The Winter Run Lifecycle Model for Scenario Analysis in the Central Valley

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UC SANTA CRUZ

QEDα

The WRLCM: a true collaboration

Model Developers

NMFS SWFSC/UCSC:

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- James Gilbert
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- Noble Hendrix
- Doug Jackson

USGS

- Russ Perry
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The Winter-Run LCM Stakeholder Group

Data

CDFW
USFWS
NOAA Fisheries
University of California Santa Cruz

Funding Agencies

US Bureau of Reclamation
California Department of Water Resources
Sites Project Authority
NOAA Fisheries
University of California Santa Cruz
Delta Stewardship Council
California Department of Fish and Wildlife

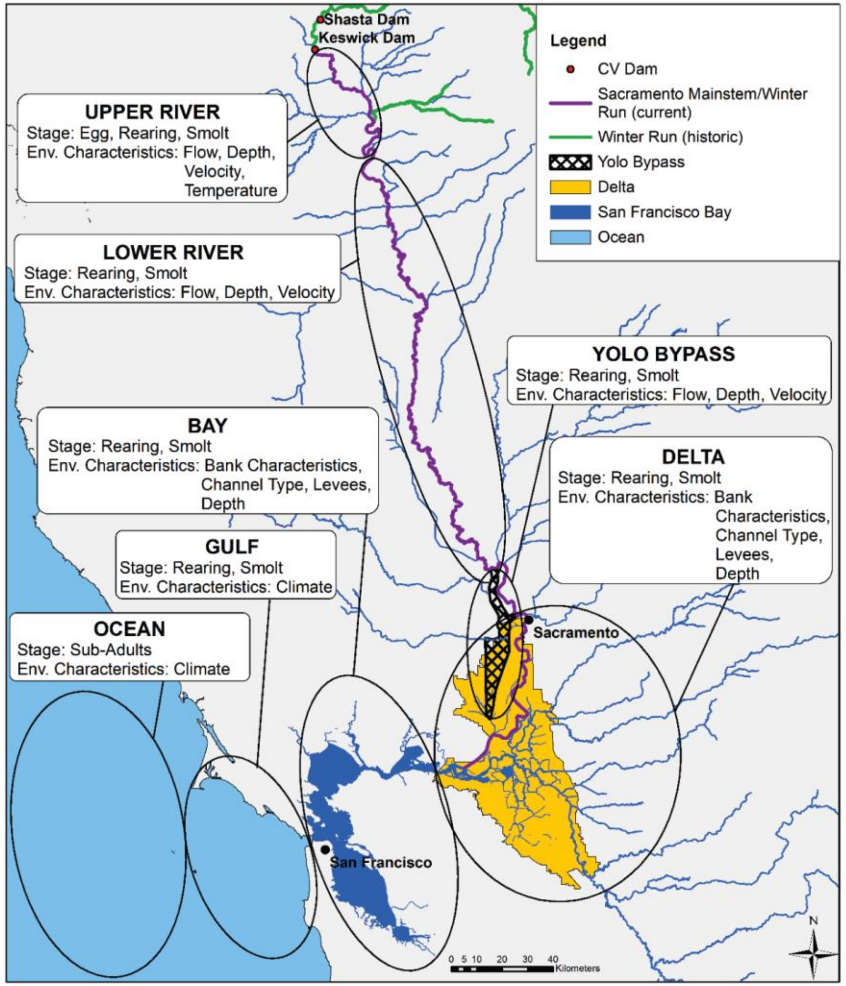
Photo: Jeremy Notch

What is the WRLCM?

- WRLCM is a stage structured simulation model that estimates winter-run abundance for each:
    - Lifestage: egg, fry, smolts, subadults, spawners
    - Timestep: monthly (freshwater lifestages), and annually for ocean lifestages
    - Location: 5 geographic locations (freshwater), and the ocean

- Developed to assess the effects of water operations on long-term population dynamics of winter-run Chinook salmon

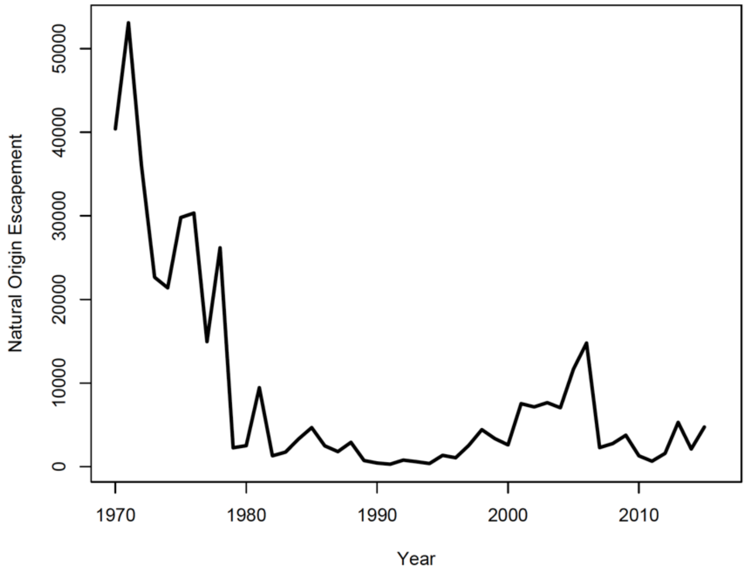
- Why was it developed? It was ordered by the court…



Some History: The Need for the WRLCM

- 1970s and 1980s: Sacramento River Winter-run Chinook started experiencing significant population decline
- Prompted listing as threatened (1989), endangered (1994)
- In 2009, NMFS concluded that proposed CVP and SWP operations are likely to "jeopardize the continued existence…" of winter-run in the Sacramento River (2009 BiOp), based on conceptual or models based on a single lifestage
- In 2011, Judge Wanger concluded a lifecycle model was necessary for NMFS to evaluate effect of operations on population dynamics:

Winter-run escapement



"…this is the last time NMFS will be permitted to avoid studying, analyzing, and applying a life cycle model. NMFS's chronic failure to do so now approaches bad faith in view of the undeniable importance of the information to resolve the perennial dispute over population dynamics. At some point, this diminishes the agency's credibility."

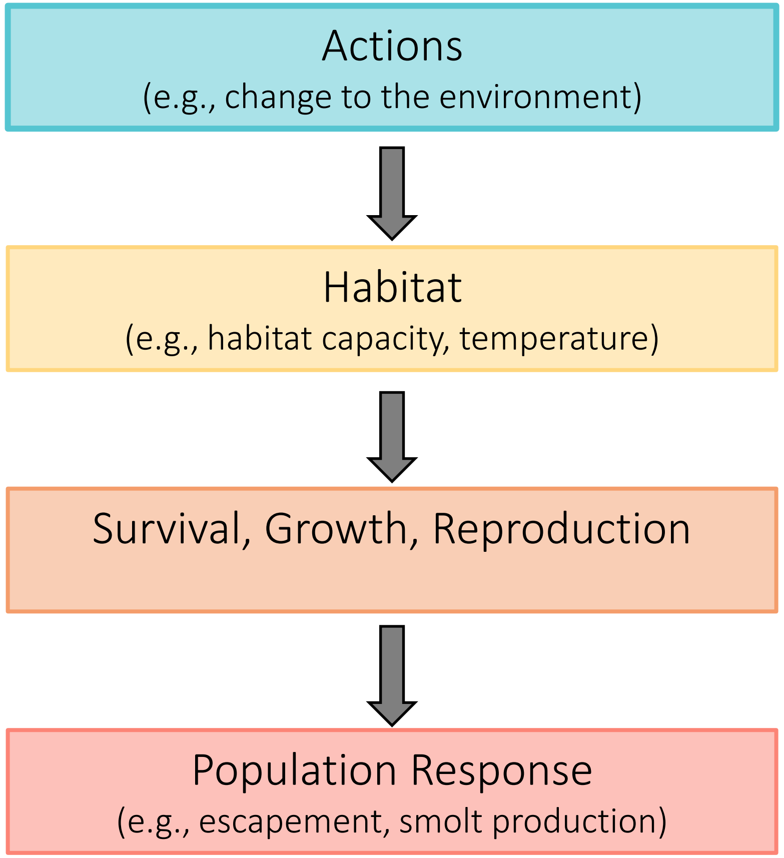
Judge Oliver W. Wanger, THE CONSOLIDATED SALMONID CASES (2011)

The need to develop the WRLCM was clear

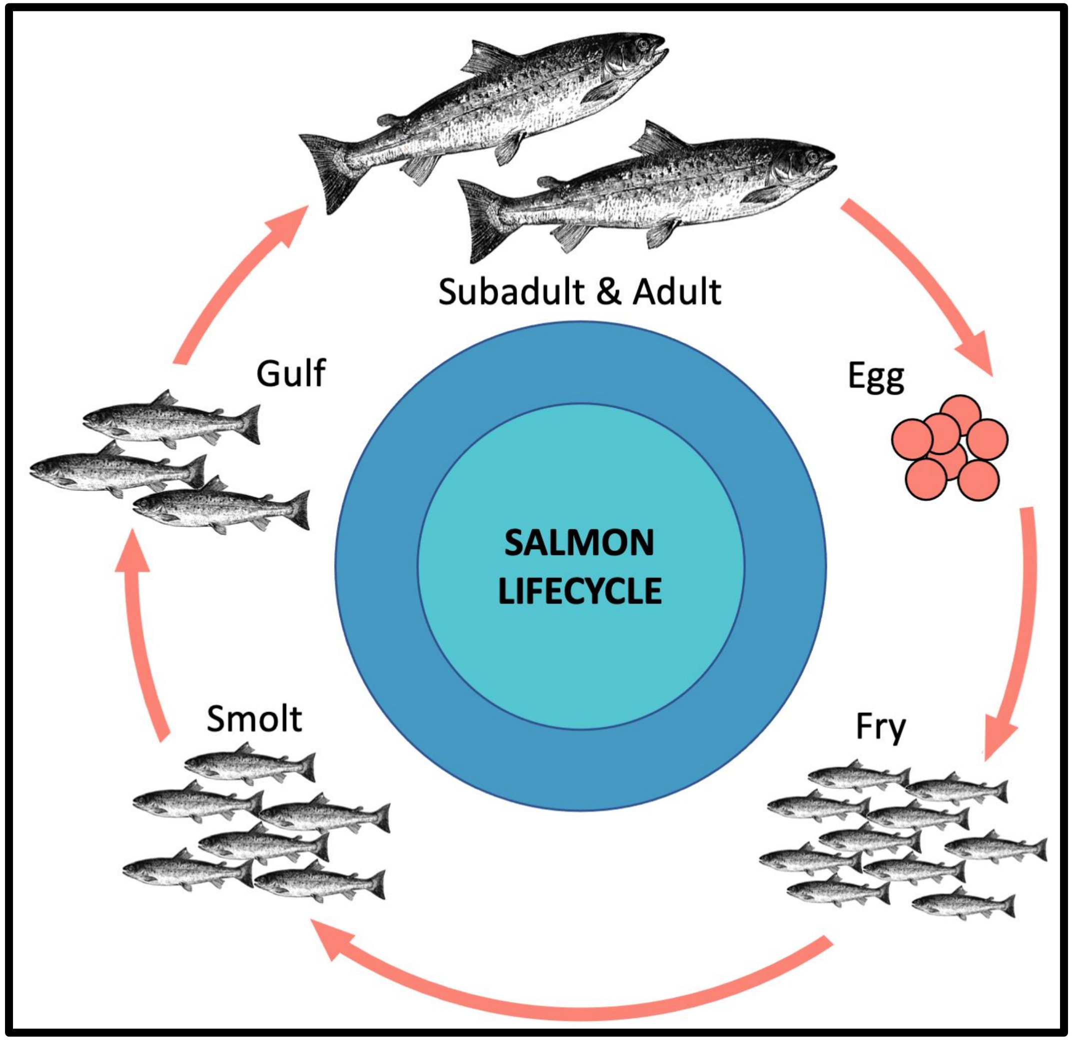
- 2012: Development of the WRLCM began with funding from the Bureau of Reclamation
- 2014: NMFS published a Tech Memo (Hendrix et al 2014) to describe the first WRLCM framework
- 2015: the Center of Independent Experts (CIE) provided external expert review of the WRLCM
- 2017 – 2022: Quarterly workshops with agencies/stakeholders to discuss development/interpretation
- 2017 – now: WRLCM was used to evaluate water operations from BAs, BOs (Cal Water Fix, LTO, DCP, Sites) on long-term population dynamics metrics, including:
    - Spawner abundance
    - Spawner replacement rate (Cohort Replacement rate)
    - Freshwater productivity (# smolts per spawner)

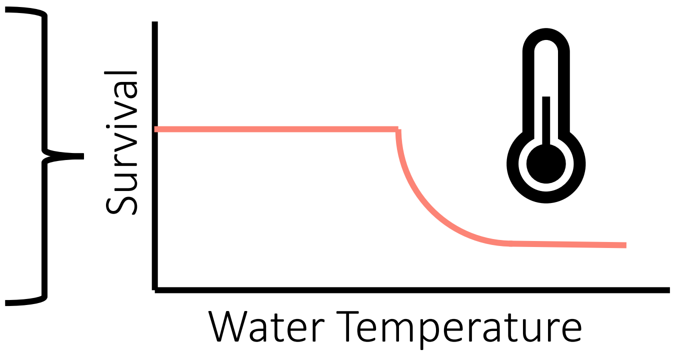
What makes lifecycle models so important?

- They integrate individual models to evaluate effects on the entire population
- Integrate management actions over multiple environmental conditions
- Provide a framework for connecting actions, habitat, vital rates, and population response
- Requires clear assumptions (math doesn’t allow for ambiguity…)

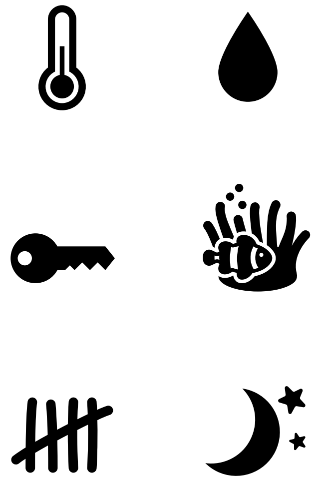


WRLCM uses mathematical ‘transition’ equations to transition the number of fish from one life stage to the next



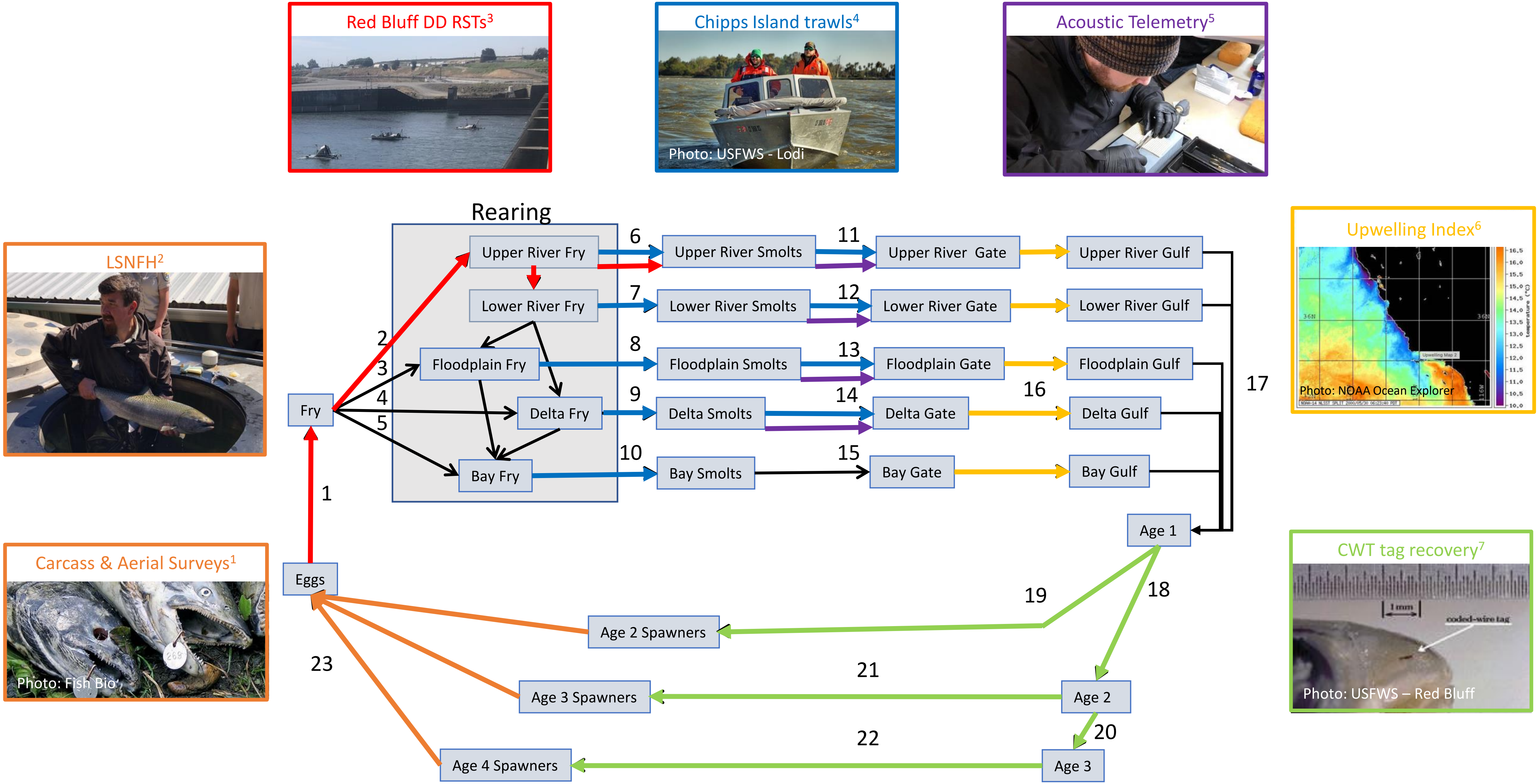


Other covariates



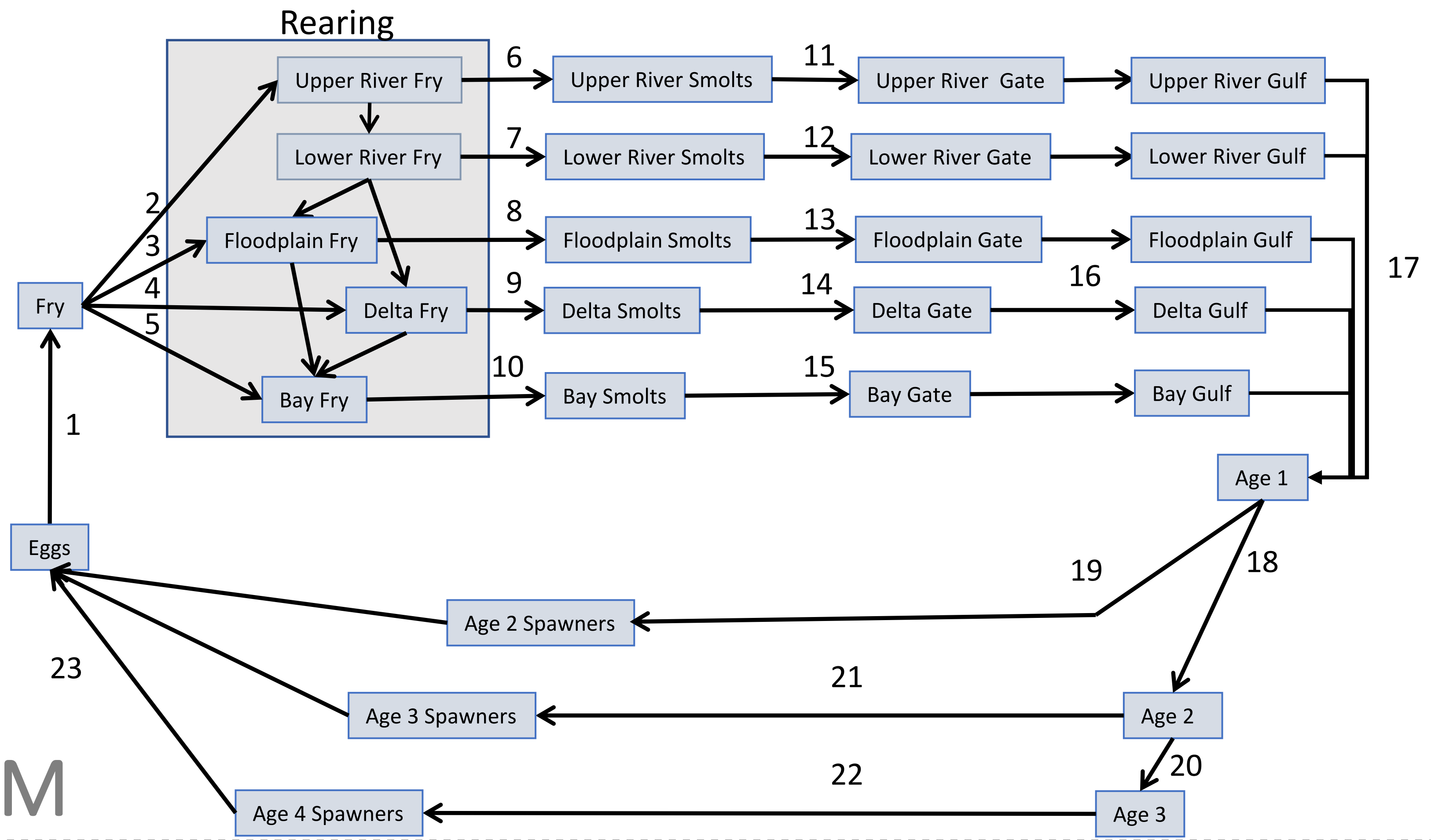
Check out the “Explore” page on the WRLCM website: https://oceanview.pfeg.noaa.gov/wrlcm/

The WRLCM has over 20 transitions, many are tied to observational data



The WRLCM also relies on a network of interconnected submodels

- WRLCM team developed submodels that operate at finer temporal/spatial scales to better reflect dynamics, but then can scale up to the coarse month and reach level of the WRLCM



The WRLCM

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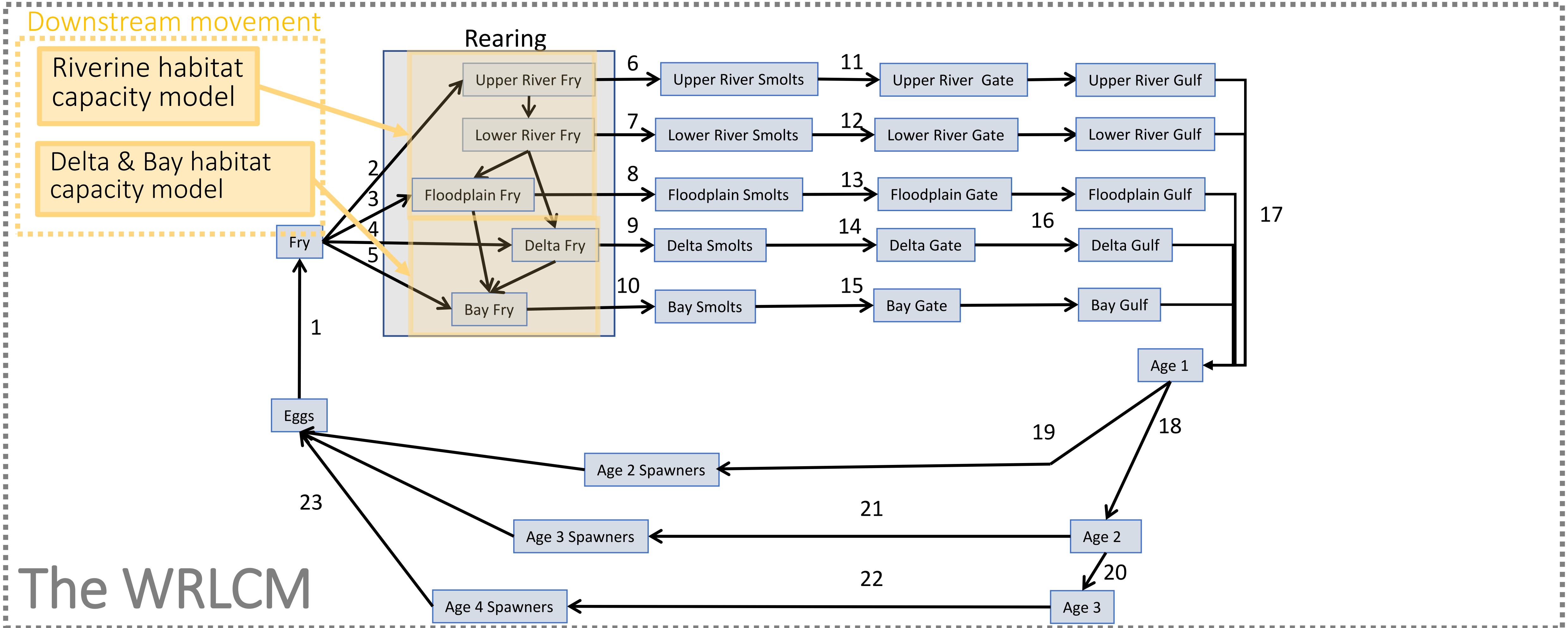

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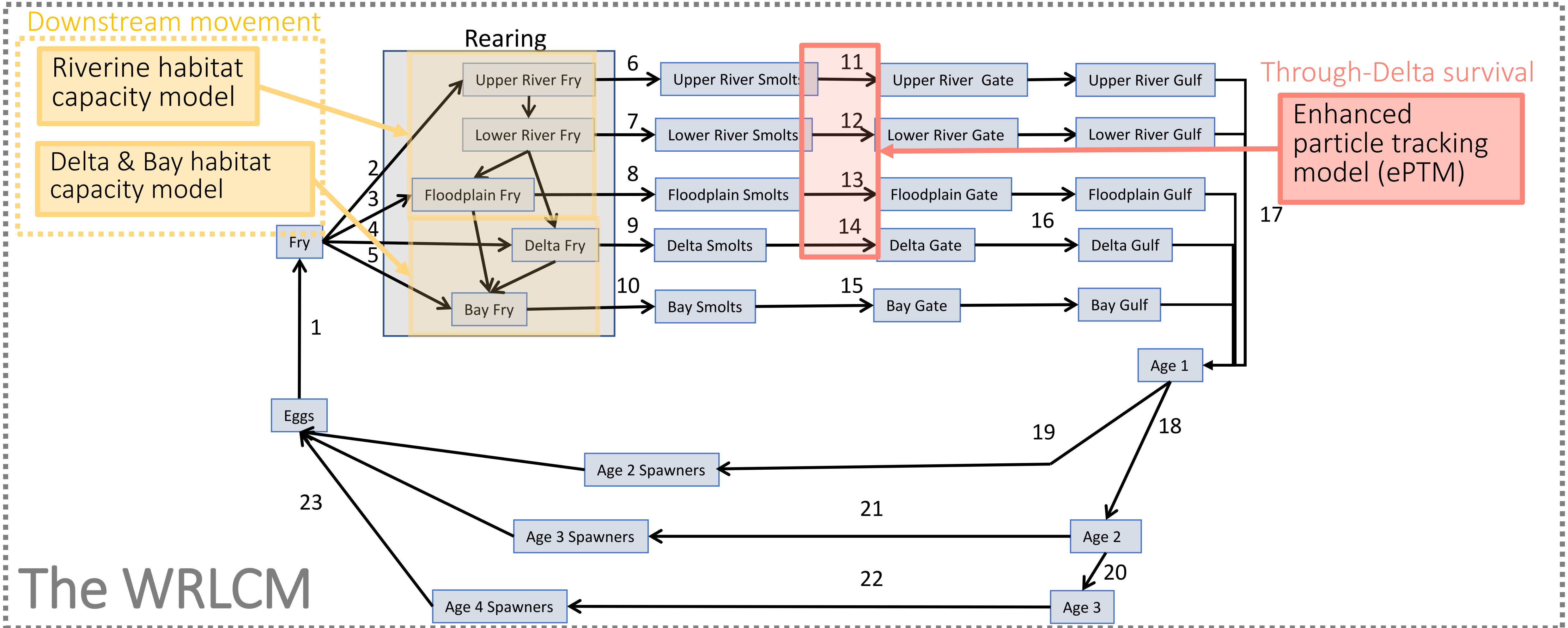

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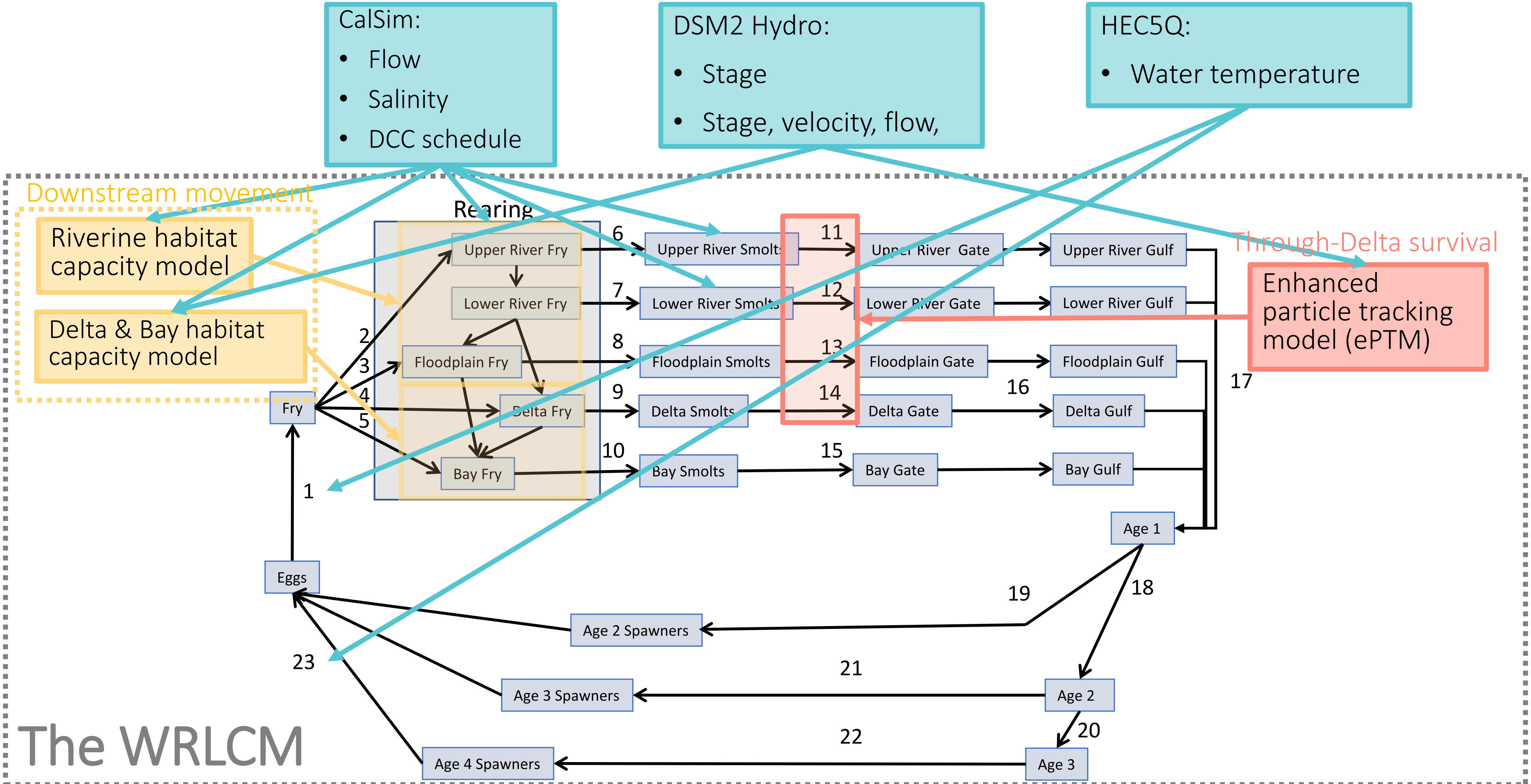


The result: a powerful model that integrates it all

- The WRLCM integrates field observations at several life stages
- Plugs directly into water planning (CalSim), hydrodynamic (DSM2 Hydro), and water temperature (HEC5Q) outputs
- Relies on submodels to better reflect habitat at finer spatial and temporal scales

By integrating field data and submodels, the WRLCM reflects observed population dynamics well

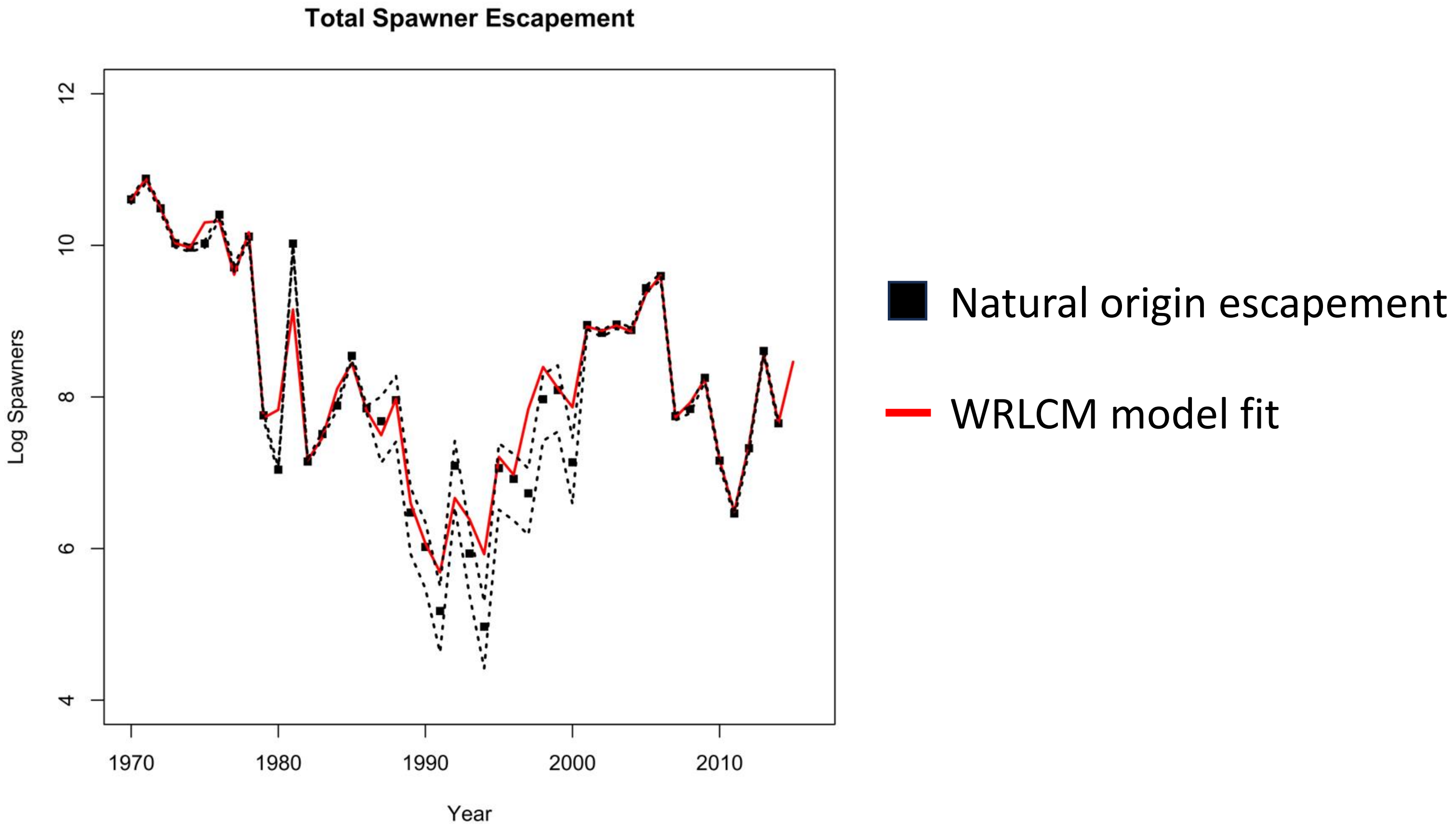


Figure 15. Model fit (red line) to log natural origin escapement data (squares) with 95% interval on measurement error (dashed lines).

Hendrix et al 2017

Typical applications of the WRLCM: Biological Assessment & Opinions

- Major water operations or changes in CVP or SWP infrastructure
  - Cal Water Fix BO
  - LTO BO
  - DCP BA
  - Sites BA

- Results are in relation to a baseline (current operations)
  - E.g., change spawner abundance (% change from baseline)
  - Way to rank which actions best support winter-run
  - Which alterative would best support winter-run?

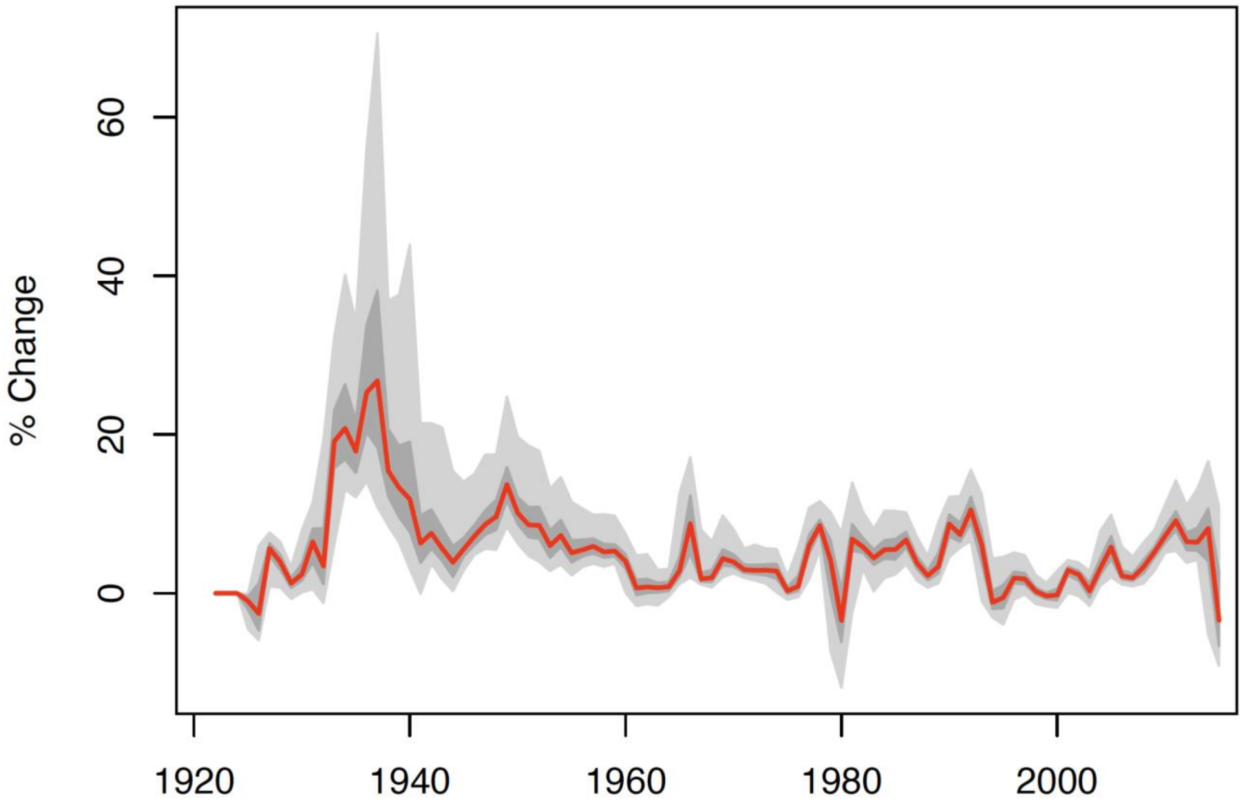


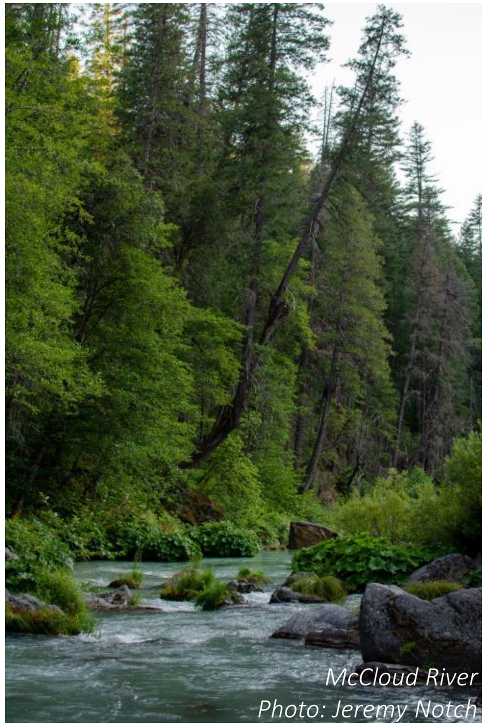
Figure 7: Percent change in spawner abundance for alternative relative to existing condition.

Future Applications: Exploring Novel Futures with the WRLCM

- Exploring effects to winter-run while simulating novel possible futures
  - Drought Analysis
  - COEQWAL: Collaboratory for Equity in Water Allocation
  - Reorienting to Recovery
  - McCloud Reintroduction

COEQWAL
COLLABORATORY FOR EQUITY IN WATER ALLOCATION

Photo: CDWR



McCloud River
Photo: Jeremy Notch

Exploring Novel Futures: Drought Analysis

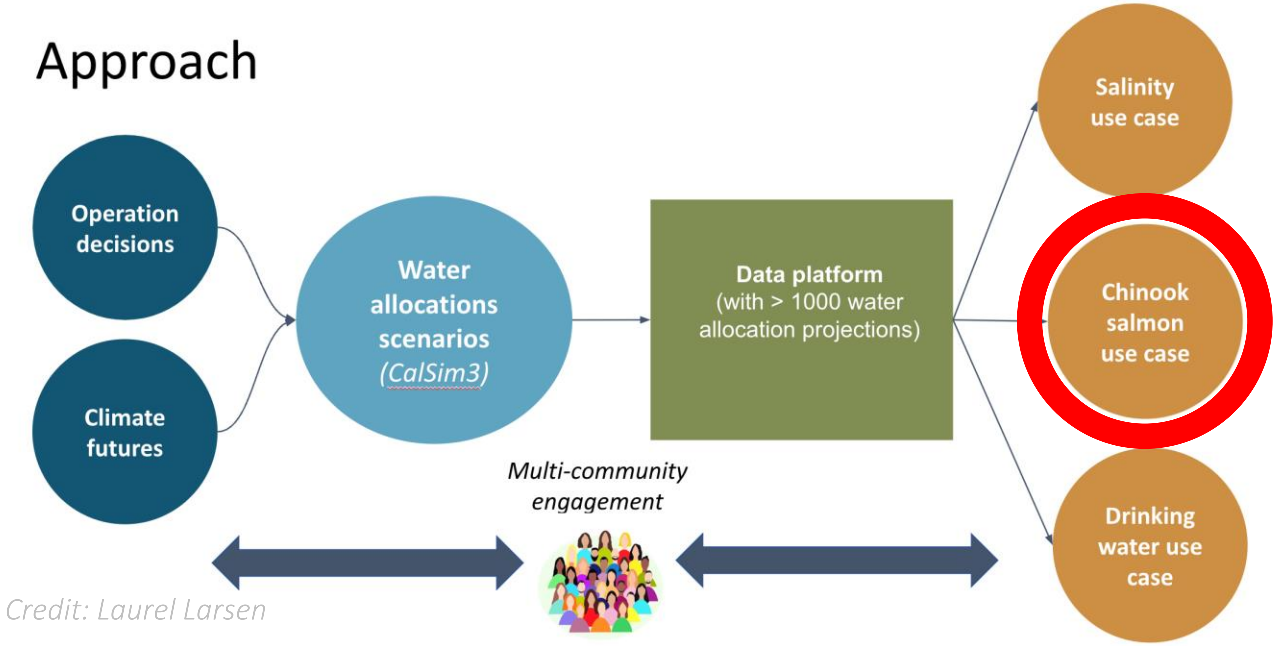
- With a changing climate, what would the effect of longer multi-year drought conditions have on winter-run?

- A plug for James Gilbert’s talk in a bit…
    - modifying CalSim to represent longer, more frequent drought scenarios
    - Evaluate drought scenarios using the WRLCM
    - What effect would longer multiyear droughts have on winter-run population dynamics?

Exploring Novel Futures:

COEQWAL: https://live-coeqwal-ca.pantheon.berkeley.edu/

- Goal: establish an inclusive participatory process that diversifies and enhances engagement in water planning and stewardship in California



- Effects on winter-run is just one value (salmon), but COEQWAL is generating metrics on a wide range of values to evaluate trade-offs (this is not salmon-centric)

- Goal: empower communities by interpreting how different water futures align with their values

Exploring Novel Futures: Reorienting to Recovery ("R2R")

- GOAL: identify preferred, broadly supported management scenarios that support salmonid recovery in the Central Valley
- Use a structured decision-making framework to:
  - define scenarios
  - evaluate trade-offs
  - Include representatives from interest groups across the CV
- Scenarios include modifications to the 4Hs:
  - Hydrology
  - Habitat
  - Hatcheries
  - Harvest
- Run scenarios through salmon life cycle to identify pathways to salmon recovery
  - CVPIA SIT model → R2R SDM SIT model (fall-run, spring-run, winter-run)
  - WRLCM (winter-run)

Reorienting to Recovery:
https://csamp.baydeltalive.com/recovery/reorienting-to-recovery

Exploring Novel Futures: McCloud Reintroduction

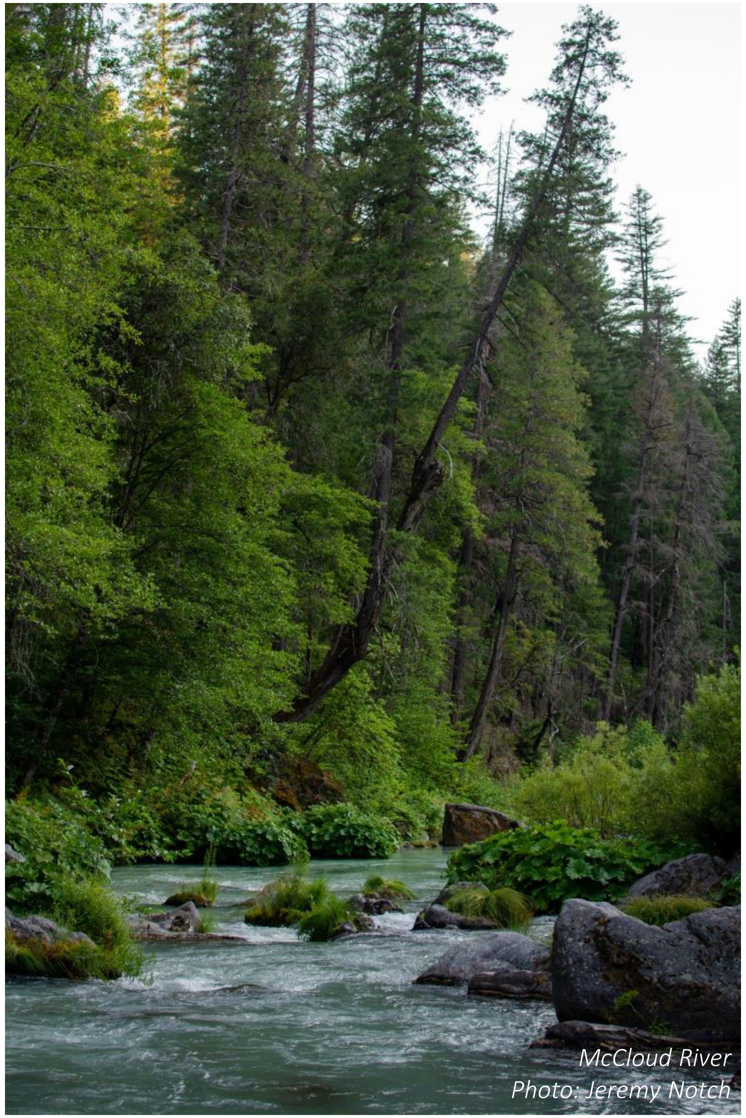
- Temperature management below Keswick is becoming more challenging in a changing climate, impacting winter-run eggs

- Reintroducing winter-run above Shasta can provide cool water, increase egg survival, and potentially reduce need for temperature management below Keswick

- Reintroduction has:
    - BENEFITS: lower water temperatures → increase egg survival
    - COSTS: capture inefficiencies/transport mortality may remove fish

- McCloud project (Rachel Johnson, SWFSC) is rearing eggs streamside in the McCloud and collecting data (survival, capture efficiencies)

- Data will be included in the WRLCM to develop reintroduction plans (e.g., when/how many winter-run should we reintroduce by WYT?)



McCloud River
Photo: Jeremy Notch

Conclusion

- The WRLCM development:
  - Court-ordered & developed specifically to evaluate large-scale water operation effects on winter-run
  - Capitalized on several data streams –observational data, submodels that operate on finer scales
  - Invested in transparency – soliciting expert feedback, quarterly community meetings
- Typical WRLCM applications
  - Evaluate the effect of proposed water operations on winter-run population (BAs, BOs)
- Novel applications of the WRLCM
  - Drought Analysis
  - COEQWAL
  - Reorienting to Recovery
  - McCloud Reintroduction

Questions?

Resources:

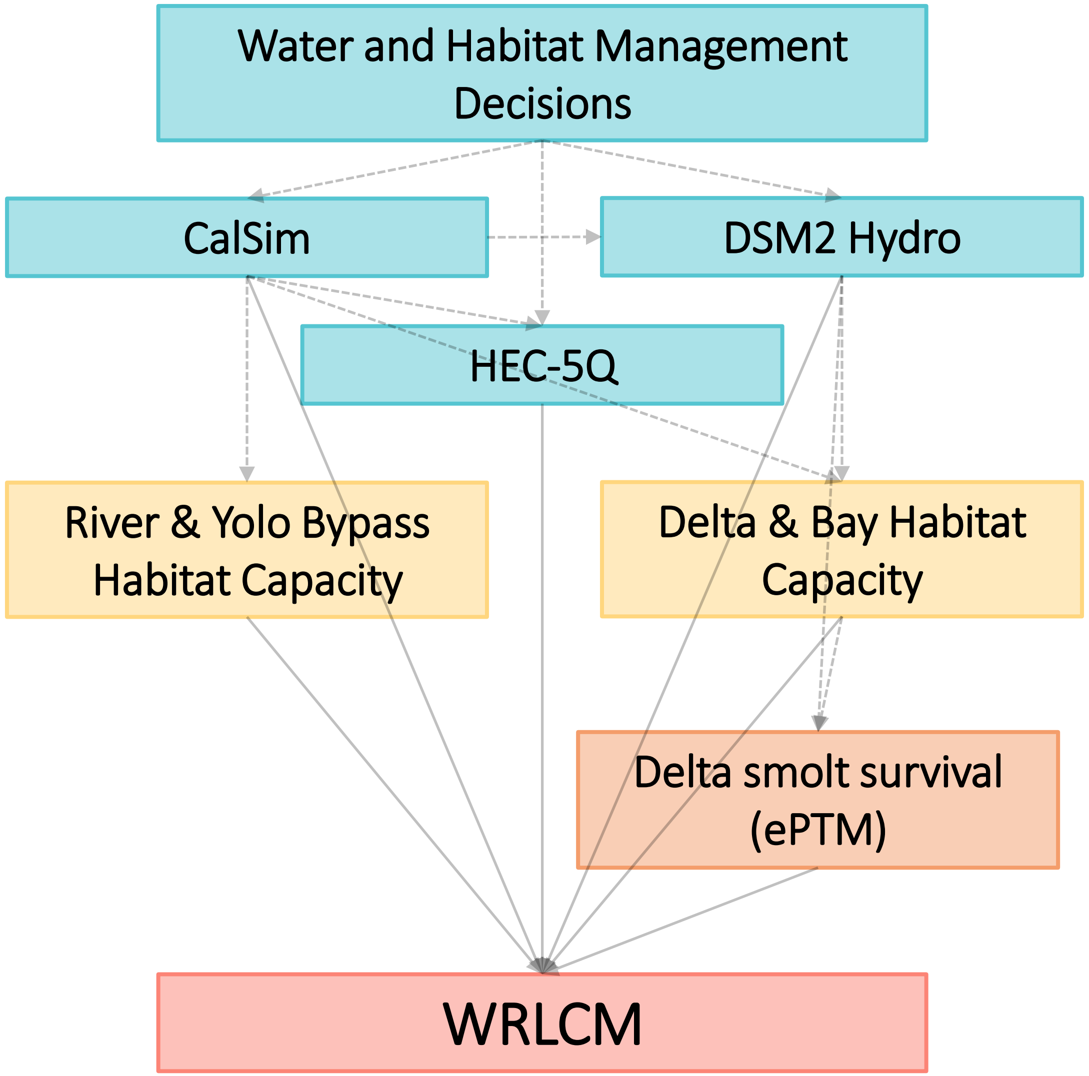
- **WRLCM website**: explore and simulate the model: https://oceanview.pfeg.noaa.gov/wrlcm/
- **WRLCM documentation**: Hendrix, N., Osterback, A.-M.K., John, S., Daniels, M., Jennings, E.D., Danner, E., and Lindley, S. 2024. Life Cycle Modeling Framework for Chinook salmon spawning in the Sacramento River. NOAA Tech. Memo. NMFS NOAA-TM-NM. doi: 10.25923/sj1b-xs90 NOAA.
- **ePTM GitHub Repo**: Model description, code and guided tutorial videos: https://github.com/cvclcm/ePTM_v2
- **ePTM publication:** Sridharan et al Sridharan, V.K., Jackson, D., Hein, A.M., Perry, R.W., Pope, A.C., Hendrix, N., Danner, E.M., and Lindley, S.T. 2023. Simulating the migration dynamics of juvenile salmonids through rivers and estuaries using a hydrodynamically driven enhanced particle tracking model. Ecol. Modell. 482. doi: 10.1016/j.ecolmodel.2023.110393.
- **COEQWAL**: https://live-coeqwal-ca.pantheon.berkeley.edu/
- **Reorienting to Recovery**: https://csamp.baydeltalive.com/recovery/reorienting-to-recovery

Photo: Jeremy Notch

EXTRA SLIDES

The WRLCM leverages data from its ecosystem of integrated models

- CalSim:
  - Riverine & Yolo Habitat Capacity Model
    - Depth & Velocity (flow at each CalSim node → HEC-RAS model)
  - Delta & Bay Habitat Capacity Model
    - Salinity (X2 location)
  - WRLCM
    - Fry dispersal (DCC schedule, flow at Rio Vista, Verona)
    - Density dependent downstream movement (flow at Verona, Wilkins)
    - Outmigration survival (flow at Bend Bridge)
- DSM2 Hydro:
  - Delta & Bay Habitat Capacity Model
    - Depth (stage data at all DSM2 nodes)
  - ePTM
    - Delta outmigration survival (stage, water velocity, flow data at all DSM2 nodes)
- HEC5Q (temperature)
  - WRLCM
    - TDM (water temperature below Keswick)
    - spawn timing (water temperature below Keswick)



The WRLCM leverages data from its ecosystem of integrated models

- **Habitat capacity models**
  - Use depth, velocity, and salinity to estimate the number of fish that can be supported by the available habitat, based on observed densities of fish
  - Serves as an input for the WRLCM as part of a density dependent movement function that moves fry downstream based on habitat availability

- **The enhanced particle tracking model (ePTM)**
  - Simulates the through-delta survival of outmigrating Chinook, seeding fish from 3 delta entry points:
    - Sacramento River
    - Yolo Bypass
    - Juveniles dispersed throughout the delta – location of origin is informed by the delta habitat capacity model (HC estimated at the finescale)
  - Uses fine-scale dynamics (15-30 minute timestep by node from DSM2 Hydro) to capture finescale habitat
  - Layers fish behavior on top (routing behavior at junctions, swim speed)
  - Mechanistic model; can be used for conditions outside of the historical range and when there are structural changes to the delta
  - Calibrated to late-fall-run AT data, successful validation using winter-run AT data