that flow alone cannot be used to restore the Delta. As stated by the NAS, "The Delta as it existed before large-scale alteration by humans cannot be recreated." (NAS 2012, p. 10). Buchanan et al. (2018, p. 663) also concluded that increased flow alone will not be sufficient to resolve the low salmonid survival in the Delta.

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