



Evolutionary mismatch of the Endangered Winter Run Chinook salmon: life history of a mountain climber on a hot valley floor



Rachel C. Johnson, Ph.D.
May 7, 2024



Evolutionary mismatch of the Endangered Winter Run Chinook salmon: life history of a mountain climber on a hot valley floor

UC DAVIS
UNIVERSITY OF CALIFORNIA

Evolved reciprocity between salmon and habitats

Ecosystem Engineers (Salmon move mountains)



Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph



Sex that moves mountains: The influence of spawning fish on river profiles over geologic timescales

Alexander K. Fremier^{a,*}, Brian J. Yanites^b, Elowyn M. Yager^c



Nutrient Cycling (Marine N feeds ecosystems)



Ecological Applications, 16(3), 2006, pp. 999–1009
© 2006 by the Ecological Society of America

SALMON, WILDLIFE, AND WINE: MARINE-DERIVED NUTRIENTS IN HUMAN-DOMINATED ECOSYSTEMS OF CENTRAL CALIFORNIA

JOSEPH E. MERZ^{1,3} AND PETER B. MOYLE²

Evolved reciprocity between salmon, habitats... and people

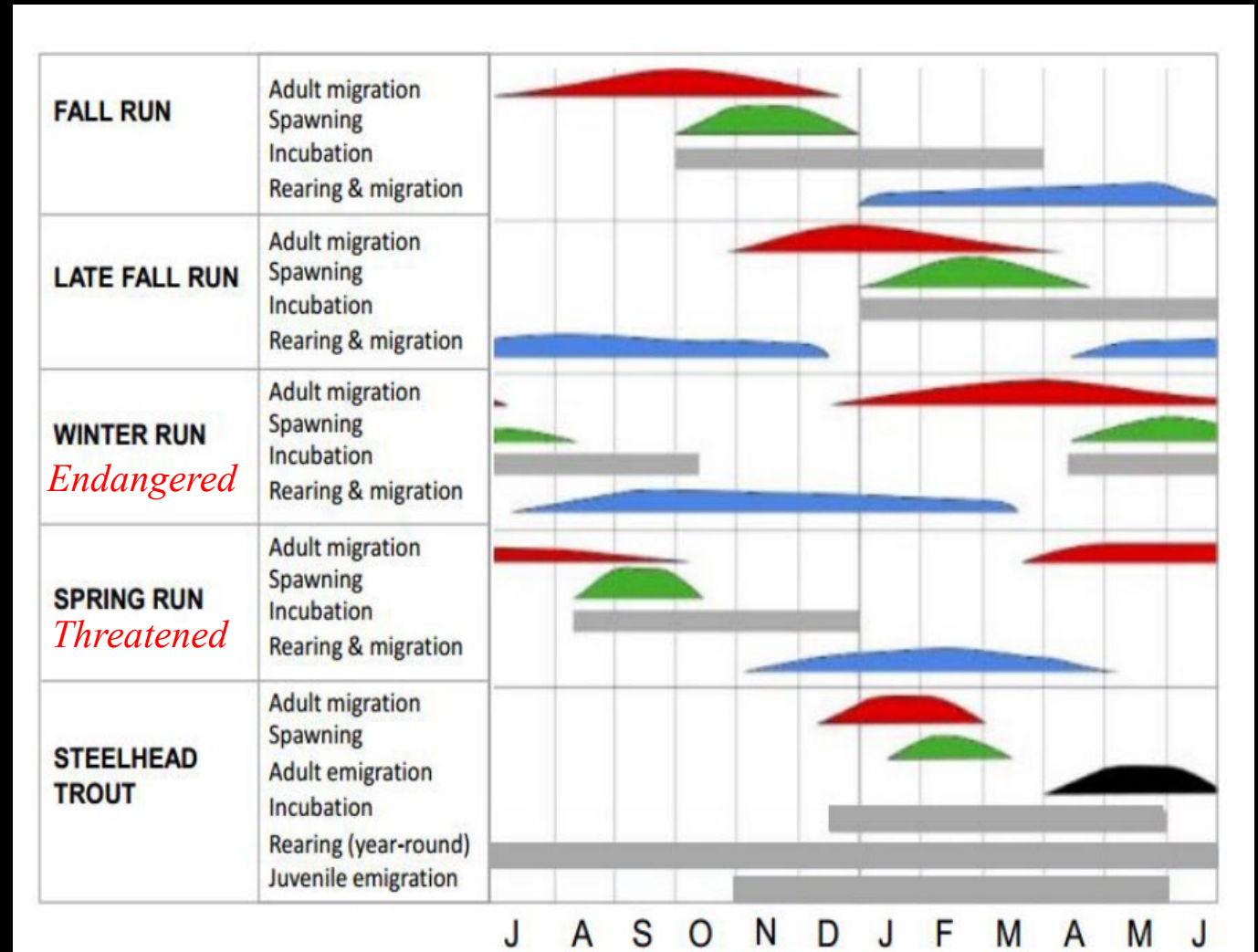


Art by Blane Bellerud (NOAA West Coast Region) based on story from Chief Sisk, Spirituall leader of the Winnemem Wintu Tribe

California habitat diversity shapes salmon life histories

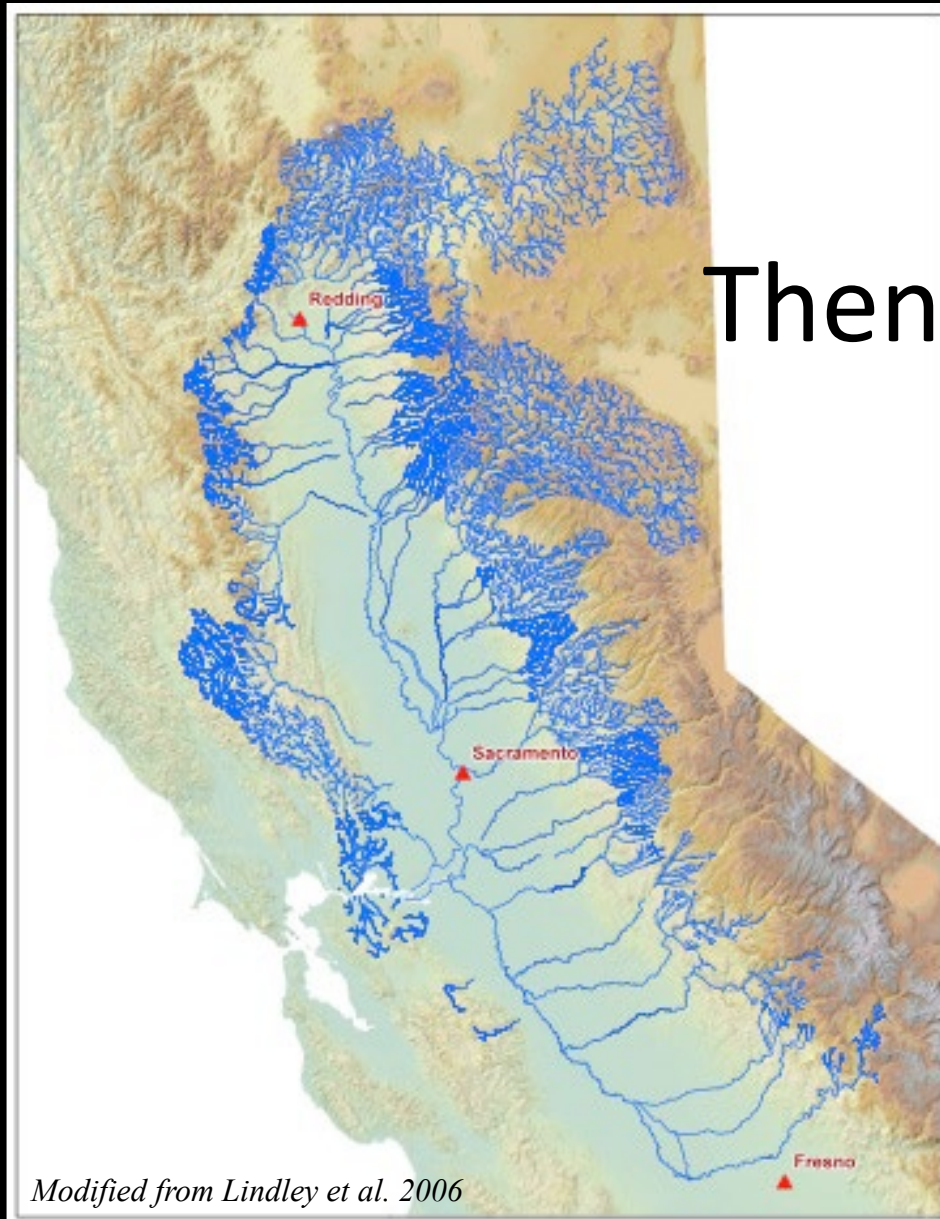


Linda Glass

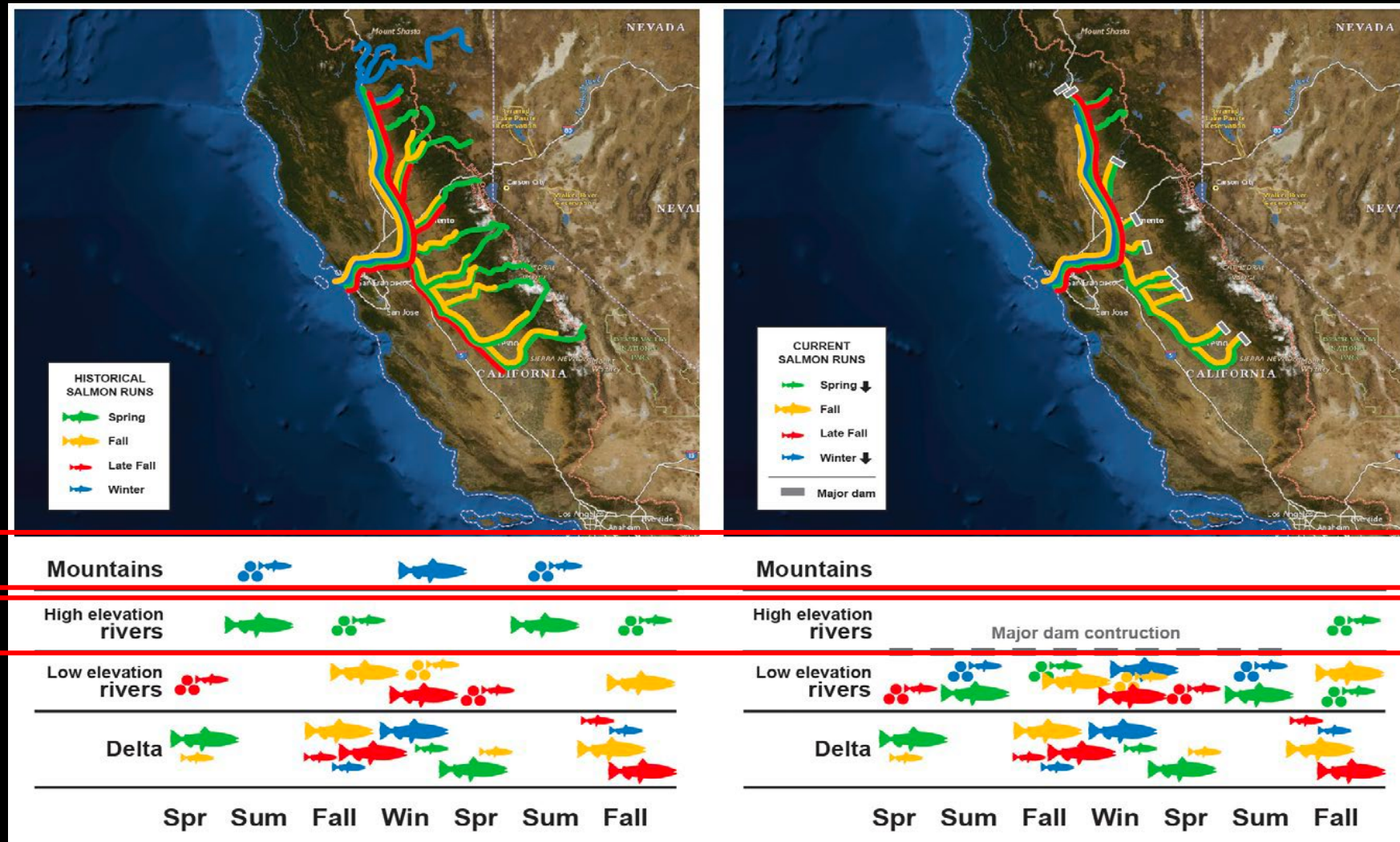


Herbold et al. 2018

Dams affect winter & spring-run the most



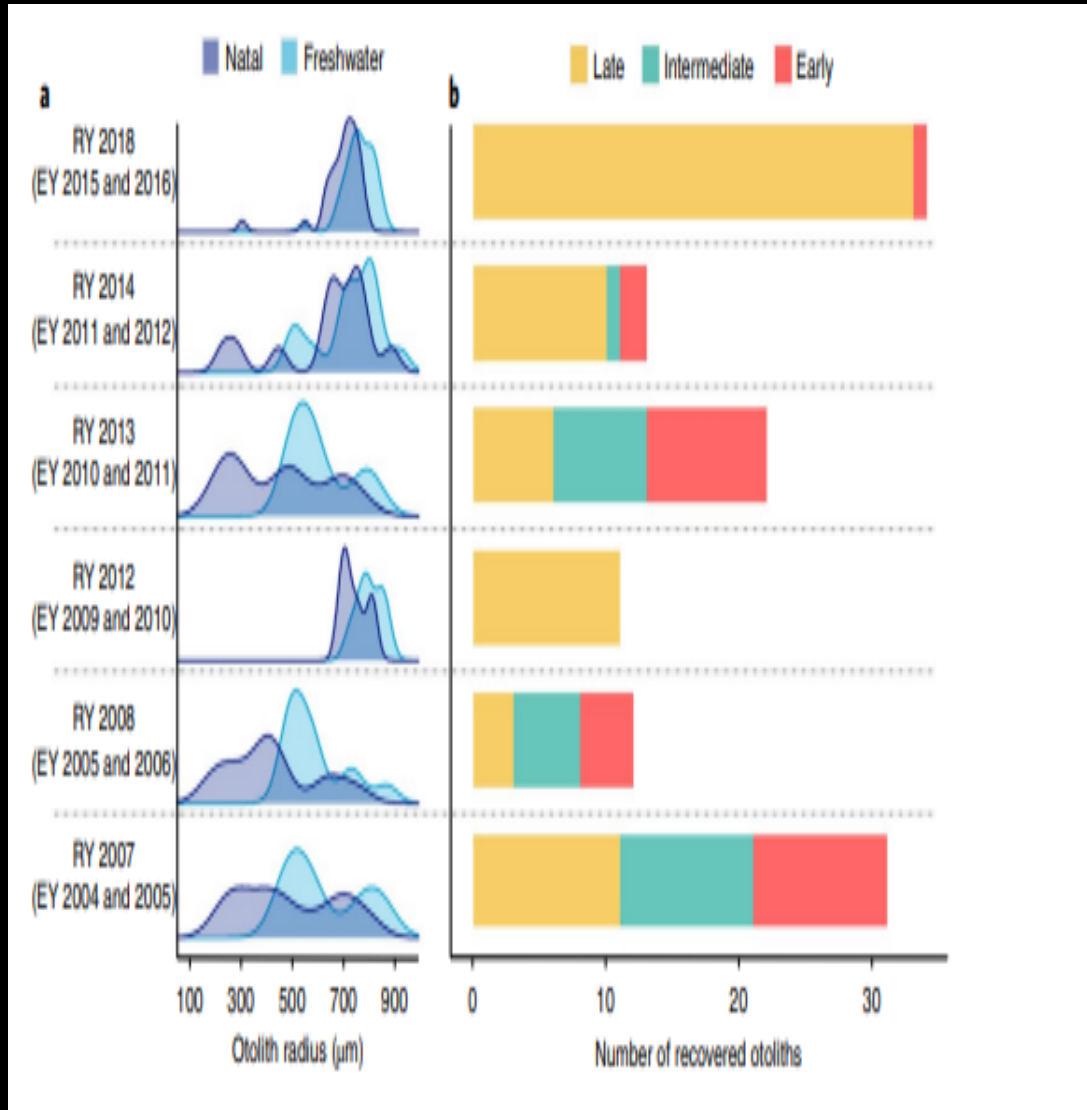
Reduced life history diversity and decline of CA salmon production system



X

Lost high-elevation juvenile life history strategies

Climate-resilient strategies



Leave Late



Leave Early

Rare yearlings are drought resilient strategy!

ARTICLES
<https://doi.org/10.1038/s41558-021-01186-4>

nature
climate change

Check for updates

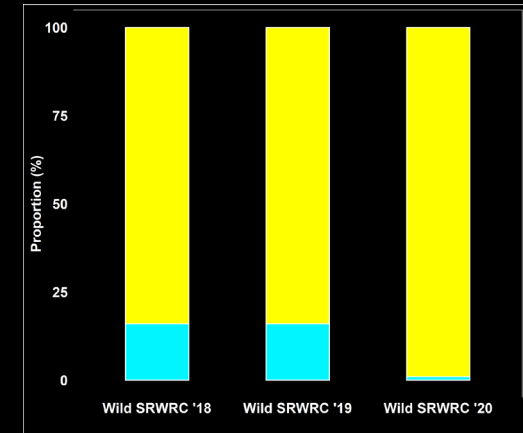
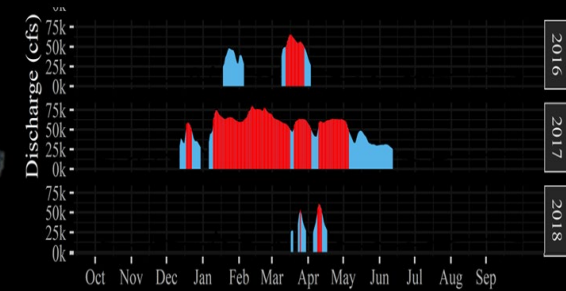
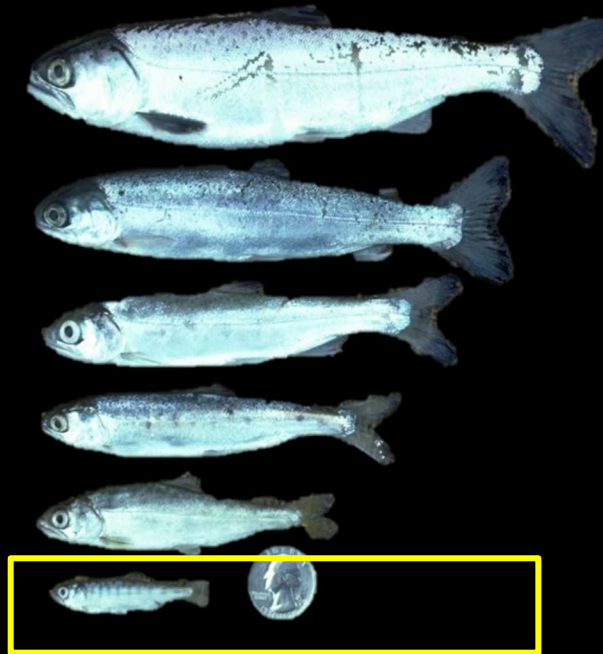
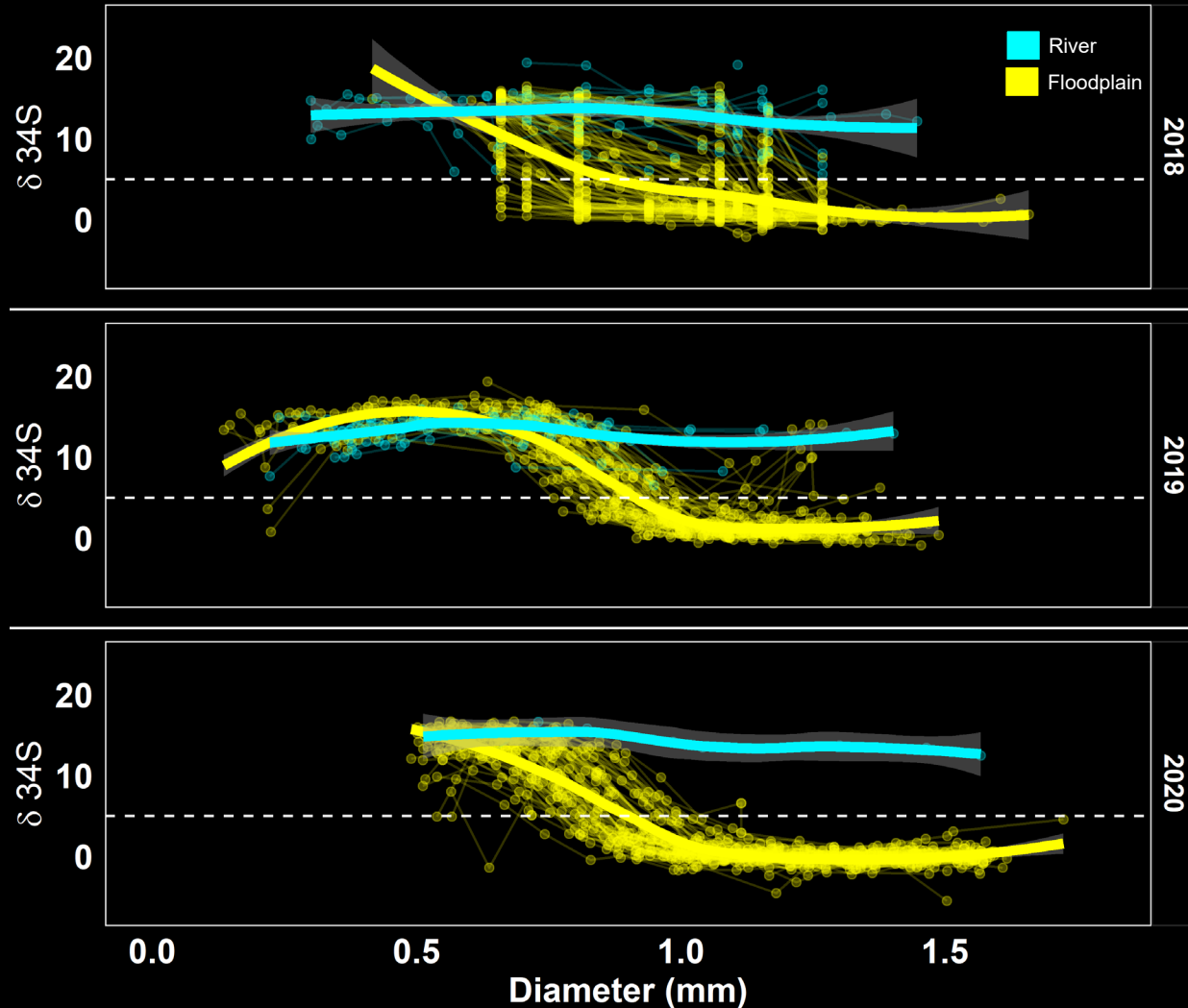
Threatened salmon rely on a rare life history strategy in a warming landscape

F. Cordoleani^{1,2}, C. C. Phillis³, A. M. Sturrock⁴, A. M. FitzGerald^{1,2}, A. Malkasian⁵, G. E. Whitman⁶, P. K. Weber⁷ and R. C. Johnson^{2,6}

Lost low-elevation floodplains for juvenile rearing

Climate-resilient strategies

Reconstruction of floodplain rearing Winter run adults



>85% Winter run use off floodplain food resources!

SEGMENT | 11:59

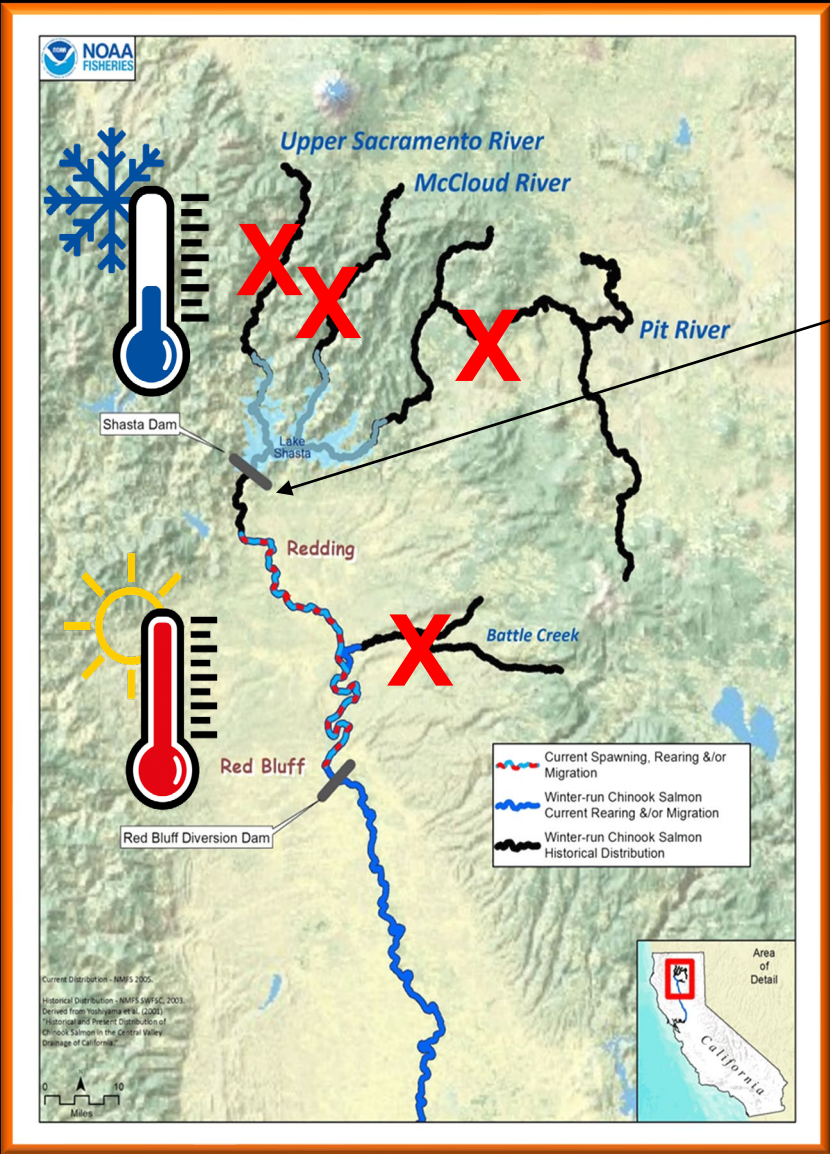
Seeing The World Through Salmon Eyes

Dissecting eyes is helping measure what fish eat—and the value of different habitats.

READ MORE →

Bell-Tilcock et 2021

Shasta Dam displaces Winnemem Wintu & their *Nur* [salmon]

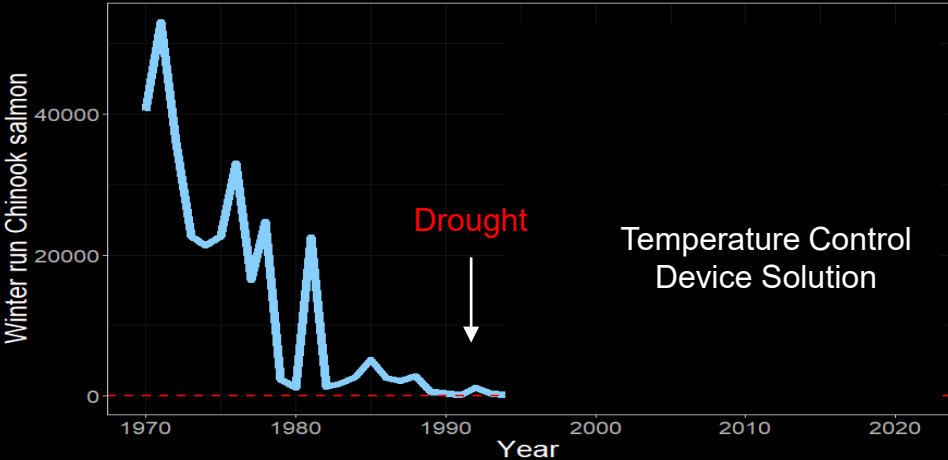


Dancing Salmon Home

go on, put all your eggs in here... what's the worst that could happen?



Toothpaste For Dinner.com



Higher elevations provide thermal refuge to warming climate

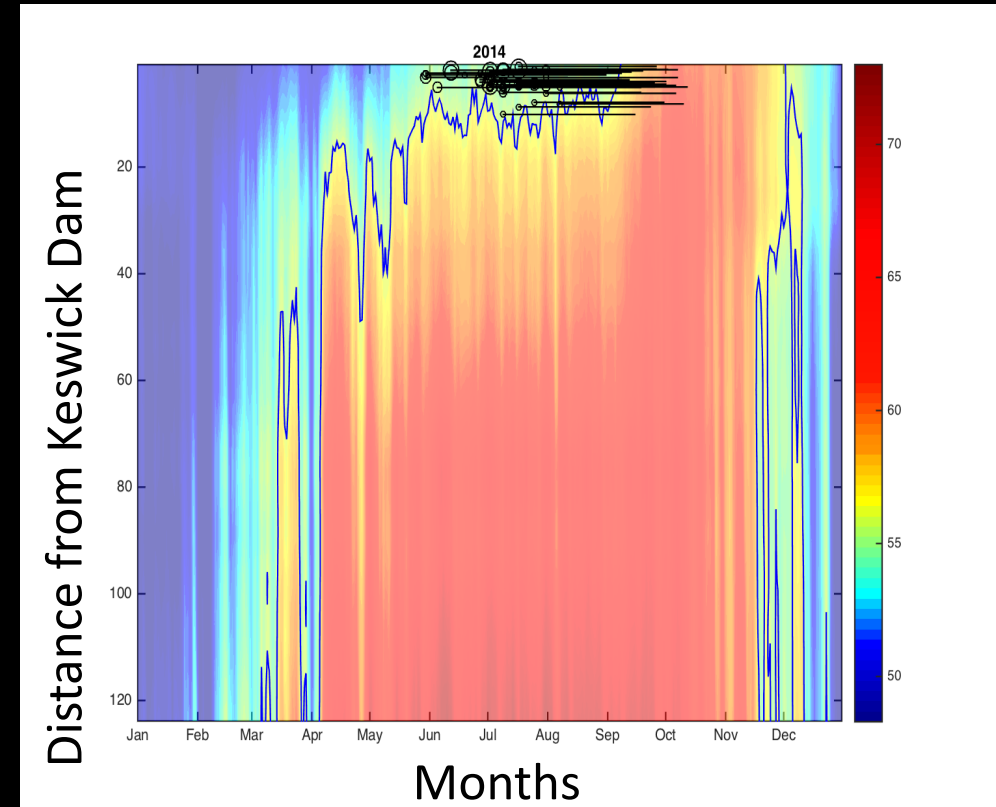
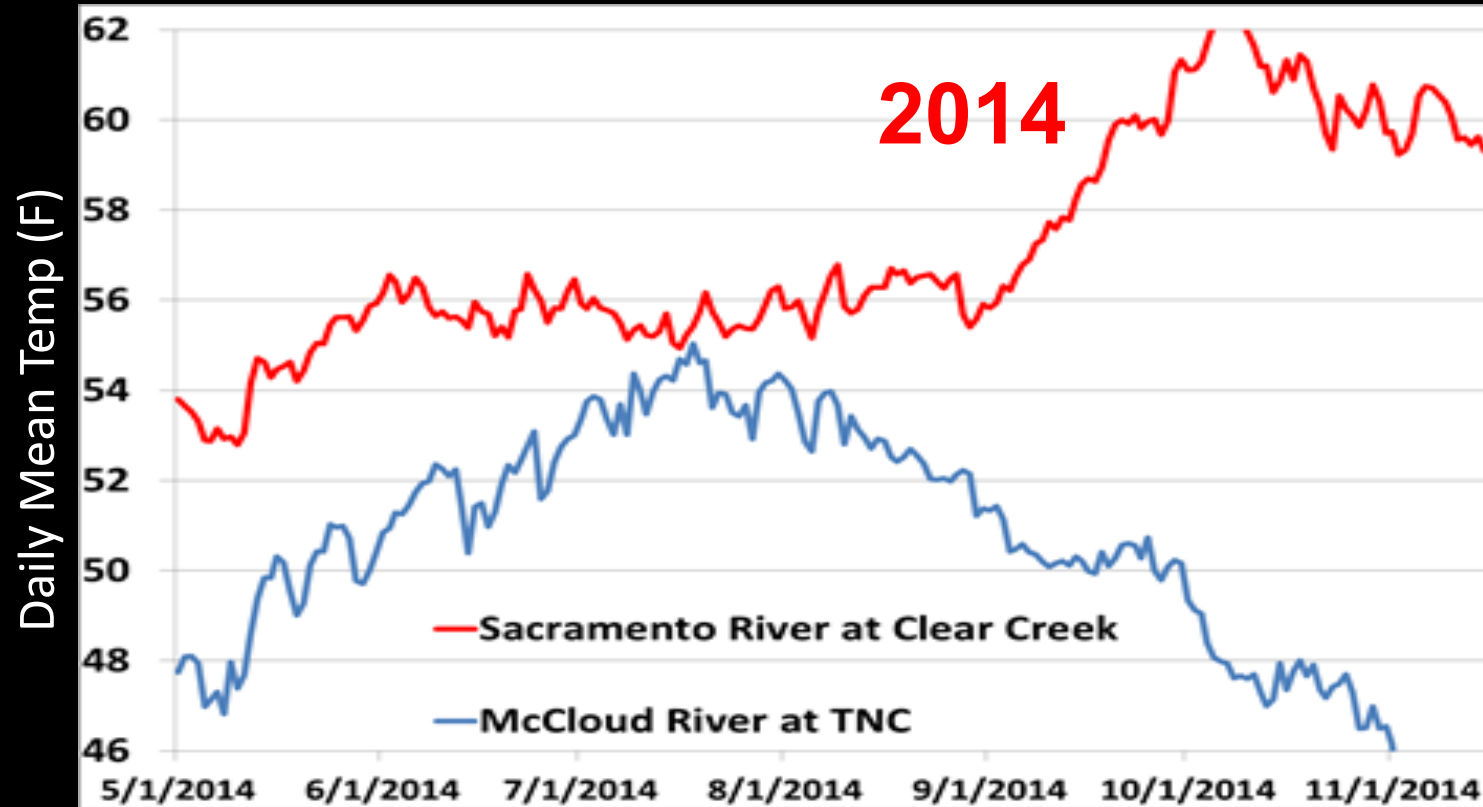
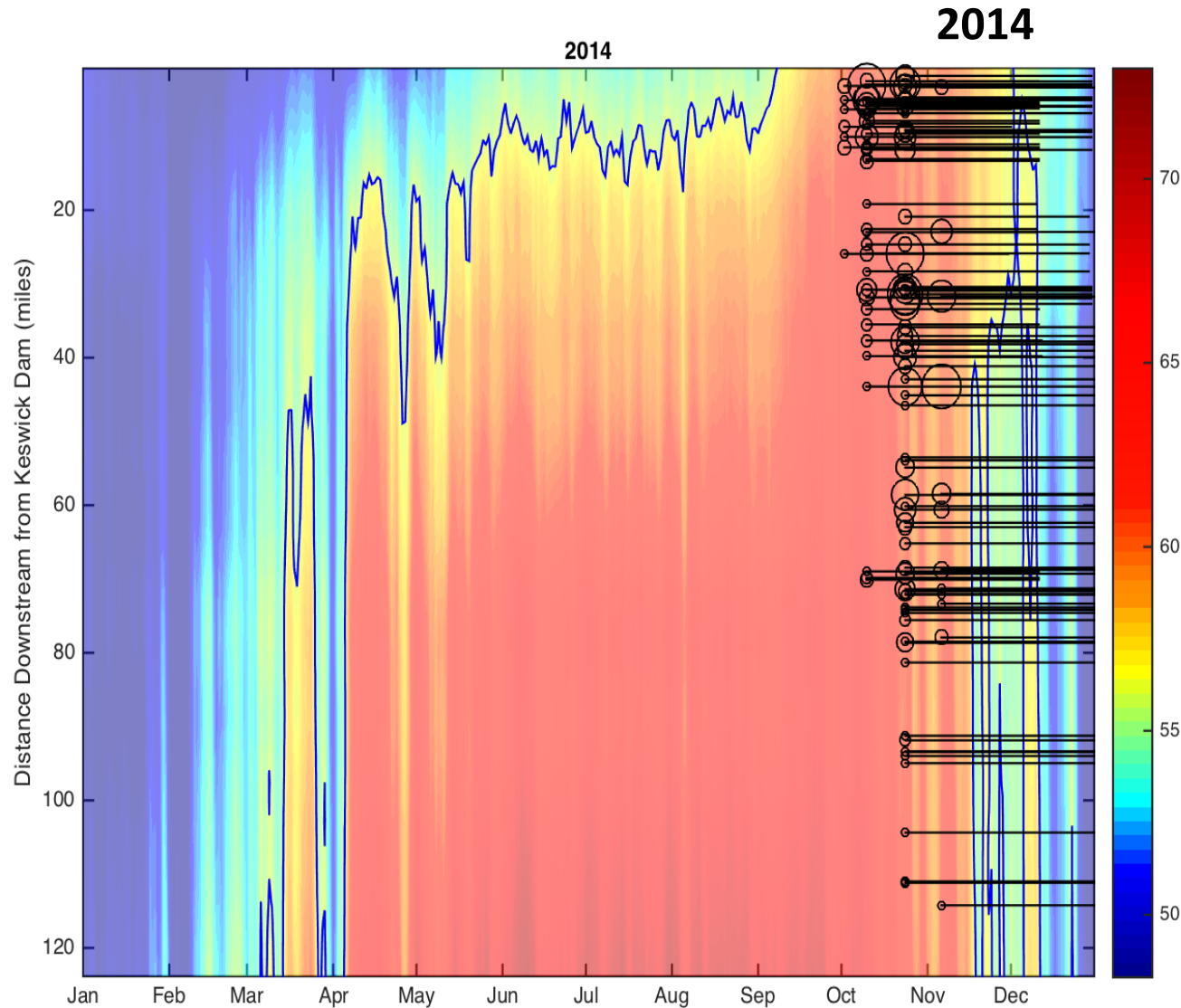


Figure courtesy of M. Daniels

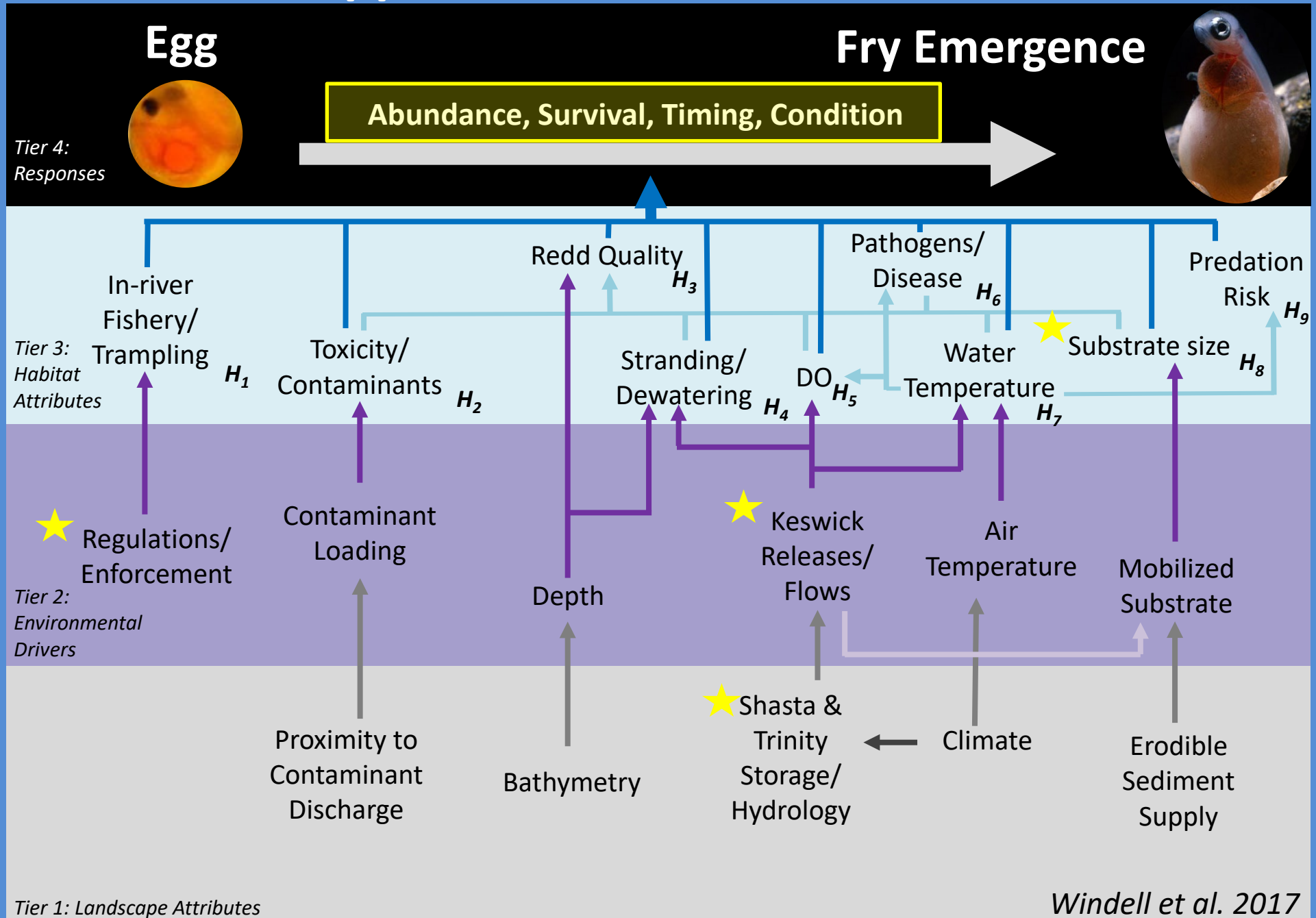
Fall-run eggs and temperature exposure



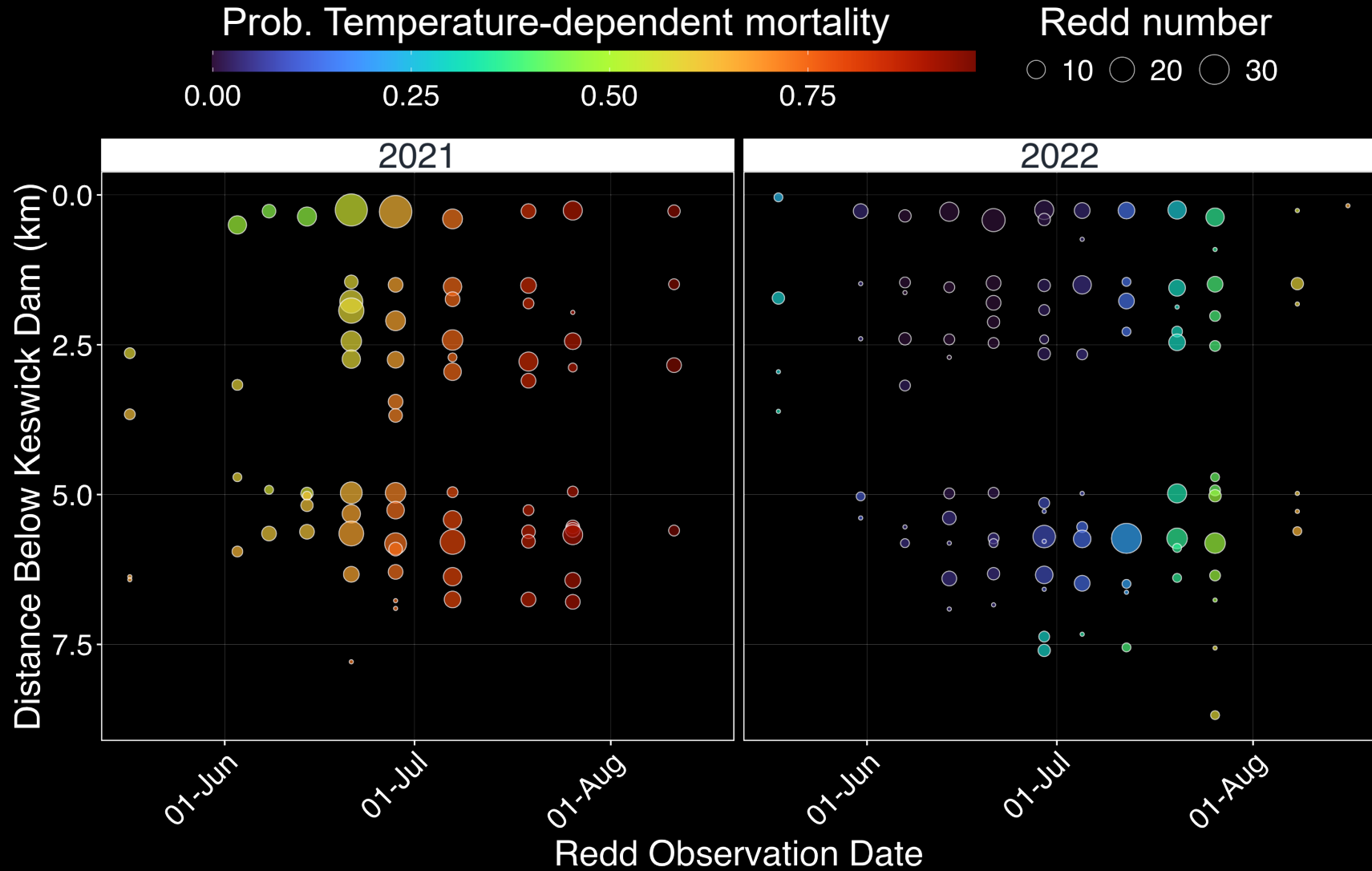
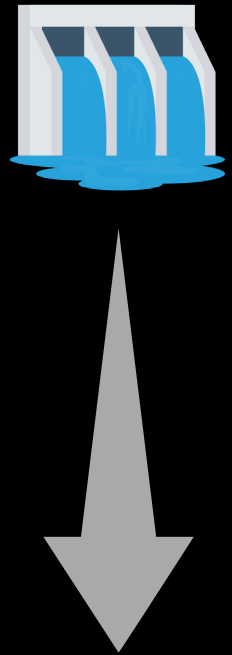
Provided by Eric Danner, NOAA/NMFS/SWFSC



Upper River

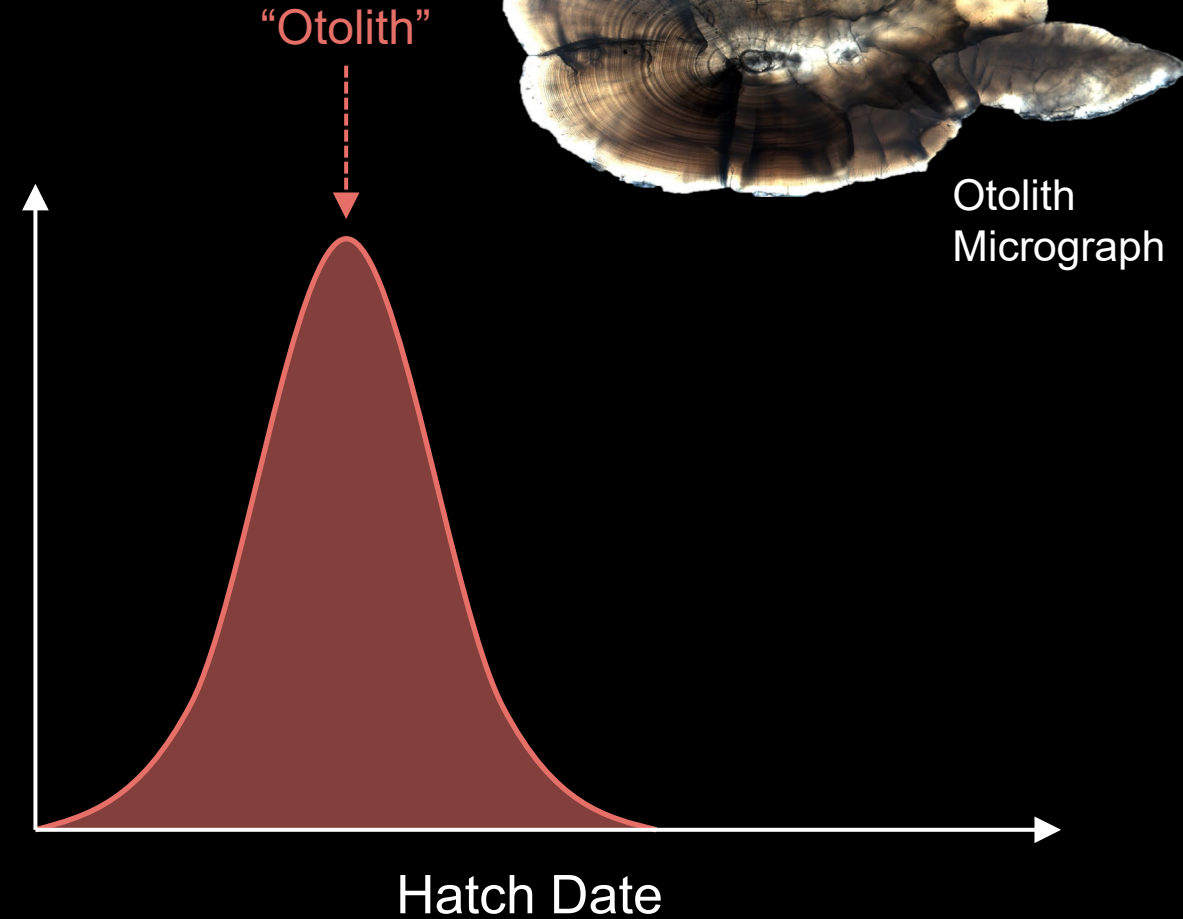
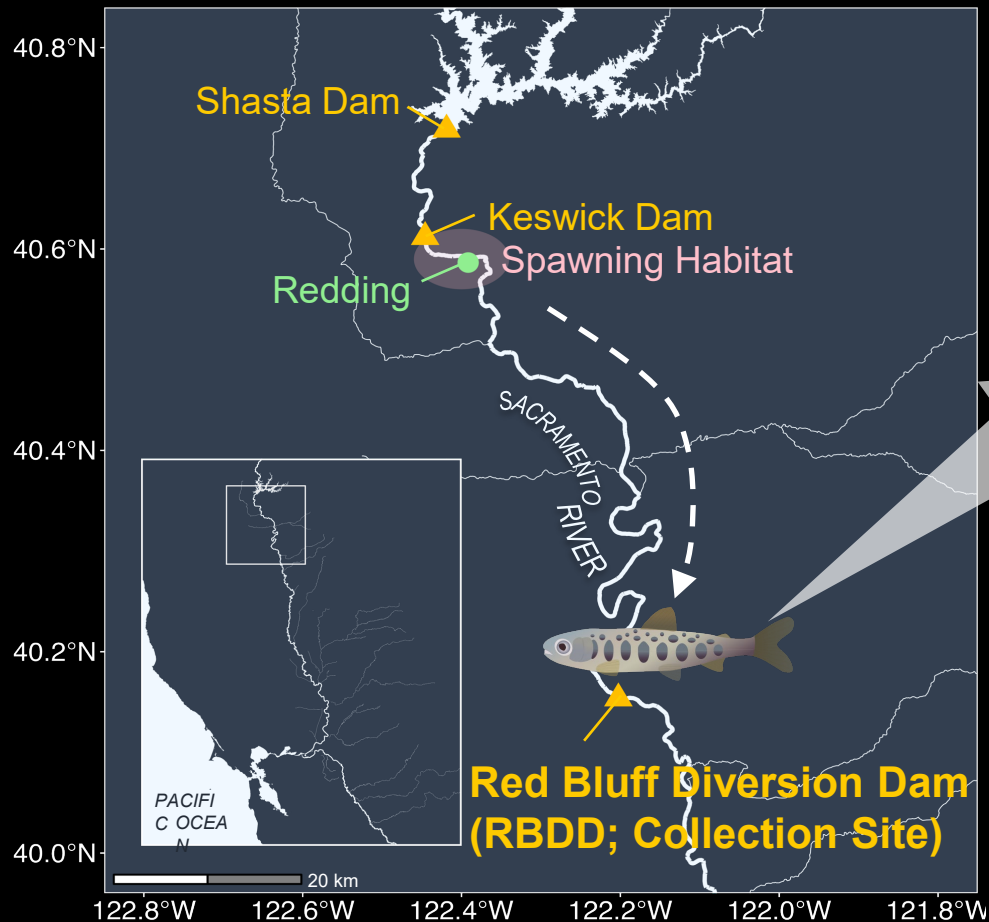


Winter run Temperature-dependent Mortality Rates



Selection for spawn timing/ hatch date

“Otolith” Hatch Date

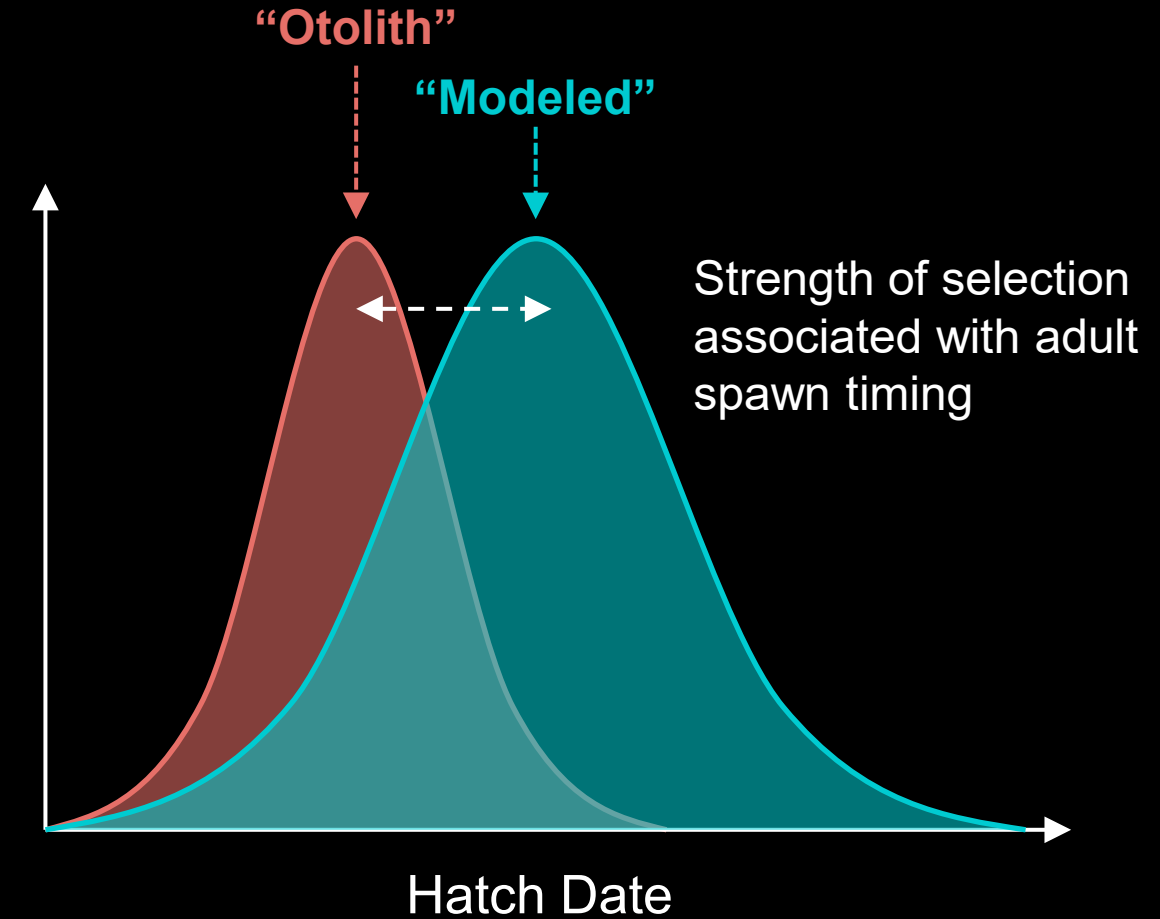
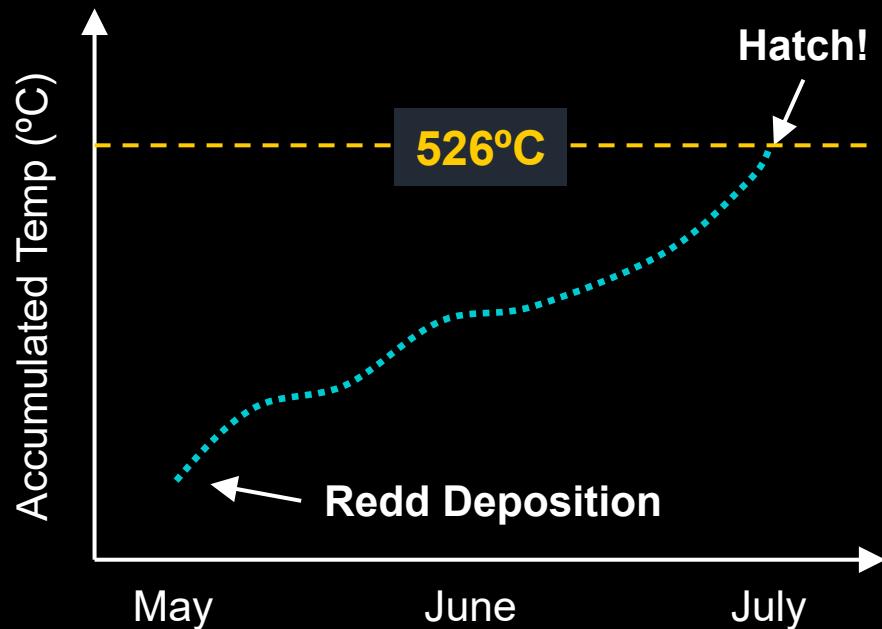


- Estimated from otolith daily increments.
- Represents “successful” hatch dates of survivors collected at Red Bluff Diversion Dam.
- Hatch Date = Collection Date – Age

“Otolith” and “Modeled” Hatch Dates

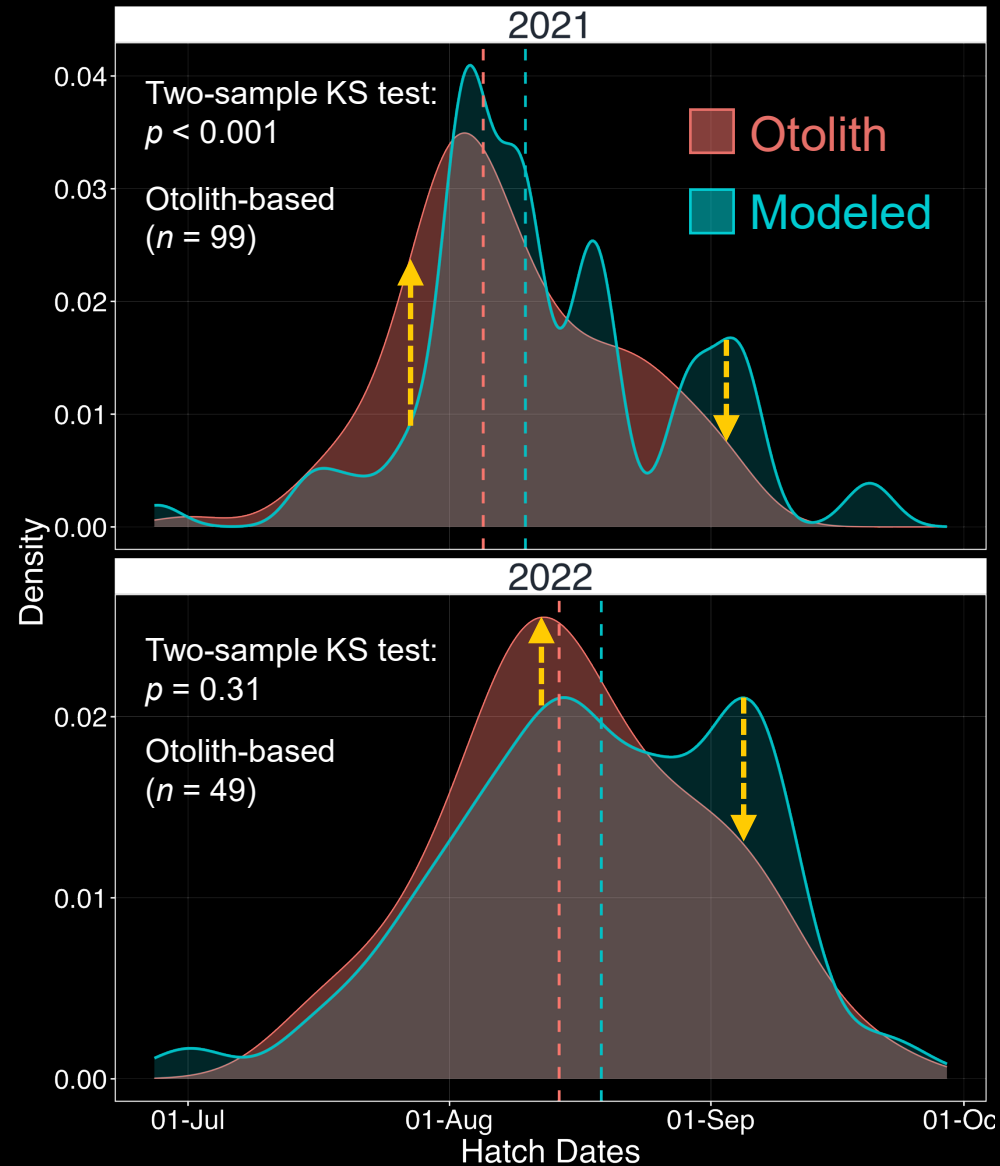
“Modeled” Hatch Date

- Based on timing, location, and exposed temperatures of redds observed in weekly aerial surveys (CDFW).
- Estimated from a degree-day model using an Accumulated Temperature of 526°C.

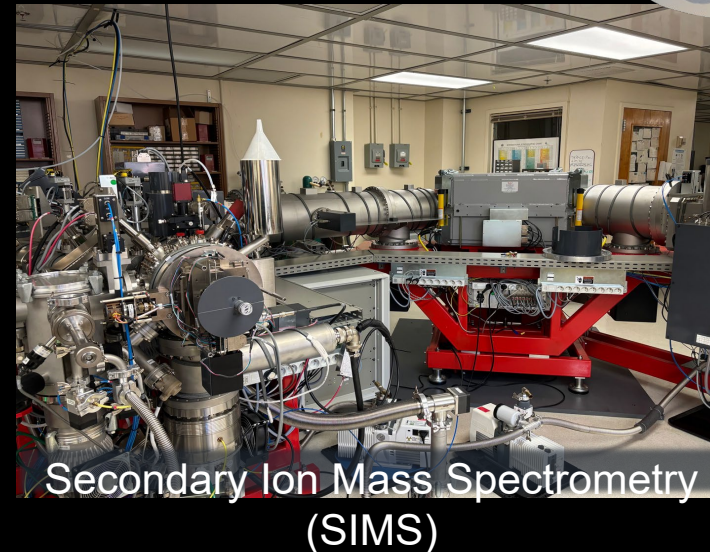
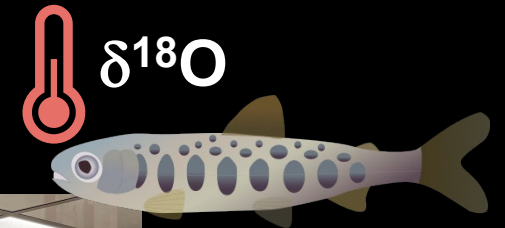


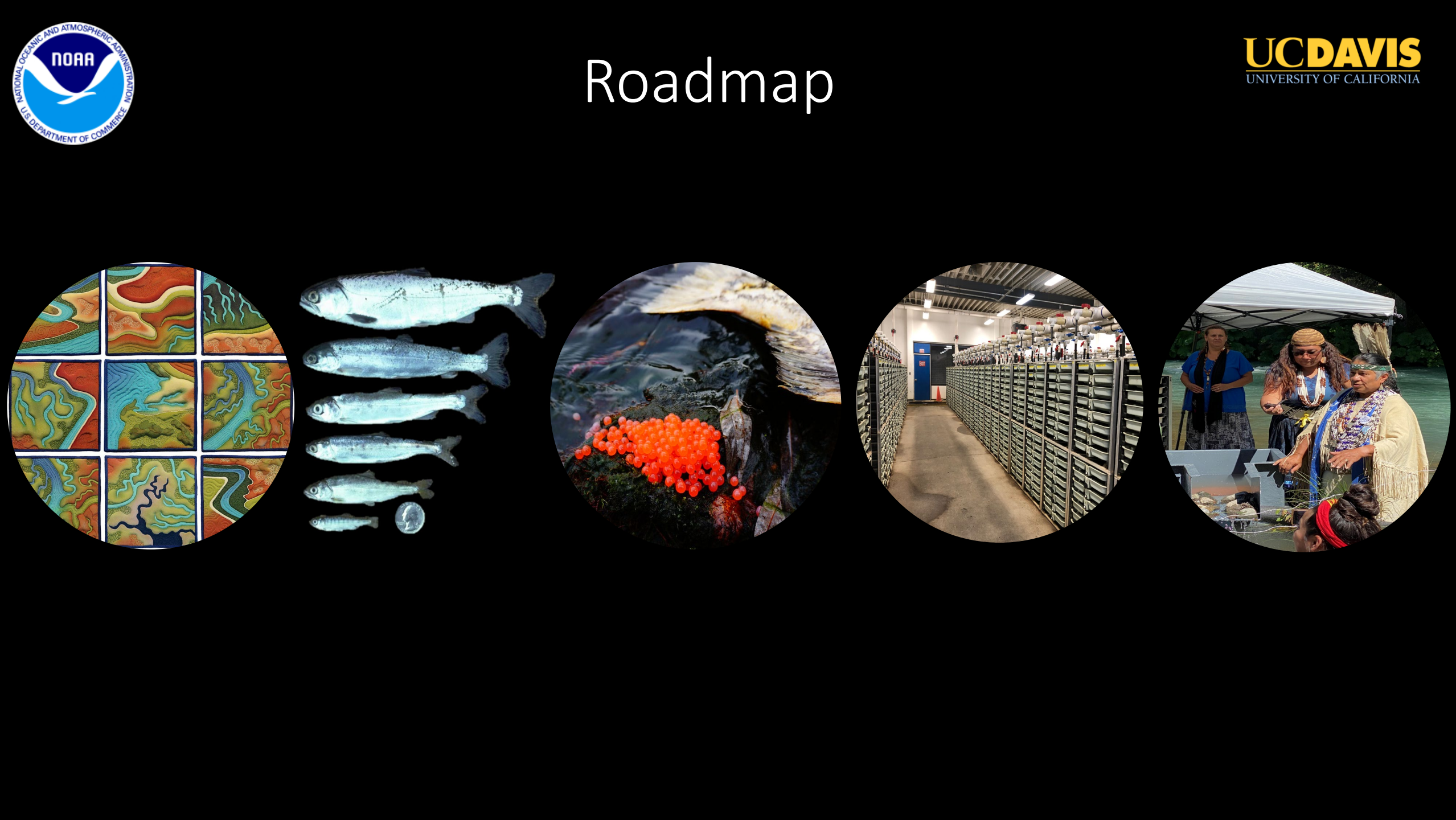
Survival related to adult spawn timing

Selection for Earlier Spawners/Hatch Dates



- Otolith “successful” hatch dates occurred earlier.
- Early hatch dates were more represented in the “successful” otolith hatch dates.
- Greater survival for early-spawned cohorts.





Extinction risk criterion and status of winter run



Criterion	Risk of Extinction		
	High	Moderate	Low
Extinction risk from PVA	> 20% within 20 years – or any ONE of –	> 5% within 100 years – or any ONE of –	< 5% within 100 years – or ALL of –
Population size ^a	$N_e \leq 50$ –or– $N \leq 250$	$50 < N_e \leq 500$ –or– $250 < N \leq 2500$	$N_e > 500$ –or– $N > 2500$
Population decline	Precipitous decline ^b	Chronic decline or depression ^c	No decline apparent or probable
Catastrophe, rate and effect ^d	Order of magnitude decline within one generation	Smaller but significant decline ^e	not apparent
Hatchery influence ^f	High	Moderate	Low

^a Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.

^b Decline within last two generations to annual run size ≤ 500 spawners, or run size > 500 but declining at $\geq 10\%$ per year. Historically small but stable population not included.

^c Run size has declined to ≤ 500 , but now stable.

^d Catastrophes occurring within the last 10 years.

^e Decline $< 90\%$ but biologically significant.

^f See Figure 1 for assessing hatchery impacts.

Hatcheries not a long-term solution

	Viability assessment		
	2010	2015	2020
Population Size	Low risk	Low risk	Low risk
Population Decline	Low risk	Moderate risk	Low risk
Catastrophe, rate, and effect	Low risk	Low risk	Low risk
Hatchery Influence	Low risk	Moderate risk	High risk



NOAA Technical Memorandum NMFS

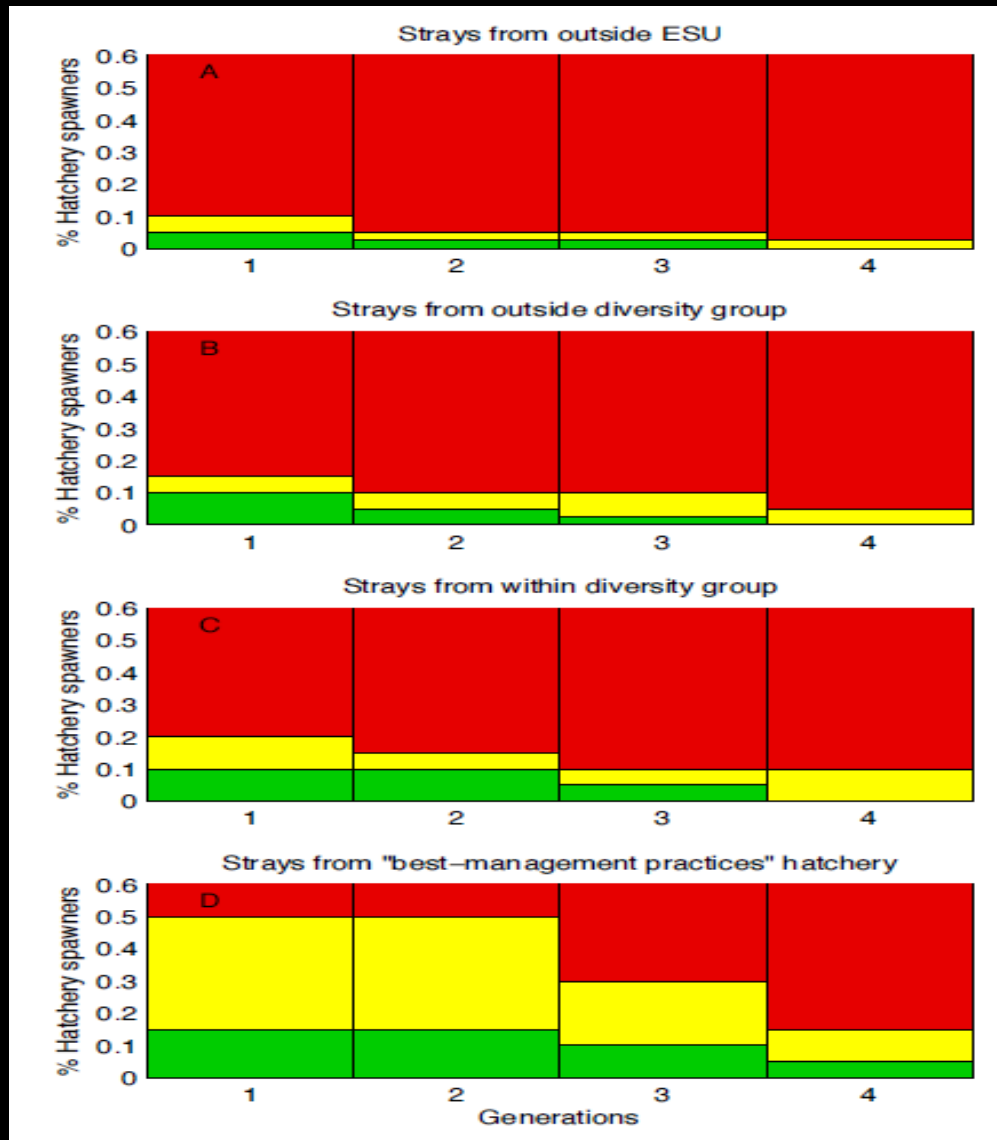
<https://doi.org/10.25923/039q-q707>

AUGUST 2023

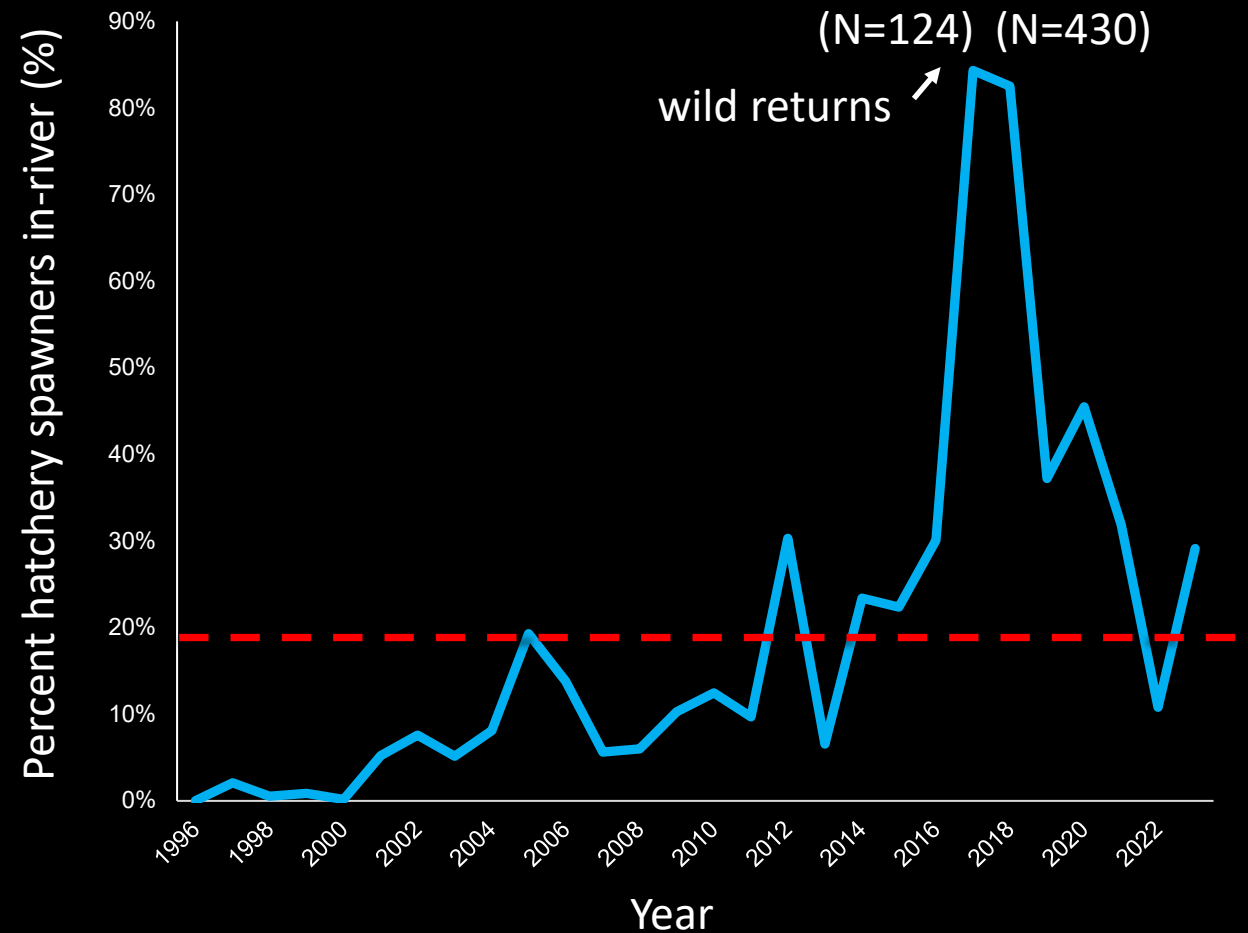
VIABILITY ASSESSMENT FOR PACIFIC SALMON
AND STEELHEAD LISTED UNDER THE
ENDANGERED SPECIES ACT: SOUTHWEST

Johnson et al. 2023

Hatchery increases winter run risk of extinction



Hatchery contribution over time



New stressor to California salmon- 2020

Thiamine (vitamin B₁) deficiency (M74) has been documented in a wide variety of animals (mussels, birds, cod, eel, salmon) worldwide, including humans. Fish and humans can't make B₁. Need it from diet.

SYMPTOMS

Reduced Growth

Reproductive failure

Neurological disorders

Damage to blood-brain barrier

Immunosuppression

Increased parasitic infestation

Normal

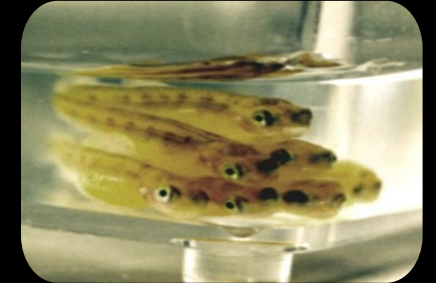


Photo courtesy Dale Honeyfield, USGS

Deficient Thiamine Levels

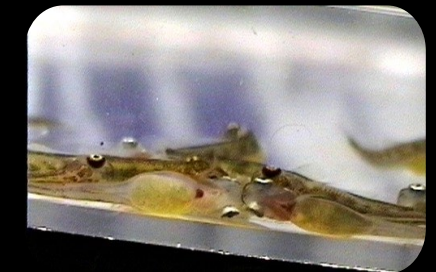
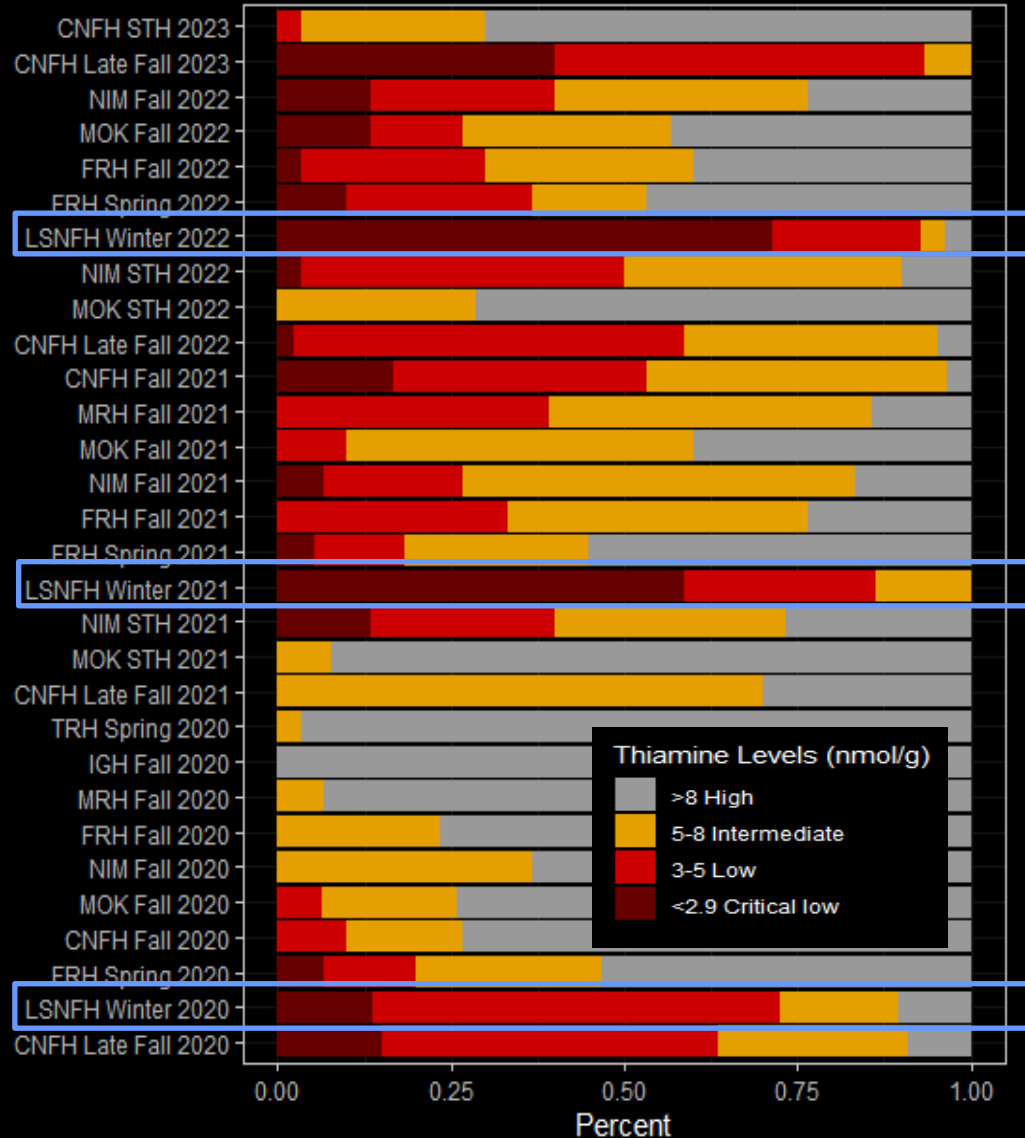


Photo courtesy Dale Honeyfield, USGS

Winter run hardest hit high thiamine-dependent mortality

Broad Scale Egg Surveillance Chinook and Steelhead TD Mortality



47%- 54%

45%

33%

Egg thiamine survival curve

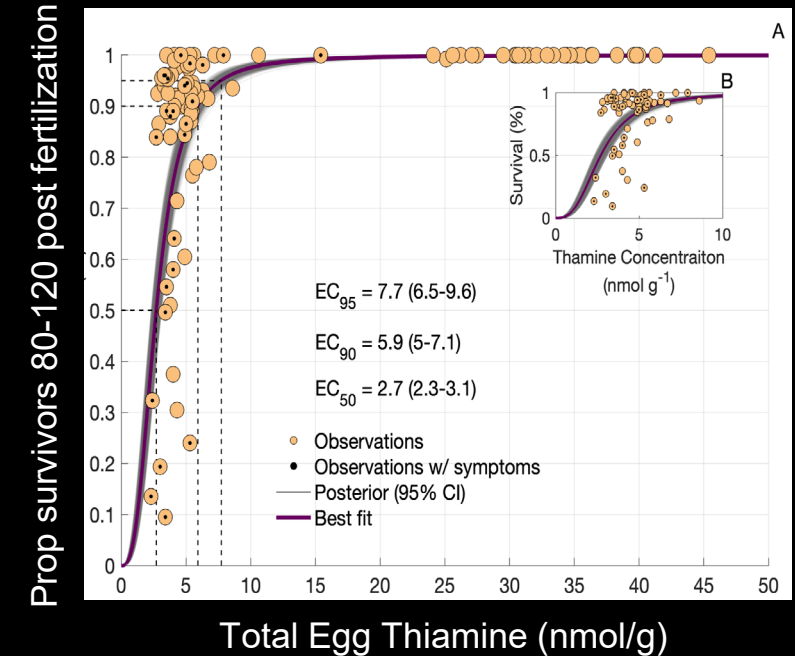


Figure courtesy Miles Daniels (UCSC); Mantua et al. in prep

Egg-to-fry survival model now accounts for **temperature** and **thiamine-dependent** mortality (multiplicative)

Winter run salmon return to ancestral waters after 80 years

Los Angeles Times

SPONSORED BY DOGFOODEXPOSE.COM

Endangered salmon will swim in California river for first time in 80 years



Caleen Sisk, chief and spiritual leader of the Winnemem Wintu Tribe, visits the McCloud River in January. (Los Angeles Times)

BY IAN JAMES | STAFF WRITER

JULY 16, 2022 5 AM PT

“We’re Praying That They Remember These Waters”: Supported By Tribal Ceremony, Salmon Eggs Return To The McCloud River After 80 Year Absence

On July 11 the Winnemem Wintu Tribe endangered salmon eggs as they were released. The action is part of new collaboration with the tribe. The watershed moment for the Tribe. Hot Summer-run Chinook, but government scientists say the glacial waters of the McCloud River, survive.

BY MARC DADIGAN • NEWS: INDIGENOUS AFFAIRS

stabbing, Live Nation faces mounting questions over concert safety



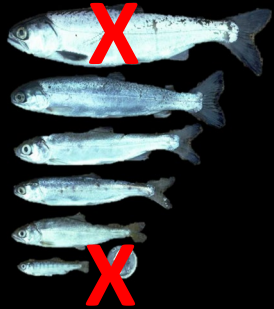
Mya Sisk, the granddaughter of Chief Caleen Sisk, places a cup of winter-run Chinook salmon eggs under the supervision of Taylor Lipscomb, Hatchery Manager at the Livingston Stone National Hatchery. The hatchery was the source of the eggs. Photo Courtesy: Taylor Lipscomb



Key Takeaways



Salmon evolved life history behaviors based on selection for **local adaptation** (co-evolved gene complexes); Can we expect same behaviors (winter, spring runs) with **different habitat template**?



Dams have altered juvenile outmigration diversity that historically helped salmon through mega droughts/ floods; Process based habitat **restoration** and **reintroduction** for **climate ready fisheries**



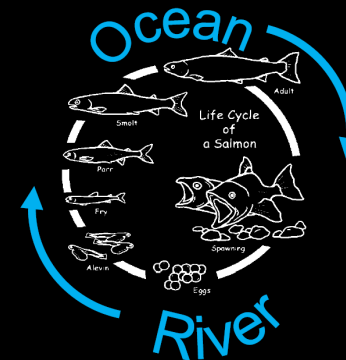
Eggs on life support. Managing to non-linear temperature threshold is risky- **back away from cliff**; environmental stochasticity, new stressors, uncertainty



Hatchery not a long-term solution. Places ESU at an **increased risk of extinction** due to fitness impacts



McCloud reintroduction is a hope spot for salmon and **cold water salmon strong hold** in CA; Emergence of yearlings in first year



Life cycle model critical to integrate stressors and management options (floodplain restoration, reintroduction) across the full life cycle of salmon

Something was killing baby salmon. Scientists traced it to a food-web mystery



... started noticing abnormal behavior and high mortality in their salmon fry, leading to concerns that a disruption in the marine ecosystem may be affecting the trans... (in hatching here) and subsequently to juvenile fish. Photo by Randall Benton/Sacramento Bee/Zuma Press/Alamy Stock Photo

The Ocean's Mysterious Vitamin Deficiency

A puzzling lack of thiamine is disrupting some marine ecosystems.

by Alastair Bland

January 28, 2021 | 2,700 words, about 14 minutes

Share this:



Disoriented little fish caught the attention of staff members at the Coleman



Search NOAA Fish

Researchers Probe Deaths of Central Valley Chinook, with Possible Ties to Ocean Changes

October 26, 2020

Deficiency in Vitamin B1 linked to higher juvenile mortality in California fish hatcheries.

Feature Story | West Coast

To learn more:



Search NOAA Fisheries

Monitoring Thiamine Deficiency in California Salmon

Our team works with anglers and fishing industry partners to monitor the nutritional status of Chinook salmon caught in the Central California coastal fishery.

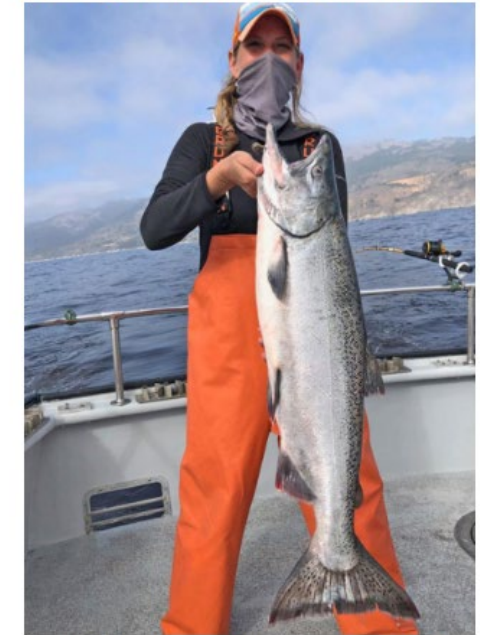
West Coast

Table of Contents

- Scientists Ask for Anglers' Help in Solving Salmon Mystery
- Piecing Together the Puzzle
- How Anglers Can Help Scientists and Salmon
- A Home-Grown California Mystery
- The Hidden Toll
- Our Funding Partners
- More Information

A project of the Southwest Fisheries Science Center's [Salmon Life History Team](#)

Scientists Ask for Anglers' Help in Solving Salmon Mystery



Patience biologist Rachel Johnson of NOAA Fisheries and UC Davis assists in sampling of salmon aboard the *Mar Rayann* to help investigate the influence of thiamine levels on the health of California Chinook populations. (Photo: Matt Blaney)

Anglers have unique opportunity to help scientists unravel a marine mystery that appears to be affecting native Chinook salmon through a deficiency of thiamine, or Vitamin B1, which is essential to all life. This deficiency was recently found to be increasing mortality of juvenile Chinook salmon in California's Central Valley.

The magnitude of its effect is not clear. However, it could affect endangered winter-run Chinook salmon and fall-run Chinook salmon, which comprise major California sport and commercial fisheries.

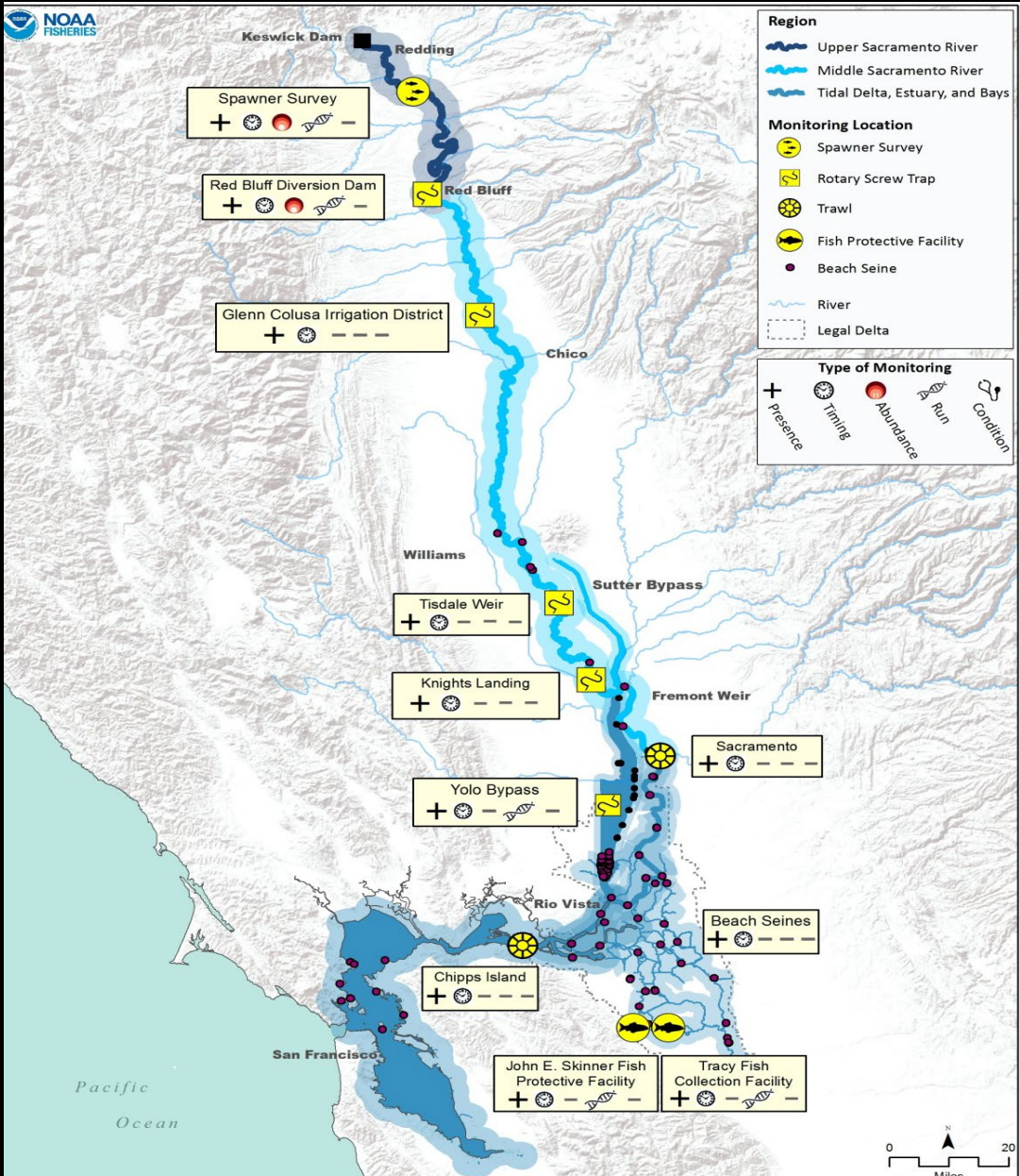
>> [Anglers, look up your fish!](#)

Scientists are now teaming up with charter fishing boat operators in the summer of 2021 to collect certain parts of the salmon caught by the anglers aboard. The heads, stomachs, and eggs of Chinook salmon that have been feeding in the ocean off the California Coast can help researchers understand what is causing the deficiency, and what might help remedy or mitigate its effects.

Questions: Rachel.Johnson@noaa.gov

<https://www.fisheries.noaa.gov/feature-story/oceans-mysterious-vitamin-deficiency>
<https://www.fisheries.noaa.gov/west-coast/science-data/monitoring-thiamine-deficiency-california-salmon>

Evaluation of Monitoring Network



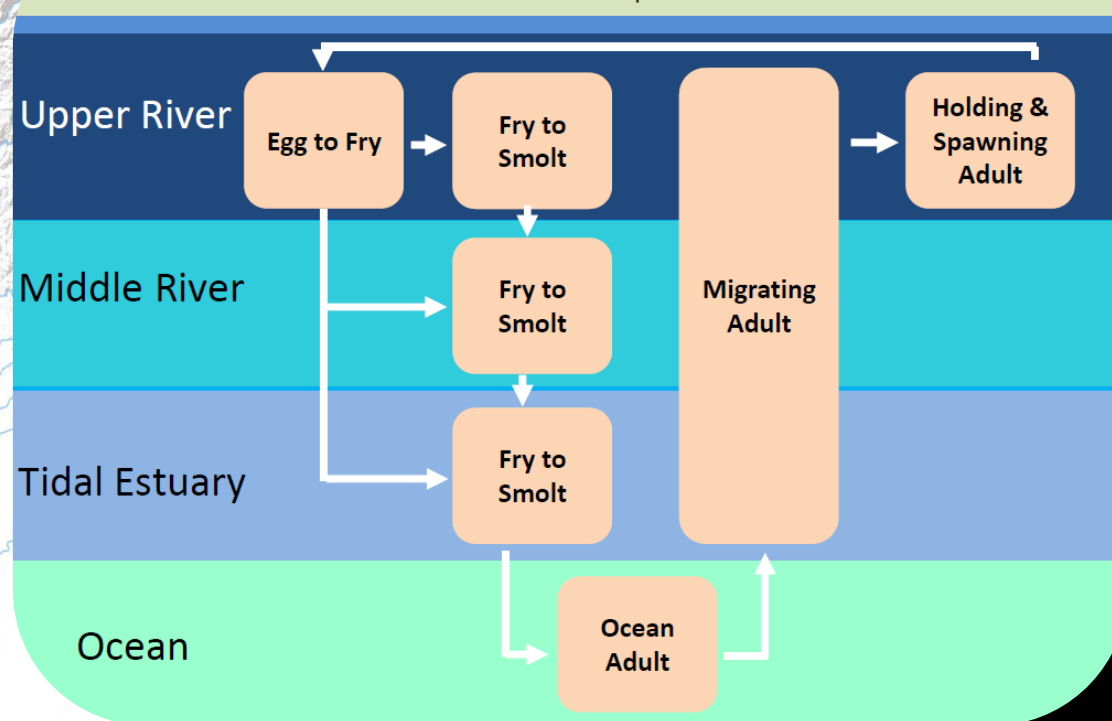
McCloud added to Winter-run Monitoring Network!

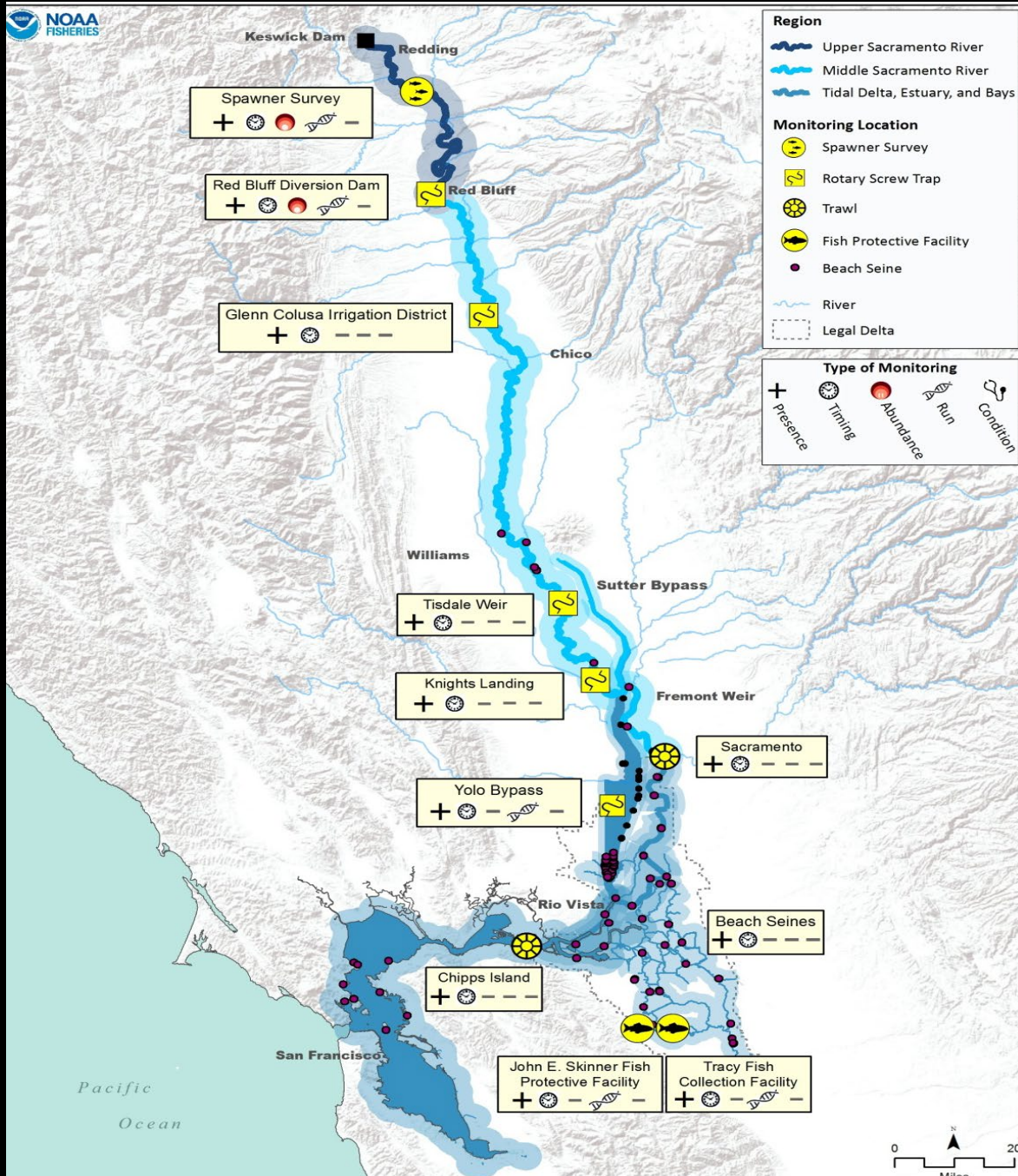


Sub-model Framework

Winter-Run Life-Cycle Conceptual Model

Sub-Model Map





Winter-run Monitoring Network

Key Fish Metrics:



Presence



Timing



Abundance



Run Identification



Condition



**Interagency
Ecological Program**
COOPERATIVE ECOLOGICAL
INVESTIGATIONS SINCE 1970

SEPTEMBER 2017

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

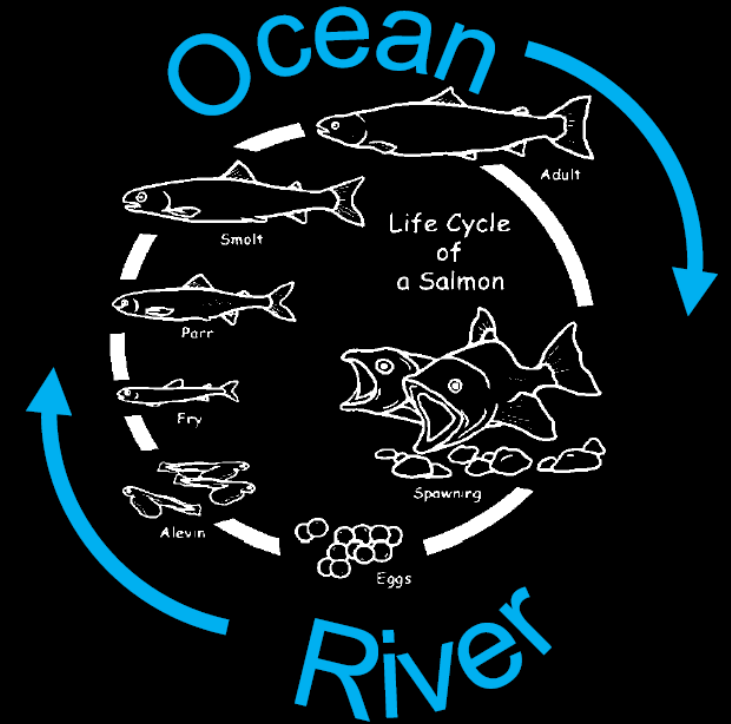
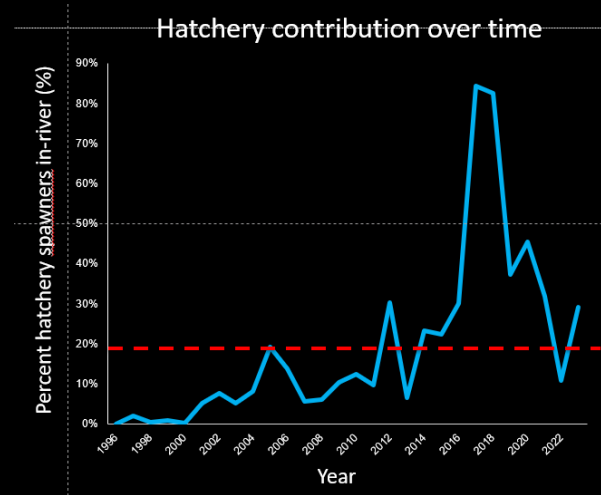
Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

RESEARCH

Science Advancements Key to Increasing Management Value of Life Stage Monitoring Networks for Endangered Sacramento River Winter-Run Chinook Salmon in California

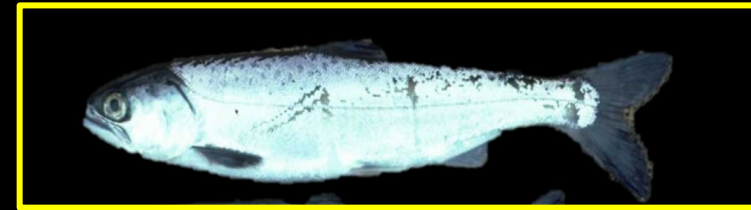
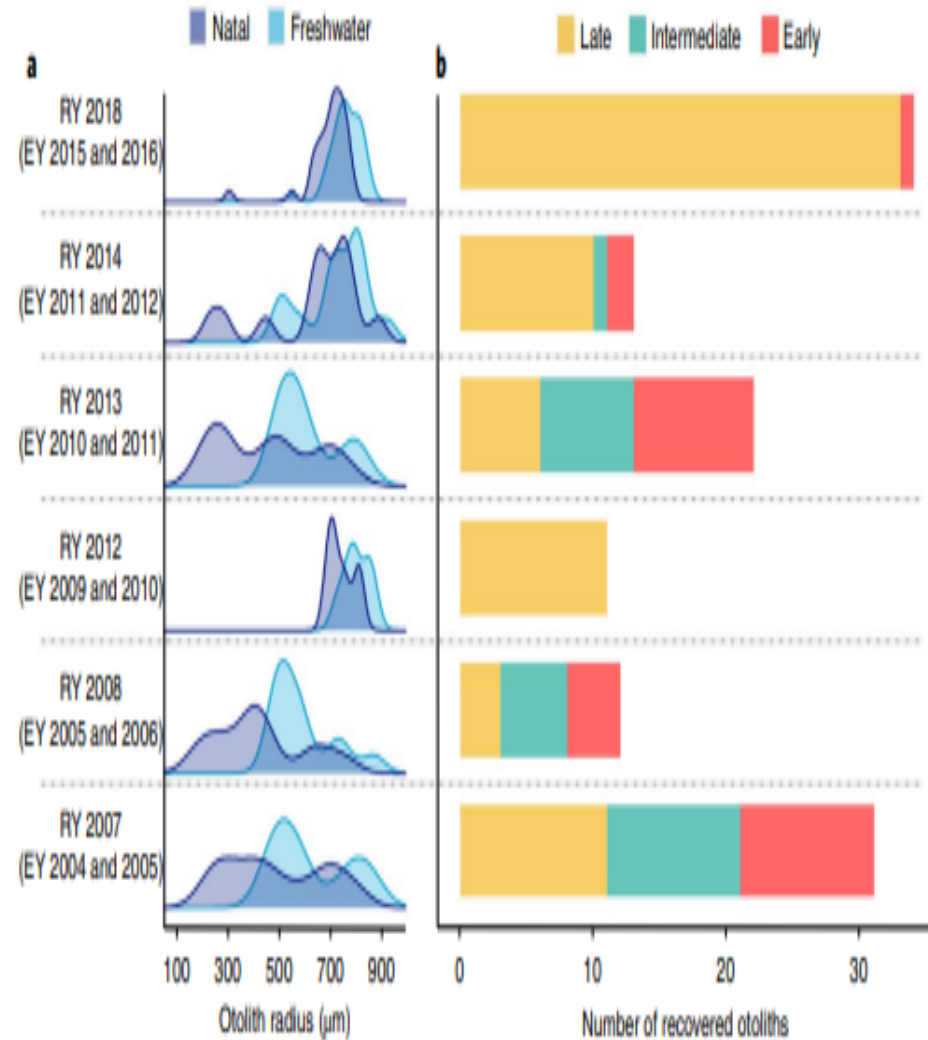
Rachel C. Johnson^{1,2,*}, Sean Windell³, Patricia L. Brandes⁴, J. Louise Conrad⁵, John Ferguson⁶, Pascale A. L. Goertler⁵, Brett N. Harvey⁵, Joseph Heublein⁷, Joshua A. Israel⁸, Daniel W. Kratville⁹, Joseph E. Kirsch⁴, Russell W. Perry¹⁰, Joseph Pisciotto⁹, William R. Poytress¹¹, Kevin Reece⁵, and Brycen G. Swart⁷

Dangers of managing for “optimized” non-linear temperature thresholds



Role of non-natal rearing and floodplains for winter run

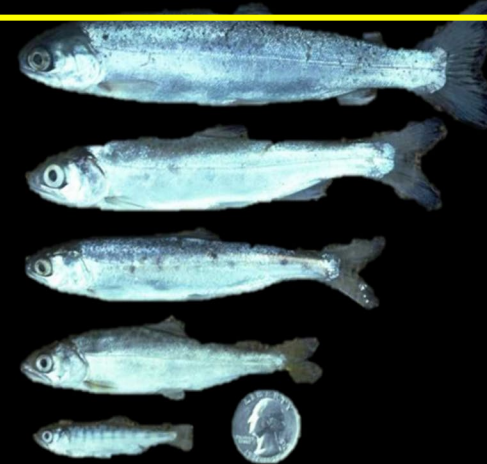
Climate-resilient strategies



Leave Late



Leave Early



ARTICLES

<https://doi.org/10.1038/s41558-021-01186-4>

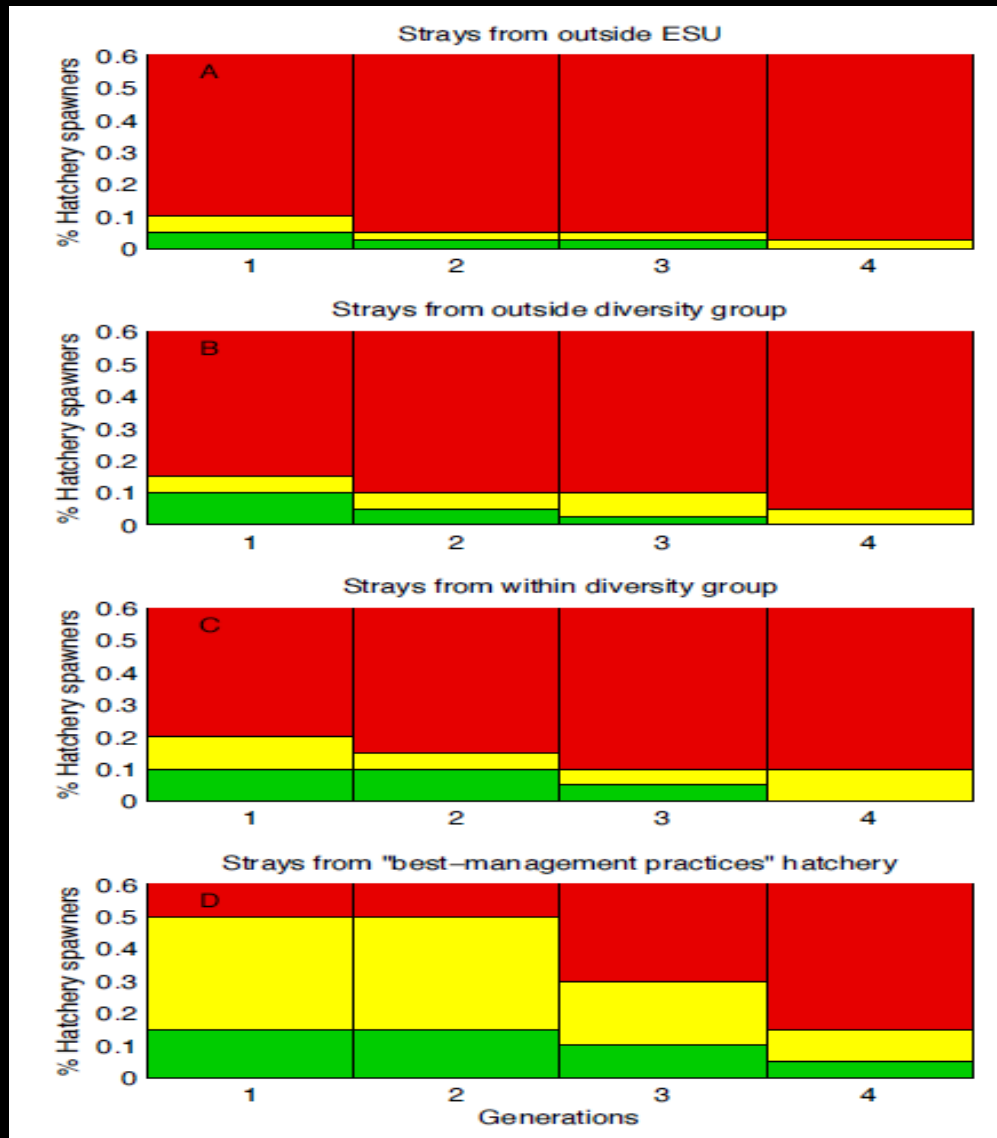
nature
climate change

Check for updates

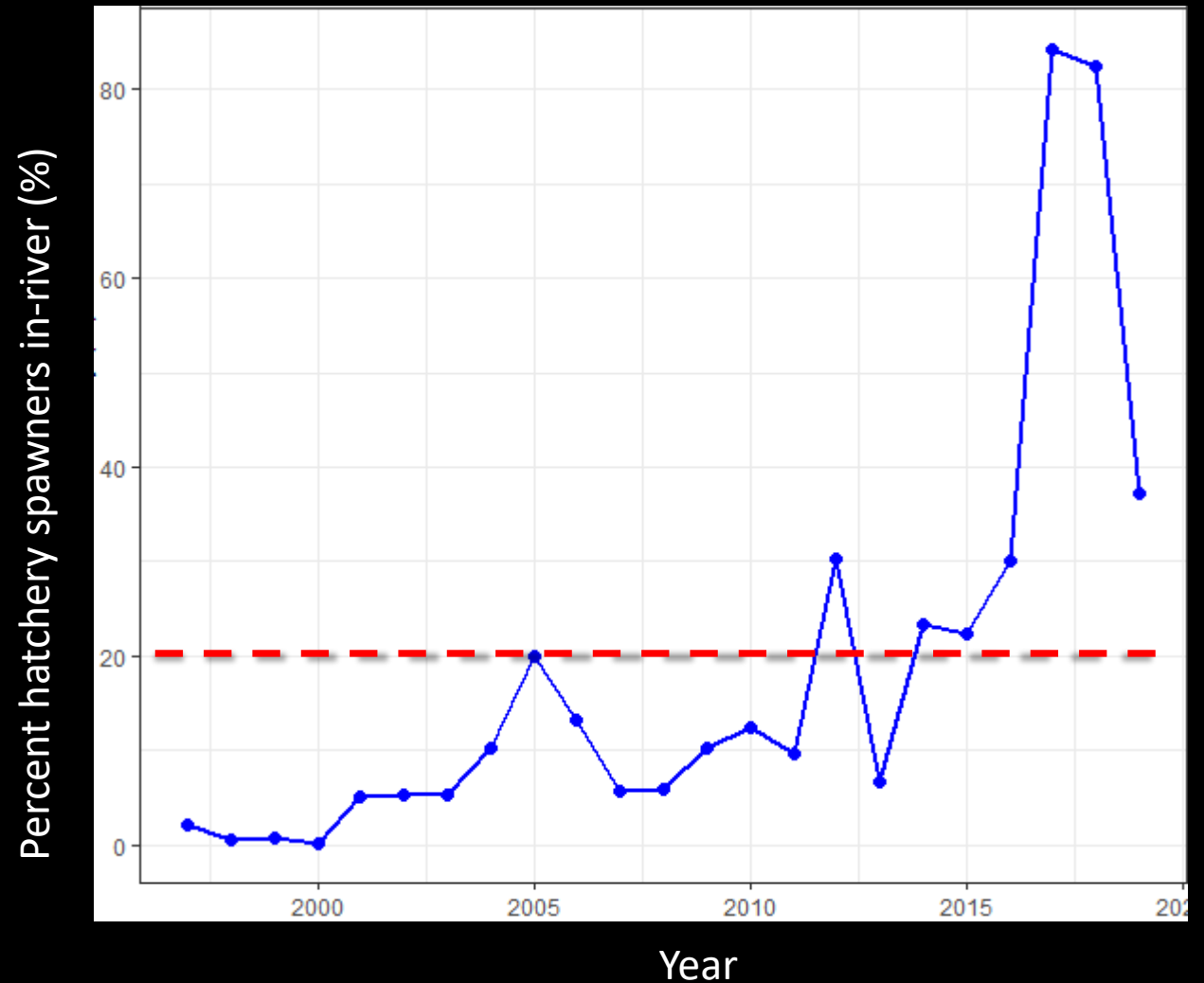
Threatened salmon rely on a rare life history strategy in a warming landscape

F. Cordoleani^{1,2}, C. C. Phillis³, A. M. Sturrock⁴, A. M. FitzGerald^{1,2}, A. Malkasian⁵, G. E. Whitman⁶, P. K. Weber⁷ and R. C. Johnson^{2,6}

Hatchery increases winter run risk of extinction



Sacramento River Spawner Escapement



Drought and Temperature-Dependent Mortality

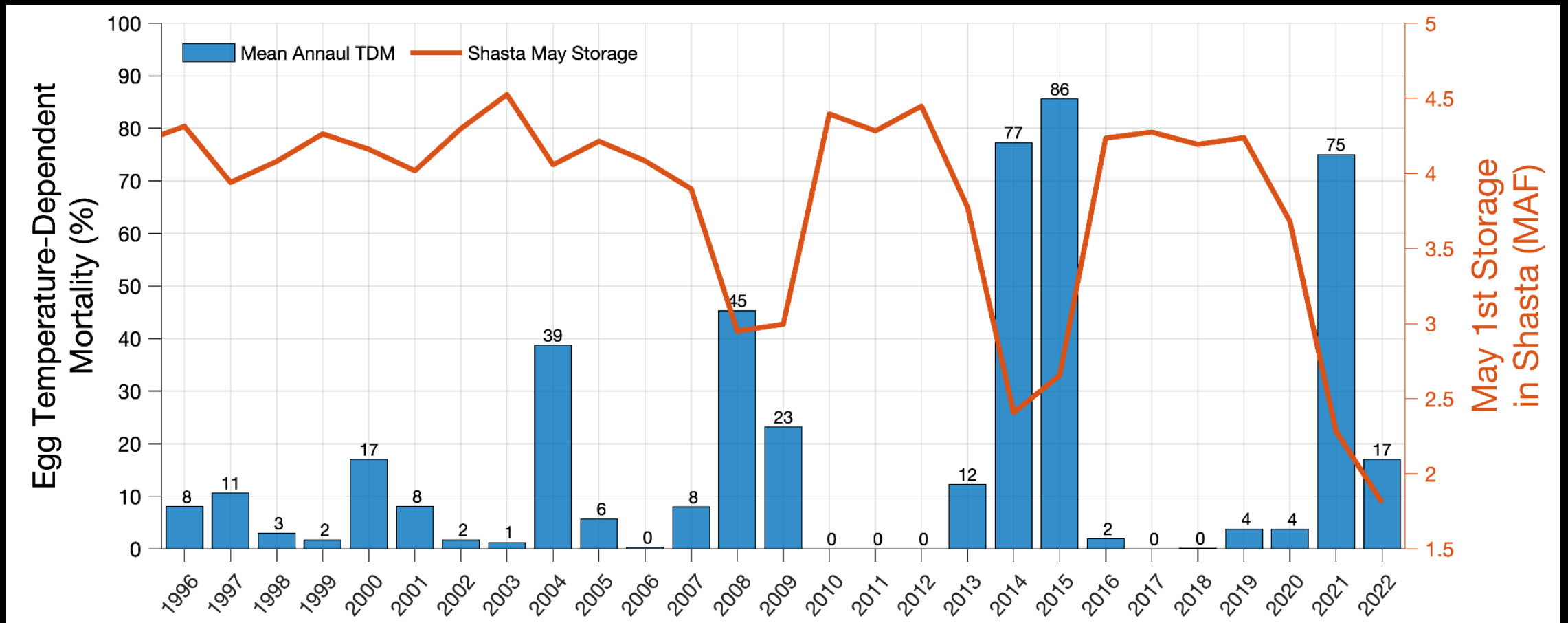
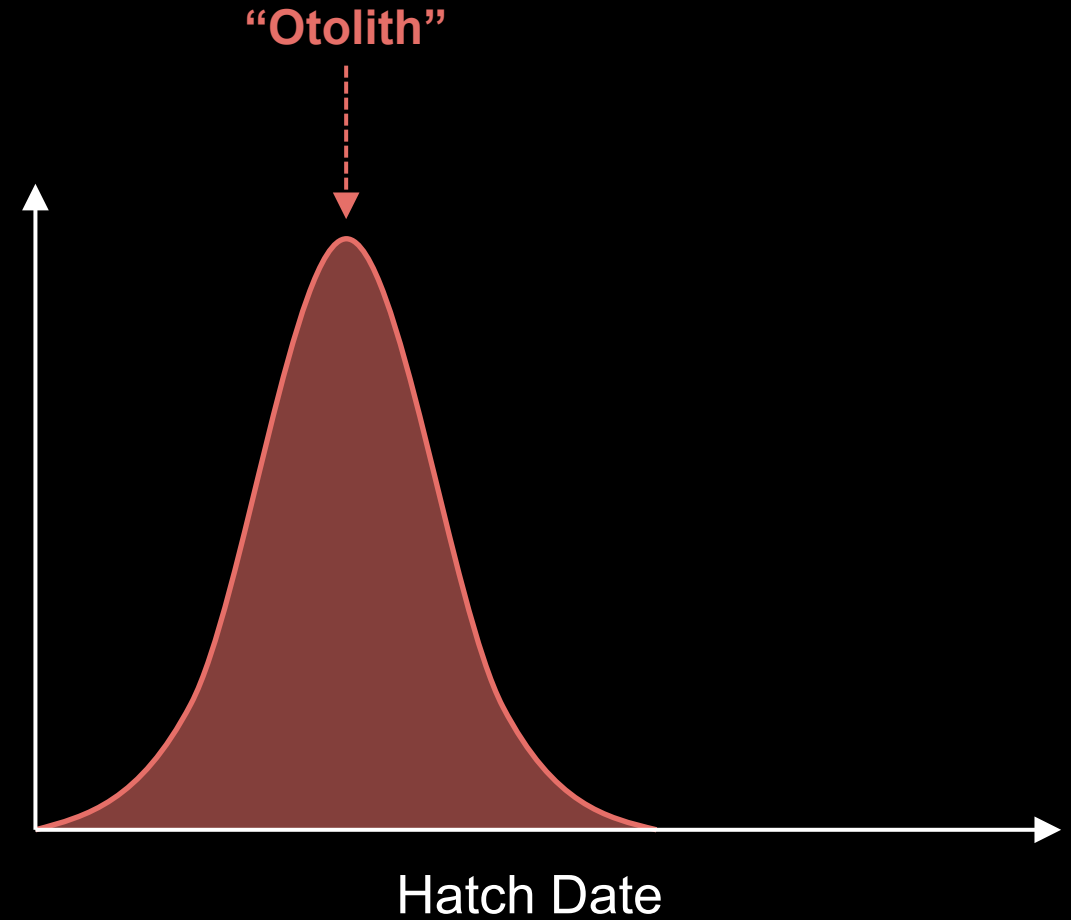
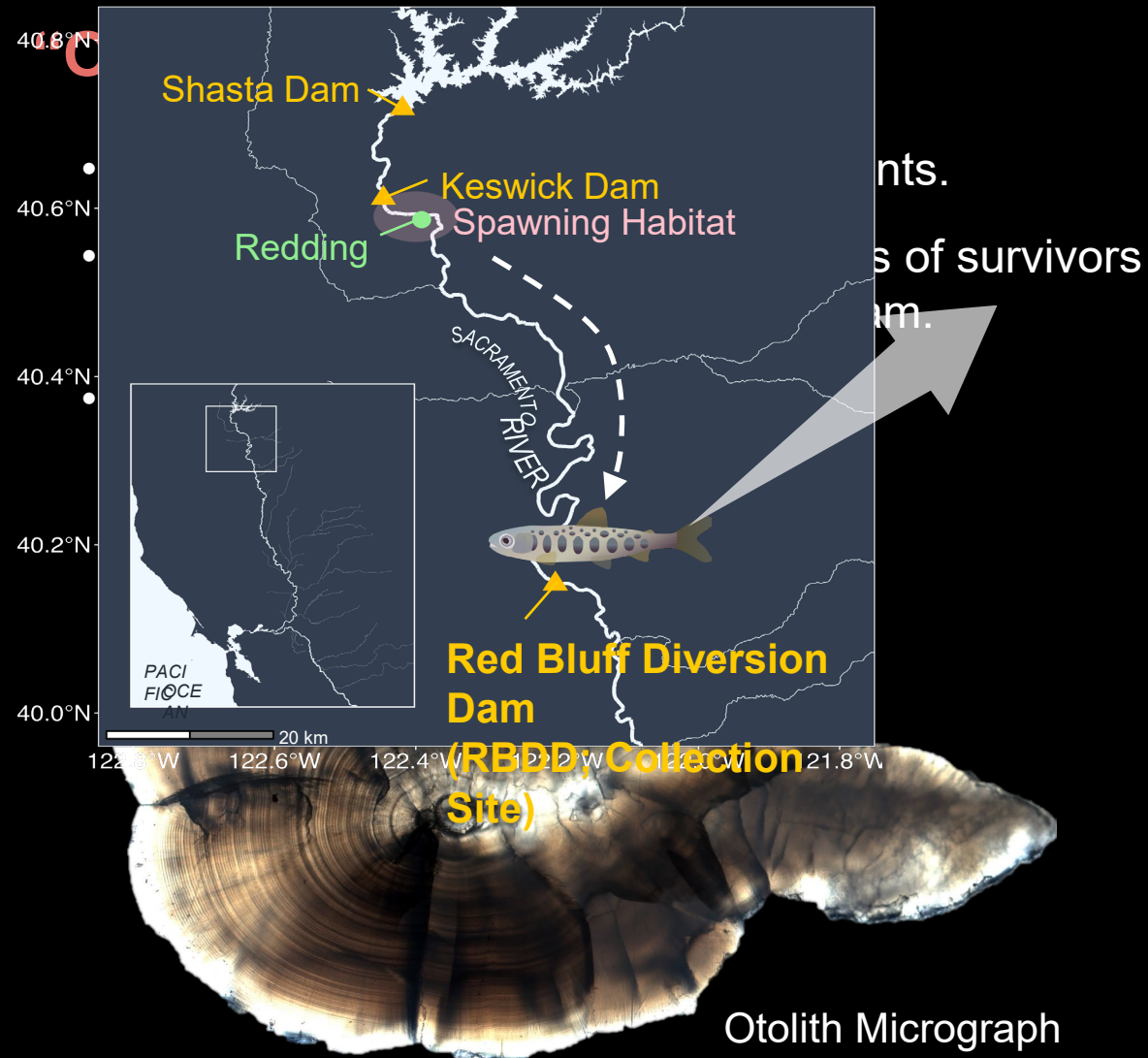
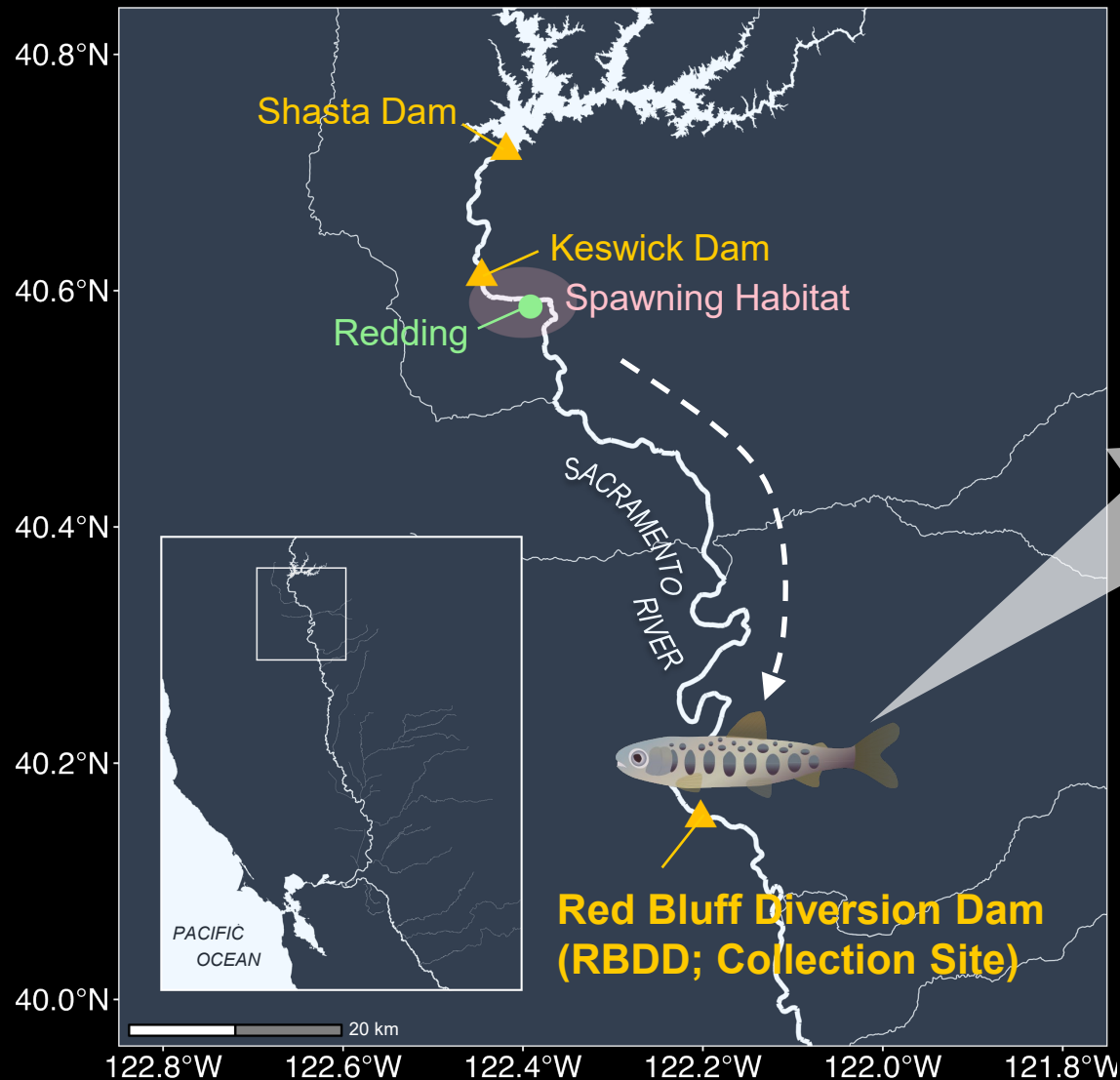


Figure courtesy of M. Daniels

“Otolith” and “Modeled” Hatch Dates



Juvenile Chinook Salmon Collection



- Rotary Screw Traps (USFWS)
- August to December 2021 and 2022
- Otoliths extracted from incidental mortalities
- Sample size: 2021 ($n = 99$) and 2022 ($n = 49$)