Sites Project: Near-Field Analyses and Far-Field Flow-Survival Analyses

California Department of Fish and Wildlife

July 16, 2019

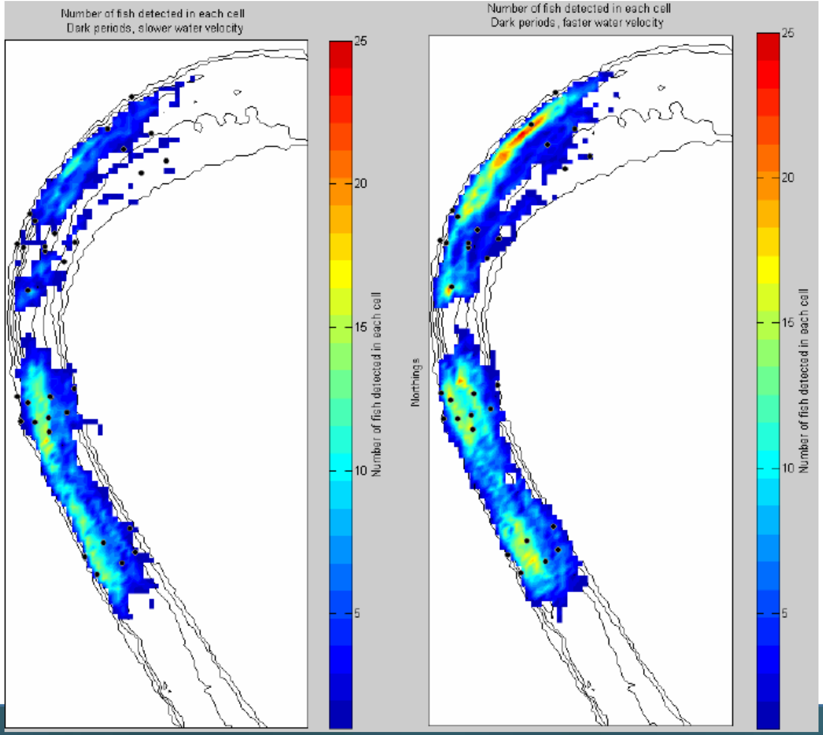
Draft – Subject to Change – For Discussion Purposes Only

Outline of Discussion

- Near-field effects
  - Spatial distribution (screen exposure)
  - Entrainment; impingement, screen contact, screen passage
  - Predation
  - Stranding behind screens during high flow
  - Attraction to screens during reservoir discharge
- Far-field effects
  - Henderson et al. migration flow-survival
  - OBAN

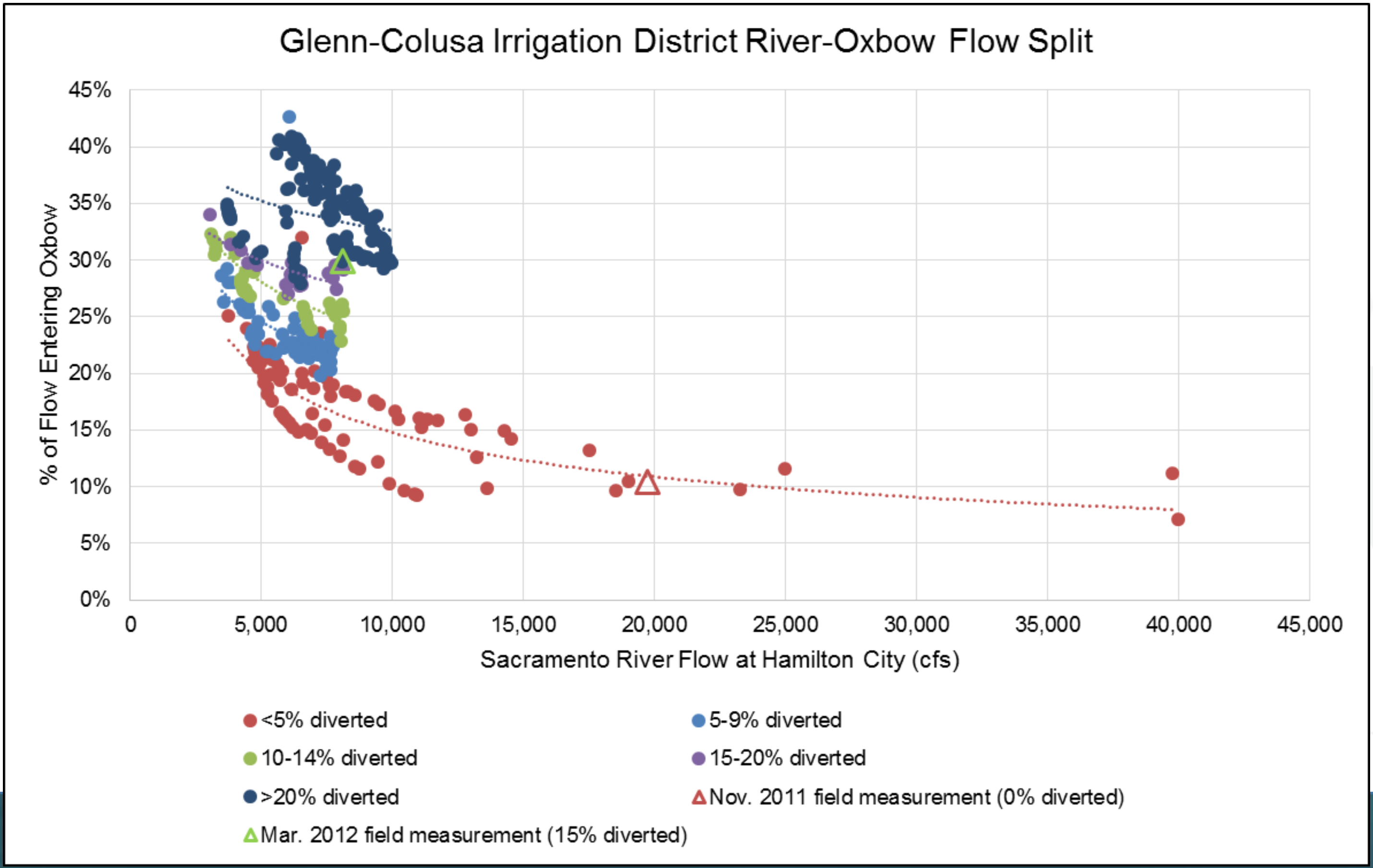
Near-field effects

- Spatial distribution (screen exposure)
  - Generally qualitative discussion based on observations at other locations (e.g., Clarksburg Bend)



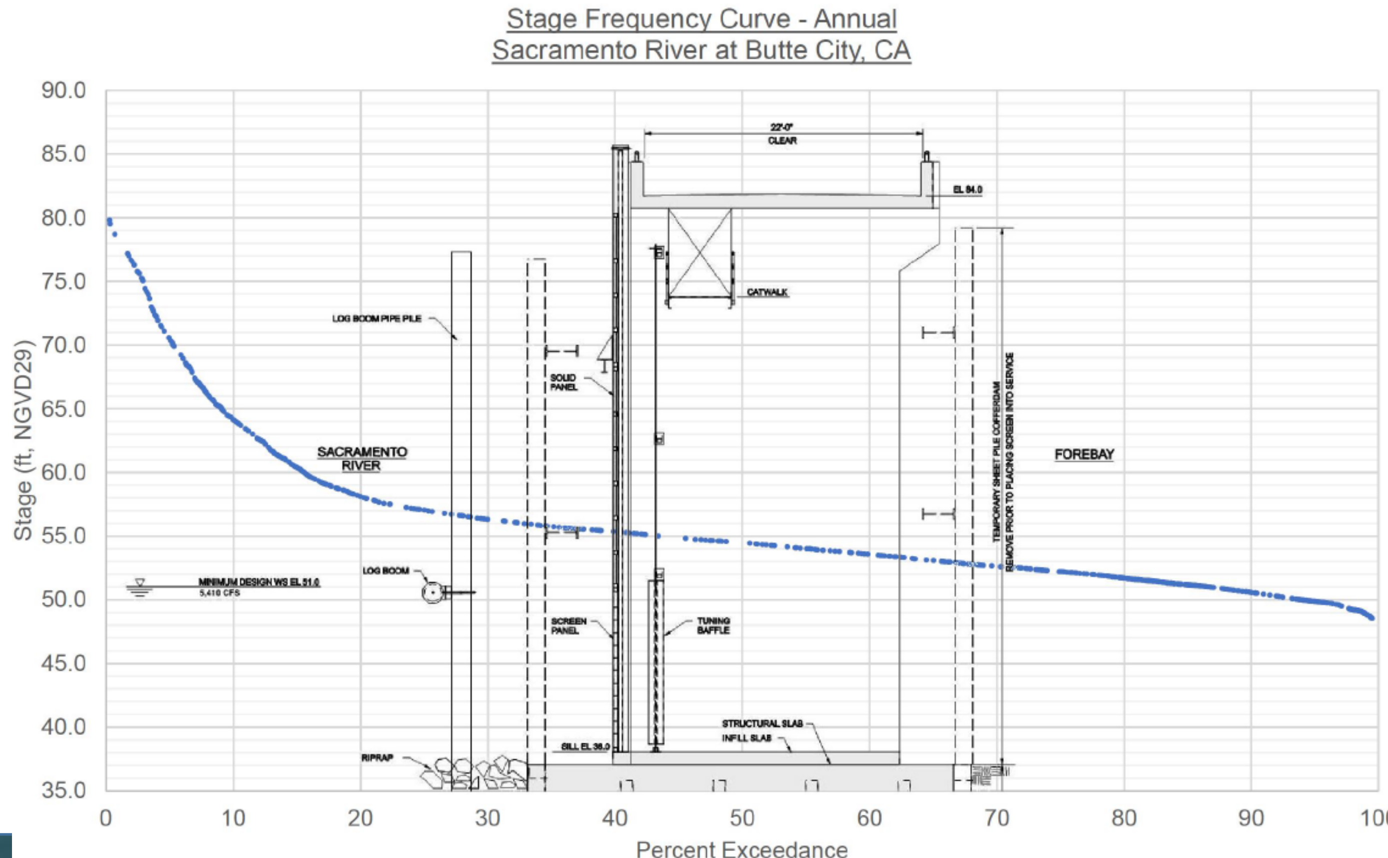
Near-field effects

- Spatial distribution (screen exposure)
  - Consideration of % flow entering GCID oxbow



Near-field effects

- Spatial distribution (screen exposure)
  - Vertical distribution in relation to screens



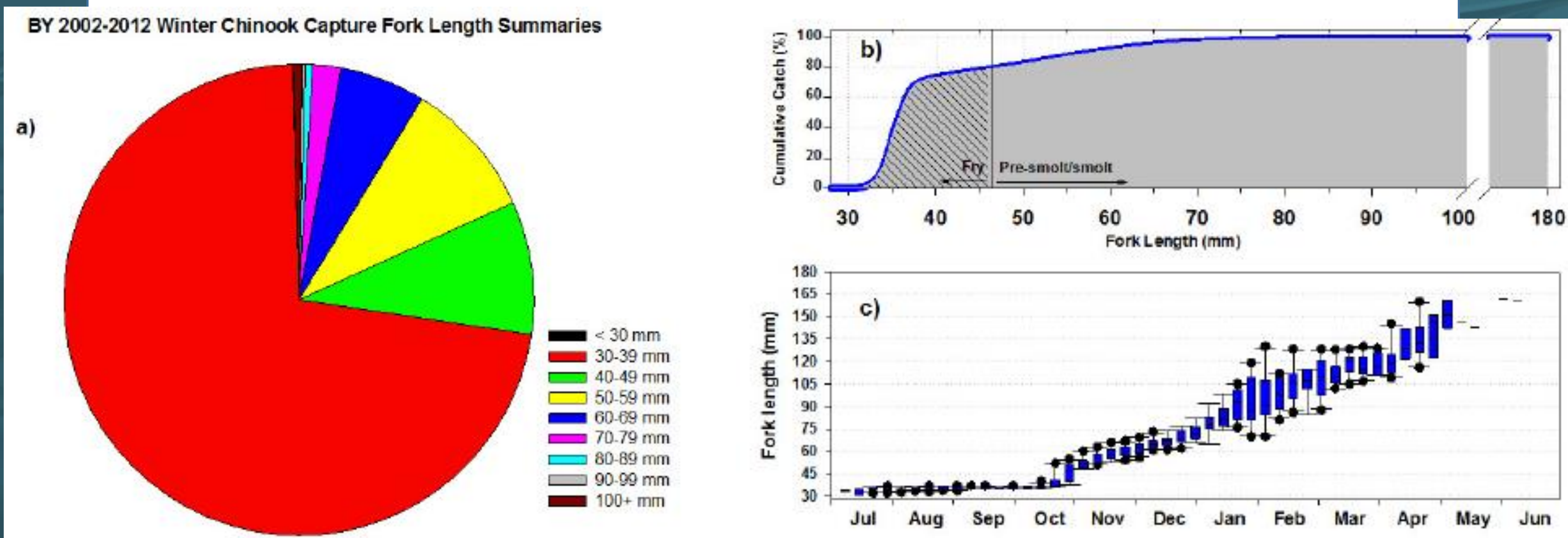
(CA Dept of Water Resources Station ID BTC: SACRAMENTO RIVER AT BUTTE CITY; Average Daily Data from January 1998 - April 2019)

Near-field effects

- Entrainment through screens
  - 1.75-mm screen opening
  - Theoretical ≥25-mm fork length (FL) exclusion (salmonids)
  - Freeport observations: one fish ~ 30-mm FL (may have been entrained at smaller size and reared within forebay)
  - Considered size distribution of fish from RBDD

Near-field effects

- Entrainment through screens
  - Very small % susceptible to entrainment based on size (e.g., Winter-Run Chinook Salmon)

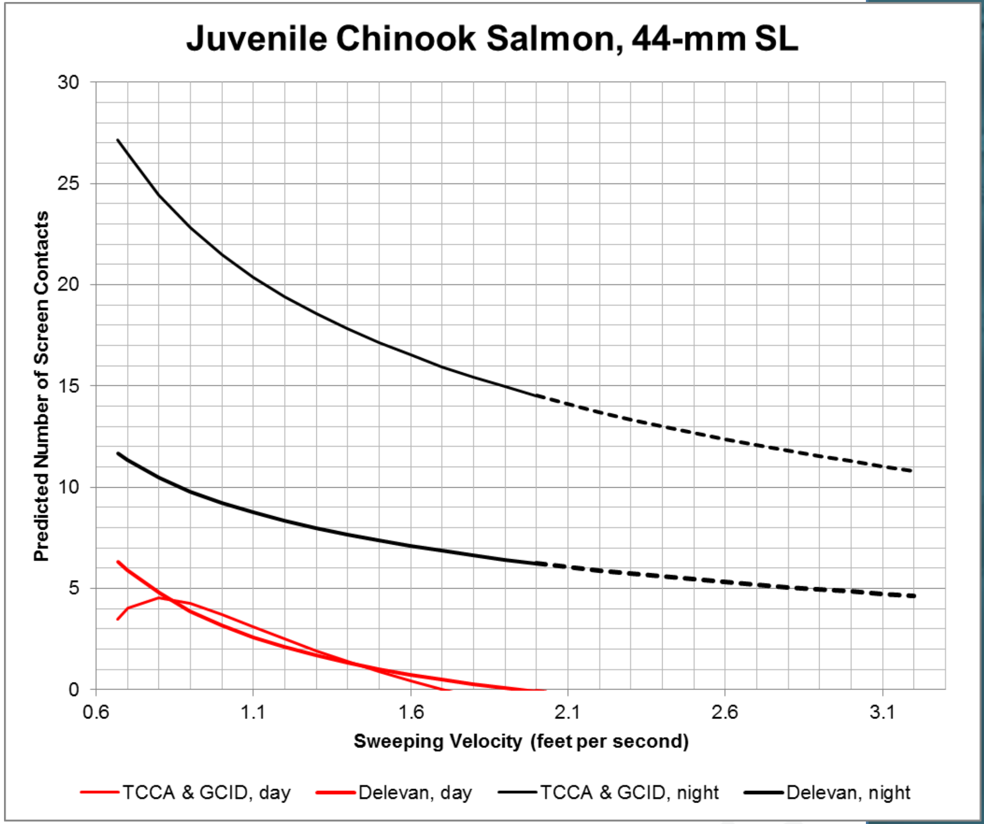


Near-field effects

- Impingement
  - Qualitative discussion based on UCD fish treadmill studies of juvenile Chinook Salmon (Swanson et al. 2004)
  - Impingement and injury rates were not related to any velocity variables; injury rate was not different between test fish and control fish

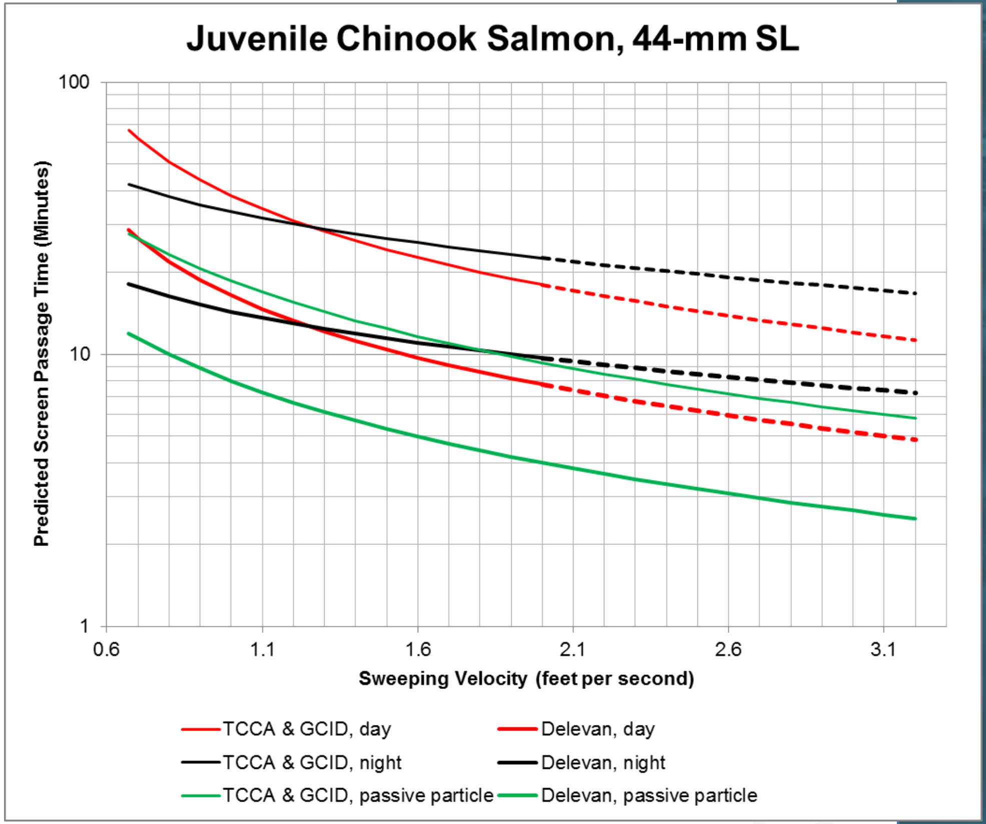
Near-field effects

- Screen contact rate
  - Estimates based on UCD fish treadmill studies (Swanson et al. 2004)
  - Approach velocity = 0.33 ft/s
  - TCCA & GCID screens ~1,100 feet long; Delevan ~480 feet long
  - Relevant only to fish passing close to the screen (test flume was 4 feet wide)



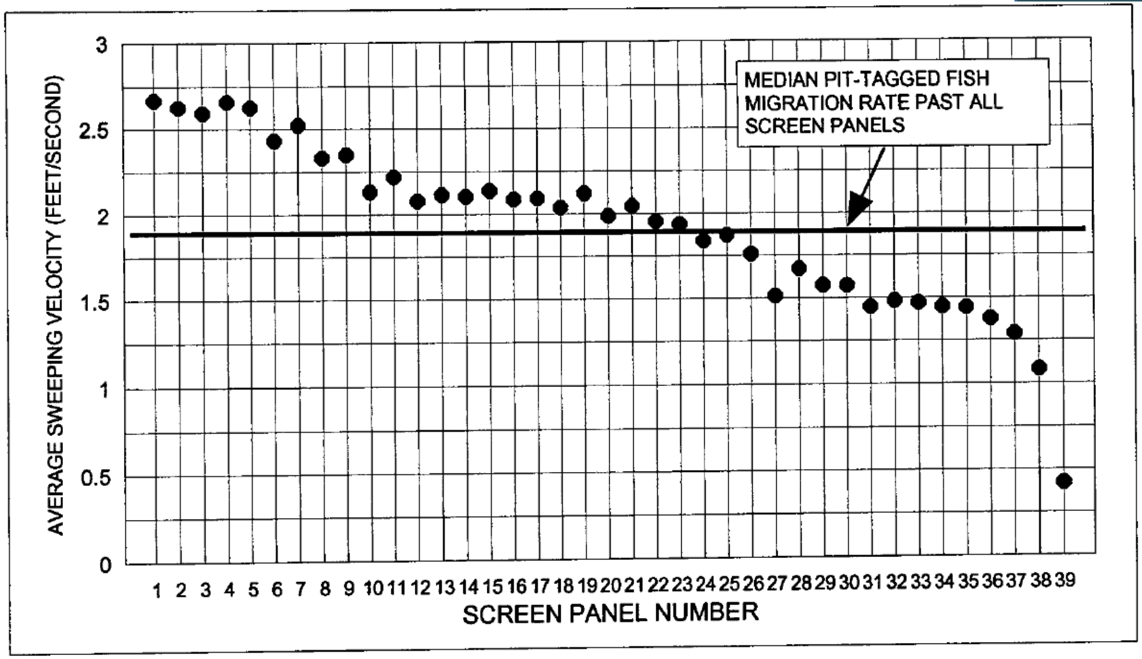
Near-field effects

- Screen passage time
  - Estimates based on UCD fish treadmill studies (Swanson et al. 2004)
  - Approach velocity = 0.33 ft/s
  - Note: estimates longer than passive particle theoretical passage time (swimming against current)



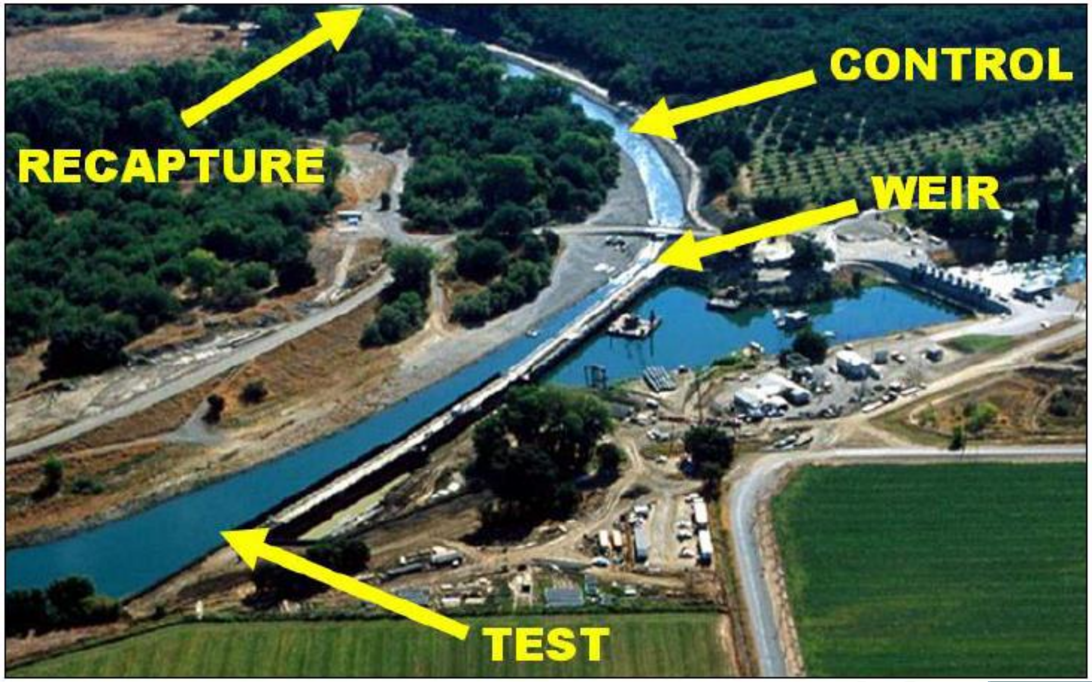
Near-field effects

- Screen passage time
  - GCID observations (Vogel & Marine 1995)
  - PIT-tagged juvenile Chinook Salmon
  - Screen passage time similar to sweeping velocity



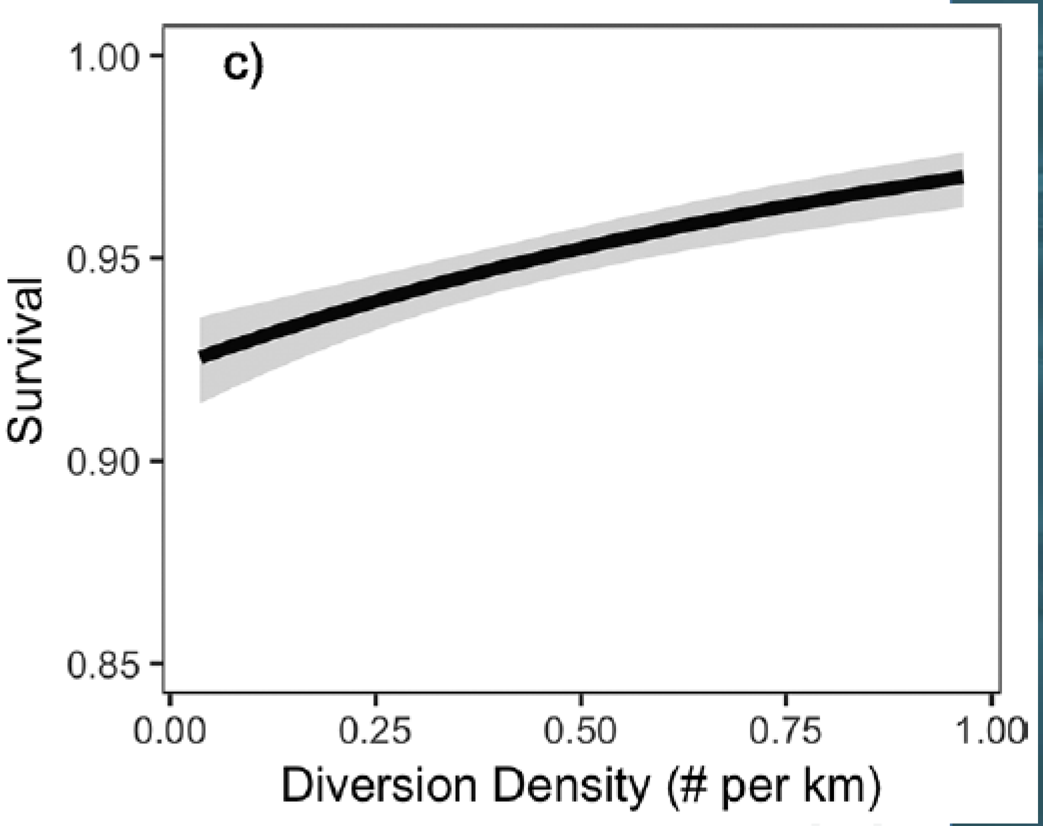
Near-field effects

- Predation
  - GCID observations (Vogel 2008)
  - Juvenile Chinook Salmon
  - Survival past screens: mean = 95%
  - However, recapture rates similar: ‘test’ to ‘recapture’ = 98% per 100 m); ‘weir’ to ‘recapture’ = 96%
  - Uncertainty because of batch release and sequential release (downstream to upstream)



Near-field effects

- Predation
  - Henderson et al. (2018) – juvenile Chinook Salmon
  - Examined significance of diversion density (number per km)
  - Found *positive* relationship with survival
  - Cautioned that this may reflect habitat conditions (e.g., riprapped banks) in diversion reaches



Near-field effects

- Stranding behind screens
  - Overtopping of screens
  - Very rare events (100-year flood at TCCA; >100,000 cfs at GCID)

Near-field effects

- Attraction to screens during reservoir discharge
  - Lift 1.75-mm screens during Delevan releases
  - Lower 19-mm picket panel (adult salmonid & Pacific Lamprey size criterion)
  - Discharge velocity ≤ 1 ft/s (salmonid criterion)
  - Initial calculations ~0.25 ft/s
  - Uncertainty in juvenile salmonids entering structure during releases

Near-field effects

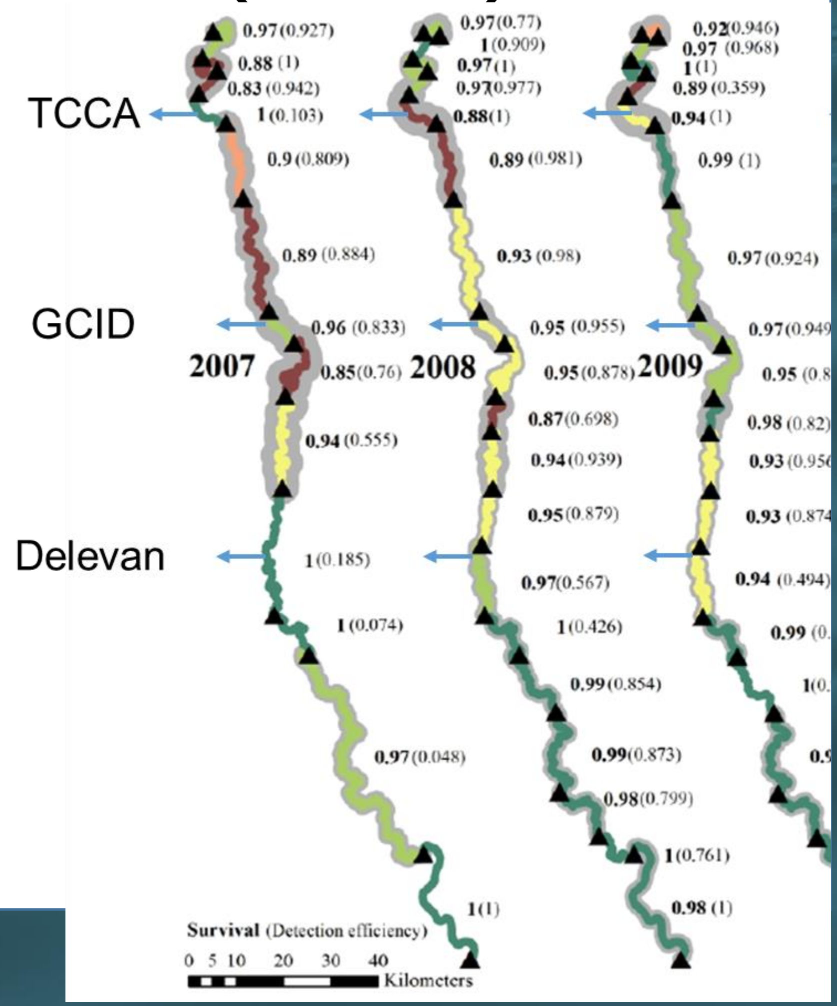
- Technical Studies and Monitoring
  - Baseline and post-construction technical studies: fish distribution (e.g., spatial); juvenile salmonid survival; predator habitat, density, and distribution; refugia field and lab studies; hydraulic screen evaluations
  - Monitoring: entrainment; impingement; stranding behind screens; attraction to screens during reservoir discharge
  - Inform assessment of biological objectives and adaptive management

Far-field effects

- Henderson et al. (2018) migration flow-survival
- OBAN model incorporating Henderson et al. adjustment

Far-field effects

- Henderson et al. (2018)
  - Peer-reviewed (CJFAS)
  - Multiple reaches from above Red Bluff down to Knights Landing
  - Focus on Sites withdrawal period (winter/spring), daily timescale
  - Incorporates flow and temperature effects
  - Also includes other (non-operations) covariates



Far-field effects: Henderson et al.

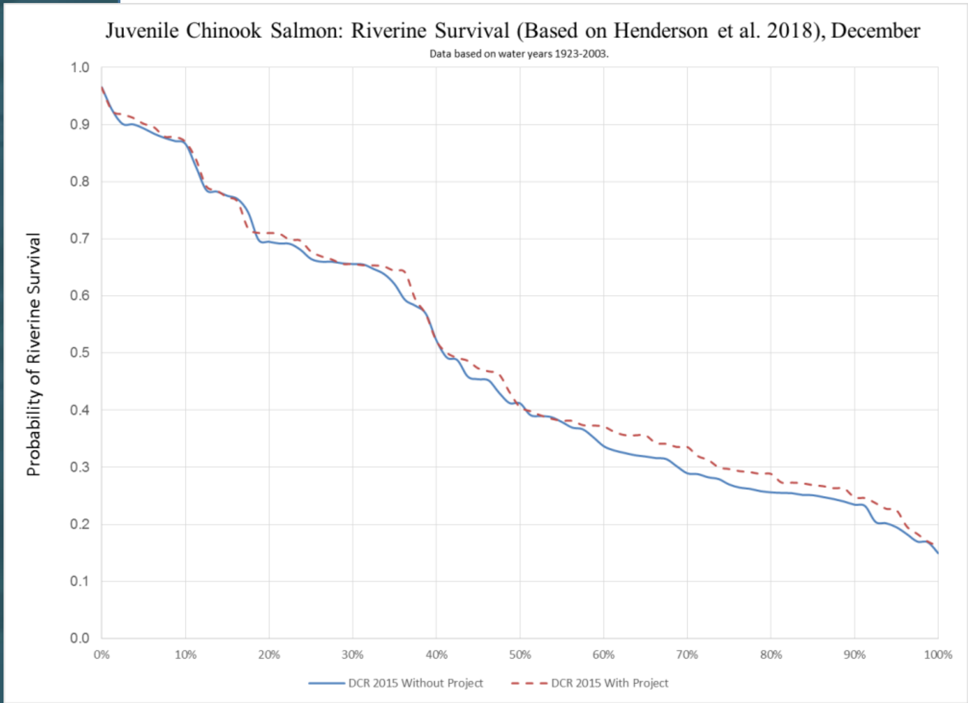
Category	Covariate	Range	Definition	Hypothesized relationship with survival	Notes/source	Source/assumption for analysis of proposed action
Individual	Transit speed	0.02–8.25 km/h	Reach-specific transit speed	Faster fish have less exposure to predators	Observed travel times and mixed effects model estimates	Assumed mean value from Henderson et al.
Release group	Batch release	Binary	Tagged fish released concurrently with large hatchery releases	Predator swamping	Observed travel times and mixed effects model estimates	Assumed fish not released with large hatchery releases
	Annual flow	179–499 cumecs (6,321–17,622 cfs)	Mean flow measured at Bend Bridge throughout outmigration (December–March)	Increased flows produce more habitat and predator refugia throughout the river	California Water Data Library	USRDOM
Reach-specific	Sinuosity	1.04–2.74	River distance divided by Euclidean distance	More natural habitats have more predator refugia	National Hydrography Dataset	Assumed same values as Henderson et al.
	Diversion density	0–1.05 diversions/km	No. of diversions per reach length	Increased predator densities near diversions	Passage Assessment Database—verified by field survey	Added one to reach 13 to account for Delevan intake; otherwise assumed same values as Henderson et al.
Time-varying	Temperature	6.2–12.9°C (42–55°F)	Mean water temperature per reach	Increased temperatures results in increased predation due to higher metabolic demands of predators	River Assessment for Forecasting Temperature (RAFT) model	USRWQM
	Intra-annual reach flow	129–902 cumecs (4,556–31,853 cfs)	Mean water flow per reach and year	Higher intra-annual flows (e.g., precipitation or dam releases) decrease predation due to increased turbidity and increased predator refugia	RAFT model	USRDOM

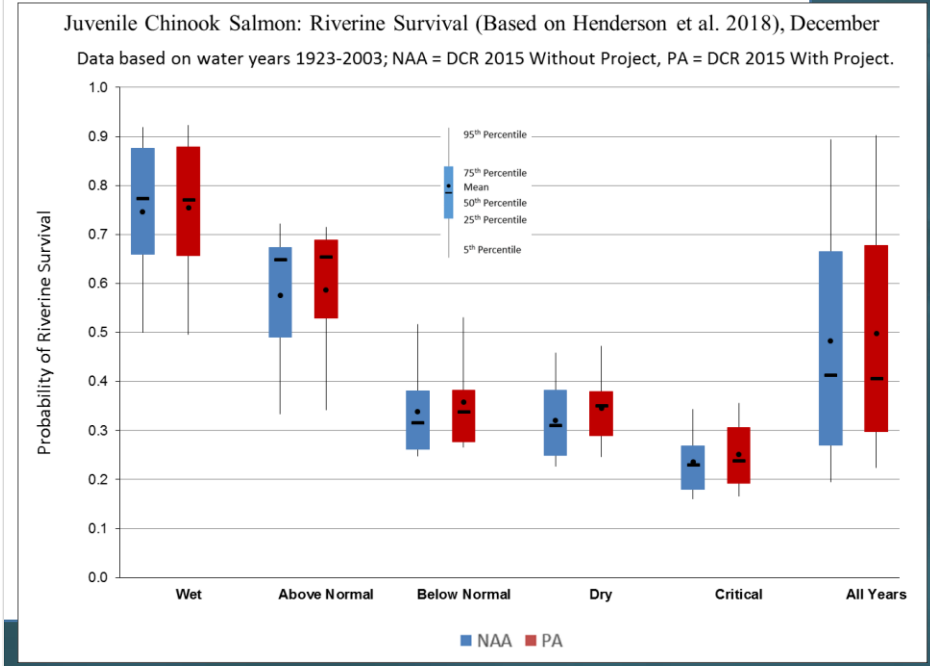
Far-field effects: Henderson et al.

- Focused on Dec-Mar
  - Limited by Bend Bridge mean flow
  - DCR 2015 With and Without Project operations
- Scenario 1
  - Equal numbers of fish beginning migrating on each day, Dec-Mar
  - All fish begin migration at Jellys Ferry (upstream of Red Bluff and all project intakes)

Far-field effects: Henderson et al.

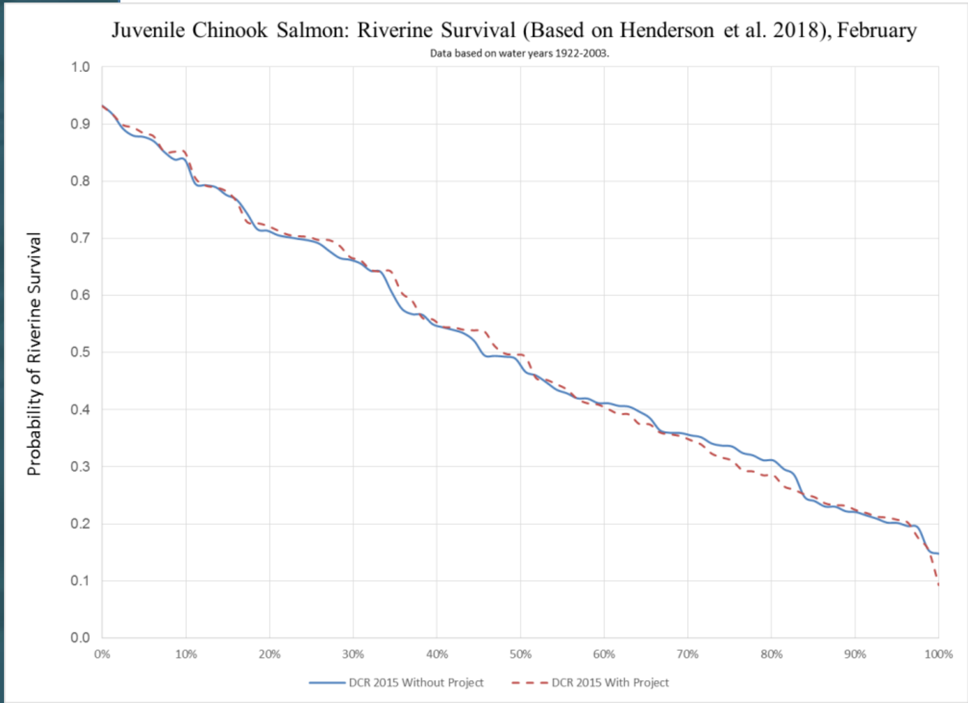
- Scenario 1 results
  - Generally similar or greater survival With Project
  - Influence of Bend Bridge flows (flow stabilization)
  - Reach-specific flows less important

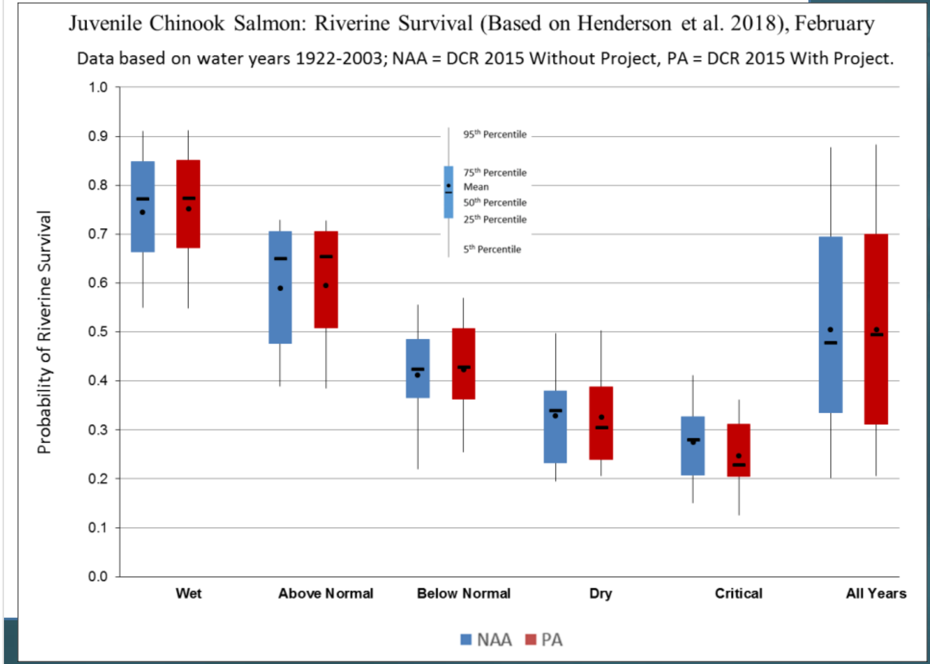




Far-field effects: Henderson et al.

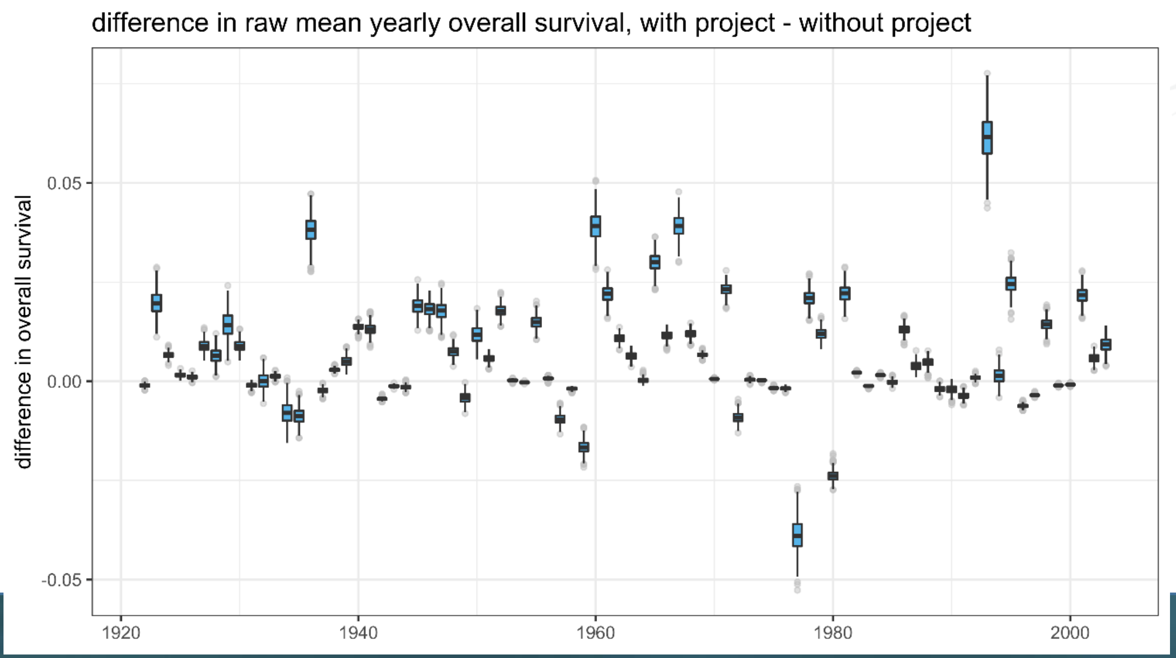
- Scenario 1 results
  - Generally similar or greater survival With Project
  - Influence of Bend Bridge flows (flow stabilization)
  - Reach-specific flows less important





Far-field effects: Henderson et al.

- Scenario 1 results
  - Generally similar or greater survival With Project
  - Influence of Bend Bridge flows (flow stabilization)
  - Reach-specific flows less important



Far-field effects: Henderson et al.

- Scenario 2
  - Equal numbers of fish beginning migrating on each day, Dec-Mar
  - Equal numbers of fish beginning migration at the upstream end of each Henderson et al. reach
- Scenario 3
  - Equal numbers of fish beginning migration at the upstream end of each Henderson et al. reach
  - Fish moving in proportion to daily proportion of flow

Far-field effects: Henderson et al.

Scenario 1: Lowest absolute survival (longest migration); largest differences (Bend Bridge flows act for longer)

	December			January			February			March		
	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without
Wet	0.75	0.75	0.01 (1%)	0.75	0.76	0.01 (1%)	0.74	0.75	0.01 (1%)	0.72	0.73	0.01 (1%)
Above Normal	0.58	0.59	0.01 (2%)	0.58	0.59	0.01 (1%)	0.59	0.60	0.01 (1%)	0.54	0.55	0.00 (1%)
Below Normal	0.34	0.36	0.02 (6%)	0.40	0.41	0.01 (2%)	0.41	0.42	0.01 (3%)	0.34	0.33	0.00 (-1%)
Dry	0.32	0.35	0.02 (8%)	0.33	0.34	0.01 (4%)	0.33	0.33	0.00 (-1%)	0.28	0.28	0.00 (0%)
Critical	0.24	0.25	0.02 (7%)	0.31	0.30	-0.01 (-4%)	0.28	0.25	-0.03 (-10%)	0.21	0.23	0.01 (6%)

Note: Results are based on all fish starting migration upstream of Red Bluff at Jellys Ferry, with equal numbers of fish starting migration each day in December–March. This scenario is referred to Scenario 1 in the text.

Scenario 2: Similar relative differences to scenario 3 in wetter years (leveling off of flow-survival relationship)

	December			January			February			March		
	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without
Wet	0.87	0.87	0.00 (1%)	0.87	0.87	0.00 (0%)	0.87	0.87	0.00 (0%)	0.85	0.86	0.00 (0%)
Above Normal	0.77	0.78	0.01 (1%)	0.77	0.78	0.01 (1%)	0.78	0.78	0.00 (0%)	0.75	0.75	0.00 (0%)
Below Normal	0.62	0.63	0.02 (3%)	0.66	0.67	0.01 (1%)	0.67	0.68	0.01 (1%)	0.61	0.60	0.00 (-1%)
Dry	0.60	0.62	0.02 (3%)	0.61	0.62	0.01 (2%)	0.61	0.61	0.00 (-1%)	0.56	0.56	0.00 (0%)
Critical	0.54	0.55	0.02 (3%)	0.60	0.59	-0.01 (-2%)	0.57	0.54	-0.03 (-5%)	0.51	0.53	0.02 (3%)

Note: Results are based on fish equal numbers of fish starting at the upstream end of each Henderson et al. (2018) reach with equal numbers of fish starting migration each day in December–March. This scenario is referred to Scenario 2 in the text.

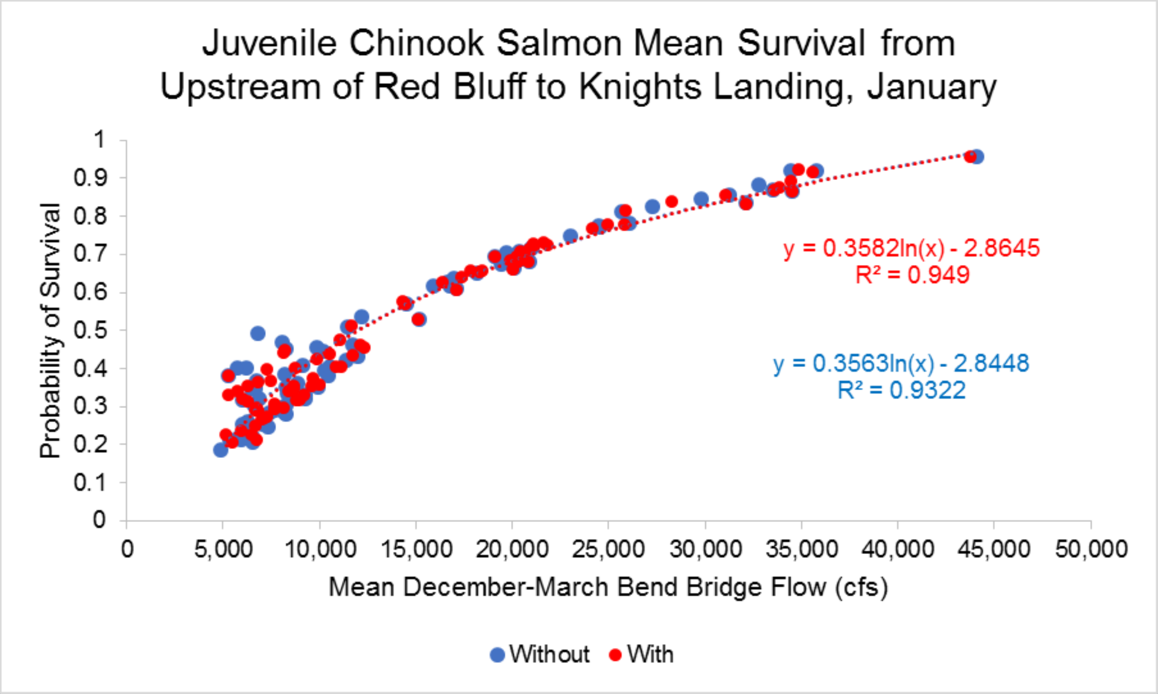
Scenario 3: Flow-weighted migration generally increases survival With Project compared to Scenario 2

	December			January			February			March		
	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without	Without	With	With vs. Without
Wet	0.87	0.87	0.00 (0%)	0.87	0.87	0.00 (0%)	0.87	0.87	0.00 (0%)	0.86	0.86	0.00 (0%)
Above Normal	0.71	0.71	0.01 (1%)	0.78	0.79	0.01 (1%)	0.79	0.79	0.00 (0%)	0.76	0.76	0.00 (0%)
Below Normal	0.61	0.63	0.02 (4%)	0.69	0.69	0.01 (1%)	0.70	0.71	0.01 (2%)	0.63	0.63	0.00 (-1%)
Dry	0.61	0.64	0.03 (4%)	0.62	0.63	0.01 (2%)	0.63	0.63	0.00 (0%)	0.58	0.59	0.00 (0%)
Critical	0.53	0.55	0.02 (4%)	0.61	0.61	0.00 (-1%)	0.59	0.56	-0.03 (-4%)	0.53	0.55	0.02 (5%)

Note: Results are based on fish equal numbers of fish starting at the upstream end of each Henderson et al. (2018) reach with fish starting migration each day in each month in proportion to flow occurring on each day. This scenario is referred to Scenario 3 in the text.

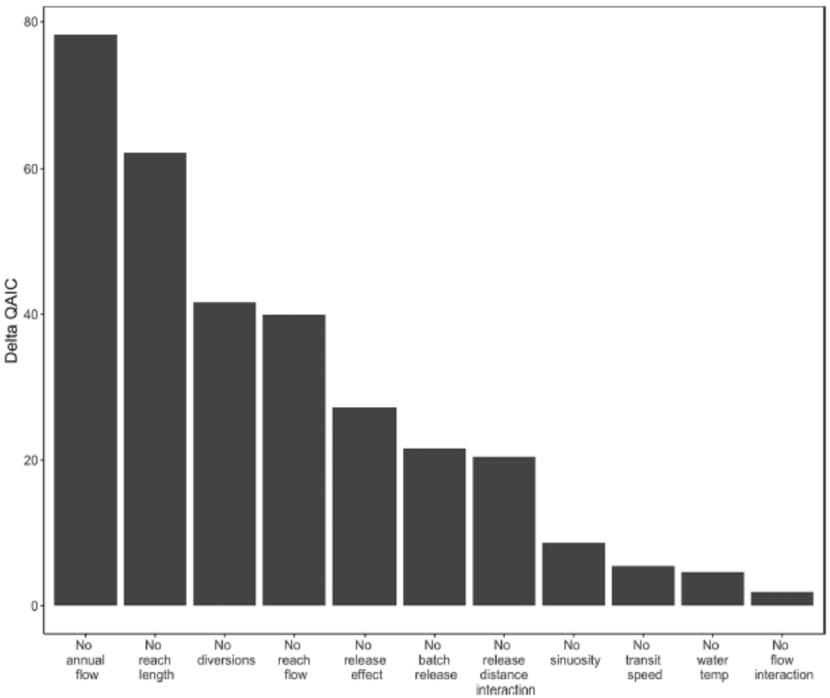
Far-field effects: Henderson et al.

- Dominance of Bend Bridge flow effect
  - Reflecting wetter vs. drier years
  - Consider exploration of same Bend Bridge flow With and Without Project

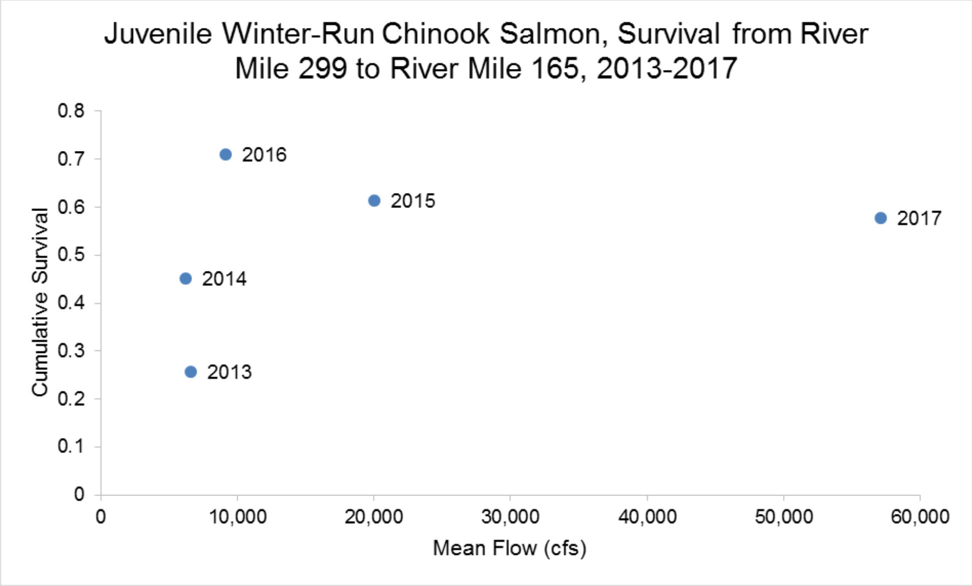


Far-field effects: Henderson et al.

- Dominance of Bend Bridge flow effect
  - Reflecting wetter vs. drier years
  - No clear flow-survival relationship for Winter-Run (Hassrick et al.)



Henderson et al. importance of covariates



Developed from data in Hassrick et al. (in prep.)

Far-field effects: OBAN

- Incorporated Scenario 1 Henderson et al. results
  - Monthly weighting (Dec = 0; Jan = 0.28; Feb = 0.36; Mar = 0.36)
  - Generally probability of greater escapement under With Project