DATE: 11/1/18

TO: Maria Rea, Assistant Regional Administrator, California Central Valley Office, West Coast Region, NOAA Fisheries

FROM: Barb Byrne, Fishery Biologist, Water Operations and Delta Consultations Branch, California Central Valley Office, West Coast Region, NOAA Fisheries
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RE: Selected science review for the reinitiation effort

Maria,

Per your request, I have compiled some materials that summarize some of the key recent science relevant for the reinitiation effort, with a focus on materials that relate to evaluation of Central Valley Project- and State Water Project-related effects in the Delta.

One of the most thorough compilations of recent science relevant to Delta operations is the Salmonid Scoping Team's January 2017 report (2017 SST Report):

> *Salmonid Scoping Team (2017). Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta. Volume 1: Findings and Recommendations. January2017.*

The 2017 SST Report not only summarizes what is known and not known about project-related effects on salmonids in the south Delta, its findings are the consensus of a technical team including representatives from agencies, water users, and non-governmental organizations that participate in the Collaborative Adaptive Management Team (CAMT) effort. Because the report is so large, it is not enclosed in this compilation, but is available online at: https://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/OCAPreports.html

Materials that are enclosed in this compilation include:

- **Enclosure A (27 pages):** Briefing materials on the "Six Year Study" results on routing and survival of Central Valley steelhead migrating from the San Joaquin basin.
    - *Erratum:* The final San Joaquin yeartype for WY 2016 should be "Dry"; not "Critical" in Table 1 on page A-3.
- **Enclosure B (6 pages):** Annotated literature review prepared by me in August 2018.
- **Enclosure C (10 pages):** Annotated literature review prepared by Jeff Stuart (Fishery Biologist, Water Operations and Delta Consultations Branch, California Central Valley Office, West Coast Region, NOAA Fisheries) in August 2018.

Briefing on Six-year Study
June 26, 2018

Key Messages

Six-Year Study

- Four years of the total six years of studies have been written up as either final (2011-2013) or draft (2014) reports. Final reports just released in May/June 2018.
- Conditions during study years dominated by drought conditions.
- Survival results *(more details in Attachment 1, prepared by Jeff Stuart)*:
  - Through-Delta steelhead survival (for all routes combined) was highest in the Wet year (2011, and ranged from 15% (in 2013) to 54% (in 2011).
  - Absolute survival through the San Joaquin River route was better than the Old River route in three of the four analyzed study years (2011, 2012, and 2014) but not statistically significant (some power limitations?).
  - Reports do not provide analysis of survival as a function of the I:E ratio or OMR flow[1], though do evaluate total Delta survival as a function of Vernalis flow and some routing proportions as a function of local flows.
- Routing results:
  - Not surprisingly, the proportion of study fish in the San Joaquin River route was highest in the years when the HORB was installed.

SWFSC mini-project on Six-Year Study data

- Heads-up that SWFSC did a mini-analysis *(more details in Attachment 2, prepared by Caren Barceló)* to understand the relationship between detections at different receivers (detections being a surrogate for fish movement) and environmental variables (e.g. flow, turbidity, temperature, diel phase).
  - Preliminary results were that flow, conductivity and turbidity were the variables that most often had the strongest relationship (positive or negative) with the arrival rate of steelhead; associations differed for specific receivers.

Chinook releases in the San Joaquin River

- USFWS led studies of Chinook releases in the San Joaquin River, and measured through-Delta survival, in 2009-2015.
- For 2010-2013, through-Delta Chinook survival was <5% for all releases and survival was often higher in the Old River route (*see Attachment 3, prepared by Barb Byrne).*

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[1] The 2013 report notes, for example, that "[The NMFS 2009 BiOp] identified flow at Vernalis, export volume, and the ratio of Vernalis flow-to-export as variables to test during this study as priority variables. Separating the effects of these covariates is difficult because the variables are likely to be correlated."

Overview of Six-year Study

- Studies released acoustically tagged **hatchery steelhead** into the San Joaquin River at Durham Ferry (most releases were from **late March to late May**) and tracked them through the Delta system using multiple releases and multiple acoustic receiver locations throughout the lower San Joaquin River and Delta (Figure 1).

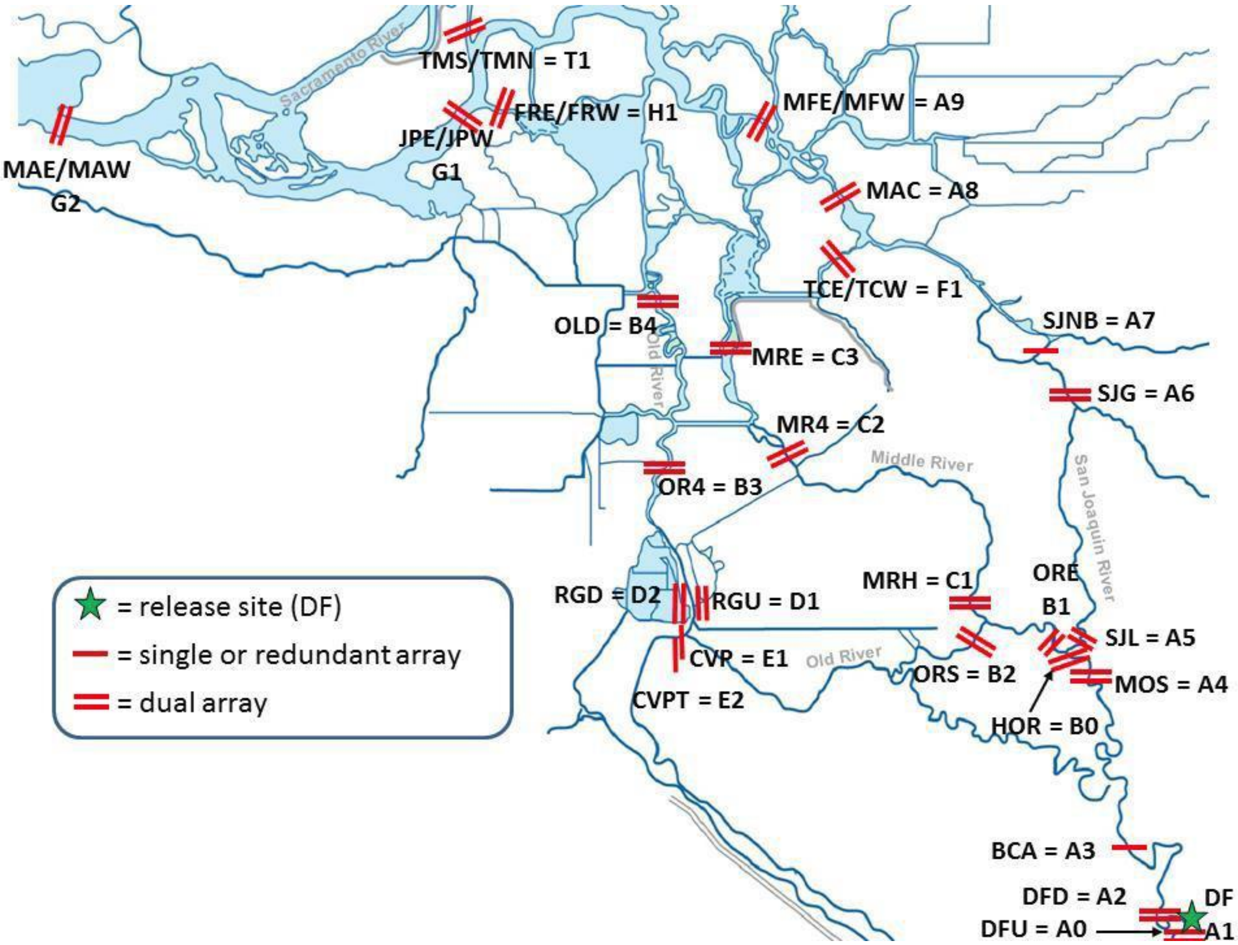


Figure 1*: Locations of Acoustic Receivers for the 2012 study. Each year's study had a small number of additional/ removed or relocated acoustic receiver locations but the release location at Durham Ferry (DF) and westernmost receivers near Chipps Island (MAE & MAW) were consistent throughout.*

- Studies occurred during a Wet year (2011) and five Dry or Critical years (2012-2016), as summarized in Table 1.

Table 1: Overview of hydrologic conditions and report status for the Six-year Study

Water Year	HORB status	San Joaquin yeartype	I:E ratio in effect	14-day OMR range (in cfs, 4/1-5/31)	Vernalis flow range (in cfs, 4/1-5/31)	Status of report
2011	Out	Wet	Vernalis flow offramp 4/1-5/10; 4:1 from 5/11-5/31	2,391 to 9,520	9635 to 28,575	Final (May 2018)
2012	In	Dry	Joint Stipulation Study* in lieu of I:E ratio	-4,218 to -1,710	1,577 to 4,418	Final (May 2018)
2013	Out	Critical	1:1	-4,050 to -130	859 to 4,176	Final (June 2018)
2014	In	Critical	1:1	-4,750 to -1,650 *(based on Index)*	510 to 3,035	Draft (May 2018)
2015	In	Critical	1:1	-1,860 to -1,170 *(based on Index)*	254 to 1,433	*No report available*
2016	In	Critical	1:1	-3,720 to -1,860 *(based on Index)*	733 to 3,215	*No report available*

*OMR requirements in Joint Stipulation Study ranged from -1,250 cfs to -5,000 cfs.

- Survival and routing estimates (Table 2) show that:
    - Through-Delta steelhead survival (for all routes combined) was highest in the Wet year (2011, and ranged from 15% (in 2013) to 54% (in 2011). See Figure 2.
    - Absolute survival through the San Joaquin River route was better than the Old River route in three of the four study years (2011, 2012, and 2014) but not statistically significant[2].
    - Not surprisingly, the proportion of study fish in the San Joaquin River route was highest in the years when the HORB was installed.

[2] Power to detect survival differences between routes (excerpt from p.11 of the 2012 Report): "Buchanan (2010) recommended a sample size of 475 for estimating survival to Chipps down the Old River and San Joaquin routes if survival in the Old River route was low (0.05). Additionally, if survival between Durham Ferry and Chipps Island was higher (0.15) and survival between Durham Ferry and the Old River junction was high (0.9), a release of 475 at Durham Ferry would be able to detect a 50% difference between survival in the San Joaquin River and Old River routes. Thus, a release group of 475 at Durham Ferry was expected to provide accurate information about route entrainment and survival for examining biotic and abiotic factors influencing juvenile steelhead survival."

__Table 2__: Summary of hatchery steelhead survival estimates from Six-Year Study: 2011 - 2014

Study Year	Proportion using Route		Survival Probability Estimate			HORB Status	Water Year Type
	San Joaquin River route	Old River route	San Joaquin River Route	Old River route	Total Survival (any route)		
2011	0.51	0.49	0.55	0.52	0.54	Out	Wet
2012	0.94	0.06	0.33	0.07	0.32	In	Dry
2013	0.12	0.88	0.11	0.15	0.15	Out	Critical
2014	0.92	0.08	0.25	0.19	0.24	In	Critical

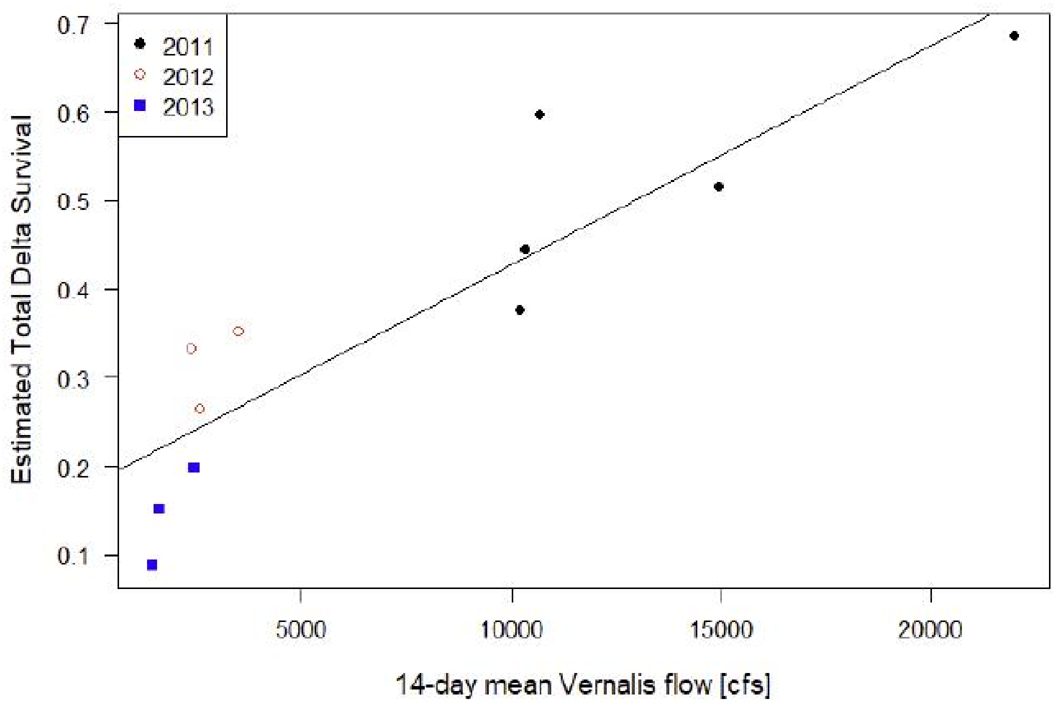


Figure 27. Estimated total delta survival (Mossdale to Chipps Island) for acoustic-tagged steelhead in the 2011, 2012, and 2013 Six-Year Study, versus 14-day mean San Joaquin River flow at Vernalis. Survival and flow data are from Tables 26 and 27. The line is the best fit linear predictor of survival as a function of 14-day Vernalis flow for these data ($r^2 = 0.8007$).

__Figure 2__: Estimated total Delta survival for hatchery steelhead from the 2011-2013 study years. (Figure 27 from the 2013 report)

- Other details available in Attachment 1:
  - Water temperatures were elevated (59 degrees F or higher) in three out of the four analyzed study years (2012-2014) during the fish releases.
  - Survival estimates by release group are provided in “heat-map” tables.
  - Releases are plotted along Vernalis flows and Mossdale water temperatures.

<u>Highlights from 2011-2014 results from Six-Year Study</u>
(summarizing 689 pages of draft and final reports)

- Four years of the total six years of studies have been written up as either final or draft reports
    - Final Reports available for 2011-2013
    - Draft report available for 2014
- 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. (see Table 1 and Figure 1)
    - 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.
- Studies occurred during a wet year (2011) and three dry/critically dry years (2012-2014; the first three years of the 5-year drought) (see Figure 2).
    - 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 2014 were considerably less, never exceeding 5,000 cfs at Vernalis, and typically less than 2,500 cfs for most of the period of interest.
    - The HOR barrier was installed during 2012 and 2014. 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 (see Table 2 and Table 3a and 3b).
- During the wet year (2011) survival was better than the drought years (2012-2014) 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. See Tables 2 and 3a and b.
    - Absolute survival through the San Joaquin River route was better than the Old River route in 3 of the 4 study years (2011, 2012, and 2014) but not statistically significant.
    - 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 (see Tables 2 and 3a, 3b) 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), 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 3 out of the 4 study years (2012-2014) during the fish releases (see Figures 3-6).
  - Waters temperatures (as measured at Mossdale) were consistently lower in 2011 compared to 2012-2014 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.
- Survival, as measured per kilometer travelled, is depicted in Tables 4 and 5, cumulative mortality /survival in Figures 7-12.
  - Overall cumulative mortality is higher in the reaches between Durham Ferry and Mossdale (Figures 7-12), which is common between the Old River route and the San Joaquin River route. The survival per kilometer is approximately 96% or higher (Table 4) but accounts for approximately 40-60% of overall mortality (Figures 7-12).
  - 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 (Figures 8,10, and12).

Table 1: Number of steelhead with acoustic tags released for each study year. Note that because of differences in routing with HORB in vs. out, the sample size for the survival estimates in the San Joaquin River route vs. the Old River route is very different.

Study Year	Total # Tags Released	Release Groups	Date of Release	Number Tags Released	Number Assigned to Old River Route	Number Assigned to San Joaquin River route
2011	2,196	1	3/22 – 3/26	477		
HORB out		2	5/3 – 5/7	474		
		3	5/17 – 5/21	477		
		4	5/22 – 5/26	480		
		5	6/15 – 6/17	285		
2012	1,435	1	4/4 – 4/7	477	20	304
HORB in		2	5/1 – 5/6	478	11	297
		3	5/17 – 5/23	480	17	150
2013	1,425	1	3/6 – 3/9	476	278	16
HORB out		2	4/3 – 4/6	477	279	31
		3	5/8 – 5/11	472	265	40
2014	1,432	1	~3/26 – 3/29	474		
HORB in		2	~4/26 -4/29	480		
		3	~5/20 -5/23	478		

Table 2: Summary of 6-Year Steelhead Parameters: 2011 - 2014

Study Year	Proportion using Route		Survival Probability Estimate			HORB Status	Water Year Type
	SJR (ψ_A)	OR (ψ_B)	SJR Route (S_A)	Old River Route (S_B)	Total Survival (S_{Total})		
2011	0.51	0.49	0.55	0.52	0.54	Out	Wet
2012	0.94	0.06	0.33	0.07	0.32	In	Dry
2013	0.12	0.88	0.11	0.15	0.15	Out	Critical
2014	0.92	0.08	0.25	0.19	0.24	In	Critical

Model Parameters estimated:

P_{hi} = detection probability: probability of detection at telemetry station i within route h, conditional on surviving to station i, where i = ia, ib for the upstream, downstream receivers in a dual array, respectively.

S_{hi} = perceived survival probability: joint probability of migration and survival from telemetry station i to i+1 within route h, conditional on surviving to station i.

Ψ_{hi} = route selection probability: probability of a fish entering route h at junction l (l =1, 2, 3), conditional on fish surviving to junction l.

$\Phi_{kj, hi}$ = transition probability: joint probability of migration, route selection, and survival; the probability of migrating, surviving, and moving from station j in route k to station i in route h, conditional on survival to station j in route k.

λ = joint transition and detection probability: joint probability of moving downstream from Chipps Island, surviving to Benicia Bridge, and detection at Benicia Bridge, conditional on survival to Chipps Island.

Table 3a: Performance metric estimates for tagged juvenile steelhead for study years 2011 -2012, excluding predator – type detections. Standard errors in parentheses.

Parameter	Year										
	2011							2012			
	Release Group							Release Group			
	1	2	3	4	5	Pop Est.		1	2	3	Pop Est
Ψ_{AA}	0.47 (0.03)	0.35 90.03)	0.37 (0.03)	0.36 (003)		0.39 (0.02)		0.72 (0.04)	0.75 (0.03)	0.58 (0.04)	0.68 (0.02)
Ψ_{AF}	0.05 (0.01)	0.16 (0.02)	0.12 (0.02)	0.17 (0.02)		0.12 (0.01)		0.21 (0.04)	0.23 (0.03)	0.26 (0.02)	0.26 (0.02)
Ψ_{BB}	0.44 (0.0)	0.46 (0.03)	0.49 (0.03)	0.45 (0.03)		0.46 (0.02)		0.06 (0.01)[a]	0.03 (0.01)[a]	0.06 (0.01)[a]	0.06 (0.01)[a]
Ψ_{BC}	0.04 (0.01)	0.03 (0.01)	0.01 (0.01)	0.03 (0.02)		0.03 (0.01)		0.00[a]	0.00[a]	0.00[a]	0.00[a]
S_{AA}	0.72 (0.04)	0.68 (0.05)	0.51 (0.05)	0.69 (0.05)		0.65 (0.02)		0.33 (0.03)	0.43 (0.03)	0.45 (0.05)	0.40 (0.02)
S_{AF}	0.33 (0.12)	0.27 (0.07)	0.26 (0.07)	0.59 (0.07)		0.36 (0.04)		0.10 (0.04)	0.14 (0.04)	0.21 (0.05)	0.15 (0.03)
S_{BB}	0.68 (0.04)	0.50 (0.05)	0.44 (0.04)	0.55 (0.05)		0.54 (0.02)		0.07 (0.04)	0.10 (0.07)	0.05 (0.03)	0.07 (0.03)
S_{BC}	0.67 (0.08)	0.30 (0.13)	0.48 (0.06)	0.22 (0.17)		0.42 (0.06)		NA	NA	NA	NA
Ψ_{A}	0.52 (0.03)	0.51 (0.03)	0.49 (0.03)	0.53 (0.03)	0.52 (0.05)	0.51 (0.02)		0.94 (0.01)*	0.97 (0.01)*	0.92 (0.02)*	0.94 (0.01)*
Ψ_{B}	0.48 (0.03)	0.49 (003)	0.51 (0.03)	0.47 (0.03)	0.48 (0.05)	0.49 (0.02)		0.06 (0.01)*	0.03 (0.01)*	0.08 (0.02)*	0.06 (0.01)*
S_{A}	0.69 (0.04)	0.55 (0.04)	0.45 (0.04)	0.66 (0.04)*	0.32 (0.06)	0.55 (0.02)		0.28 (0.03)	0.33 (0.03)	0.36 (0.04)	0.33 (0.02)
S_{B}	0.68 (0.04)	0.48 (0.04)	0.44 (0.04)	0.53 (0.05)*	0.44 (0.07)	0.52 (0.02)		0.07 (0.04)	0.10 (0.07)	0.05 (0.03)	0.07 (0.03)
S_{Total}	0.69 (0.03)	0.52 (0.03)	0.44 (0.03)	0.60 (0.03)	0.38 (0.05)	0.54 (0.01)		0.26 (0.02)	0.35 (0.03)	0.33 (0.04)	0.32 (0.02)
$S_{A(MD)}$	0.82 (0.03)*	0.50 (0.04)*	0.39 (0.04)*	0.52 (0.04)*		0.56 (0.02)		0.32 (0.03)	0.46 (0.03)	0.45 (0.04)	0.41 (0.02)
$S_{B(MD)}$	0.53 (0.04)*	0.05 (0.02)*	0.09 (0.03)*	0.06 (0.02)*		0.18 (0.01)		0.00[a]	0.00	0.00	0.00
$S_{Total(MD)}$	0.68 (0.03)	0.28 (0.03)	0.24 (0.03)	0.30 (0.03)		0.37 (0.01)		0.30 (0.03)	0.45 (0.03)	0.41 (0.04)	0.39 (0.02)
$S_{A(SD)}$	0.89 (0.03)	0.83 (0.03)	0.74 (0.04)	0.85 (0.03)		0.83 (0.02)		0.78 (0.04)	0.82 (0.02)	0.89 (0.03)	0.83 (0.02)
$S_{B(SD)}$	0.91 (0.03)	0.75 (0.04)	0.71 (0.04)	0.77 (0.04)		0.78 (0.02)		0.80 (0.08)	0.62 (0.17)	0.23 (0.11)	0.55 (0.07)
$S_{Total(SD)}$	0.90 (0.02)	0.79 (0.03)	0.72 (0.03)	0.81 (0.03)		0.81 (0.01)		0.78 (0.04)	0.81 (0.02)	0.84 (0.03)	0.81 (0.02)

[*] Significantly different at $\alpha = 0.05$

[a] No tags were detected in subroute "C" or insufficient tags were detected to subroute "C" for use in analysis. No estimate for survival in subroute C was available.

Table 3b: Performance metric estimates for tagged juvenile steelhead for study years 2013 -2014, excluding predator – type detections. Standard errors in parentheses.

Parameter	Year								
	2013					2014			
	Release Groups					Release Groups			
	1	2	3	Pop Est.		1	2	3	Pop Est
Ψ_{AA}	NA[a]	0.07(0.02)	0.11 (0.02)	NA[a]		NA[a]	0.66 (0.03)	0.77 (0.08)	0.71 (0.04)
Ψ_{AF}	NA[a]	0.06 (0.02)	0.05 (0.02)	NA[a]		NA[a]	0.30 (0.03)	0.11 (0.07)	0.21 (0.04)
Ψ_{BB}	0.89 (0.02)	0.85 (0.02)	0.83 (0.02)	0.86 (0.01)		0.87 (0.03)	0.04 (0.01)	NA[a]	NA[a]
Ψ_{BC}	0.03 (0.01)	0.02 (0.01)	0.01 (0.01)	0.02 (<0.01)		0.04 (0.02)	0.00 (<0.01)	NA[a]	NA[a]
S_{AA}	NA[a]	0.19 (0.07)	0.31 (0.07)	NA[a]		NA[a]	0.57 (0.03)	0.07)0.03)	0.32 (0.02)
S_{AF}	NA[a]	0.06 (0.05)	0.00	NA[a]		NA[a]	0.13 (0.03)	NA[a]	NA[a]
S_{BB}	0.17 (0.02)	0.08 (0.02)	0.20 (0.03)	0.15 (0.01)		0.20 (0.04)	0.33 (0.09)	NA[a]	NA[a]
S_{BC}	0.07 (0.05)	0.06 (0.04)	0.06 (0.06)	0.06 (0.03)		0	NA[a]	NA[a]	NA[a]
Ψ_{A}	0.08 (0.02)	0.12 (0.02)	0.16 (0.02)	0.12 (0.01)		0.09 (0.02)	0.96 (0.01)	0.88 (0.03)	0.92 (0.02)
Ψ_{B}	0.92 (0.02)	0.88 (0.02)	0.84 (0.02)	0.88 (0.01)		0.91 (0.02)	0.04 (0.01)	0.12 (0.03)	0.08 (0.02)
S_{A}	0.00	0.13 (0.05)	0.20 (0.06)	0.11 (0.03)		0	0.43 (0.03)	0.06 (0.02)	0.25 (0.02)
S_{B}	0.16 (0.02)	0.08 (0.02)	0.20 (0.02)	0.15 (0.01)		0.19 (0.03)	0.31 (0.09)	0.07 (0.07)	0.19 (0.06)
S_{Total}	0.15 (0.02)	0.09 (0.02)	0.20 (0.02)	0.15 (0.01)		0.18 (0.03)	0.43 (0.03)	0.06 (0.02)	0.24 (0.02)
$S_{A(MD)}$	0.00	0.13 (0.05)	0.24 (0.06)	0.12 (0.03)		NA[a]	0.44 (0.03)	0.07 (0.03)	0.26 (0.02)
$S_{B(MD)}$	0.01 (0.01)	0.01 (0.1)	0.06 (0.02)	0.03 (0.01)		NA[a]	0	NA[a]	NA[a]
$S_{Total(MD)}$	0.01 (0.01)	0.03 (0.01)	0.09 (0.02)	0.04 (0.01)		NA[a]	0.43 (0.03)	NA[a]	NA[a]
$S_{A(SD)}$	NA[a]	0.23 (0.07)	0.37 (0.07)	NA[a]		NA[a]	0.77 (0.02)	0.16 (0.04)	0.46 (0.02)
$S_{B(SD)}$	0.53 (0.03)	0.56 (0.03)	0.75 (0.03)	0.61 (0.02)		0.56 (0.04)	0.83 (0.09)	NA[a]	NA[a]
$S_{Total(SD)}$	NA[a]	0.52 (0.03)	0.69 (0.03)	NA[a]		NA[a]	0.77 (0.02)	NA[a]	NA[a]

[a] NA estimates resulted when there were too few tags detected in the route to estimate route selection and/or survival.

Table 4: Heat Map Depicting Steelhead Survival Rates ($S^{(1/km)}$) Through San Joaquin River Reaches to Chipps Island.

Reach Name	km	Survival Estimate per km ($S^{(1/km)}$)					
		2011		2012		2013	2014
		CAMT SST	6-year Rpt	CAMP SST	6-year Rpt	6-year Rpt	6-year Rpt
Durham Ferry to Banta Carbona	11	0.962	0.9765	0.967	0.986	0.988	0.973
Banta Carbona to Mossdale	10	0.982	0.985	0.978	0.980	0.985	0.980
Mossdale to Lathrop/Old River	4	0.985	0.985	0.995	0.995	0.995	0.966
Lathrop to Garwood Bridge (SJR)	18	0.995	0.995	0.997	0.997	0.948	0.974
Garwood Bridge to Navy Bridge	3	0.993	0.993	0.990	0.990	0.958	0.976
Navy Bridge to Turner Cut/MacDonald Island	15	0.997	0.997	0.994	0.994	0.984	0.984
MacDonald Island to Medford Island	5	0.942	0.949	0.923	0.941		
Turner Cut to Jersey Point (includes interior Delta route but not SJR route)	28	0.958	0.957	0.934	0.933		
Medford to Jersey Point	21	0.992		0.987			
Jersey Point to Chipps Island	22	0.997		0.989			

Note: Darker red boxes have lower survival values and lighter boxes indicate higher survival rates (white ≥ 99% survival/km). Missing values reflect sparse data in the reach in question or the study had deficiencies that prevented estimates to be made.

Table 5: Heat Map depicting Survival Rates ($S^{(1/km)}$) through Old River Reaches to Chipps Island.

Reach Name	km	Survival Estimate per km ($S^{(1/km)}$)					
		2011		2012		2013	2014
		CAMT SST	6-year Rpt	CAMP SST	6-year Rpt	6-year Rpt	6-year Rpt
Old River (Head) to Middle River Head/ Old River (south)	6	0.990	0.9897	0.977	0.977	0.990	0.948
Old River (South) to CVP/CCF/HWY4	20	0.994	0.988	0.977	0.977	0.981	0.983
Old River (HWY4) to Jersey Point	60	0.992	0.992	0.958		0.972	0.978
CVP Holding Tank to Chipps Island	15	0.988	0.992	0.973	0.965	0.987	1.0/0.98
CCF Radial Gate (interior) to Chipps Island	24	0.979	0.983	0.924	0.914	0.957	0/ 0.95

Note: Darker red boxes have lower survival values and lighter boxes indicate higher survival rates (white ≥ 99% survival/km). Missing values reflect sparse data in the reach in question or the study had deficiencies that prevented estimates to be made.

Yellow highlighted cells have two survival estimates. Estimate from the first release in 2014 have a survival rate of 98% from the CVP holding tank to Chipps Island, and a survival rate of 95% from the CCFB interior radial gates to Chipps Island based on a joint tag survival and fish survival estimates due to premature tag failures occurring in the first release group. The 100 % survival for the CVP estimate is based on the second and third releases with a total of 12 fish detected in the holding tank and 12 fish detected at Chipps Island. The zero survival for the

CCFB radial gate to Chipps Island is based on 3 fish detected at the interior radial gate with none subsequently detected at Chipps Island.

Figure 1: Locations of Acoustic Receivers (general locations) as each study had a small number of additional/ removed or relocated acoustic receiver locations. (2012 study locations used as an example).

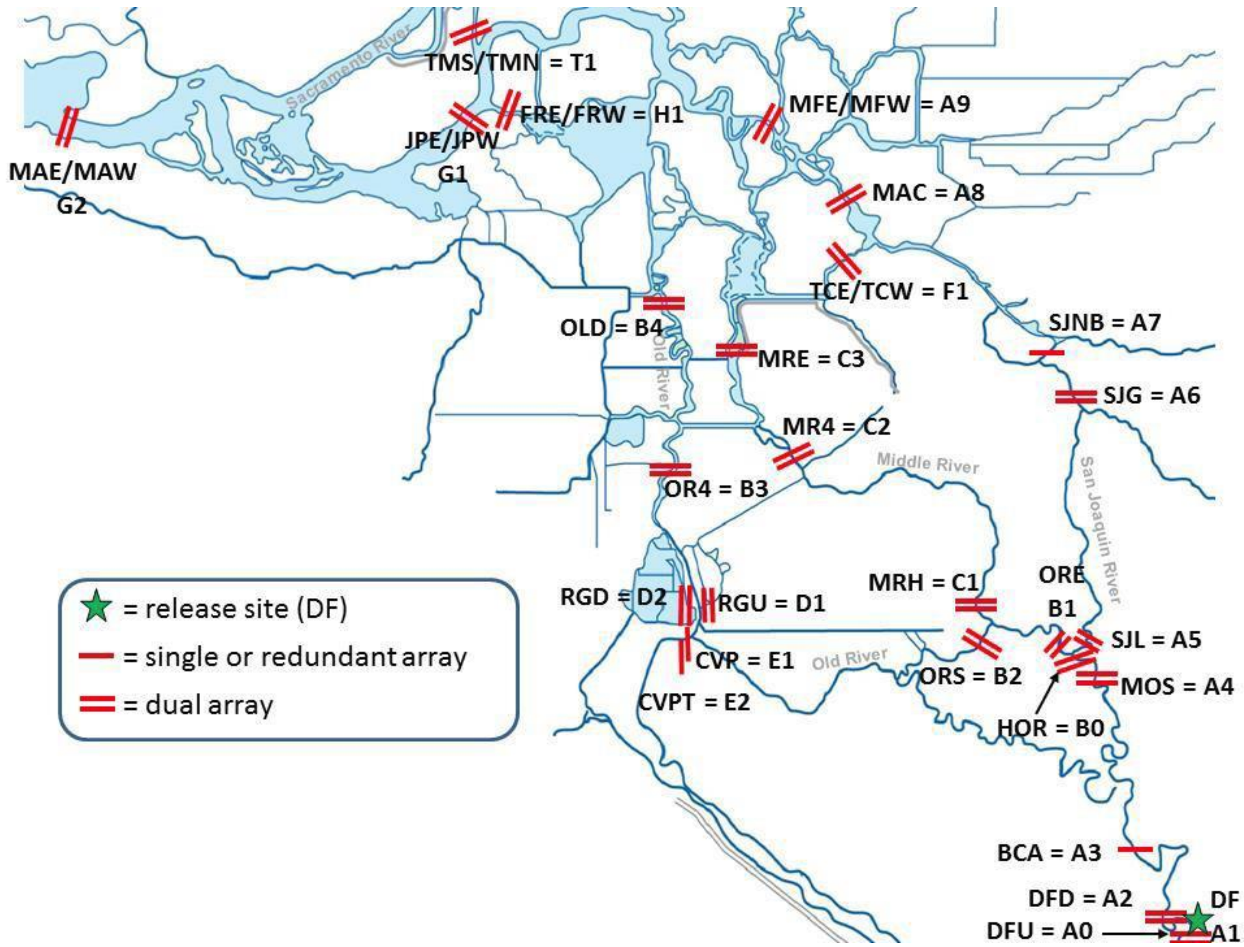


Figure 2: March through June Vernalis Flows for Study Years 2011 – 2014 with release groups.

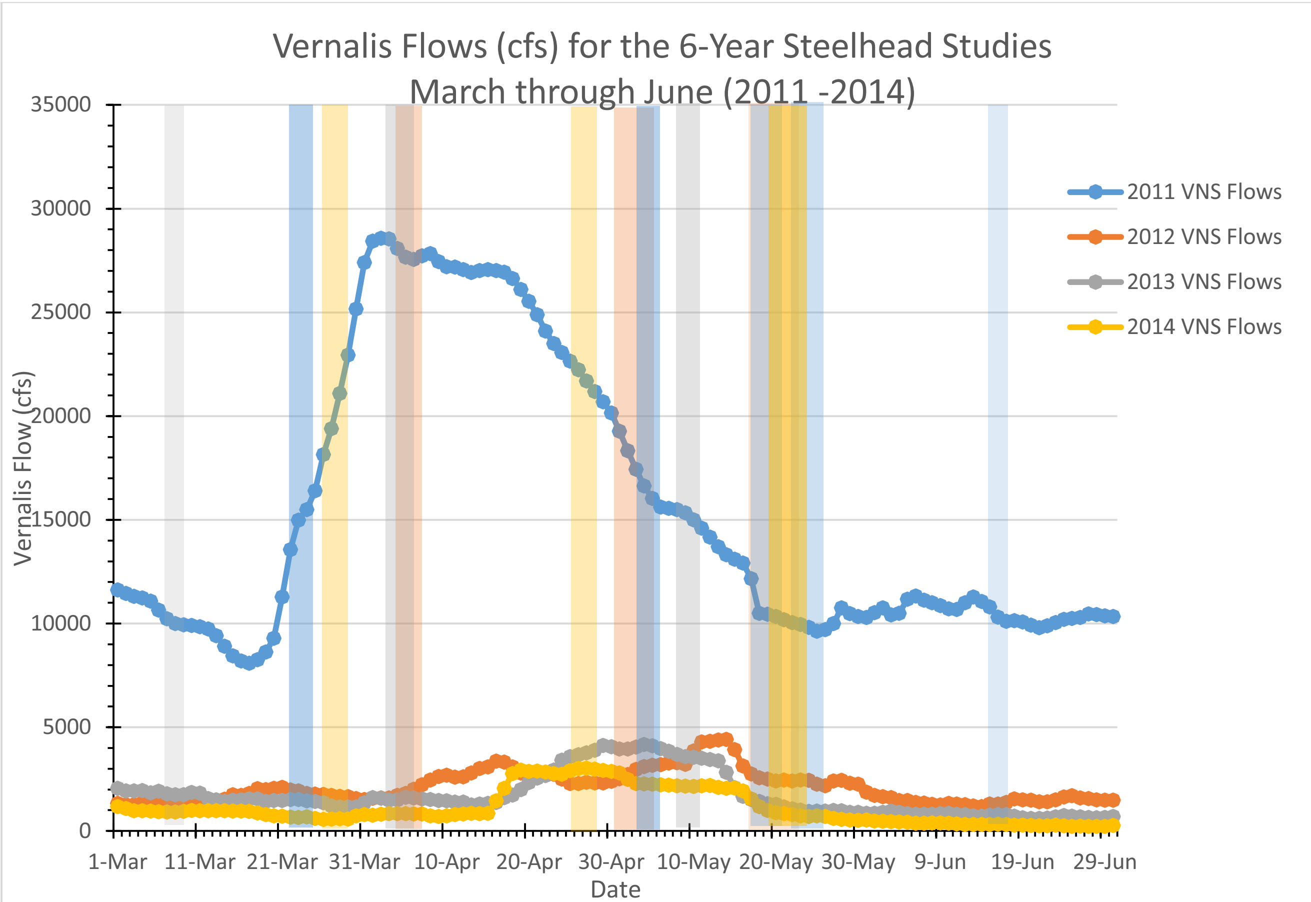
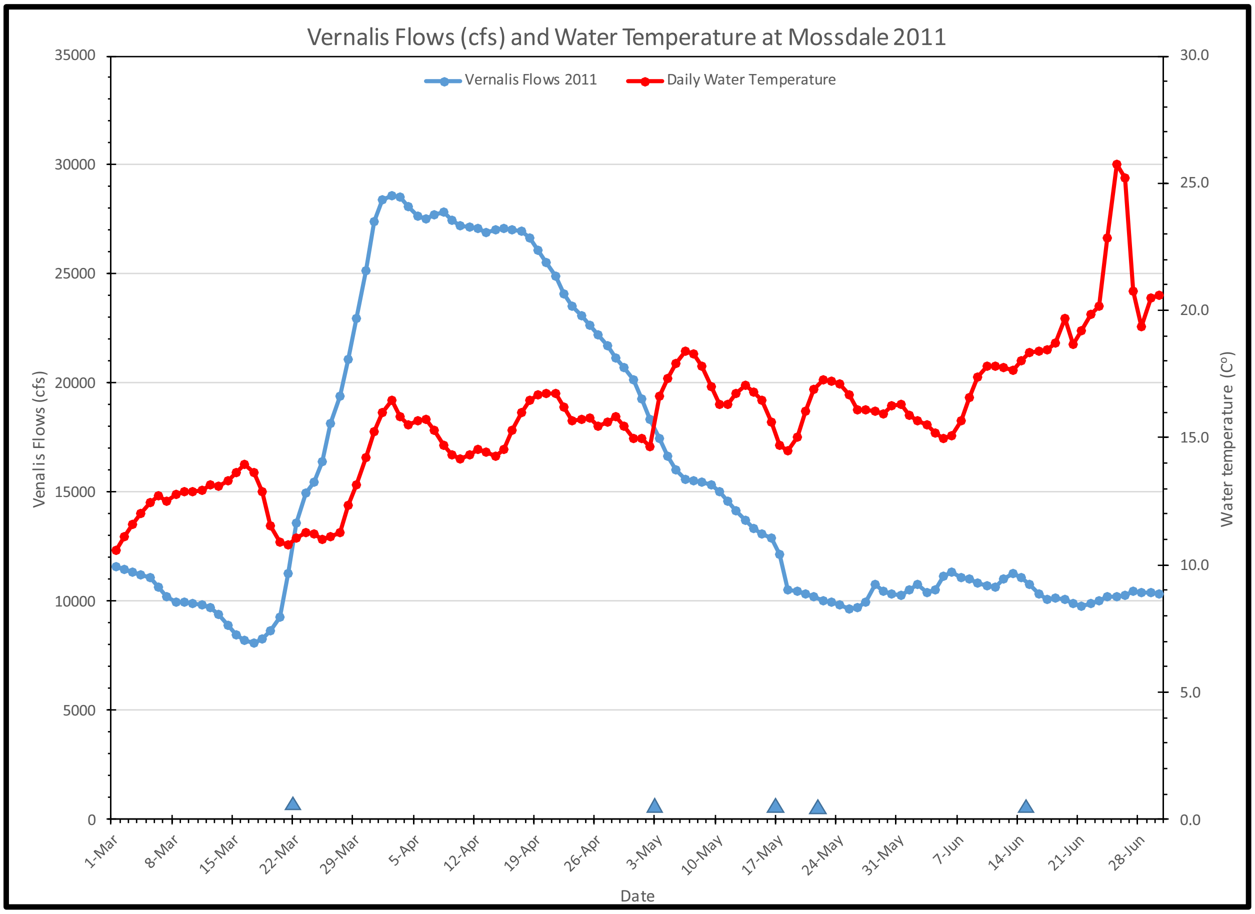
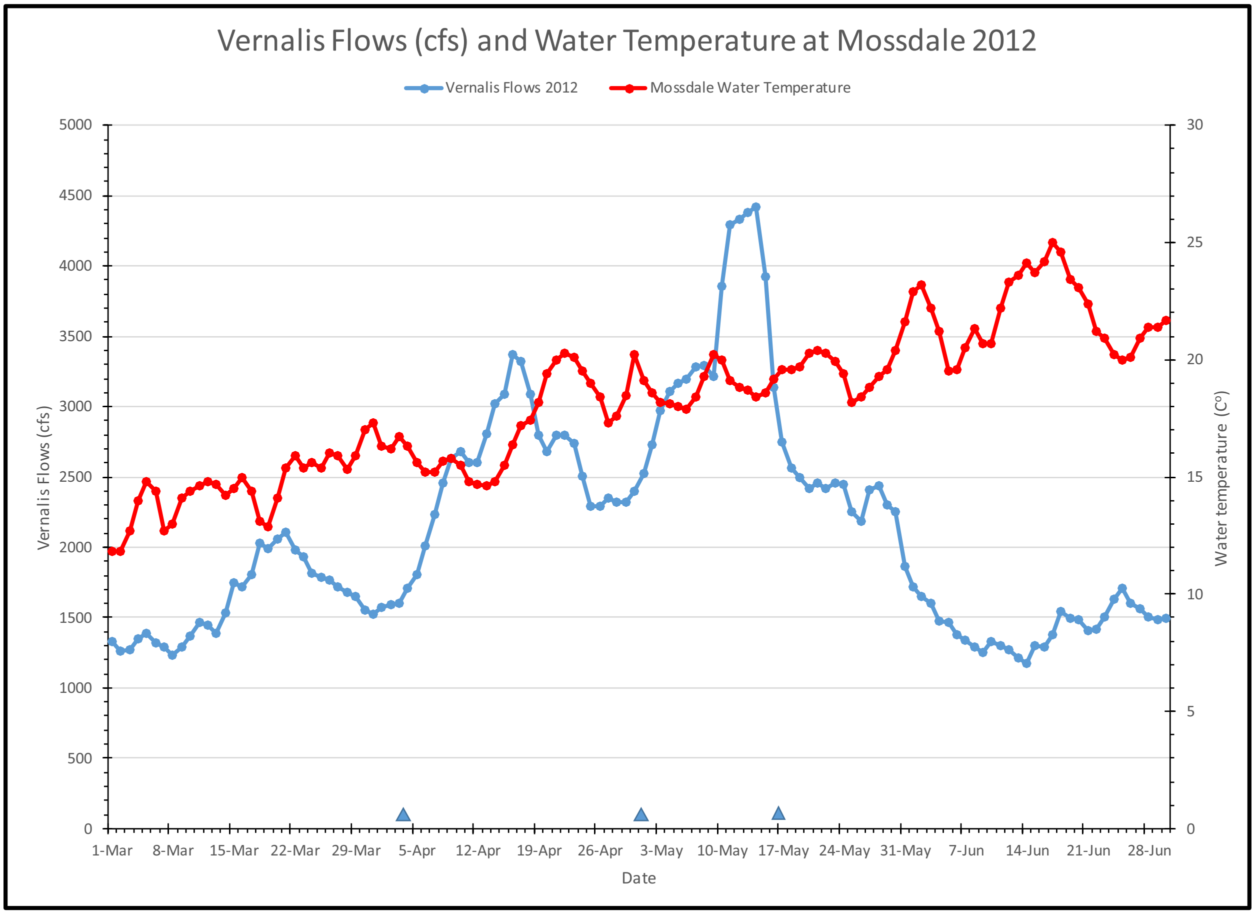


Figure 3:Vernalis Flows and Mossdale Water Temperatures March through June 2011



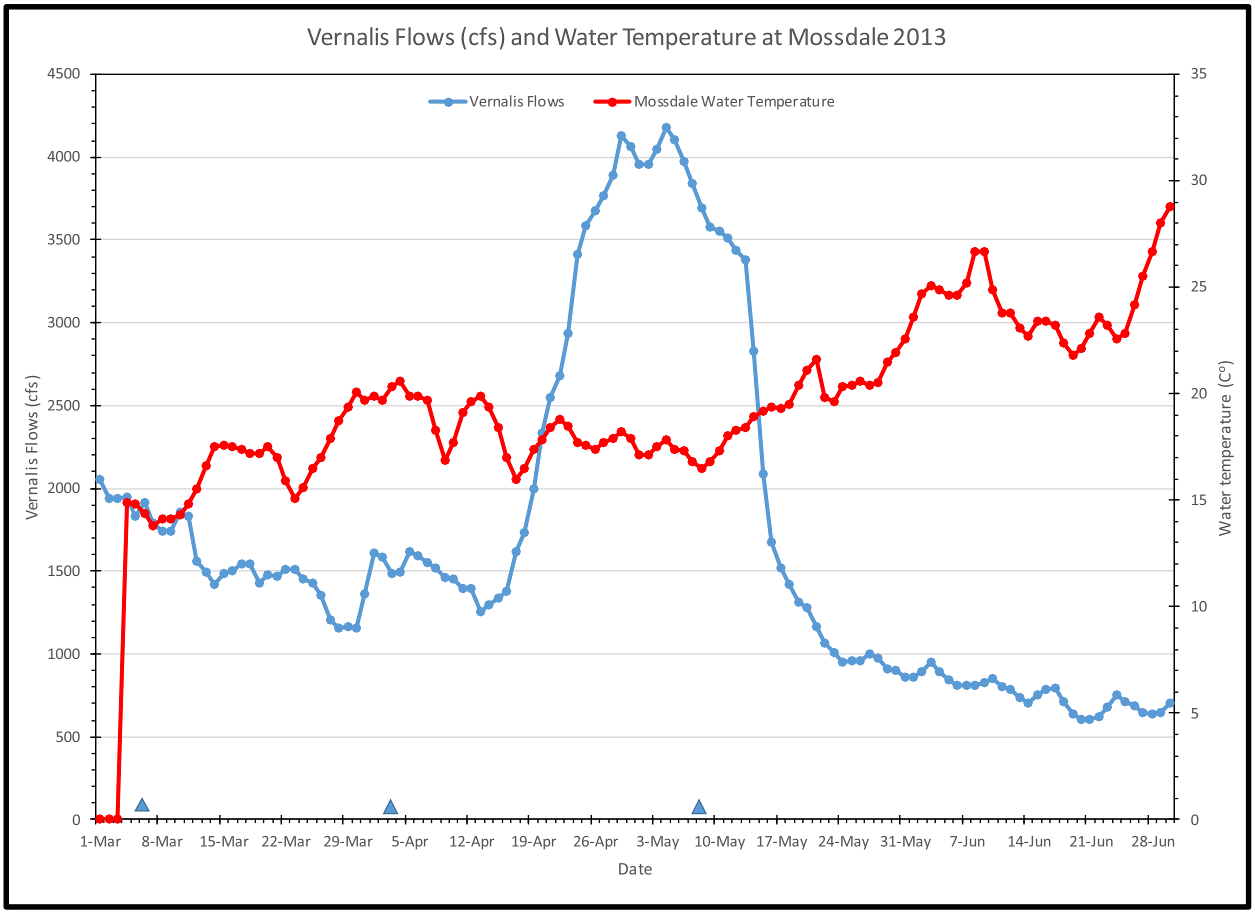
Triangles depict the initial date of releases for each release groups

Figure 4: Vernalis Flows and Mossdale Water Temperatures March through June 2012



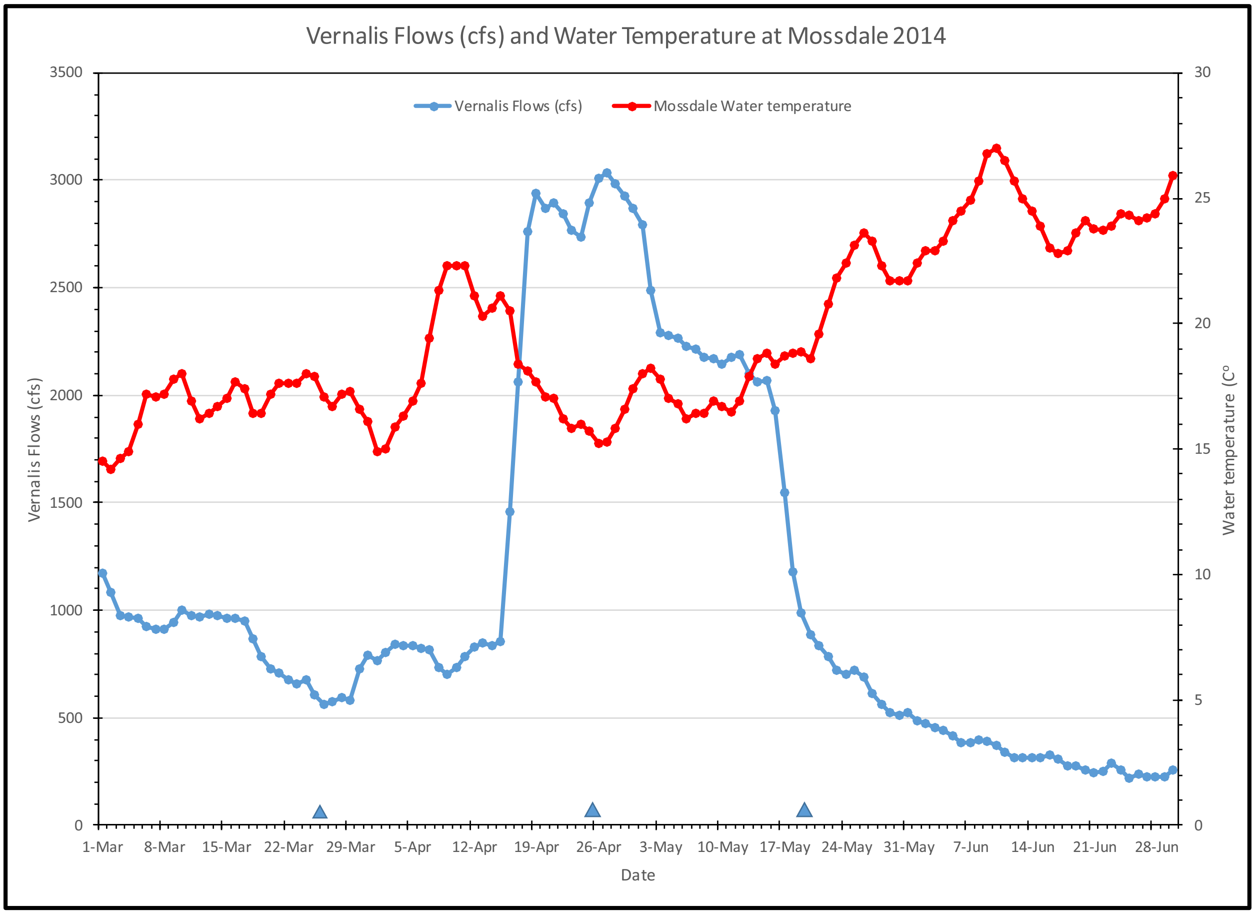
Triangles depict the initial date of releases for each release groups

Figure 5: Vernalis Flows and Mossdale Water Temperatures March through June 2013



Triangles depict the initial date of releases for each release groups

Figure 6: Vernalis Flows and Mossdale Water Temperatures March through June 2014



Triangles depict the initial date of releases for each release groups

Figure 7: Cumulative survival from releases at Durham Ferry to various points along the San Joaquin River route to Chipps Island by surgeon (2012 study). Error bars are 95% confidence intervals.

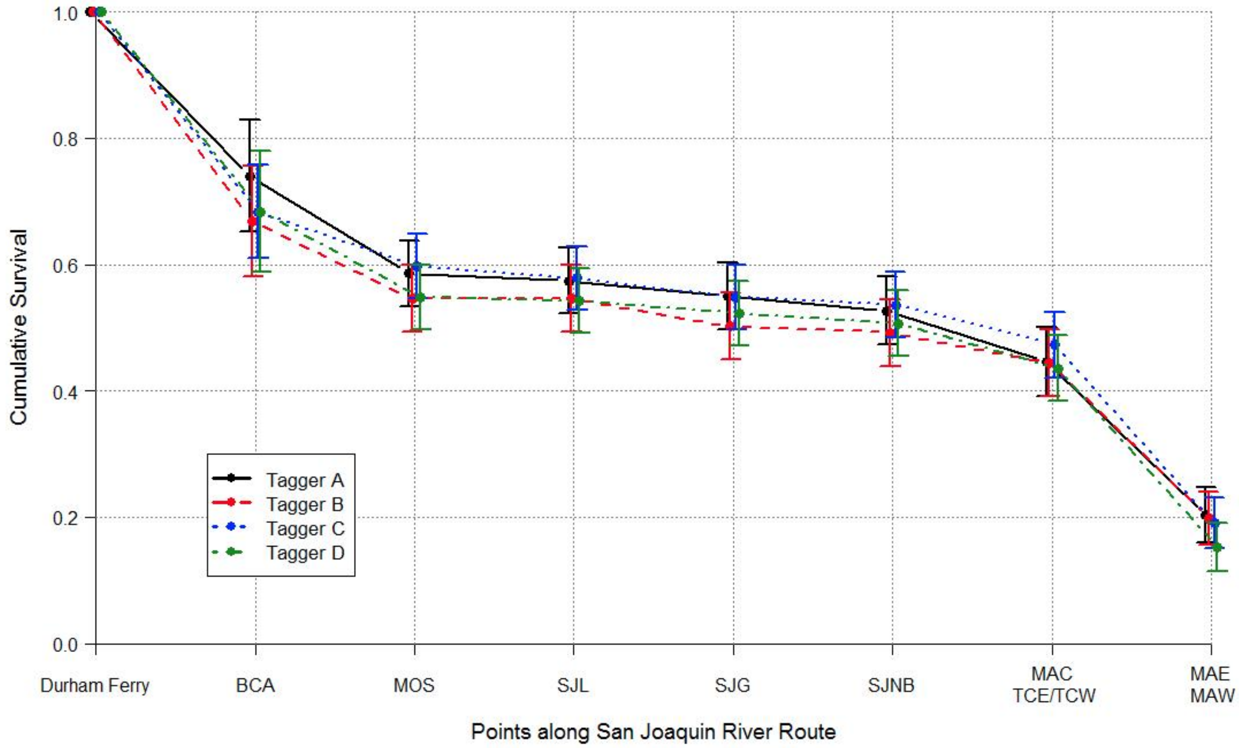


Figure 8: Cumulative survival from releases at Durham Ferry to various points along the Old River route to Chipps Island by surgeon (2012 study). Error bars are 95% confidence intervals.

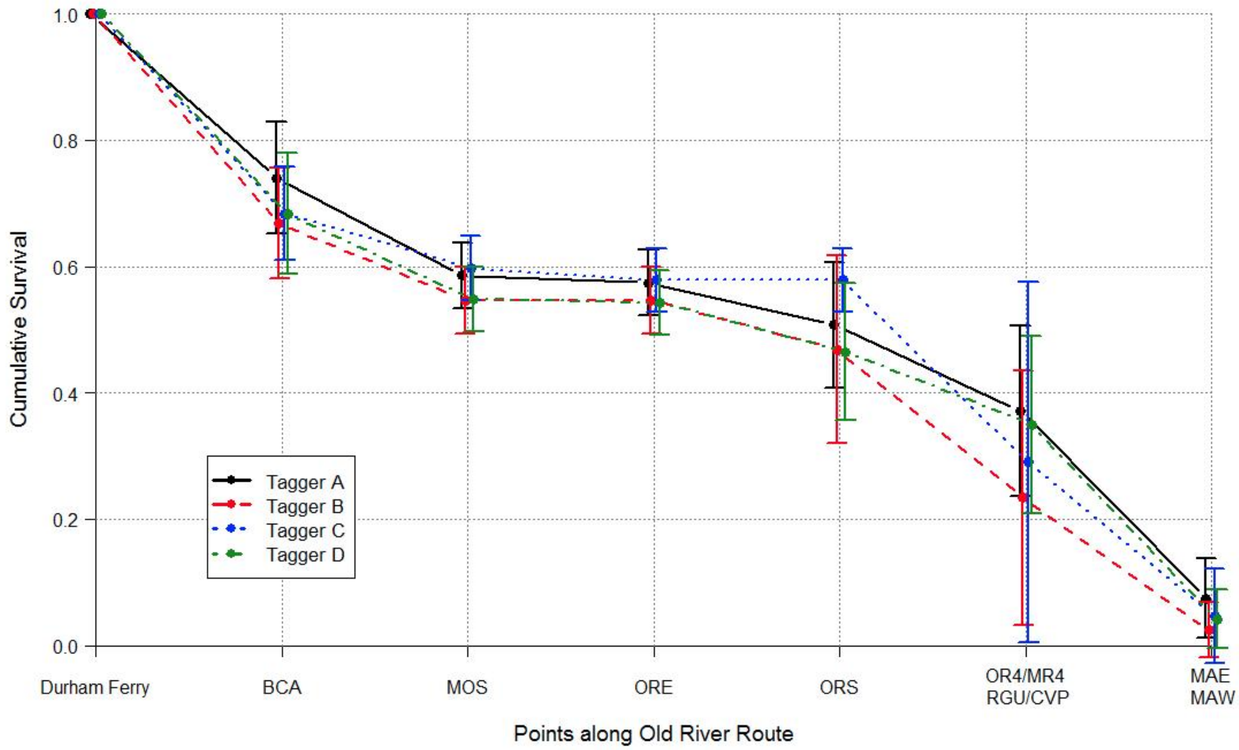


Figure 9: Cumulative survival from releases at Durham Ferry to various points along the San Joaquin River route to Chipps Island by surgeon (2013 study). Error bars are 95% confidence intervals.

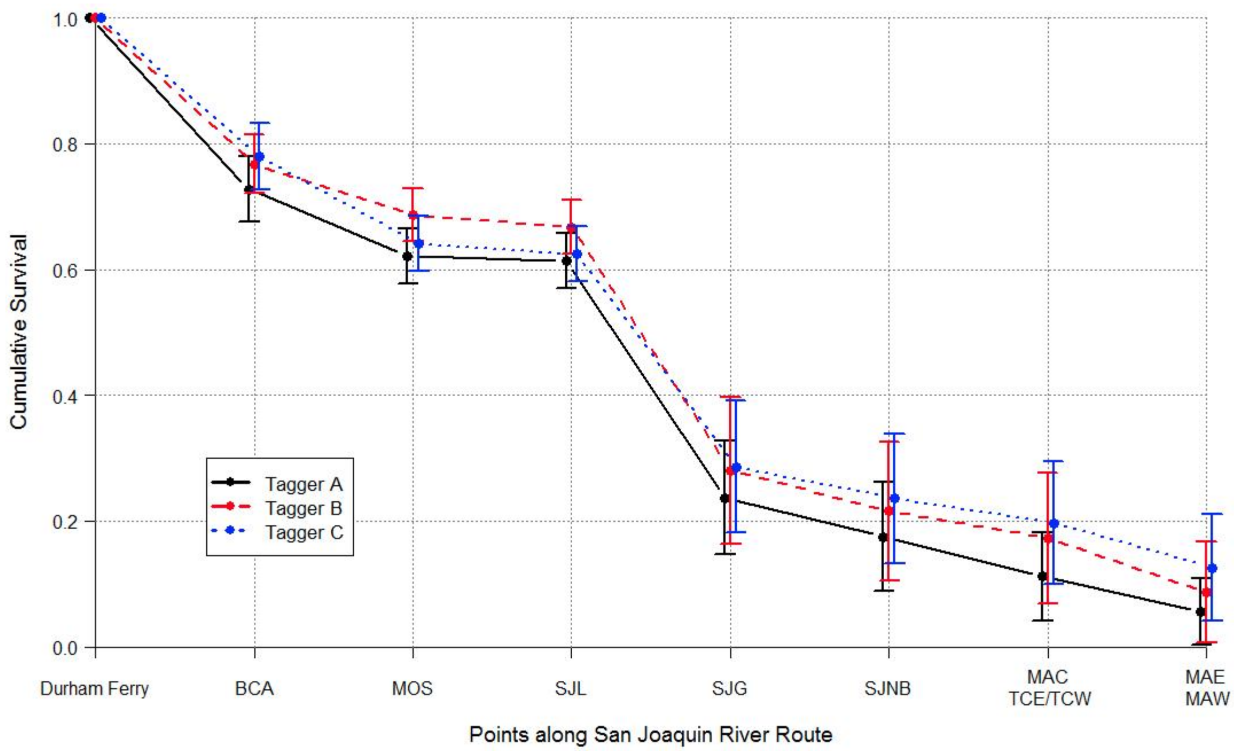


Figure 10: Cumulative survival from releases at Durham Ferry to various points along the Old River route to Chipps Island by surgeon (2013 study). Error bars are 95% confidence intervals.

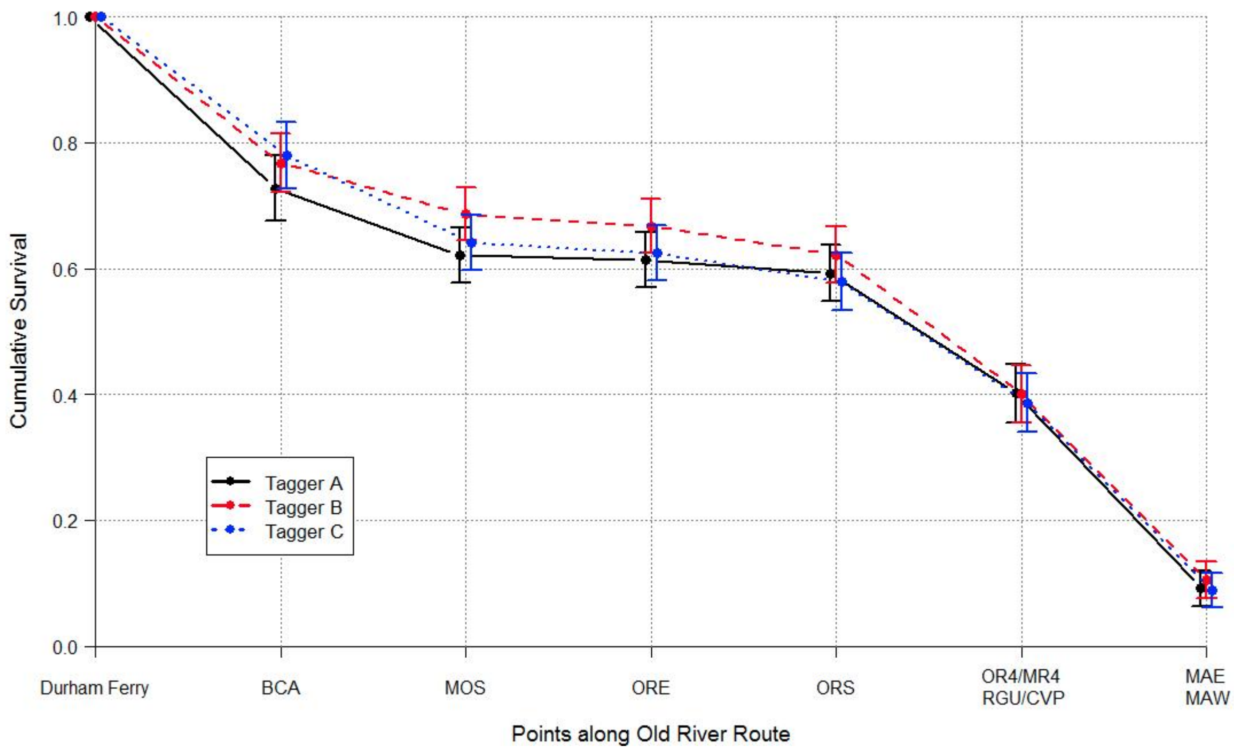


Figure 11: Cumulative survival from releases at Durham Ferry to various points along the San Joaquin River route to Chipps Island by surgeon (2014 study). Error bars are 95% confidence intervals. Estimates are of joint fish-tag survival.

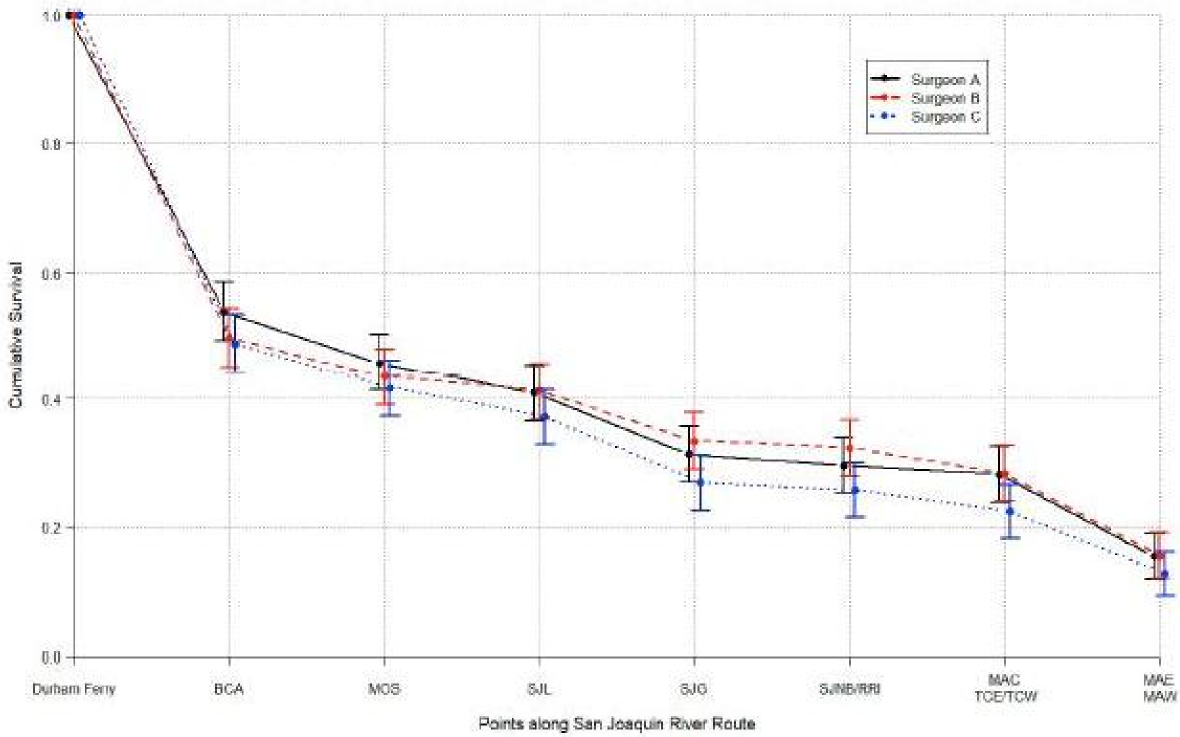
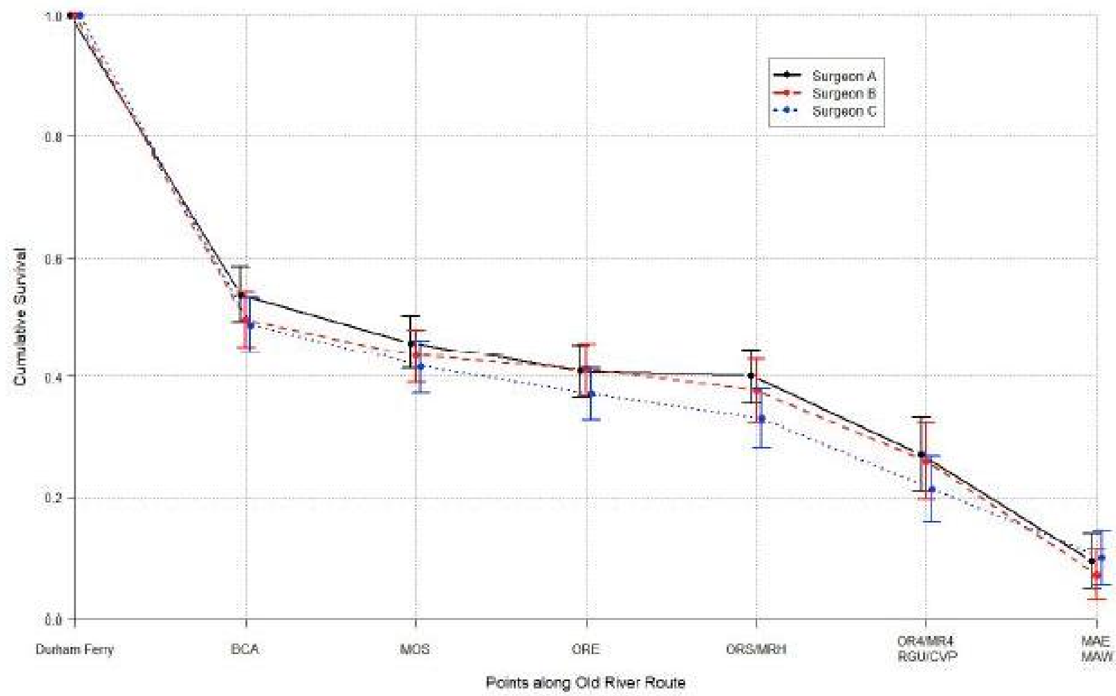


Figure 12: Cumulative survival from releases at Durham Ferry to various points along the Old River route to Chipps Island by surgeon (2014 study). Error bars are 95% confidence intervals. Estimates are of joint fish-tag survival.



Summary of SWFSC report to USBR on analysis on subset of Steelhead "6-year Study" acoustic telemetry data

Background: The SWFSC (Dr. Andrew Hein) used a subset of six-year study steelhead acoustic telemetry data at five hydrophone arrays in the Delta to understand the relationship between the instantaneous migration rate and environmental variables using a novel point process statistical model framework. The instantaneous migration rate refers to the minute-by-minute fish movements into the zone within range of detection by a hydrophone array, rather than the long-term movements of fish throughout the system.

Methods (refer to Fig. 1): Acoustically tagged fish were released at Durham Ferry (release location) and subset for analysis purposes to include mostly 2011 data. The environmental variables of interest were turbidity, conductivity, temperature, diel phase, discharge, and the rate of discharge over time. These data were subjected to a symbolic regression (point process model) aimed at generating a variety of models to predict the instantaneous movement behavior in response to different environmental variables, specifically the expected arrival of fish at location x and time t.

Results (refer to Fig. 2): Discharge, conductivity and turbidity were the variables that most often had the strongest relationship with the arrival rate of steelhead at the subset of hydrophone arrays investigated. The conditional effects of each environmental variable (varying one variable at a time while holding all others at their mean value) for each hydrophone array location are described below:

- At **BCA** (near release site), arrivals of fish were negatively related to discharge, and positively related with warmer and more turbid water conditions.
- At **SJL,** turbidity and temperature exerted dominant effects on arrival rates with a slightly less pronounced effect of water conductivity, however discharge did not have a strong influence. The conductivity effect was stronger than at other arrays higher in the river.
- At **Turner Cut (C18/16),** a more tidally influenced region, the fish moved most with high conductivity, discharge, temperature and turbidity – with discharge and conductivity having the strongest positive relationship with arrivals. (More tidal region)
- At **Jersey Point (JPT),** arrival rates were positively correlated with conductivity with less influence to no relationship with other variables. (More tidal region)
- At the **Old River (ORN)** hydrophone array, there was a different pattern in arrivals in relation to environmental variables than at other arrays investigated here. Specifically, predicted fish arrival rates increased with strong negative flows and with positive flows (a non-linear relationship) with also a small net positive effect of turbidity.

Caveats: The analysis in this report was done as a proof of concept for the modelling framework, not to answer specific management related questions. Only one full year of data was used (2011) and as such results only provide a partial understanding of conditions that might affect steelhead movement during dry years. Further, models assume that detection probability for a given hydrophone array are constant but there is likely different detection probabilities through time for each array. The models also do not necessarily use the most representative (closest) gauge data for environmental data to model with arrival detections. Other gauges or hydrological models might be appropriate to use here to couple environmental conditions with arrival detections at hydrophone locations.

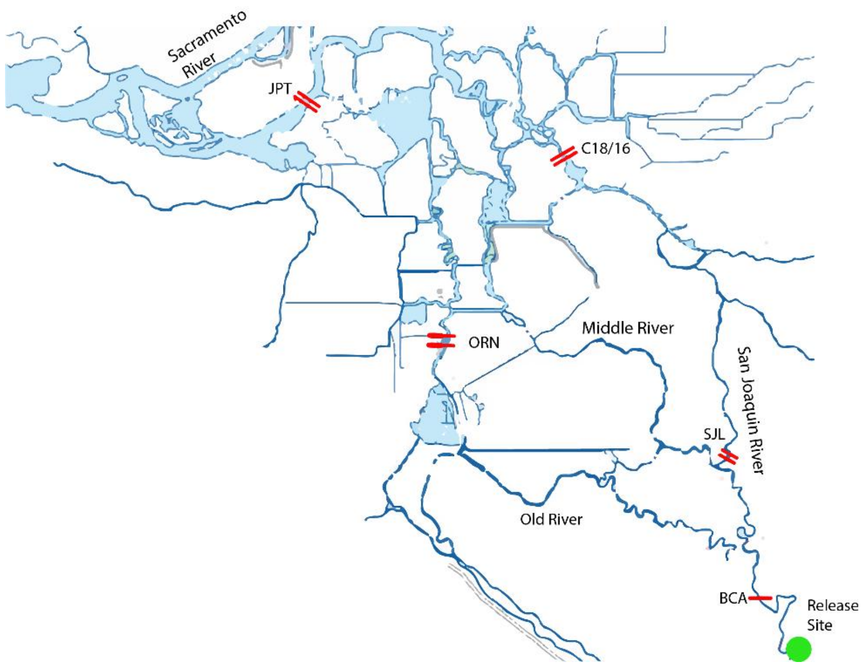


Fig. 1) Map of the Sacramento/San-Joaquin Delta with locations of single or dual hydrophone arrays (represented by one and two red bars, respectively) used in the analysis.

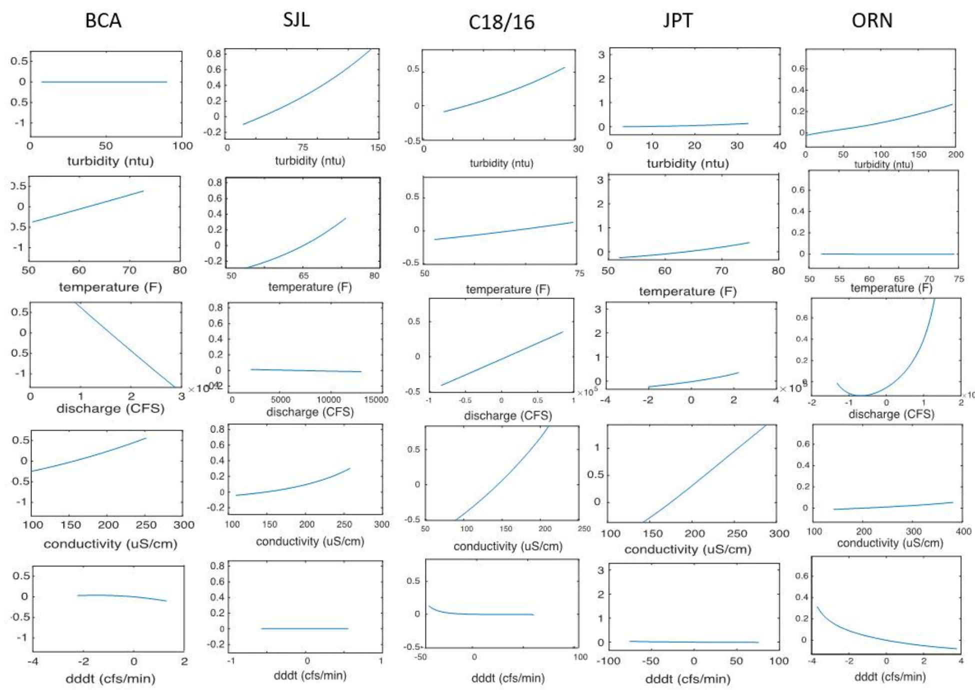


Fig. 2) Model averaged conditional effect of each environmental variable (holding others constant at mean values) on arrival rates for each hydrophone array within the Delta. Column names (BCA, SJL, C18/16, JPT, ORN) refer to individual hydrophone arrays within the Delta identified in Fig 1.

Chinook survival results

Results from:

Brandes et al. 2017, Multivariate San Joaquin River Chinook Salmon Survival Investigation, 2012-2013. USFWS report. 6 October 2017.

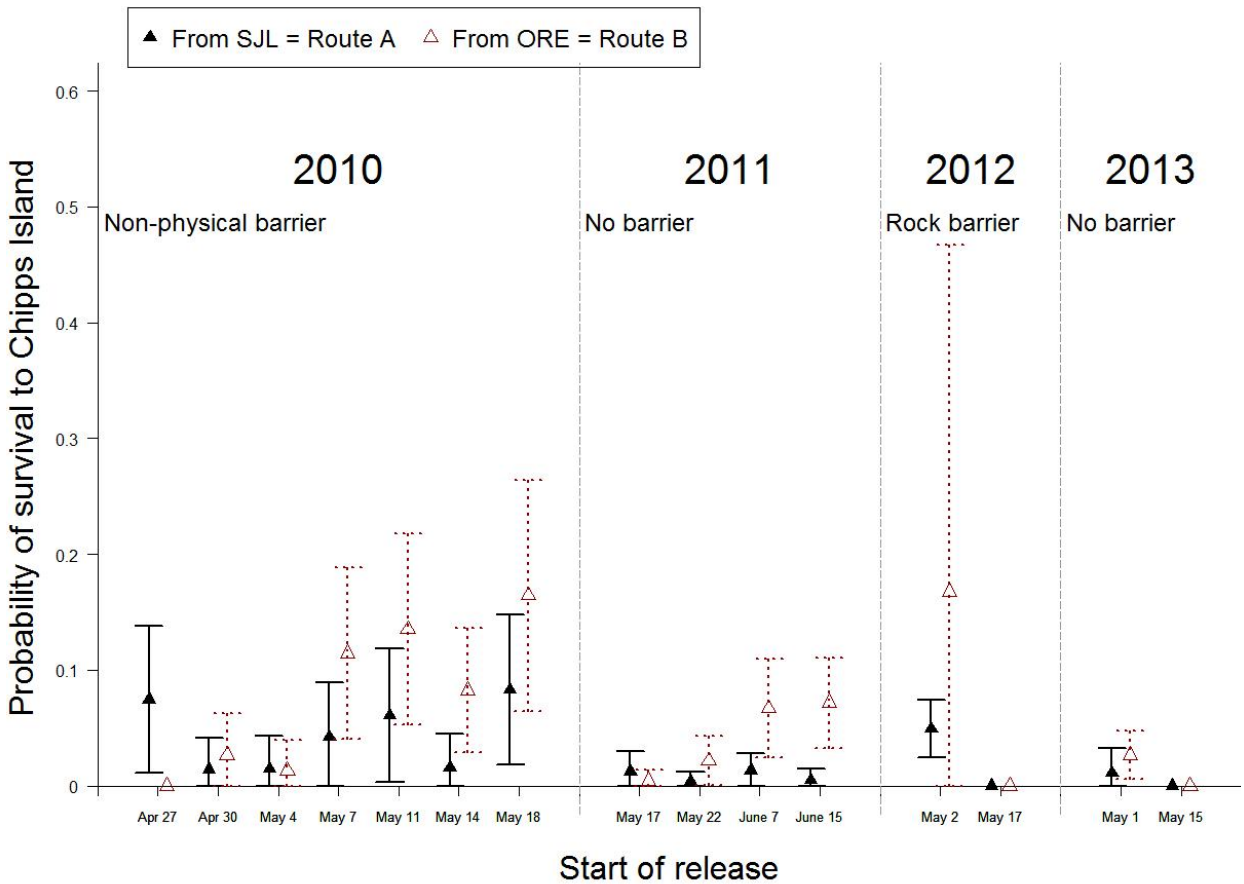


Figure 1. Estimated probabilities of surviving from the head of Old River (SJL or ORE receivers) to Chipps Island for the San Joaquin River route (Route A) and the Old River route (Route B), for each study year and release group; bars indicate asymptotic 95% confidence intervals. Route is determined at the head of Old River; salmon in the San Joaquin River route may enter the interior Delta further downstream.

<u>Selected Delta-related references relevant to water project-related effects in the south Delta</u>

Prepared by Barb Byrne, NMFS California Central Valley Office
August 2018

Note: *Takeaway bullets and quotes have been selected as being most relevant to the recently proposed draft Initial Actions in the reinitiation effort related to OMR management or the I:E ratio and do not represent all key conclusions of the citations.*

1) California Department of Water Resources (2014). Stipulation Study: Steelhead Movement and Survival in the South Delta with Adaptive Management of Old and Middle River Flows. Prepared by David Delaney, Paul Bergman, Brad Cavallo, and Jenny Melgo (Cramer Fish Sciences) under the direction of Kevin Clark (DWR). February 2014.

http://baydeltaoffice.water.ca.gov/announcement/Final_Stipulation_Study_Report_7Feb2014.pdf

Takeaway Bullet: I believe that the conclusions drawn in this report are overbroad and only weakly caveated in the report. Analysis focused primarily on junctions with the San Joaquin River rather than on movement behavior within south Delta channels yet draws broad conclusions about effects of OMR in general.

Quote (p. ES-4): The statement "Under the OMR flow treatments tested in this study, there appeared to be little influence of OMR flows tested on steelhead tag travel times on the route-level and steelhead tag movement at the junctions and routes examined in this study (p. ES-3)" is technically correct but may be misleading to those not aware that the bulk of the analysis was in the mainstem San Joaquin River route and thus not necessarily applicable to the OMR corridor itself. Despite the limited range of OMR flows, small sample sizes, and focus on conditions in the mainstem San Joaquin River, the executive summary goes on to conclude (in my opinion, improperly) that "There is little evidence that altering OMR flows within the range that we examined in this study would alter fish behavior in a meaningful way".

Caveat: Limitations in the range of OMR conditions tested, changes to OMR within treatment periods, and relatively low power tests should be taken into consideration when interpreting the results of the stipulation study. The report reflects the outcomes of the statistical analysis of selected hypotheses at a few locations in the south Delta and, in my opinion, does not support broad conclusions about fish movement in the interior Delta in relation to OMR flows.

2) del Rosario, R. B., Y. J. Redler, K. Newman, P. L. Brandes, T. Sommer, K. Reece and R. Vincik (2013). "Migration Patterns of Juvenile Winter-run-sized Chinook Salmon (*Oncorhynchus tshawytscha*) through the Sacramento–San Joaquin Delta." <u>San Francisco Estuary and Watershed Science</u> 11(1).

https://escholarship.org/uc/item/36d88128

Takeaway Bullet: Winter-run Chinook salmon enter the Delta as early as October in some years and may make their way to the south Delta and be exposed to water-project-related hydrodynamic effects.

*Quote (from abstract): "*Winter-run passed Knights Landing…between October and April, with substantial variation in peak time of entry that was strongly associated with the first high flows of the migration season. Specifically, the first day of flows of at least 400 m3 s-1 [~14,000 cfs] at Wilkins Slough (rkm 190) coincided with the first day that at least 5% of the annual total catch was observed at Knights Landing. … Differences in timing of cumulative catch at Knights Landing and Chipps Island indicate that apparent residence time in the Delta ranges from 41 to 117 days, with longer apparent residence times for juveniles arriving earlier at Knights Landing."

Caveat: Juvenile Chinook salmon were identified to race based on the length-at-date classification system, which has some uncertainty, but probably less so in the October and November time-frame when winter-run Chinook are essentially the only young-of-year Chinook run present in the system.

3) Hankin, D., D. Dauble, J. Pizzimenti, and P. Smith (2010). The Vernalis Adaptive Management Program (VAMP): Report of the 2010 Review Panel. Prepared for the Delta Science Program. May 13, 2010.

http://www.sjrg.org/peerreview/review_vamp_panel_report_final_051110.pdf

Takeaway Bullet: Complex hydrodynamics in the Delta, multiple stressors affecting salmonid survival, and a limited range of experimental conditions limit the inferences possible from the VAMP studies.

Quotes:
(p. 9) "Regarding export objectives, our feeling is that it makes sense during VAMP to continue limiting exports to some fraction of San Joaquin River flow at Vernalis so that the entire flow of the San Joaquin River is not diverted and so that reverse flows, if they occur, are not large. We cannot, however, offer any guidance as to what the Vernalis flow/export ratio should be…However, we do not believe that migration through Old River and subsequent salvage trucking and release is a desirable route for downstream migrating smolts. To the maximum extent possible, migration through the mainstem San Joaquin channel should be encouraged."

(p. 3) "The complexities of Delta hydraulics in a strongly tidal environment, and high and likely highly variable impacts of predation, appear to affect survival rates more than the river flow, by itself, and greatly complicate the assessment of effects of flow on survival rates of smolts. And overlaying these complexities is an apparent strong trend toward reduced survival rates at all flows over the past ten years in the Delta. Nevertheless, the evidence supports a conclusion that increased flows generally have a positive effect on survival and that it is desirable, to the extent feasible, to reduce or eliminate downstream passage through the Old River channel. The panel understands, of course, that flow, exports, and the placement of barriers in the Delta are the variables affecting survival that are most easily managed."

Caveat: See takeaway bullet.

4) Johnson, R. C., S. Windell, P. L. Brandes, J. L. Conrad, J. Ferguson, P. A. L. Goertler, B. N. Harvey, J. Heublein, J. A. Israel, D. W. Kratville, J. E. Kirsch, R. W. Perry, J.

Pisciotto, W. R. Poytress, K. Reece and B. G. Swart (2017). "Science Advancements Key to Increasing Management Value of Life Stage Monitoring Networks for Endangered Sacramento River Winter-Run Chinook Salmon in California." San Francisco Estuary and Watershed Science 15(3).

https://doi.org/10.15447/sfews.2017v15iss3art1

Takeaway Bullet: Our ability to evaluate risks to listed salmonids at finer spatial and temporal scales may require changes to our monitoring.

*Quote (from abstract): "*We concluded that the current monitoring network was insufficient to diagnose when (life stage) and where (geographic domain) chronic or episodic reductions in SRWRC cohorts occur, precluding within- and among-year comparisons. …We identified six system-wide recommended actions to strengthen the value of data generated from the existing monitoring network to assess resource management actions: (1) incorporate genetic run identification; (2) develop juvenile abundance estimates; (3) collect data for life history diversity metrics at multiple life stages; (4) expand and enhance real-time fish survival and movement monitoring; (5) collect fish condition data; and (6) provide timely public access to monitoring data in open data formats."

Caveat: Most of the recommended actions will require additional resources for implementation.

5) Monismith, S., M. Fabrizio, M. Healey, J. Nestler, K. Rose and J. Van Sickle (2014). Workshop on the Interior Delta Flows and Related Stressors: Panel Summary Report. Prepared for the Delta Science Program. July 2014.

http://deltacouncil.ca.gov/sites/default/files/documents/files/Int-Flows-and-Related-Stressors-Report.pdf

Takeaway Bullet: The migration of both Chinook fry and smolts may be disrupted by interior Delta flow fields; steelhead may also be affected but less so given their larger size.

Quotes:
(p. 37): "Chinook salmon fry are not strong swimmers and typically hold in shallow embayments or use structures to keep from being carried along by the prevailing current. Kjelson et al. (1982) noted that beach seine catches of Chinook salmon fry in the Delta dropped significantly at night, suggesting fry were moving away from shallow nearshore areas at night. Larger fry were captured further offshore, near the surface during the day but broadly distributed in the water column at night. If the fry move away from shore at night they would lose visual and tactile clues to their position and would likely simply be carried by the currents. This is characteristic of salmon fry (and smolt) behavior during downstream migration, which occurs primarily at night due to passive drift, but may be less functional in the tidal Delta. In the historic Delta, with its extensive marshes and many blind ending dendritic channels, simply drifting at night might not take the fry very far. In the modern Delta, however, with open trapezoidal channels and high-velocity tidal currents, fry might be carried a considerable distance in the Delta and find themselves in unfavorable habitats when light returns."

(p. 39-40): "Although Chinook salmon smolts do not go with the flow strictly in proportion to discharge they do make use of flow during migration. This raises the possibility that they could be confused by reverse flows in OMR. Because of the reverse flows in OMR when exports are large, the smolts are likely to receive mixed signals from tidal flux as water could be moving toward the pumps on both flood and ebb tides depending on the operation of the gates to Clifton Court Forebay (CCF). In this case, smolts may find themselves virtually trapped within OMR over several tidal cycles and potentially attracted into CCF because of inappropriate signals from water chemistry and flow. Since conveyance through the Delta is designed to ensure high quality of export waters (i.e., low salinity) it may be that near the pumps there is insufficient salinity signal on the tidal flow to direct the smolts and they simply go with the flow toward the pumps expecting that it is carrying them downstream. Salmon also make use of compass orientation during their migrations although the extent to which they might use this ability in the Delta is uncertain. It is possible that they might recognize that moving southward in OMR was inappropriate but whether they would be motivated to make some kind of corrective action is unknown."

(p. 44): "It appears that steelhead, which are larger than Chinook salmon smolts, are less affected by interior Delta flow fields, move through the Delta more quickly than Chinook salmon and experience greater survival. Nevertheless, steelhead are entrained into CCF and into the export pumps suggesting that some of the cues and clues they receive during their migration through the Delta lead them in the wrong direction."

Caveat: The report notes that "*(p. 74)* the vast majority of inferences about the effects of flows in the Delta on listed species are based on correlation analyses. Although correlation analysis is a useful first step when searching for relationships among variables, it often tells little or nothing about cause and effect" and "*(p. 75)* Fish in the Delta are subject to a large number of stressors and untangling the independent effects of these stressors has proven very difficult."

6) Perry, R. W., R. A. Buchanan, P. L. Brandes, J. R. Burau and J. A. Israel (2016). "Anadromous Salmonids in the Delta: New Science 2006–2016." San Francisco Estuary and Watershed Science 14(2).

http://dx.doi.org/10.15447/sfews.2016v14iss2art7

Takeaway Bullet: This paper covers a lot of topics relevant to the draft proposed Initial Action so have not selected a single takeaway bullet. My selected quote emphasizes the point that more is known about the behavior of salmonid smolts compared to salmonid parr or fry.

Quotes:
(from abstract) "Although much has been learned, knowledge gaps remain about how very small juvenile salmon (fry and parr) use the Delta. Understanding how all life stages of juvenile salmon grow, rear, and survive in the Delta is critical for devising management strategies that support a diversity of life history strategies."

Caveat: None specific to this paper; each of the studies summarized in this paper have their own associated caveats.

7) Salmonid Scoping Team (2017). Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta. Volume 1: Findings and Recommendations. January 2017.

http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/OCAPreports.html

Takeaway Bullet: See selected quotes for key takeaways.

Quotes:
(p. ES-6): "Water export operations contribute to salmonid mortality in the Delta via direct mortality at the facilities, but direct mortality does not account for the majority of the mortality experienced in the Delta; the mechanism and magnitude of indirect effects of water project operations on Delta mortality outside the facilities is uncertain."

(p. ES-6): "The evidence of a relationship between exports and through-Delta survival is inconclusive; the key findings presented in this table are supported by medium or high basis of knowledge, but our basis of knowledge on the relationship between exports and through-Delta survival is low (Appendix E, Section E.6.2.1)."

(p. ES-7): "It is unknown whether equivocal findings regarding the existence and nature of a relationship between exports and through-Delta survival is due to the lack of a relationship, the concurrent and confounding influence of other variables, or the effect of low overall survival in recent years. These data gaps support a recommendation for further analysis of available data, as well as additional investigations to test hypotheses regarding export effects on migration and survival of Sacramento and San Joaquin River origin salmonids migrating through the Delta."

(p. ES-10): "Uncertainty in the relationships between I:E, E:I, and OMR reverse flows and through-Delta survival may be caused by the concurrent and confounding influence of correlated variables, overall low survival, and low power to detect differences (Appendix E, Section E.2.3)."

(p. ES-10):

"• I:E: The relationship between Delta survival of San Joaquin River Chinook salmon and I:E is variable but generally positive for lower I:E values (e.g., I:E less than 3) (Appendix E, Section E.11, Figure E.11-1). Results of these studies are confounded by the use of flow ratios since the same I:E ratio can represent different absolute flow and export rates. These results are further confounded by installation and operations of various South Delta barriers. Data are available from only two years of AT studies using steelhead (Appendix E, Section E.11-4).

• Exports: There was a weak positive association between the through-Delta survival of San Joaquin Chinook salmon and combined exports using the CWT data set, but comparisons are complicated by the correlation between exports and San Joaquin River inflow (Appendix E, Section E.6.2.1)."

Caveat (p. ES-12): "Current understanding of juvenile salmon and steelhead survival in the Delta is constrained by a variety of factors…" [See the list of "Constraints on Understanding" on pages ES-12 to ES-13]

8) Salmonid Scoping Team (2017). Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta. Volume 2: Responses to Management Questions. January 2017.

http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/OCAPreports.html

Takeaway Bullet: If the in-season risk assessments in the draft proposed Initial Actions result in a start to OMR management later than January 1, ESA-listed salmonids (winter-run in most years, spring-run in many years, and steelhead in some years) may not have protection equal to that provided by implementation of the 2009 NMFS BiOp.

Quote (p. ES-2): "Although not capturing the seasonal variation in juvenile movement, the January 1 onset of Old and Middle rivers (OMR) reverse flow management coincides with the presence of winter-run Chinook salmon in most years, spring-run Chinook salmon in many years, and steelhead in some years (Figures 4-1, 4-2, 4-3, and 4-4 in Section 4). If OMR reverse flow management were initiated based on first detection in the Delta rather than a fixed date, OMR reverse flow management would often begin earlier than January 1 for the protection of winter-run or spring-run Chinook salmon, and later than January 1 for the protection of steelhead. The January 1 trigger date provides a general approximation of a date by which juvenile winter-run Chinook have likely entered the Delta and, based on its simplicity for triggering management actions, has utility."

Caveat: See some technical disagreements about OMR management described on pages ES-2 to ES-3

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 18°C for the second and third releases. Water temperatures following the first release were between 15 and 18°C.
    - Water temperatures in 2013 were slightly below 15°C during the first release, but were above 15°C during the second and third releases.
    - Water temperatures in 2014 were between 15 and 18°C 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.