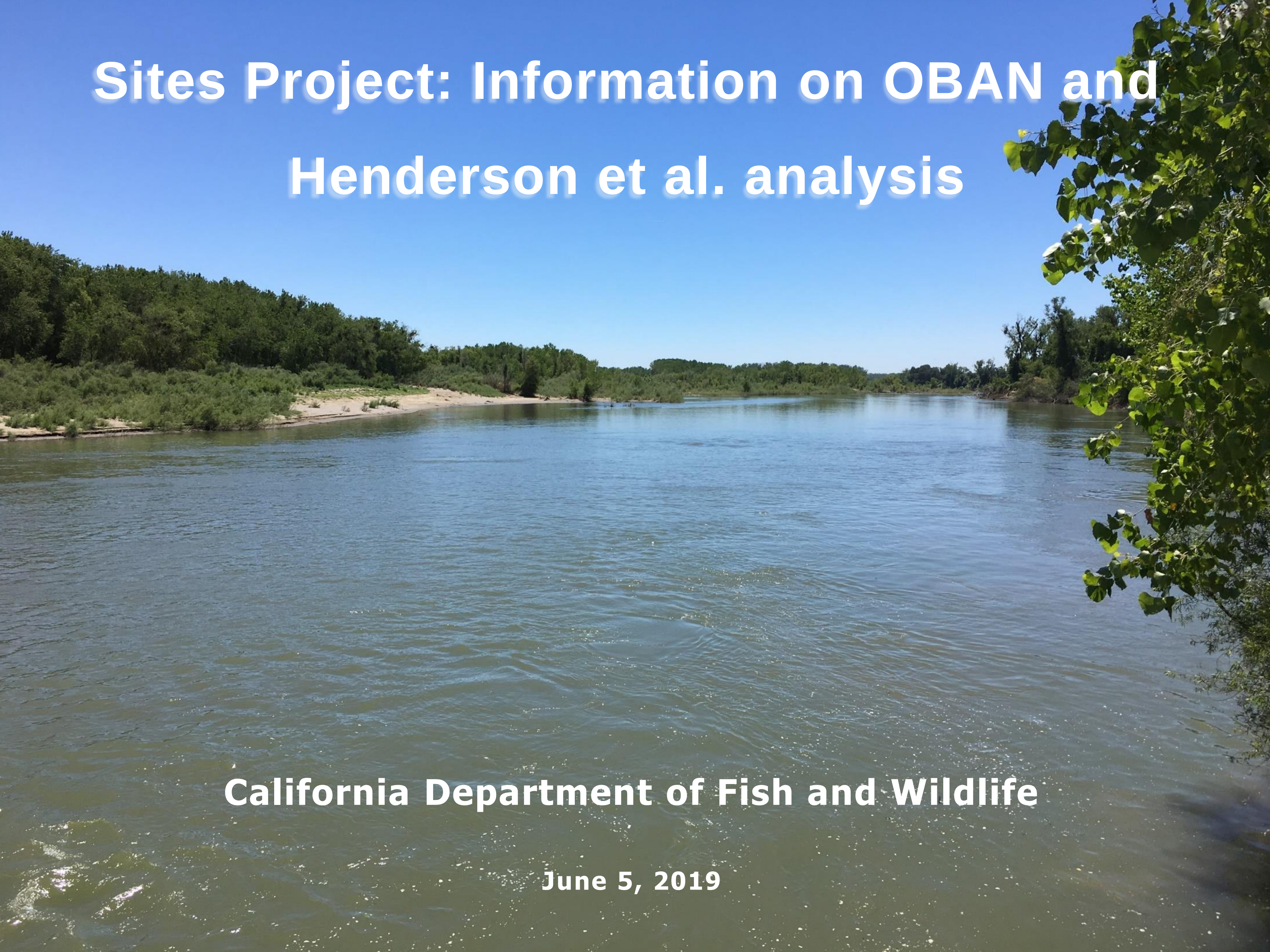
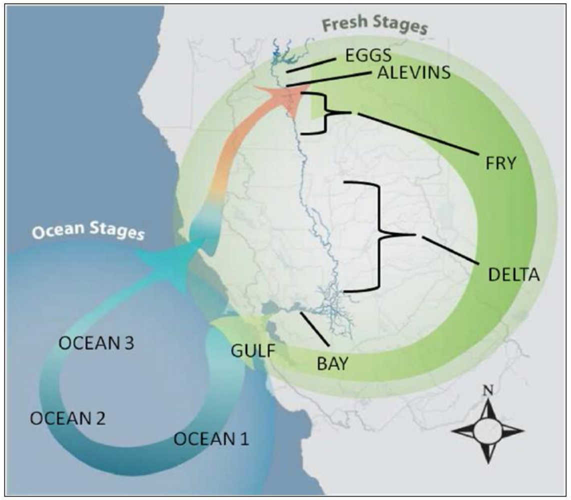


Sites Project: Information on OBAN and Henderson et al. analysis

California Department of Fish and Wildlife

June 5, 2019

Life Cycle Modeling: OBAN



General Details:

- Winter-Run Chinook Salmon
- Egg/alevin temperature effects
- Fry rearing flow effects
- Juvenile Yolo flow effects
- Juvenile south Delta export effects
- Juvenile DCC effects
- Ocean conditions not affected by project but included in model (productivity and harvest)
- More specifics in California WaterFix BA methods: Section 5.D.3.2.5 of Appendix 5D, https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/petitioners_exhibit/dwr/part2/dwr1142/App_5.D_Methods_update.pdf
- Use in WSIP: Section A.1.3 in https://cwc.ca.gov/-/media/CWC-Website/Files/Projects/Sites-Project/Appeal/AttachA.pdf

Life Cycle Modeling: OBAN

<u>OBAN covariates</u>:

- July-Sep temp. (eggs/alevins) - USRWQM
- Aug-Nov flow (fry) - USRDOM
- Dec-Mar Yolo flow (juveniles) - CalSim
- Dec-Jun exports (juveniles) - CalSim
- DCC (Dec-Mar) (juveniles) - CalSim
- Harvest; wind stress curl index – historical values
- Additional covariates considered but not included because of weak relationships: maximum monthly Bend Bridge flow (Aug-Nov); Delta bass catch per unit vessel; sea level height (Apr-Jun); Farallones upwelling (Apr-Jun); PDO (Oct-Mar); sea surface temp. (Jul-Feb)

Flow-Survival in OBAN

<u>WISP - OBAN adjustment for flow-survival</u>:

- WSIP: Survival downstream of RBDD adjusted for With Project
- Considered:
  - Michel (2016)
  - NMFS Winter-Run Life Cycle Model
  - Iglesias et al. (2017)
- Chose Iglesias et al. (2017):
  - Completed report (vs. preliminary analysis by Michel 2016)
  - Based on acoustic telemetry (vs. calibration to fitted data, i.e., WRLCM)

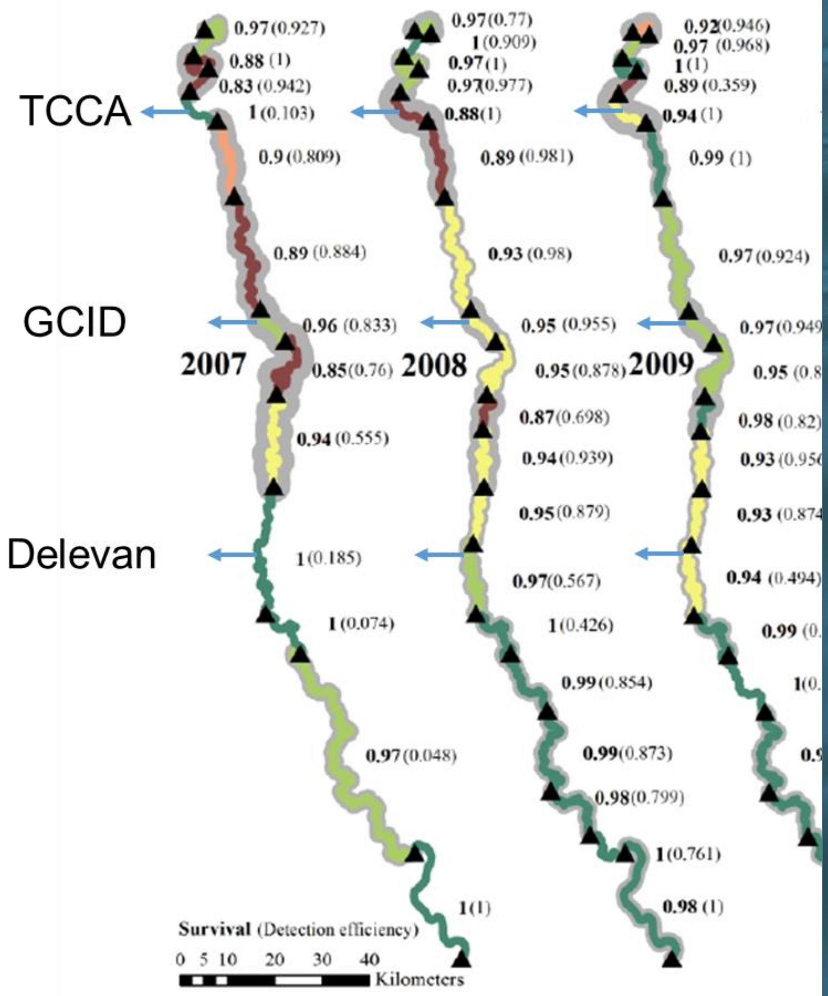
Flow-Survival in OBAN

BA - OBAN adjustment for flow-survival:

- For BA/ITP Application, use Henderson et al. (2018) model
- As with WSIP:
  - Adjust With Project scenario for relative change in survival compared to Without Project
  - Weighted annual survival difference
    - WRLCM monthly smolt timing: 0.269 (Jan.), 0.366 (Feb.), 0.348 (Mar.), 0.017 (Apr.)
    - Spatial variation in smolt starting location

Henderson et al. Flow-Survival Analysis

- 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



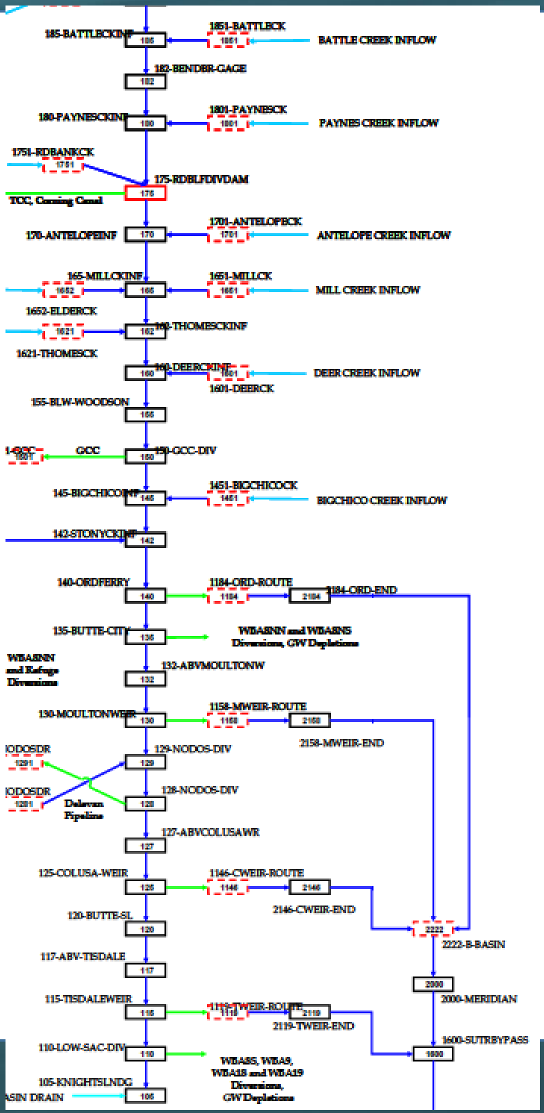
Henderson et al. Flow-Survival Analysis

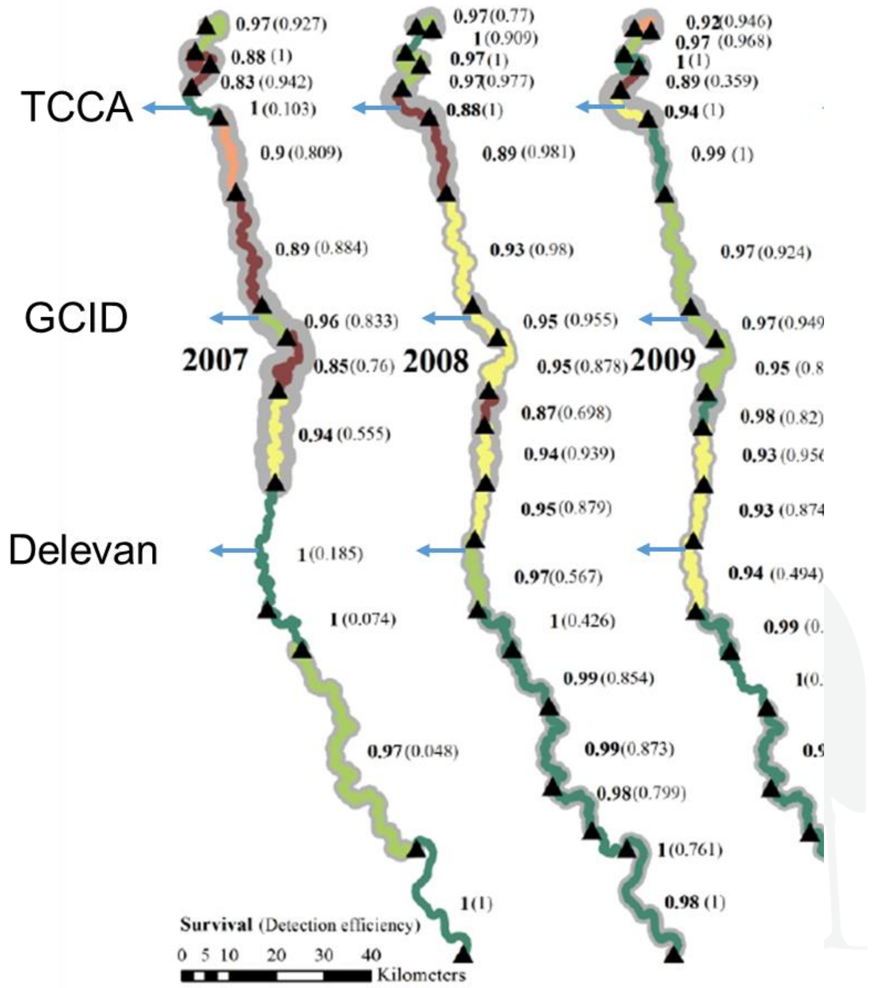
Table 1: A description of the covariates included in the mark recapture model.

Category	Covariate	Range	Definition	Hypothesized relationship with survival
Individual	Fish Length[1]	135 - 204 mm	Fork length	Larger fish may exceed gape width of predators
	Fish Condition[1]	0.59 - 1.32	Fulton's K	Increased condition improves predator escape capability
	Transit speed[2]	0.02 - 8.25 km h^{-1}	Reach specific transit speed	Faster moving fish have less exposure to predators
Release group	Batch release[2]	Binary	Tagged fish released concurrently with large hatchery releases.	Predator swamping
	Release reach[1]	Binary	Difference in survival between newly released fish and those released upstream.	Newly released hatchery fish are naïve and susceptible to predation
	Annual flow[3]	179 - 499 cms	Mean flow measured at Bend Bridge throughout outmigration (December-March).	Increased flows produce more habitat and predator refugia throughout the river
Reach specific	Sinuosity[4]	1.04 - 2.74	River distance divided by Euclidean distance.	More natural habitats have more predator refugia
	Diversion density[5]	0 - 1.05 num km^{-1}	Number of diversions per reach length.	Increased predator densities near diversions
	Adjacent cover density[6]	0.2 - 0.76 %	Percent of non-armored river bank with adjacent natural woody vegetation.	Increased cover produces more predator refugia
	Off-channel habitat density[6]	0 - 1.62 %	Off-channel habitat within 50 m of river expressed as percentage of river area	Increased off-channel habitat produces more predator refugia
Time varying	Temperature[7]	6.2 - 12.9 °C	Mean water temperature per reach	Increased temperatures results in increased predation due to higher metabolic demands of predators
	Inter-annual Reach flow[7]	215 – 447 cms	Mean water flow per reach	Higher flows within a reach will produce more habitat and predator refugia within that reach
	Intra-annual Reach flow[7]	129 – 902 cms	Mean water flow per reach and year	Higher intra-annual flows (e.g., precipitation or dam releases) decreases predation due to increased turbidity and increased predator refugia.

[1]Measured during tagging and release; [2]Observed travel times and mixed effects model estimates; [3]California Water Data Library; [4]National Hydrography Dataset; [5]Passage Assessment Database - verified by field survey; [6]Department of Water Resources; [7]River Assessment for Forecasting Temperature (RAFT) model

Implementing Henderson Flow-Survival





Implementing Henderson Flow-Survival

- Flow translation complete
- Next step is temperature translation
- +1 diversion in Delevan reach

Henderson reach (km)	USRDOM
518	185-BATTLECKINF
511	185-BATTLECKINF
504	182-BENDBRGAGE
492	180-PAYNESCKINF
480	180-PAYNESCKINF
475	175-RDBLFDIVDAM
456	165-MILLCKINF
421	150-GCC_DIV
412	150-GCC_DIV
389	142-STONYCKINF
380	140-ORDFERRY
363	135-BUTTE-CITY
349	132-ABV-MOULTONWEIR
325	125-COLUSA-WEIR
309	120-BUTTE-SL
287	117-ABV-TISDALE
259	110-LOW-SAC-DIV
239	105-KNIGHTSLNDG
227	Not in USRDOM

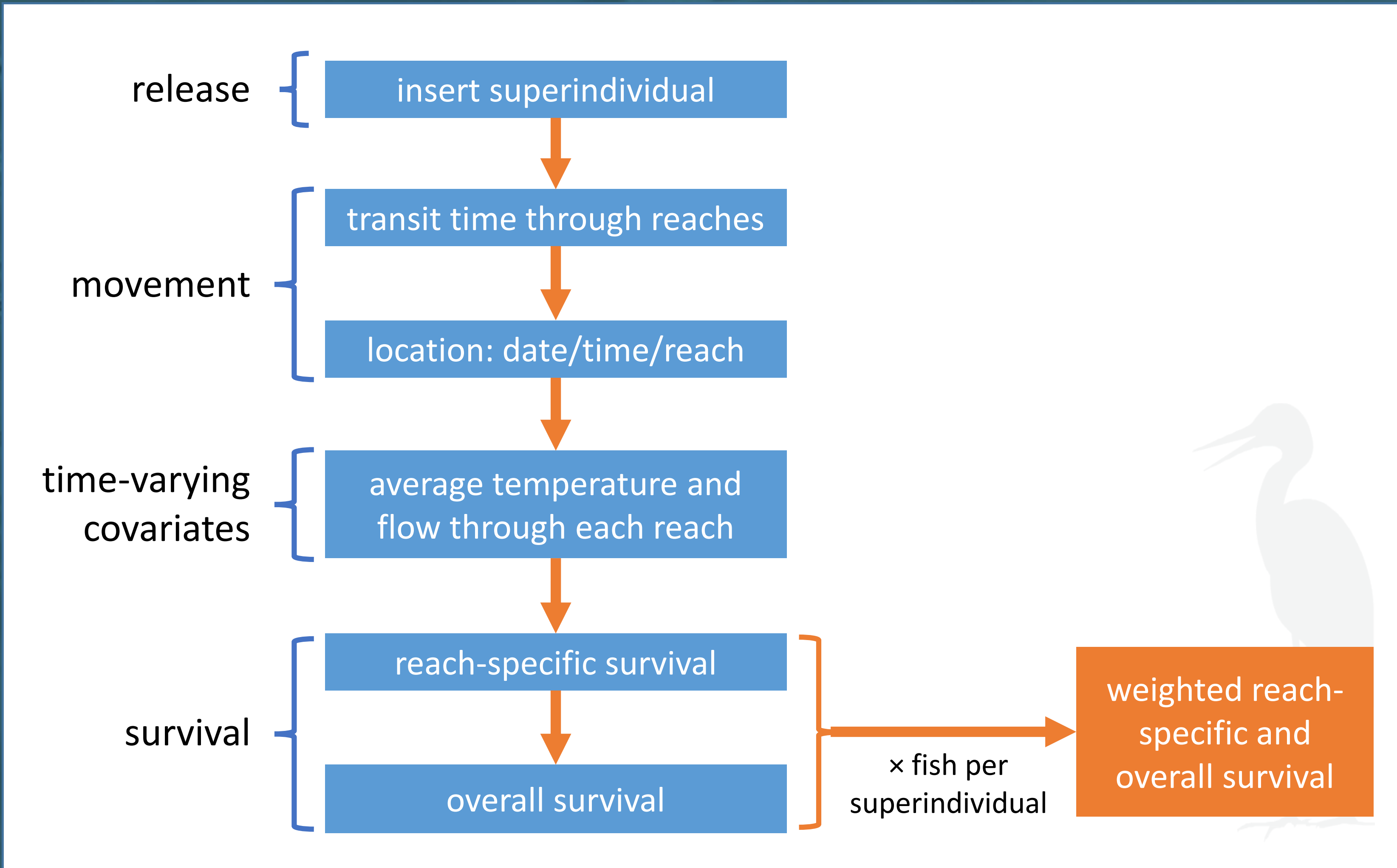
Implementing Henderson Flow-Survival

- Follows Henderson et al. approach: calculate time-varying covariates for individual fish based on temperatures and flows they experience
- Utilize flow and temperature effects on survival estimated from mark-recapture analysis by Henderson et al.
- Individual fish trajectories (which reach they're in at a given time) calculated based on initial time/location, reach lengths, and reach-specific average transit speeds
- Hourly time step to accommodate sub-daily reach transit times
- Flow and temperature data upsampled to hourly resolution using cubic spline interpolation

Implementing Henderson Flow-Survival

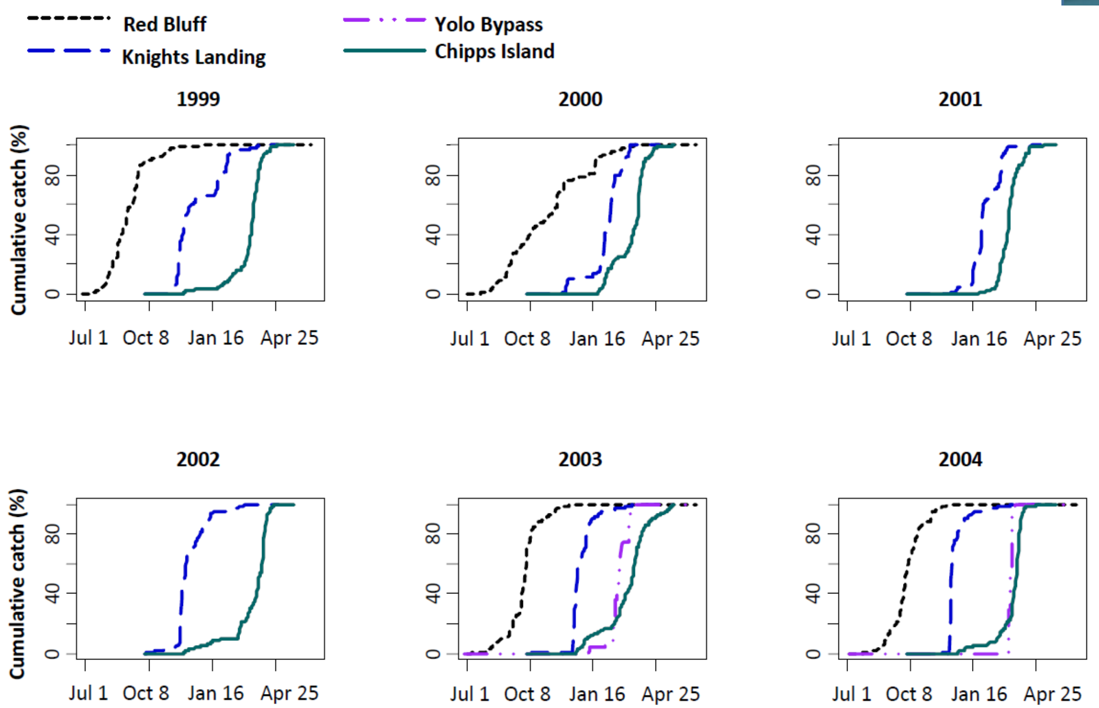
- “Superindividuals”: each modeled individual represents multiple fish beginning migration at the same time
- Overall survival probability = average across all individuals weighted by the number of fish represented by each superindividual
- Annual survival rate integrates across all superindividuals
- Annual survival rates calculated for “With Project” and “Without Project”
- OBAN link:
  - Adjust With Project scenario for relative change in survival compared to Without Project
  - Run OBAN model over multiple cohorts representing multiple annual conditions

Implementing Henderson Flow-Survival



Initial Smolt Locations

- Many juveniles pass Red Bluff before Sites diversion period begins…
- Where do they go?



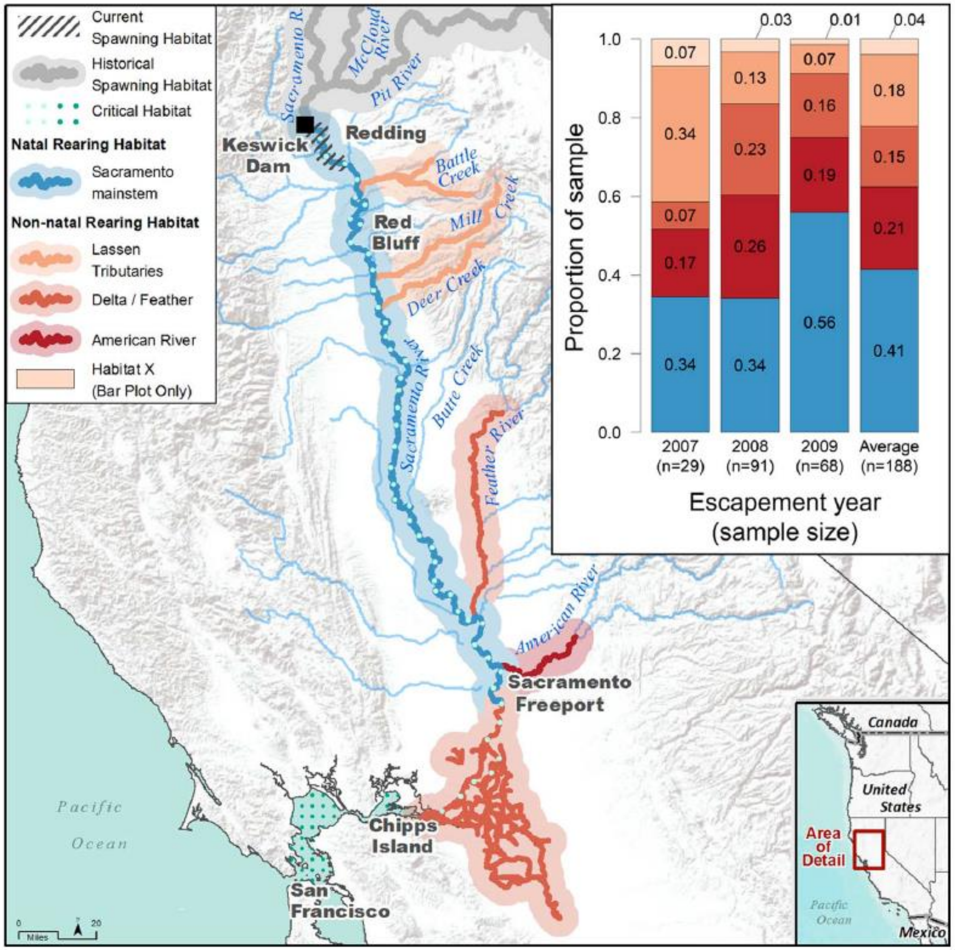
Migration Patterns of Juvenile Winter-run-sized Chinook Salmon (*Oncorhynchus tshawytscha*) through the Sacramento–San Joaquin Delta

Rosalie B. del Rosario[1], Yvette J. Redler[2], Ken Newman[3], Patricia L. Brandes[3], Ted Sommer[4], Kevin Reece[4], and Robert Vincik[5]

Initial Smolt Locations

<u>Other considerations</u>:

- Simplest case: all fish migrate from Jellys Ferry
- But…
  - Phillis et al. (2018) show diverse rearing habitat
  - Where are juveniles starting from, and when?
- Proposed approach: Analysis of beach seine data to estimate locations



Initial Smolt Locations

<u>Other considerations</u>:

- Johnson, R.R., D.C. Weigand, and F.W. Fisher. 1992. Use of Growth Data to Determine the Spatial and Temporal Distribution of Four Runs of Juvenile Chinook Salmon in the Sacramento River, California. November. 18 p.

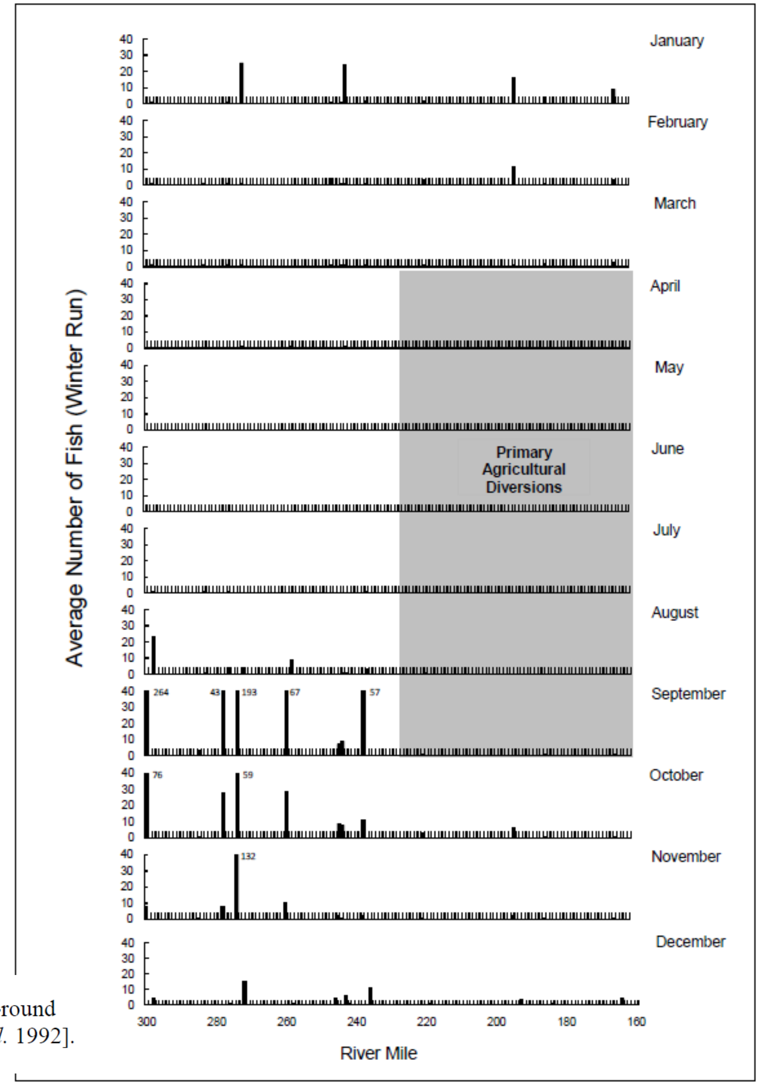


Figure 31. Spatial and temporal distribution of winter-run Chinook captured by the USFWS during year-round monthly beach seining at 13 sites in the Sacramento River, 1981 – 1991 [(N = 10,778) from Johnson *et al.* 1992].