1). **Vogel, D. 2002. Juvenile Chinook salmon radio-telemetry study in the Southern Sacramento-San Joaquin Delta, December 2000-January 2001.**

Take Home Bullet: Fish released at Woodward Island on Old River during higher export conditions (~8,000 to 11,000 cfs) encountered more negative ambient flow conditions in Old River and consistently moved farther south towards the Projects than fish released under low export conditions (2,000 to 4,700 cfs) with more positive net flow conditions in Old River.

Quote: "The single most evident difference in results between the two medium export experiments and the two low export experiments was the behavior of radio-tagged fish during the first day after release. Radio-tagged salmon in releases 1 and 2 (medium export) experienced minimal or no positive (downstream) flow on the first day whereas fish releases 3 and 4 (low export) experienced long periods of high positive flow. The medium export levels dampened out or nearly eliminated any positive or north flows in Old River. Most fish in releases 1 and 2 exhibited a rapid, southerly migration responding to the high negative flow conditions. In contrast, most fish in releases 3 and 4 moved back and forth (i.e. north and south in Old River in response to the ebb (positive) and flood (negative) flow conditions and remained detectable in Old River for a longer duration than those fish in releases 1 and 2."(Page 20)

Caveat: Final disposition of the radio tagged fish was difficult to discern using mobile tracking only during the day. Night time tracking was not feasible in this study. However, if fish were last detected in close proximity to the Projects, it was assumed that they were entrained either into Clifton Court Forebay or the CVP if they were not detected the next morning.

2) **Vogel, D. 2005. The effects of Delta hydrodynamics conditions on San Joaquin River juvenile salmon.**

Take Home Bullets:
1) The overwhelming effects of tidal flows and site specific hydrodynamic conditions at critical channel junctions are likely masking any relationships between survival based solely on Vernalis flows or export levels.
2) Environmental noise overwhelms any survival relationship signal and makes detection of a statistical relationship between physical parameters nearly impossible without increasing sample size or replicates (i.e. low recovery of CWT fish in the VAMP experiments).
3) Fish moved into junctions in proportions that were not anticipated based on flow splits, and that once fish had left the mainstem San Joaquin River into one of the South Delta distributaries, they typically did not re-enter the mainstem at a later date. The lowest entrainment of fish occurred when the net reverse flows and SWP and CVP exports were lowest.

Quote:

"The "zone of influence" delineating exactly where in the central and south Delta that exports have an overriding influence on salmon "entrainment" into the south Delta is presently unknown and would vary depending on export levels. The smolt telemetry study conducted in December 2000-January 2001 provided empirical evidence that the zone of influence extends at least as far north as the northwestern tip of Woodward Island, a distance of approximately nine river miles

north of the CC gates. The two smolt telemetry studies conducted in the mainstem San Joaquin River suggest that the zone of influence is probably much further north (e.g., Turner Cut and Columbia Cut) but the unknown specific regions would depend on many complex and interrelated hydrodynamic variables (e.g., exports, river flows, tides, tidal prisms, localized channel velocities, channel geometry, etc.) combined with fish behavior." (Page 11).

"Also it appears that some smolts, once they move into those south channels do not re-emerge back into the San Joaquin to continue normal migration toward salt water. This latter phenomenon is also not understood. Because of net reverse flows that fish encounter in specific channels south of the San Joaquin River, outmigrating salmon apparently have difficulty re-emerging back into the mainstem. The magnitude of the net reverse flows increases with closer proximity to the south Delta export facilities. Once salmon enter this region of the Delta, the fish likely experience high mortality rates caused by predation and entrainment into unscreened diversions and the export facilities. Some fish are known to be survive the migration all the way to the export facilities, are salvaged, and transported out to the western Delta or San Francisco Bay. However, the proportion of total numbers of salmon unsuccessfully navigating these interior Delta channels is unknown." (Pages 15-16)

Caveats: The report utilizes data from both CWT fish and radio-tagged fish to draw conclusions. It was pointed out that the CWT studies were of low resolution due to the low recovery rates at the terminal sampling location and the lack of internal sampling locations – it could only draw conclusions from point A (release site) to point B (terminal sampling site) with no information regarding what happened in between those two points. The radio tag telemetry studies had higher resolution due to active mobile tracking, but also had issues with low sample numbers and difficulty of tracking fish during the night. However, radio telemetry provided much greater information regarding the movements of fish within the overall migratory route. This initial data reflects the trends of information gained in later studies using acoustic tag technology.

3.) San Joaquin River Group Authority 2007. 2006 Annual Technical Report.

Take Home Bullets:

1) Data reinforces the benefit of installing a temporary barrier at the head of Old River which provides protection to juvenile salmon migrating out of the SJ River basin and prevents them from entering the Old River channel.
2) San Joaquin River flows, and flows relative to exports, between April 15 and June 15 was positively correlated to adult escapement in the San Joaquin River basin 2.5 years later. Both relationships were statistically significant ($p<0.01$) with the ratio of flow to exports accounting for slightly more of the variability in escapement than flow alone ($r^2 = 0.58$, vs. $r^2 = 0.42$).
3) With HORB in place, increasing Vernalis flows increased survival of upstream release groups relative to downstream release groups and was statistically significant ($p< 0.01$).
4) Without the HORB in place, there was no clear relationship between the survival rates as measured by differential recovery rates/ combined differential recovery rates for upstream versus downstream releases and flow using the Chipps Island, Antioch, and ocean recoveries for the Mossdale and Durham Ferry releases relative to the Jersey Point releases. There was more variability associated with smolt survival at any given flow without the HORB since the

flow and proportion of fish moving into the Old River channel varies more without the HORB.

5) Flows alone explained survival better than flows relative to exports alone, but the flow/export ratio did increase the fit of the survival correlation and reduced variability in the model.
6) Total absolute prediction error is about 15% less using the model that incorporated the flow/export variable, indicating that it better predicts the survival data than the model using flow alone.
7) Increasing temperature in the San Joaquin River appears to be a confounding factor in determining the role of exports and flow, particularly in late season releases.

Quotes:

"One potential explanation for these results is that the level of exports were low and did not vary enough during these experiments to provide sufficient differences to be detected in our measurements of smolt survival. Exports ranged between 1,450 and 2,350 cfs during these experiments which is much lower than those incorporated into the adult escapement relationships. Another complication is that exports and San Joaquin River flows were correlated with higher exports observed during times of higher flows (Figure 5-16). It is also likely the relationship of exports to smolt survival is different with the HORB in place than when it is absent…..the HORB was not installed during the majority of the years incorporated into the adult relationships." (page 60)

"These adult relationships would indicate that as you increase flows and decrease exports relative to flows there should be corresponding increases in smolt survival and adult escapement 2 ½ years later." (page 63).

"It is not surprising that there is some uncertainty and noise in these relationships because escapement data does not incorporate the varying age classes within annual escapement, the impact of declining ocean harvest in recent years, and the imprecision in the escapement estimates." (page 63).

Caveats:
As indicated in the report, the lack of recoveries of fish at the terminal sampling points decreases the sensitivity of the study to detect relationships between the different parameters of interest. Statistically significant relationships are typically only seen for "strong" relationships where the signal of the relationship can be detected over the "noise" in the environment, subtle relationships are typically not seen as statistically significant due to the signal being overwhelmed by the environmental noise. Likewise, the VAMP studies did not test all of the flow and export combinations that were initially proposed, thus the ability to discriminate the nature of relationships between the parameters of interest are diminished due to an over representation of only a few parameter pairings, and a lack of pairings at the extremes of the parameter pairings, which would allow for better resolution of parameter effects and relationships.

4) **Newman, K.B., 2008, An Evaluation of Four Sacramento-San Joaquin River Delta juvenile salmon survival studies.**

Take Home Bullets:
1) Newman used Bayesian Hierarchical models (BHMs) to reanalyze data from the four different studies (DCC gate operations, Interior Delta survival, Delta Action 8, and VAMP). The BHMs accounted for unequal sampling variation and between release variations. Recoveries from multiple locations were analyzed in combination. The BHM framework is more statistically efficient and coherent compared to previous analyses.

2) Results from the reanalysis of the Delta Action 8 studies indicate that there was a negative association between export volume and relative survival; that is a 98% chance that as exports increased, relative survival decreased. Environmental variation in the relative survival was very large, however, and a paired low export release could have a high probability of a lower relative survival than a paired high export release due to differences in the environmental parameters and their influence on the relative survival of the paired release.

3) For the VAMP studies, (a) The expected probability of surviving to Jersey Point was consistently larger for fish staying in the San Joaquin River (i.e., passing Dos Reis) than fish entering Old River, but the magnitude of the difference varied between models some-what; (b) thus if the HORB effectively keeps fish from entering Old River, survival of out-migrants should increase; (c) there was a positive association between flow at Dos Reis and subsequent survival from Dos Reis and Jersey Point release sites, and if data from 2003 and later were eliminated from analysis the strength of the association increased and a positive association between flow in Old River and survival in Old River appeared; (d) associations between water export levels and survival probabilities were weak to negligible given the magnitude of environmental noise.

4) In general, data limitations inherent to release-recovery data, i.e., that only one capture is possible, relatively low capture probabilities, relatively high environmental variation, and in the case of VAMP the lack of balance in the release strategy, affect the accuracy of estimates of effects on survival.

5) Given the apparently high environmental variation, it may take many replications of temporally paired releases to more accurately quantify the effects of DCC gate position, exports, flow, and HORB on survival.

Quotes:
1) (For the Delta Action 8 Studies) “The key parameter is β_1 (the coefficient for exports in the logistic regression of θ; see equation 29). It had a 98% probability of being negative, indicative of a negative association between the relative survival of Georgiana Slough and Ryde releases (θ) and exports.” And “The plot shows the decline in mean θ as exports increases (when exports are at 2000 cfs, mean θ is 0.62, and when exports are at 10,000 cfs, mean θ is 0.31).” (Page 59)

2) (For the VAMP Studies) “The expected survival probability down Old River was always less than the survival down the San Joaquin River. Different models yielded somewhat different expected values, but the survival down Old River was generally, if not always, lower than those for the San Joaquin.” (Page 62).

3) “Covariate values affect precision, too. For the DA 8 studies, increasing the number of observations at the “extremes” of export levels will increase the precision in the estimate of the slope parameter (β_1 in Equation 29). Similarly, for the VAMP studies, increasing the number of observations at the “extremes” of flow and exports will increase the precision of the related (partial) slope parameters (Equations 43-46).” (Page 68).

4) “However, with HORB in, survival of releases made above the head of Old River was significantly related to flow, but the relationship with exports and flow/exports was inconsistent and sometimes paradoxical (e.g., exports were positively associated with survival, weakly statistically significant using Antioch and Chipps Island recoveries and insignificant using ocean recoveries). The fact that the presence of the HORB affected the relationships with flow suggests an interaction between flow and HORB.” (Page 75).

5) “For the various models fitted, there were two in-common conclusions: (1) flow is positively associated with the probability of surviving from Dos Reis to Jersey Point and (2) the survival probability for that reach is generally greater than the survival probability for fish traveling down Old River. Assuming that the HORB effectively keeps out-migrating salmon from entering Old River, the second conclusion implies that the HORB can increase salmon survival. For fish that do enter Old River, there was some evidence that flow in Old River was positively associated with survival between Old River and Jersey Point, but the evidence was not as consistently strong as for the Dos Reis to Jersey Point reach. There was little evidence for any association between exports and survival, and what evidence there was pointed towards a somewhat surprising positive association with exports.” (Page 75-76).

Caveats:

There is an apparent paradoxical relationship for export effects and survival – it is a negative relationship for salmon coming from the Sacramento River side of the Delta as depicted in the results for the Delta Action 8 studies, yet has either a negligible or slightly positive relationship for fish migrating out of the San Joaquin River basin. This may be an artifact of the relationship between higher flows in the San Joaquin River fostering higher survival for SJ basin fish, and the relationship between high flows in the SJ River and increased export levels at the Projects. It is possible that the higher survival is due mainly to higher flows, and not do to a positive relationship with exports.

5) **Newman and Brandes, 2010. Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports.**

Take Home Bullets:

1) Study used temporally paired releases of LFR Chinook salmon in the Delta: Sacramento River at Ryde and within Georgiana Slough, downstream from its junction with the Sacramento River (15 paired releases over the period between 1993 and 2005).

2) Reanalysis of earlier work (Brandes and McLain, 2001), this time only using the LFR Chinook salmon releases; and using Bayesian hierarchical modeling for the statistical analysis.

3) Analysis looked for the relationship of exports by the south Delta Projects on survival of fish released at the different release points using Chipps Island trawl recoveries (recaptured relatively immediately after release) and the ocean and inland recovery data of study fish over the next 2-4 years.

4) Analysis of the data found a consistently negative relationship between the level of exports and survival of fish released in Georgiana Slough (which are presumed to enter the central and south Delta waterways where the effects of the exports are manifested). There is an 86 – 92% probability that the relationship is negative based on the Bayesian modeling.

5) A consistently greater fraction of fish that were released in Georgiana Slough were recovered in salvage at the Projects compared to those fish released at the Ryde location, and this fraction increased with greater export levels.

6) The analysis of this data also pointed out how the low signal to environmental noise ratio diminishes the sensitivity of the analysis to detect the relationships between the parameters of interest and find statistically significant relationships. There was very little difference between models that had exports and those which did not.

Quotes:
1) "The recovery fractions for the Georgiana Slough releases were consistently less than those for the Ryde releases, with the exception of the fraction recovered at the fish facilities."

2) "(A)t the fish facilities, Georgiana Slough releases were about 16 times more likely to be recovered. Also, the fraction of fish facility recoveries from the Georgiana Slough releases tended to increase (from about 0.001 to 0.025) as exports increased from 2,000 cfs to 10,000 cfs (1 cfs = 0.028 m3/s), although there was considerable variability at any given level of exports (Figure 3). This suggested a higher probability of ending up at the pumps with greater exports."

3) "Regarding the relationship between relative survival and export level, the point estimates of the effects of exports were consistently negative and for the BHMs the probability that the effects are negative was 86–92%. However, as a result of the low signal-to-noise ratio, the DIC values and posterior model probabilities indicate that the predictive ability of models without exports is equivalent to that of models with exports."

Caveats:
As with other studies using CWT fish, the low absolute number of fish recovered in monitoring efforts impacts the ability of the study to detect relationships between the parameters of interest. These studies are limited by the low signal to environmental noise ratios that are typically present in these types of studies. Improving the sensitivity of these studies requires either using better methods (i.e. better/newer technology) or increasing the sample sizes/replications substantially to detect relationships, which would likely require many more years of studies to have a sufficient number of replicates to increase the sensitivity of the study. The failure to reach a statistically significant relationship does not automatically exclude that a true relationship exists between the parameters, it could very likely be obscured by the low signal to noise ratio.

6) Dauble et al. 2010. The Vernalis Adaptive Management Program (VAMP): Report of the 2010 Review Panel.

Take Home Bullets:

1) Simple solutions are unlikely to consistently enhance survival of salmon smolts through the Delta over time. The Delta has complex hydraulics in a strongly tidal environment, and high and likely variable predation effects, that are likely to affect survival rates more than river flow by itself.

2) The panel, however, found that increasing flows in the San Joaquin generally has a positive effect on smolt survival through the Delta and that reducing or eliminating downstream passage through the Old River channel was desirable. The Panel also understood that flow, exports, and the placement of a barrier at the Head of Old River were the variables affecting survival that were most easily manipulated and managed.

3) Apparent downstream migration survival of juvenile Chinook salmon was very poor during 2005 and 2006 even though Vernalis flows were unusually high (10,390 cfs and 26,020 cfs, respectively). These recent data serve as an important indicator that high Vernalis flow, by itself, cannot guarantee strong downstream migrant survival.

4) The panel observed that there is an apparent decline in smolt survival over the 10 year period between 2000 and 2010 at several different levels of San Joaquin River flows ranging from very low to high and that this may be the "new" future smolt survival environment.

5) The panel found that although exports did not have a detectable statistical relationship with survival, that the study results should still be considered inconclusive due to the abbreviated range of conditions under which the data was collected.

6) The panel found that both the empirical evidence and logical inference support the conclusion that installation of a barrier at the head of Old River improves survival of downstream migrating Chinook salmon smolts.

Quotes:

1) "(R)ecent data serve as an important indicator that high Vernalis flow, by *itself*, cannot guarantee strong downstream migrant survival."

2) "analyses (summarized in SRJTC, 2008) and Bayesian hierarchical modeling (BHM) analyses (Newman, 2008) were unable to detect any statistical associations between exports and smolt survival through the Delta using the VAMP CWT study data. For a number of reasons, however, we do not believe these findings should be interpreted as meaning that exports, especially at high levels, have no effect on survival rates. CWT study data were not collected over an adequate range of export levels to achieve enough statistical power to identify an export effect."

3) “The five years (2000-2004) of actual VAMP CWT studies done with a HORB in place investigated a range of exports only between 1,450 and 2,250 cfs. We believe this is much too narrow a range in exports to allow detection of a statistically significant export-survival relationship for the San Joaquin River.”

4) “We believe that any "Export" effect must be masked by this "Old River" effect, and that the lower survival observed for the Old River route is at least partially attributable to export effects, both direct and indirect. One reason we believe this is that while predation might naturally be higher along Old River, the export facilities themselves seem to attract additional predators to the south Delta. A second reason is that the data show that the numbers of CWT study smolts detected in the salvage at the fish facilities are always higher for releases on upper Old River versus Dos Reis. Thus there are clear differences in direct entrainment losses between the two routes. Finally, if a fish traveling the Old River route does successfully navigate past the fish facilities during periods of high exports, it is then subjected to the reverse net flows, caused by exports, in the reaches of Old and Middle Rivers north of the facilities. It is difficult to imagine that migrating salmon smolts, cueing mostly on flow direction, will not have greater difficulty navigating to the north through these reaches to San Francisco Bay in a direction that might appear as “upstream” to their senses. Losses of smolts due to altered hydrodynamic conditions or migration cues in the Delta related to exports are referred to as “indirect” losses or mortality.”

5) “Although lack of an ability to detect an "Export effect" on survival rates can be in large part attributed to lack of variation in recent export flows, we are reluctant to recommend substantial increases in export flows so as to improve the ability to detect an export effect. Among other things, the potential negative consequences of increased exports during downstream migration of juvenile Chinook salmon (and also on survival of juvenile delta smelt) probably outweigh any possible increase in knowledge.”

Caveats:
These comments and findings are the results of deliberations by an independent science review panel convened to assess the VAMP studies.

7) **High level Summary of the Six-year Steelhead Study for the years 2011-2015**

- Four years of the total six years of studies have been written up as either final or draft reports
    - Final Reports available for 2011-2015
    - Finals for years 2014 and 2015 sent July 30, 2018
- Studies released acoustically tagged hatchery steelhead into the San Joaquin River at Durham Ferry and tracked them through the Delta system using multiple releases and multiple acoustic receiver locations throughout the lower San Joaquin River and Delta.
    - 2011 – Five releases, total of 2,196 fish tagged and released at Durham Ferry from late March through mid-June.
    - 2012 – Three release, total of 1,435 fish tagged and released at Durham Ferry from early April through mid-May.
    - 2013 – Three releases, total of 1,425 fish tagged and released at Durham Ferry from early March through early May.

    - 2014 – Three release, total of 1,432 fish tagged and released at Durham Ferry from late March through late May.
    - 2015 – Three releases, total of 1,427 fish tagged and released at Durham Ferry from early March to late April.
- Studies occurred during a wet year (2011) and four dry/critically dry years (2012-2015; the first four years of the 5-year drought).
    - Flows during the wet year (2011) were typically above 10,000 cfs at Vernalis, and peaked at approximately 29,000 cfs.
    - Flows during 2012 through 2015 were considerably less, never exceeding 5,000 cfs at at Vernalis, and typically less than 2,500 cfs for most of the period of interest.
    - The HOR barrier was installed during 2012, 2014, and 2015. In 2014 the HOR barrier went in after the first release of fish occurred. With the barrier in, few fish were entrained into the Old River route at the junction of Old River and the San Joaquin River. In 2015, the barrier went in shortly after the second release of fish in late March, being present for the passage of approximately 35% of the released fish past the bifurcation of Old River and the mainstem San Joaquin River.
- During the wet year (2011) survival was better than the drought years (2012-2015) for both the San Joaquin River route (S_A) and the Old River route (S_B), as well as total survival (S_{total}) through the system.
    - Absolute survival through the San Joaquin River route was better than the Old River route in 4 of the 5 study years (2011, 2012, 2014, and 2015).
    - Survival through the sub-routes; south Delta and middle Delta (S_{SD} and S_{MD}), were variable and release group dependent. Clear distinctions between the Old River and San Joaquin River routes were not consistent.
- The presence of the HOR barrier was important in determining the proportion of fish entering Old River in relation to those remaining in the San Joaquin River route.
    - During low flow years, when the barrier was out, (2013, first release in 2014, first and second release in 2015), and fish were released into the system at Durham Ferry, higher numbers of fish entered the Old River route at the HOR junction. This appears to be a function of river stage, tides, and shunting of flow into the Old River channel.
    - When flows were high (2011) the distribution of fish into Old River and the San Joaquin were nearly equal.
- Water temperatures were elevated in 4 out of the 5 study years (2012-2015) during the fish releases.
    - Waters temperatures (as measured at Mossdale) were consistently lower in 2011 compared to 2012-2015 during fish releases.
    - Water temperatures in 2012 were consistently above 18ºC for the second and third releases. Water temperatures following the first release were between 15 and 18ºC.
    - Water temperatures in 2013 were slightly below 15ºC during the first release, but were above 15ºC during the second and third releases.
    - Water temperatures in 2014 were between 15 and 18ºC during the three releases, with spikes following the first and third releases.

    - Water temperatures in 2015 were between 16 and 20ºC for the first release in early March, between 17 and 20 ºC for the late March release, and 19 and 23ºC for the late April release.
- Survival, as measured per kilometer travelled, is generally as follows:
    - Overall cumulative mortality is higher in the reaches between Durham Ferry and Mossdale, which is common between the Old River route and the San Joaquin River route. The survival per kilometer is approximately 96% or higher but accounts for approximately 40-60% of overall mortality.
    - Cumulative mortality in the San Joaquin River route is inconsistent, with some years having high mortality in the reach between Mossdale and the Stockton Deepwater Ship Channel (Garwood Bridge/ Navy Bridge) and again in the lower reaches of the San Joaquin River route (MacDonald Island to Chipps Island).
    - Increased cumulative mortality in the Old River route occurs between the entrance to the Old River corridor (Old River south) and Chipps Island via the fish collection facilities.