Central Valley Spring-Run Monitoring, Modeling, and Reintroduction



A Concurrent Session at the 42nd Annual Salmonid Restoration Conference
Santa Cruz, California, April 29 - May 2, 2025

Session Coordinators: *Brett Harvey and Pete Nelson, California Department of Water Resources*



Central Valley spring-run Chinook Salmon are protected under both the state and federal Endangered Species Act, but measures to protect and recover spring-run are challenged by difficulties such as tracking status and life stages across multiple streams and agency programs, or understanding the feasibility of reintroduction above dams. The California Department of Fish and Wildlife, California Department of Water Resources, NOAA Fisheries, U.S. Fish and Wildlife Service, and Bureau of Reclamation, plus agency partners, are collaborating on multiple fronts to improve our ability to protect and recover Central Valley spring-run. These efforts include expanded monitoring and special studies, new genetics tools, a coordinated data management system among more than 20 data stewards and across multiple state and federal agencies, a cloud-based data entry platform that ensures rapidly-reported cross-compatible data from over 40 individual sources, multiple models to track juvenile production, survival, pathogen impacts, and abundance across life stage and locations, publicly accessible databases and model code, and a pilot reintroduction study in the Feather River above Oroville Dam. This session describes seven examples of these efforts.

Presentations



- **The Road ToData-Driven Water Management: Re-Envisioning the Data Lifecycle to Support a Spring-Run Juvenile Production stimate**

  Ashley Vizek FlowWest & Brett Harvey Department of Water Resources.....Slide 4

- **Rapid Genetic Identification of Central Valley Spring-Run Chinook Salmon**

  Sean Canfield Department of Water Resources.....Slide 31

- **Forecasting the Timing and Abundance of Juvenile Spring Run Chinook Salmon Outmigrants from Sacramento River Tributaries to Support a Juvenile Production Estimate**

  Josh Korman, Ecometric Research.....Slide 52

- **Uncovering Genetic and Life History Resilience in Spring Run Chinook Salmon**

  Flora Cordoleani, UC Santa Cruz & NOAA Fisheries.....Slide 85

- **Movement and Survival of Acoustic Tagged Hatchery SpringRun Chinook Salmon from the Feather River**

  Arnold Ammann NOAA SFSC.....Slide 152

- **Developing an improved Understanding of Pathogen Impacts for Feather River Spring-Run Chinook Salmon**

  Miles Daniels, UC Santa Cruz & NOAA SFSC.....Slide 198

- **Spring-Run Chinook Salmon Reintroduction Pilot Study in the North Fork Feather River Upstream of Oroville Dam**

  Michelle Prepping Department of Water Resources.....Slide 222





salmon sprint

a data user story about Central Valley spring run Chinook



Central Valley spring run Chinook

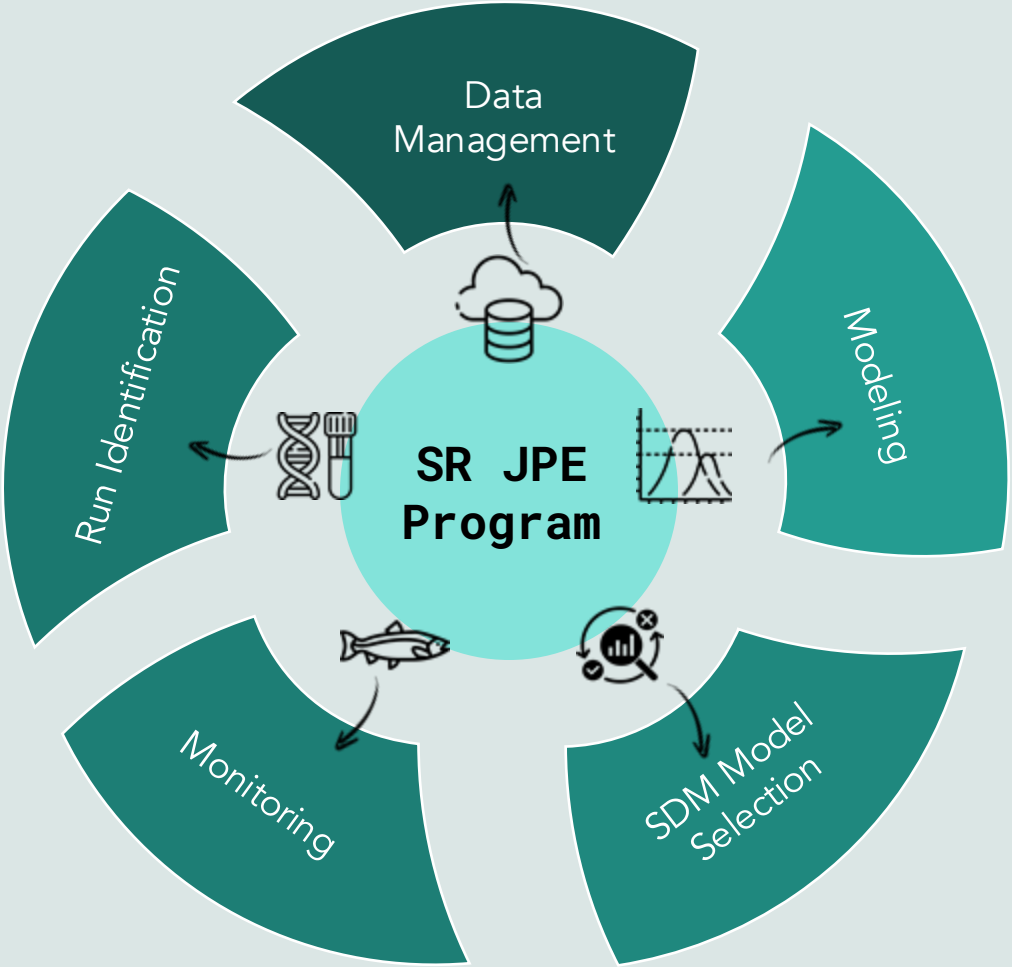



0 10 20 40 mi
Spring Run Salmonid Historical Habitat Extents
Clear Creek
Battle Creek
Cottonwood Creek
Antelope Creek
Deer Creek
Butte Creek
Sutter Creek
Yuba River
Feather River
American River
North Delta
Mokelumne River
South Delta
Stanislaus River
Tuolumne River
Merced River
Upper San Joaquin River
N


0 10 20 40 mi
Spring Run Salmonid Current Habitat Extents
Clear Creek
Battle Creek
Mill Creek
Deer Creek
Butte Creek
Yuba River
Feather River
North Delta
Cottonwood Creek
N



Spring run juvenile production estimate


Data Management
Modeling
SDM Model Selection
Monitoring
Run Identification
SR JPE Program

California Department of Fish and Wildlife (CDFW)

California Department of Water Resources (DWR)

Metropolitan Water District of Southern California (MWD)

National Marine Fisheries Service (NMFS/NOAA Fisheries)

U.S. Bureau of Reclamation (BOR)

U.S. Fish and Wildlife Service (USFWS)

Natasha, Mike, Sam, Gabby, Teresa *USFWS, Battle and Clear*

Anna, Grant *CDFW, Butte*

Ryan, Chanel *CDFW, Deer and Mill*

Kassie, Casey, Brian *DWR, Feather and Yuba*

Nick, Corey, Drew *CDFW, Sacramento*

Josh Korman, *Ecometrics*

Brett Harvey, *DWR*

Pete Nelson, *DWR*

Flora Cordoleani, *NMFS*

Kimberly Horndeski, *Community Consulting*

This map was developed to support the SR JPE modeling work led by DWR and CDFW, and is currently only available to the SR JPE Team. In the future this map may be developed for public use. Until then, please do not share this broadly.

Zoom to River

(Default View)

Rotary Screw Traps

- Single Trap
- Multiple Traps

Private rotary screw trap sites are illustrated as general vicinities (half mile radius).

Adult Survey Reaches

- Holding Surveys
- Redd Surveys
- Carcass Surveys

Reach midpoints are shown; zoom in to see ✖ reach breaks and footprints where data is available. Select to filter:

(All Survey Types)

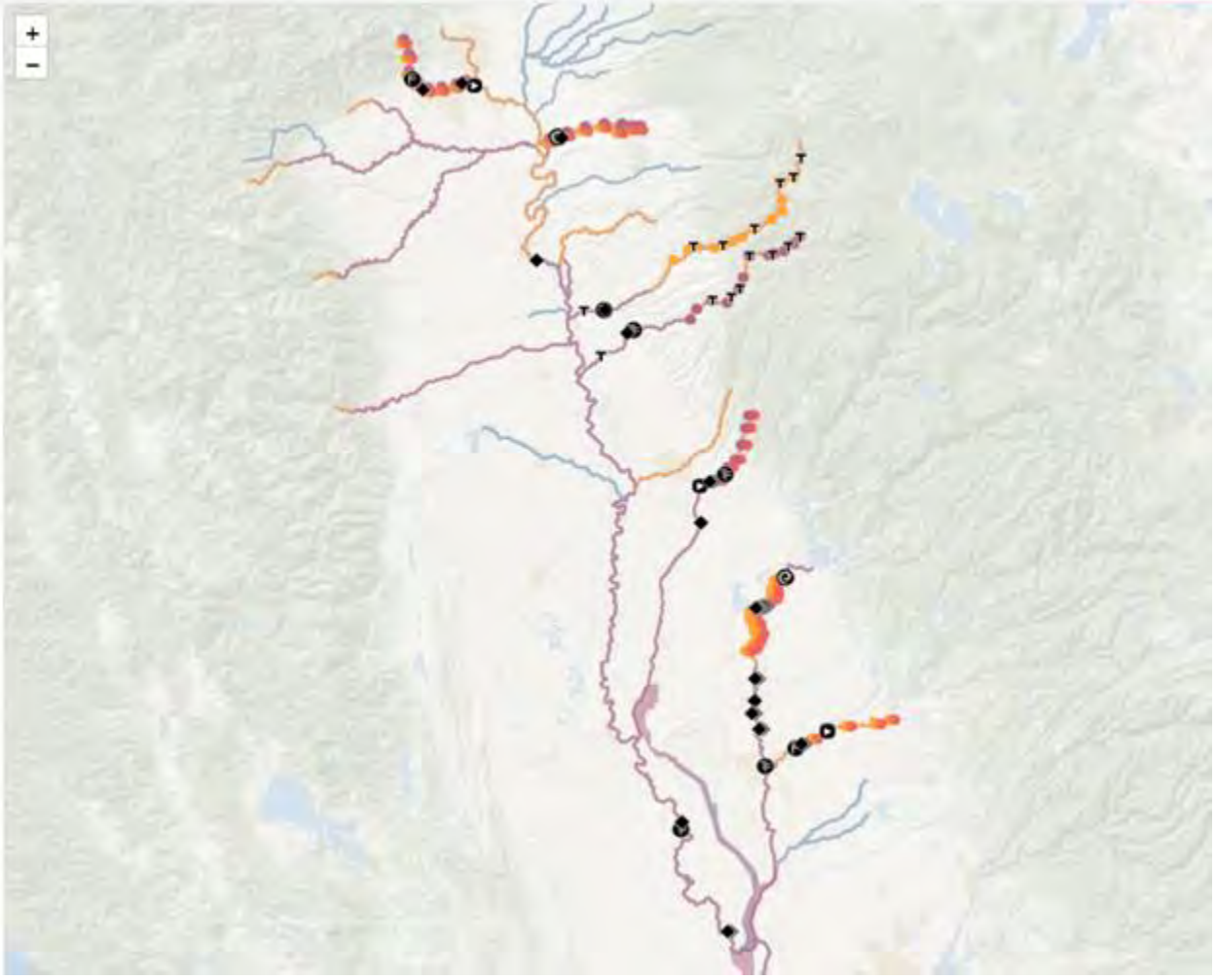
Upstream Passage Video Systems

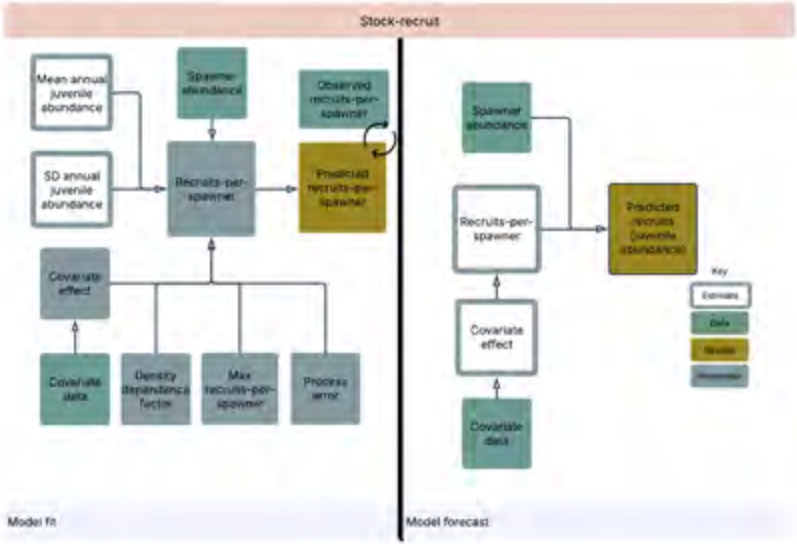
VAKI video monitoring system locations are illustrated as general vicinities (half mile radius).

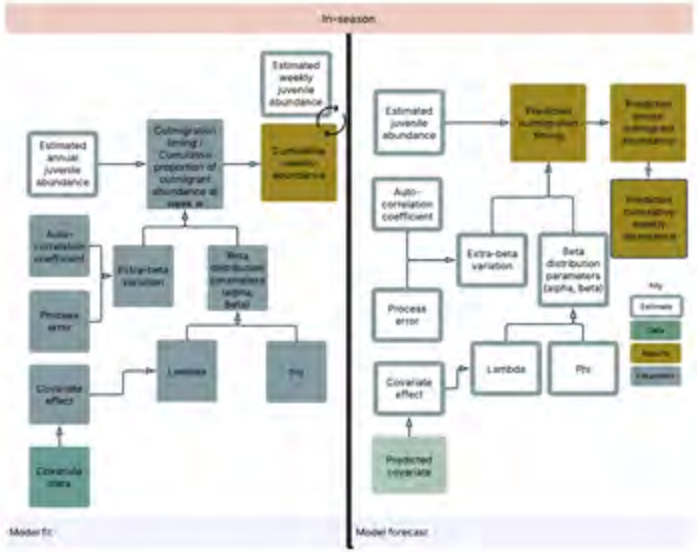
Gages and Temperature Loggers

- P CDEC/USGS flow gage
- T CDEC/USGS temperature gage
- PT CDEC/USGS flow and temperature gage
- T USFWS/CDFW temperature logger

Fish Hatcheries




Stock-recruit
Mean annual juvenile abundance
Spawner abundance
Observed recruits-per-spawner
SD annual juvenile abundance
Recruits-per-spawner
Predicted recruits-per-spawner
Covariate effect
Covariate data
Density dependence factor
Max recruits-per-spawner
Process error
Spawner abundance
Recruits-per-spawner
Predicted recruits (juvenile abundance)
Covariate effect
Covariate data
Key
Estimate
Data
Model fit
Model forecast


In-season
Estimated annual juvenile abundance
Estimated weekly juvenile abundance
Process error
Covariate effect
Covariate data
Estimated juvenile abundance
Auto-correlation coefficient
Extra-beta variation
Beta distribution parameters (alpha, beta)
Process error
Covariate effect
Lambda
Phi
Predicted covariate
Key
Estimate
Model fit
Model forecast

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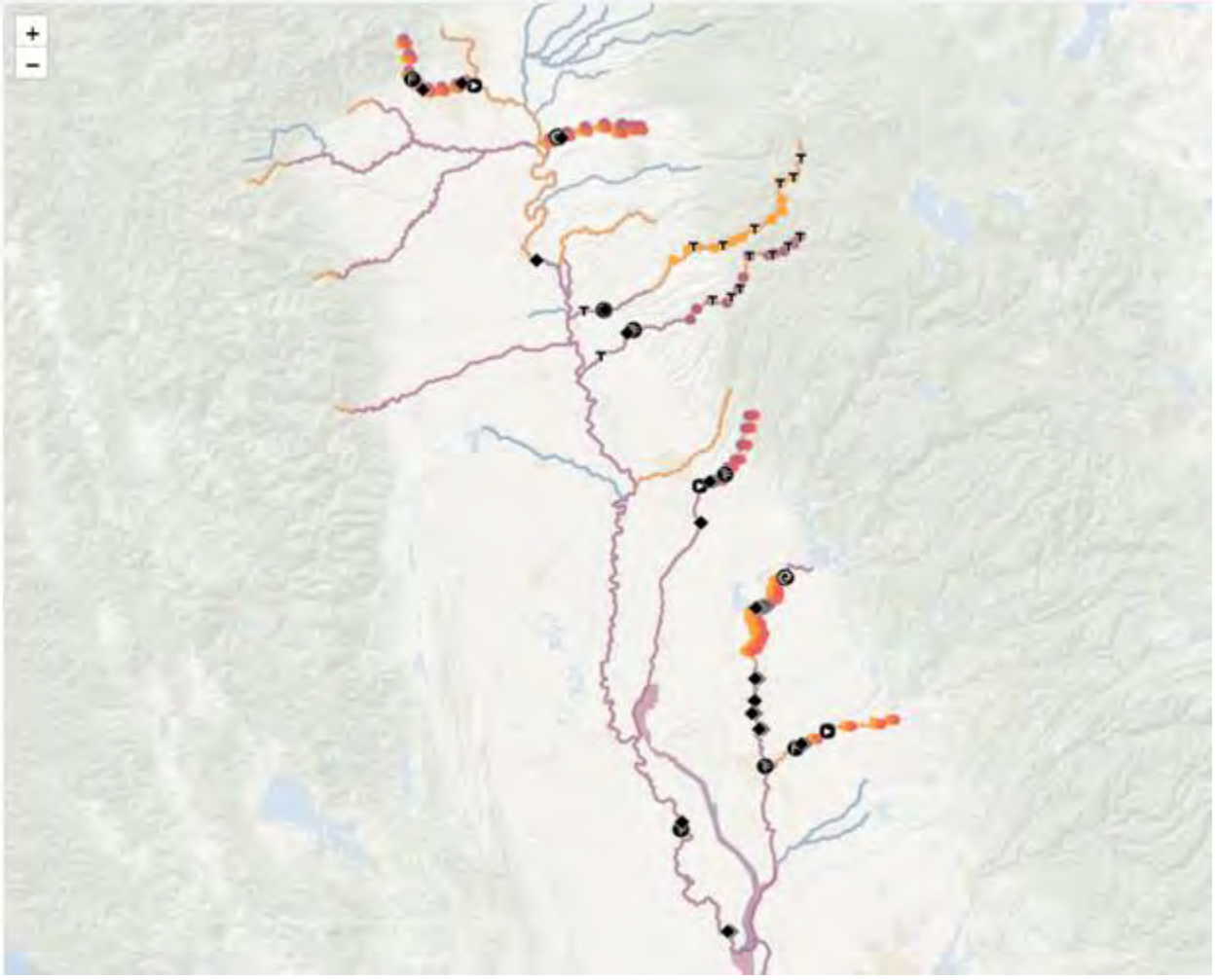
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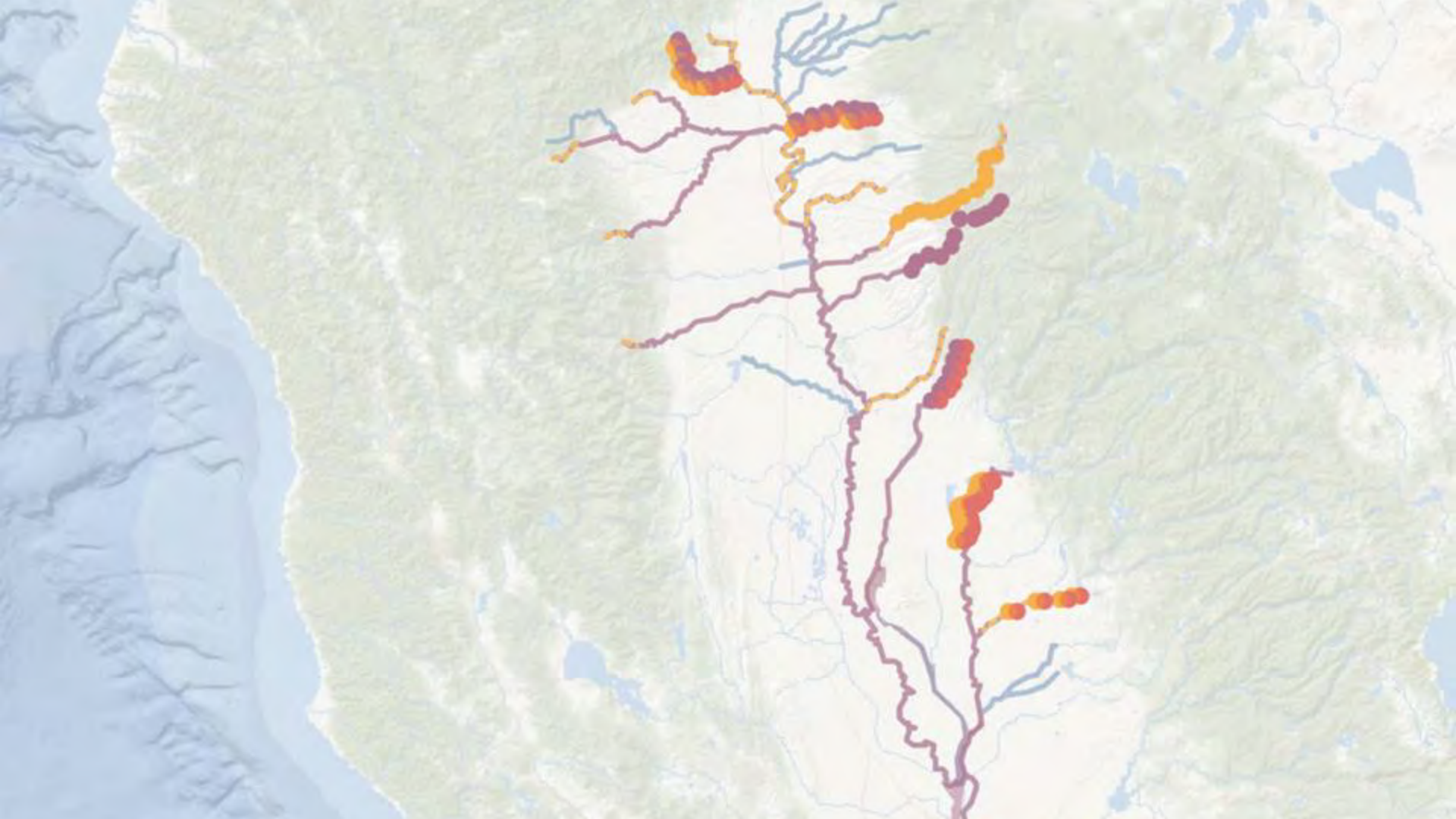
Gages and Temperature Loggers

- P CDEC/USGS flow gage
- T CDEC/USGS temperature gage
- PT CDEC/USGS flow and temperature gage
- T USFWS/CDFW temperature logger

Fish Hatcheries











SUPER
COOL!

Metadata Entry Interface

Quality Control Interface

Data Entry Interface

With Validation Quality Assurance Checks





Brave volunteers: Mill & Deer













More traps! At Feather & Yuba




DANGER
FISH TRAP
KEEP CLEAR





Welcome!

Select the action you would like to perform.

QC Data

Collect Data

Generate Report

Thank you!

Questions

Contact:

avizek@flowwest.com

Resources

SRJPEdata R package for data access

SRJPEmodel R package for model functions

SR JPE GitHub Organization

References

https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/central-valley-spring-run-chinook-salmon

https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/nmfs/spprt_docs/nmfs_exh4_dfg_report_98_1.pdf

Rapid Genetic Identification of Central Valley Spring-Run Chinook Salmon



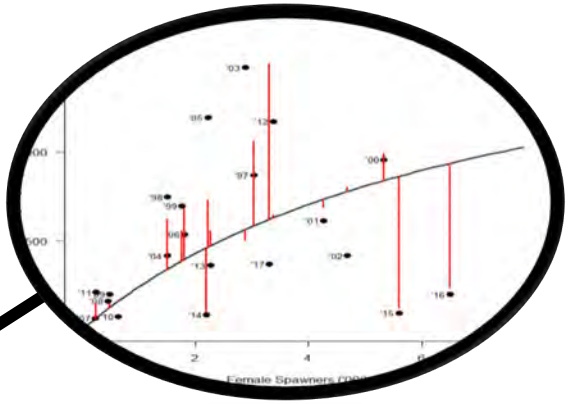
Sean Canfield, Jeff Rodzen, Joy Gaines, Noble Hendrix, Sarah Brown, Brett Harvey, Melinda Baerwald

Run Identification

Data Management



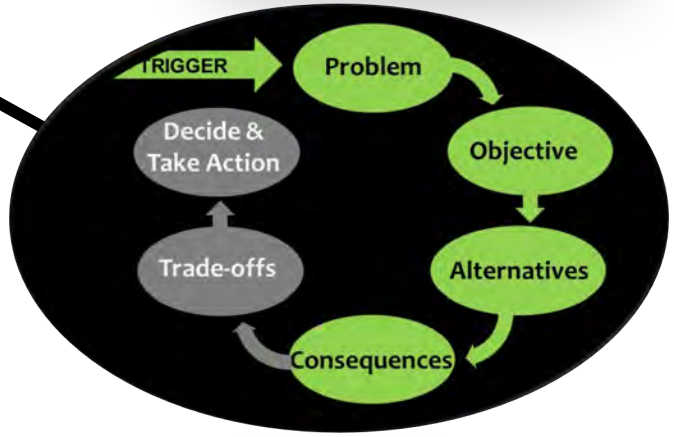
Modeling





SR-JPE Program





Monitoring

SDM Model Selection

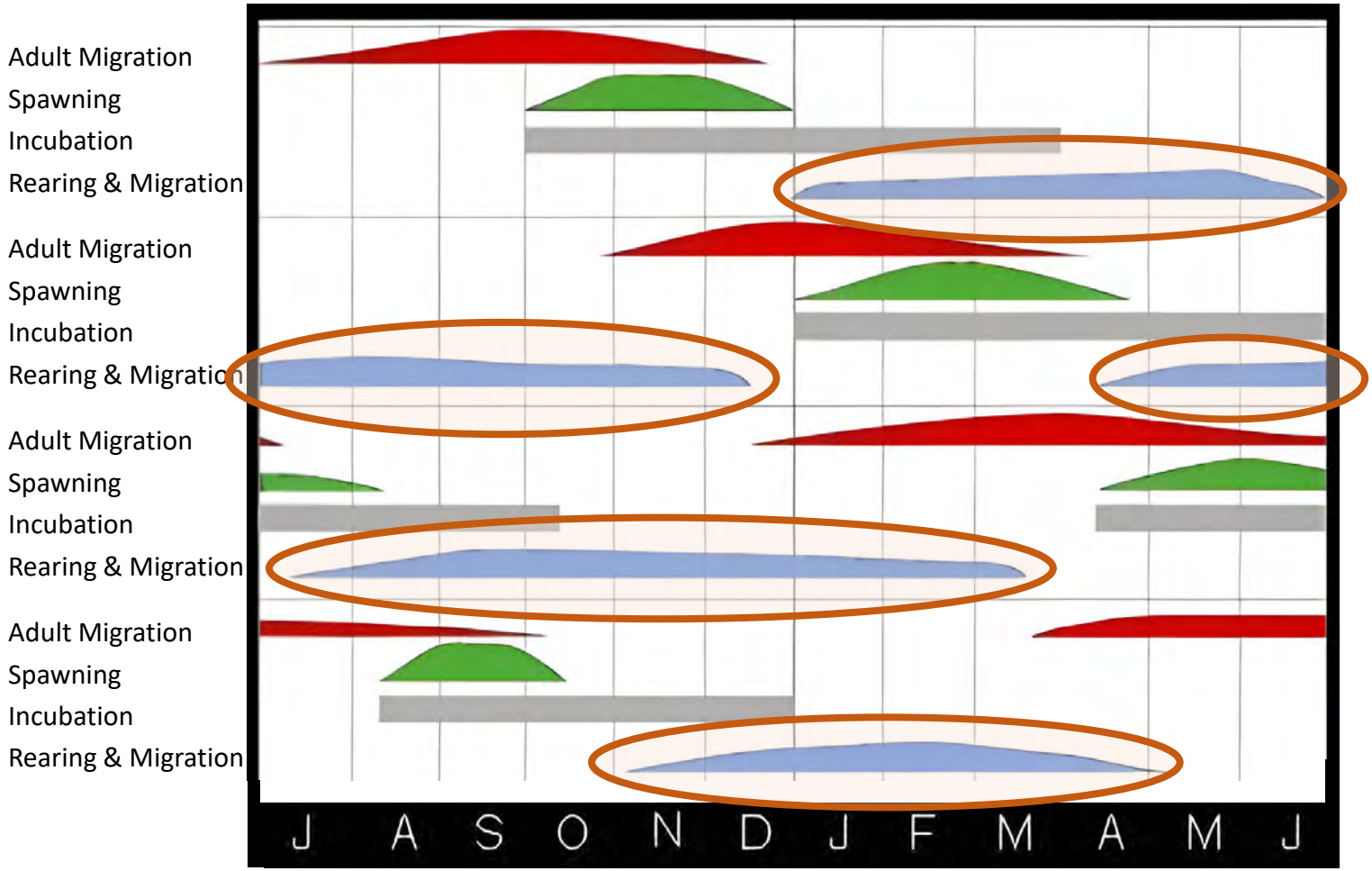
4 Distinct Central Valley Chinook Salmon Runs

"Late" Migrating

- Fall run
- Late Fall run

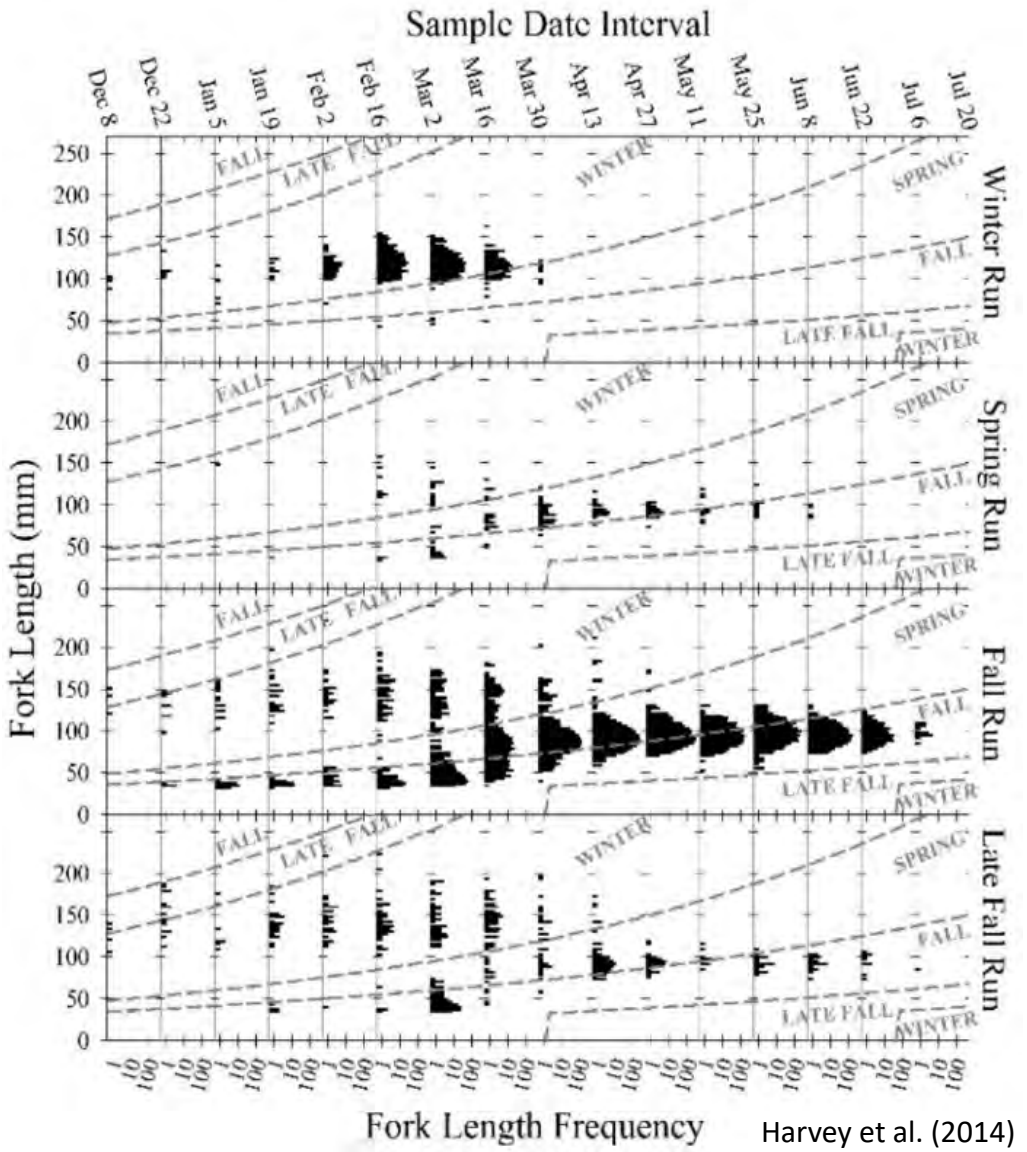
"Early" Migrating

- Winter run
- Spring run

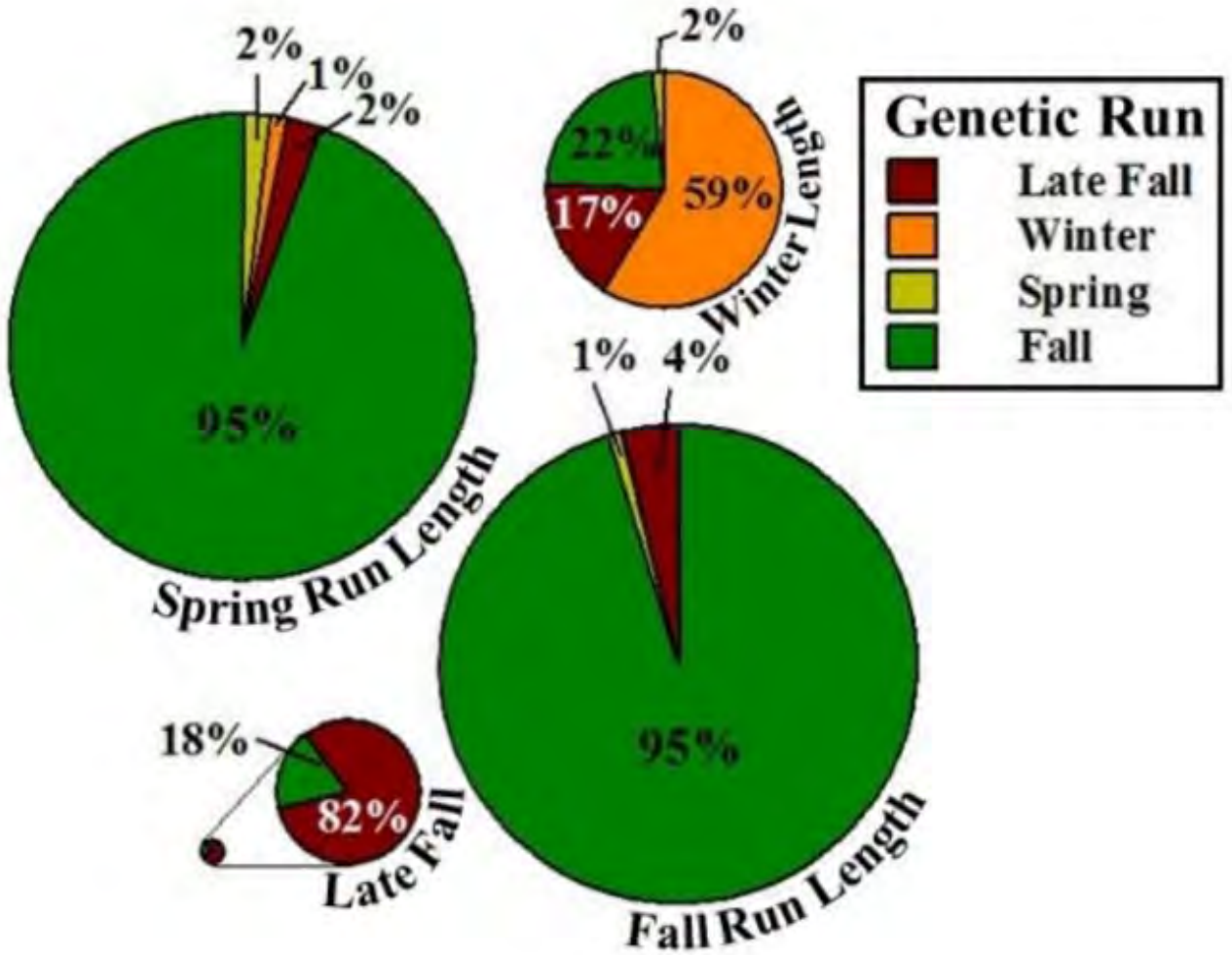




Length-at-Date



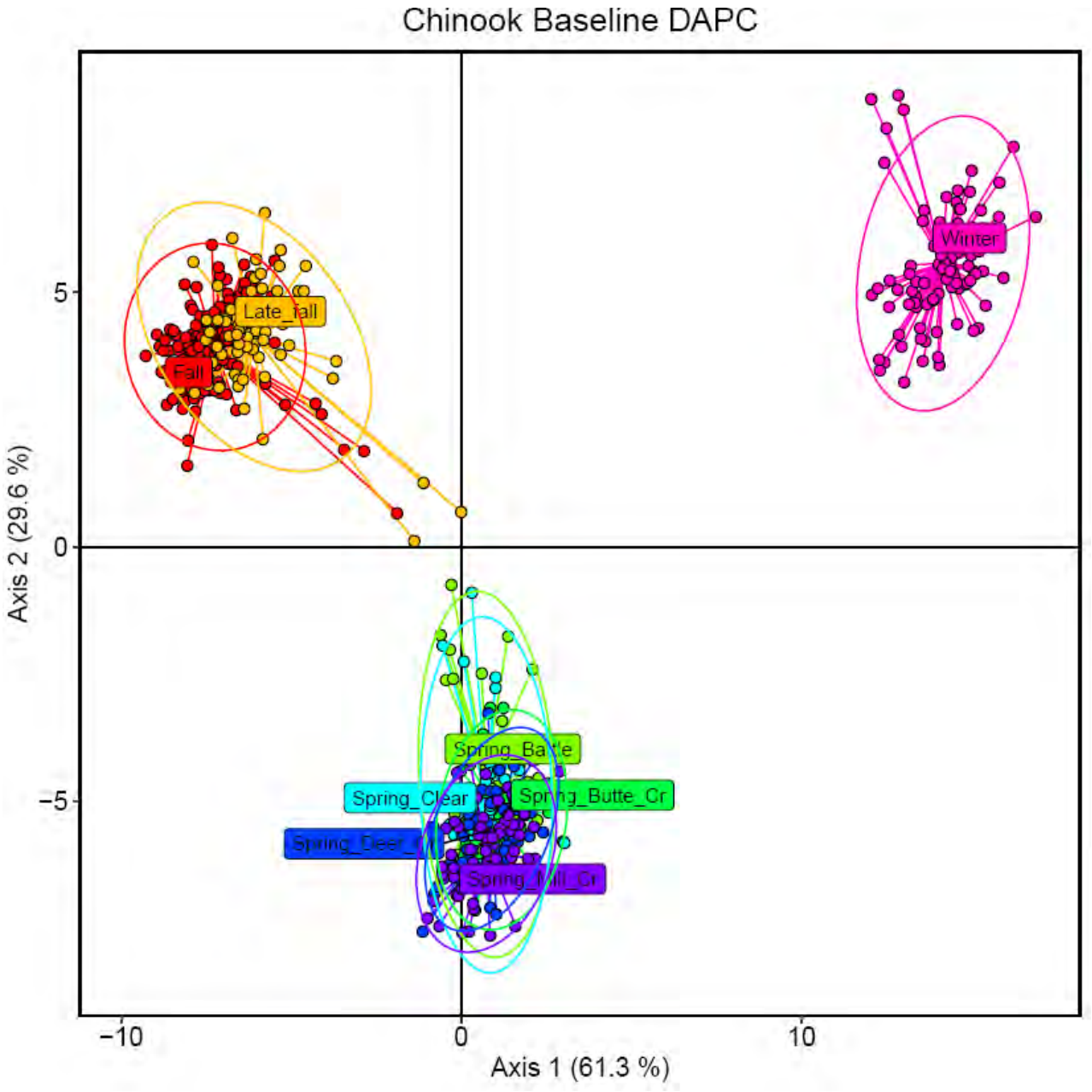
Harvey et al. (2014)



Harvey and Stroble (2013)

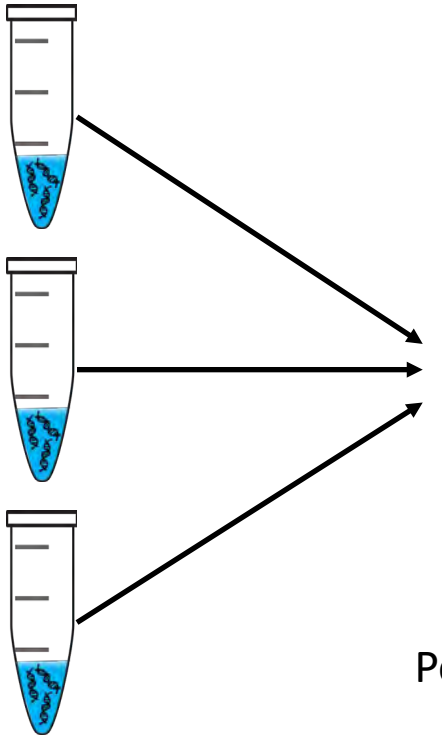
Genetics for Run-Type Assignment

- Genetic markers can reliably identify the four Central Valley run types
- Can use hundreds of genetic markers per individual for run assignments (typically ~80-200)
- A handful of markers on Chromosome 28 can distinguish between “early” and “late” run phenotypes (*Greb1L/rock1*)

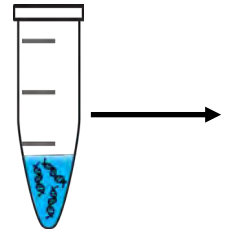


Spring Run JPE Genetics Workflow

GT-seq Genotyping



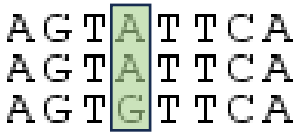
DNA Extraction
&
Library Preparation



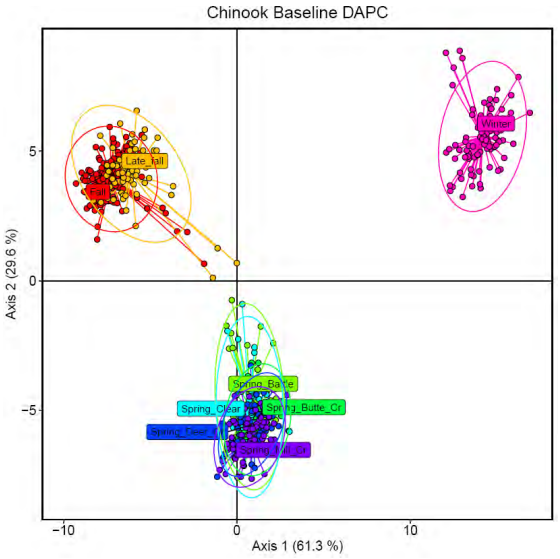
Pooling



Sequencing

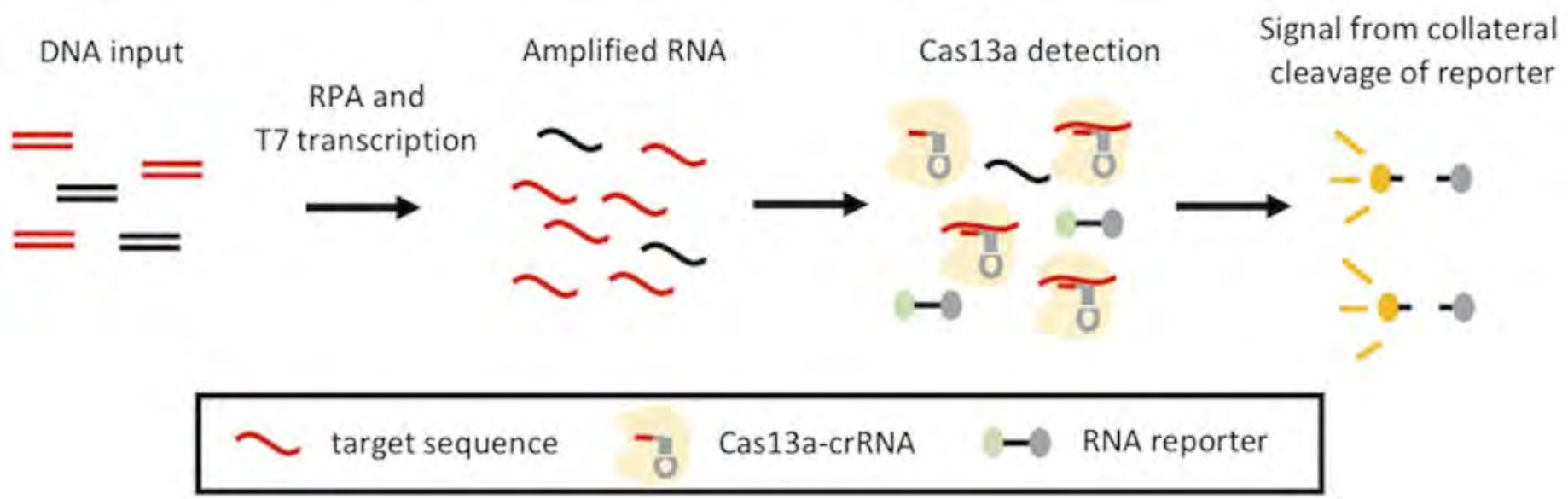


Genotyping



Population
Assignment

SHERLOCK: Specific High-Sensitivity Enzymatic Reporter UnLOCKing

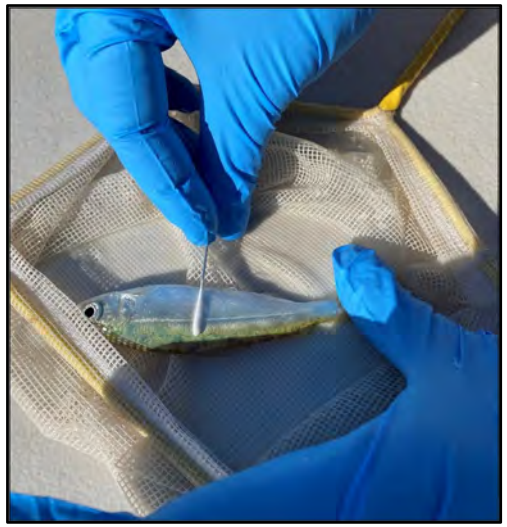


37°C

Baerwald et al. (2020) – *Molecular Ecology Resources*

Spring Run JPE Genetics Workflow

SHERLOCK Genotyping



SHERLOCK #1 (Ots28)

SHERLOCK #2 (Ots16)

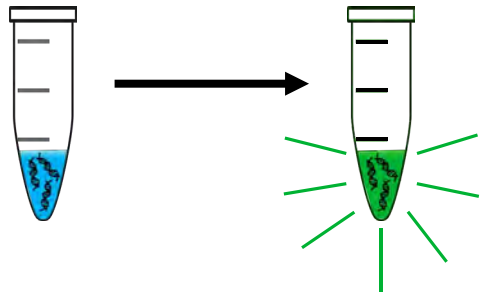
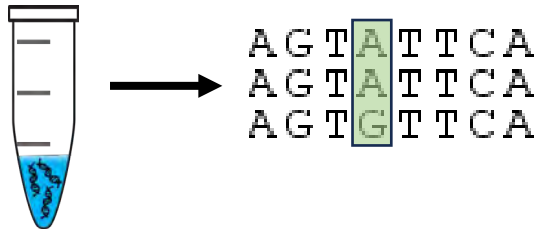
Early (Spring/Winter run)

Late (Fall/Late Fall run)

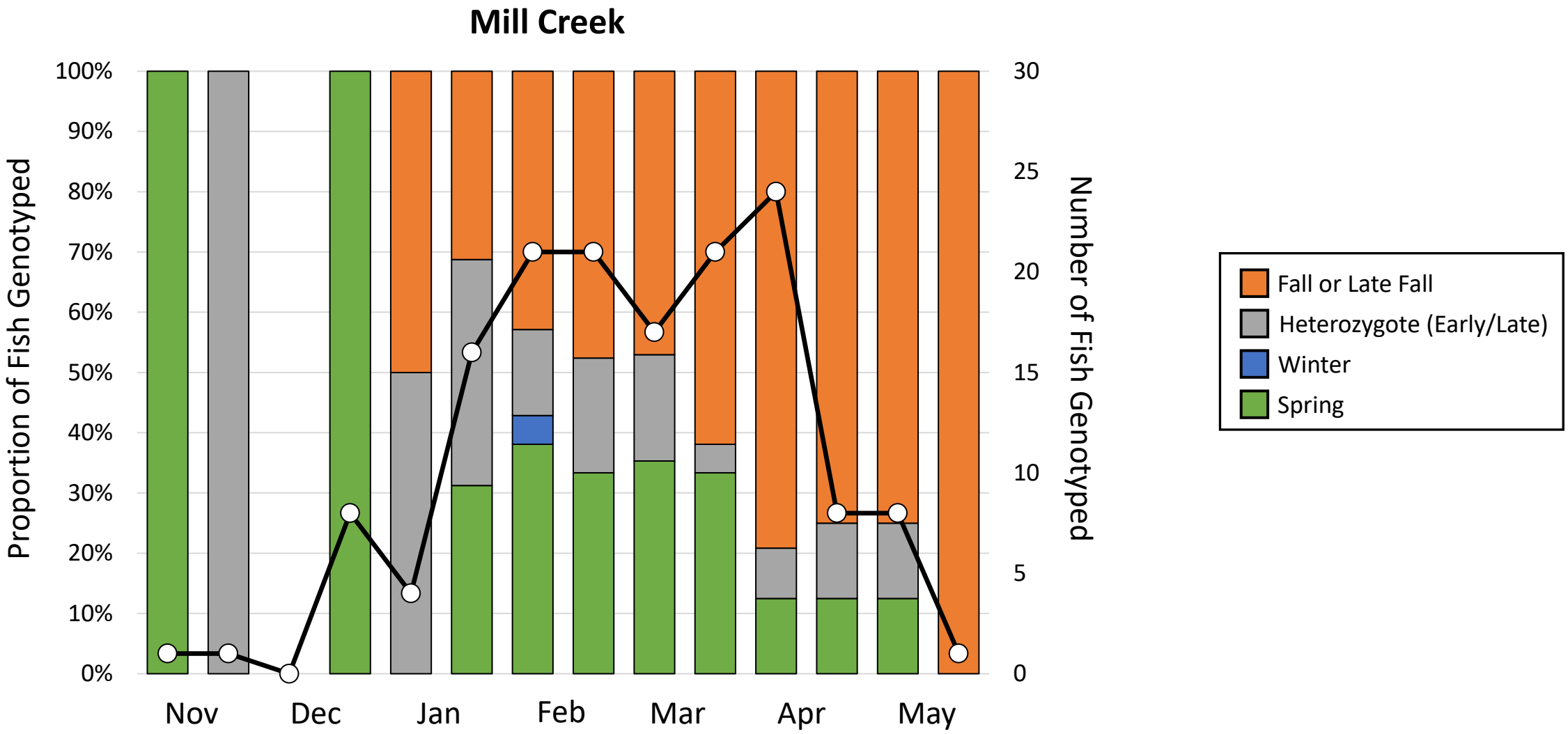
Spring run

Winter run

Baerwald et al. (2023) – *Molecular Ecology Resources*

	SHERLOCK	GT-seq
		
Speed		
Throughput	High or Low	Highest
Cost per Sample	$	$ to $$$
Field Deployable	✓	X

Example Run-Type Time Series (JPE 2024)



Preliminary Data – Do Not Cite

Preliminary Data – Do Not Cite

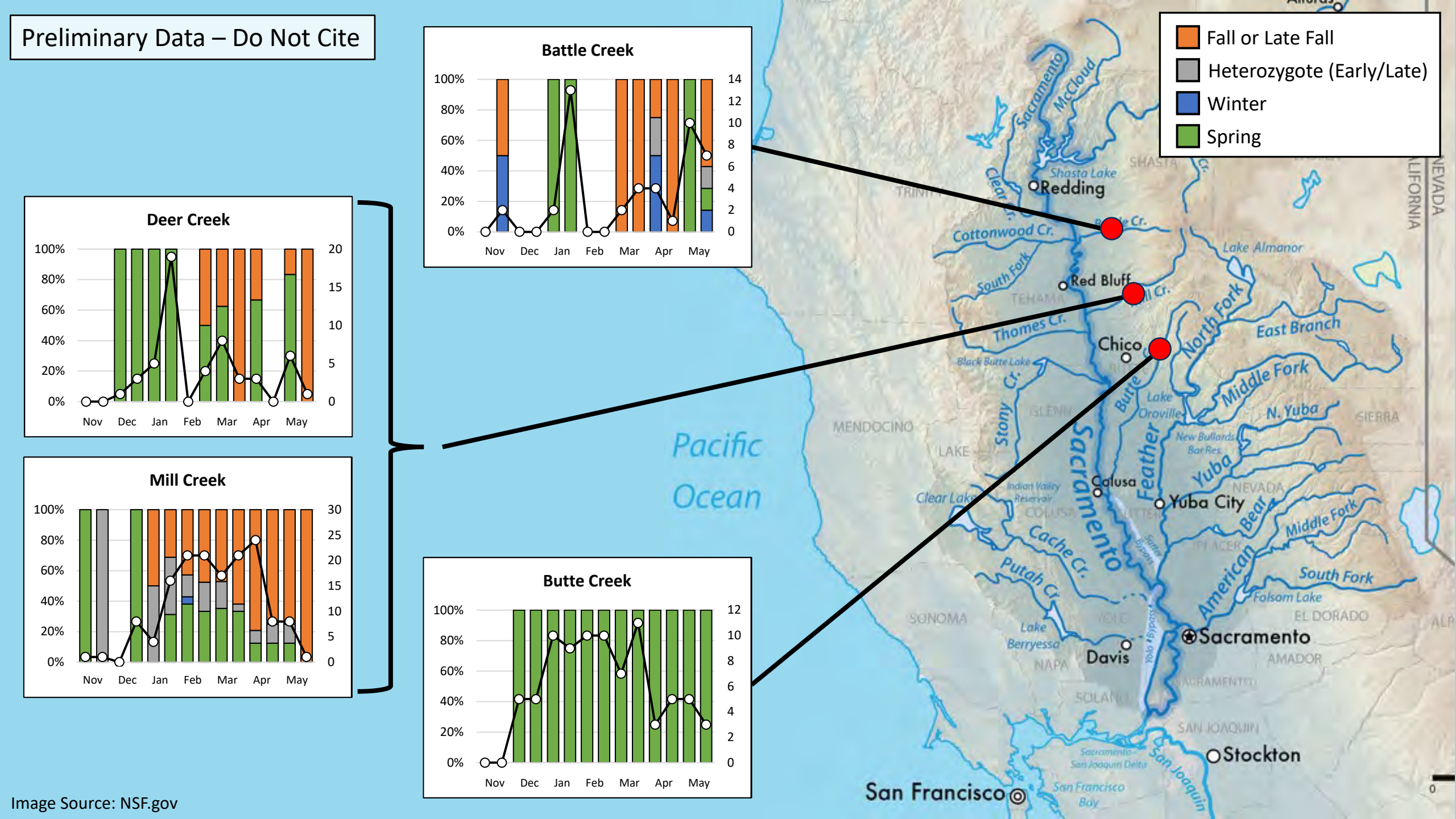


Image Source: NSF.gov

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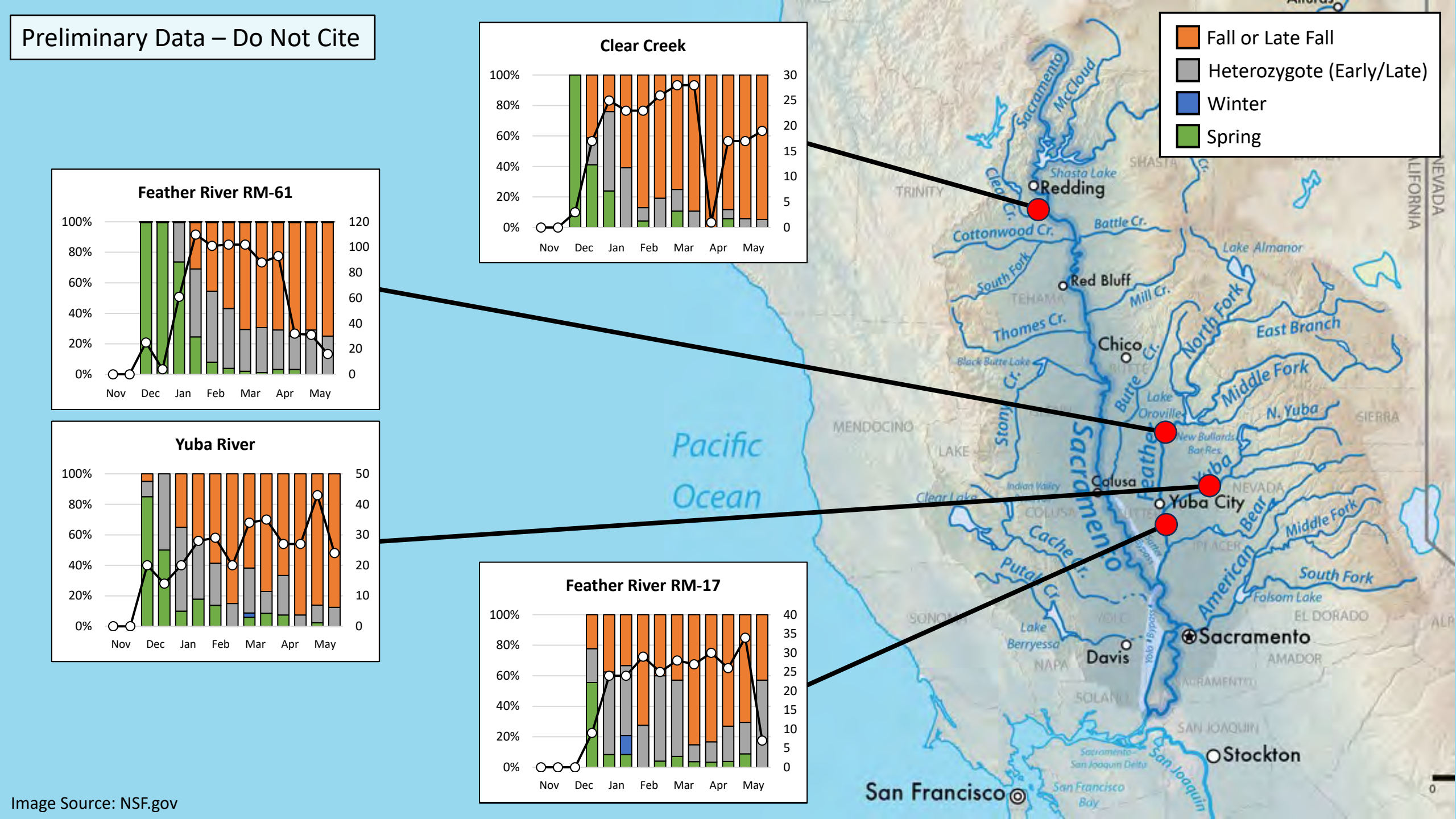
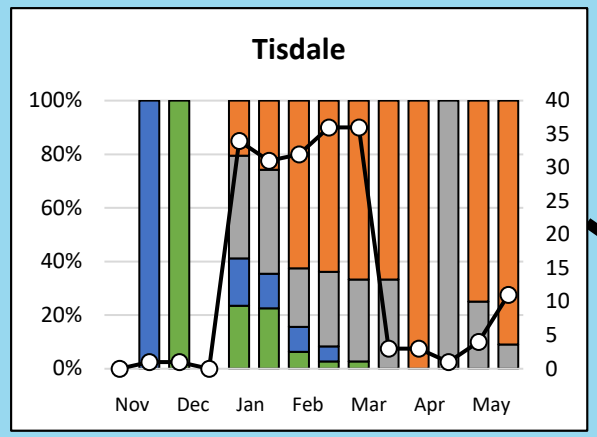
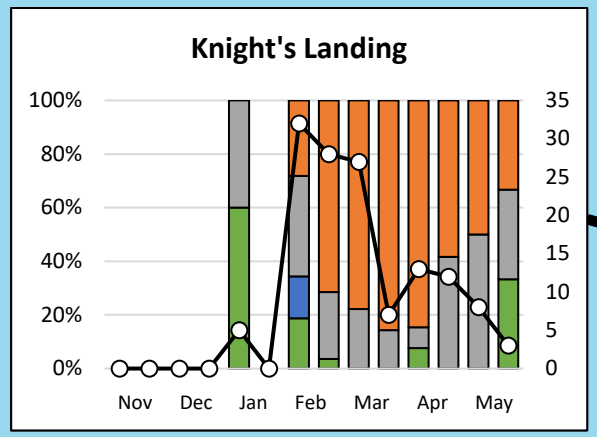
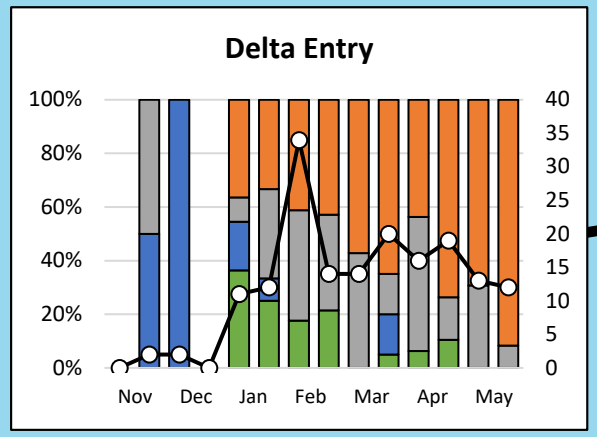


Image Source: NSF.gov

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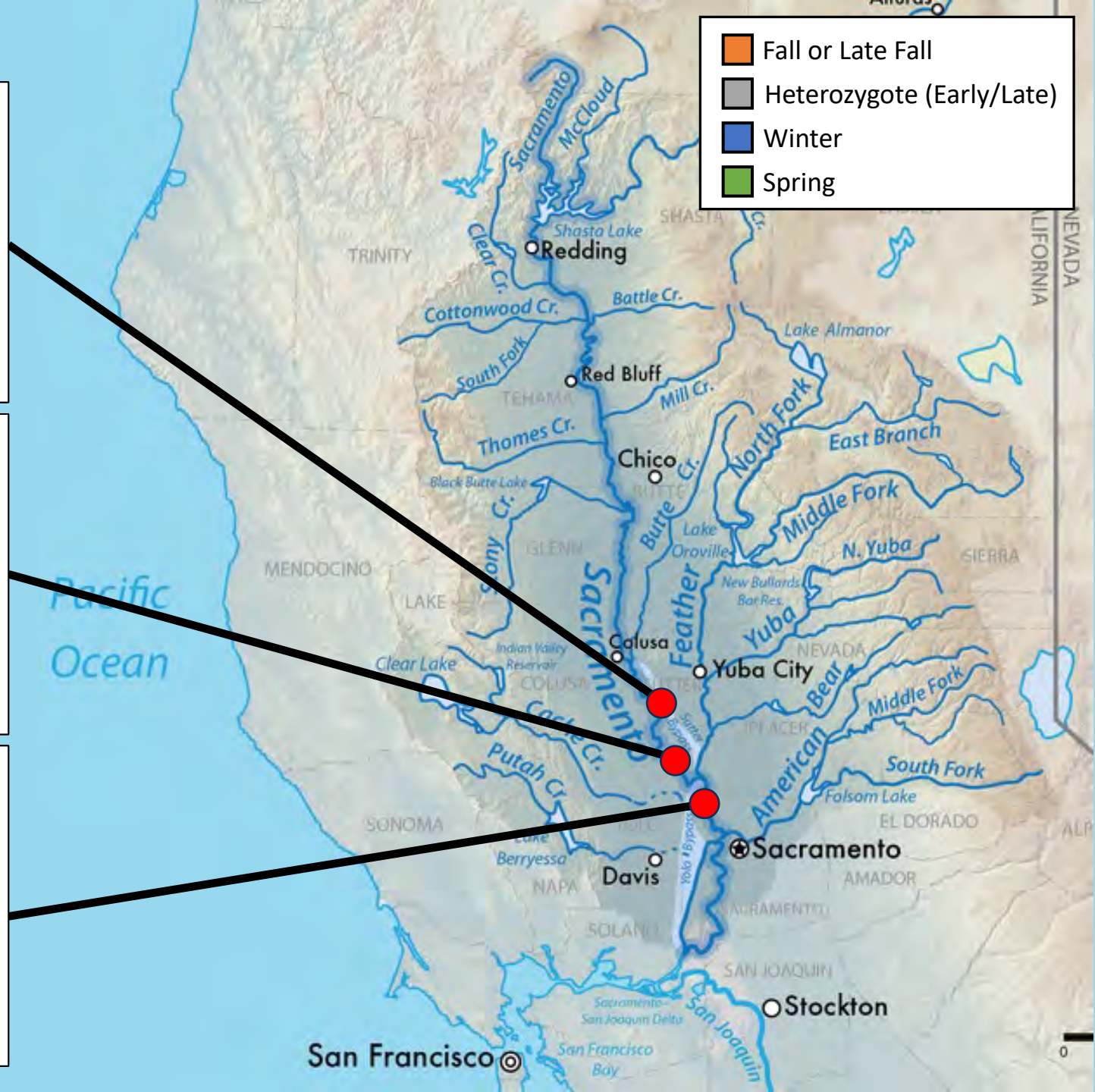
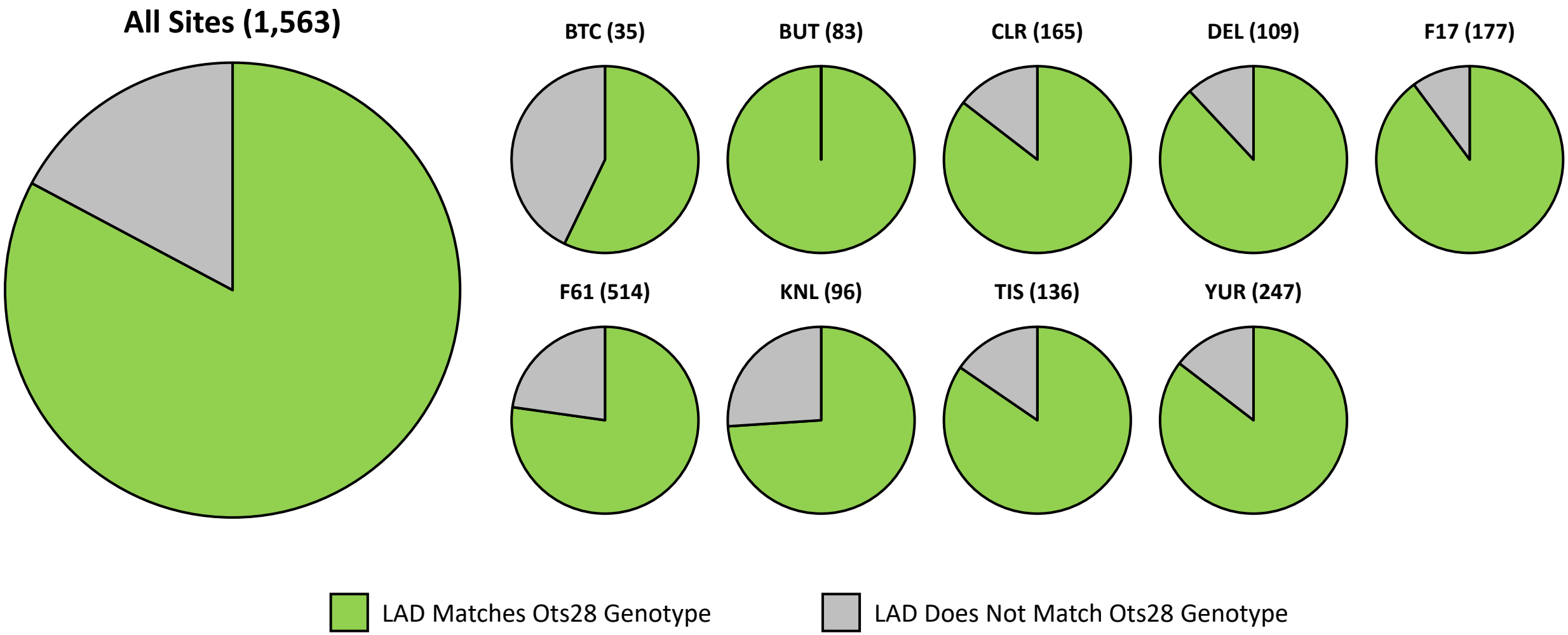


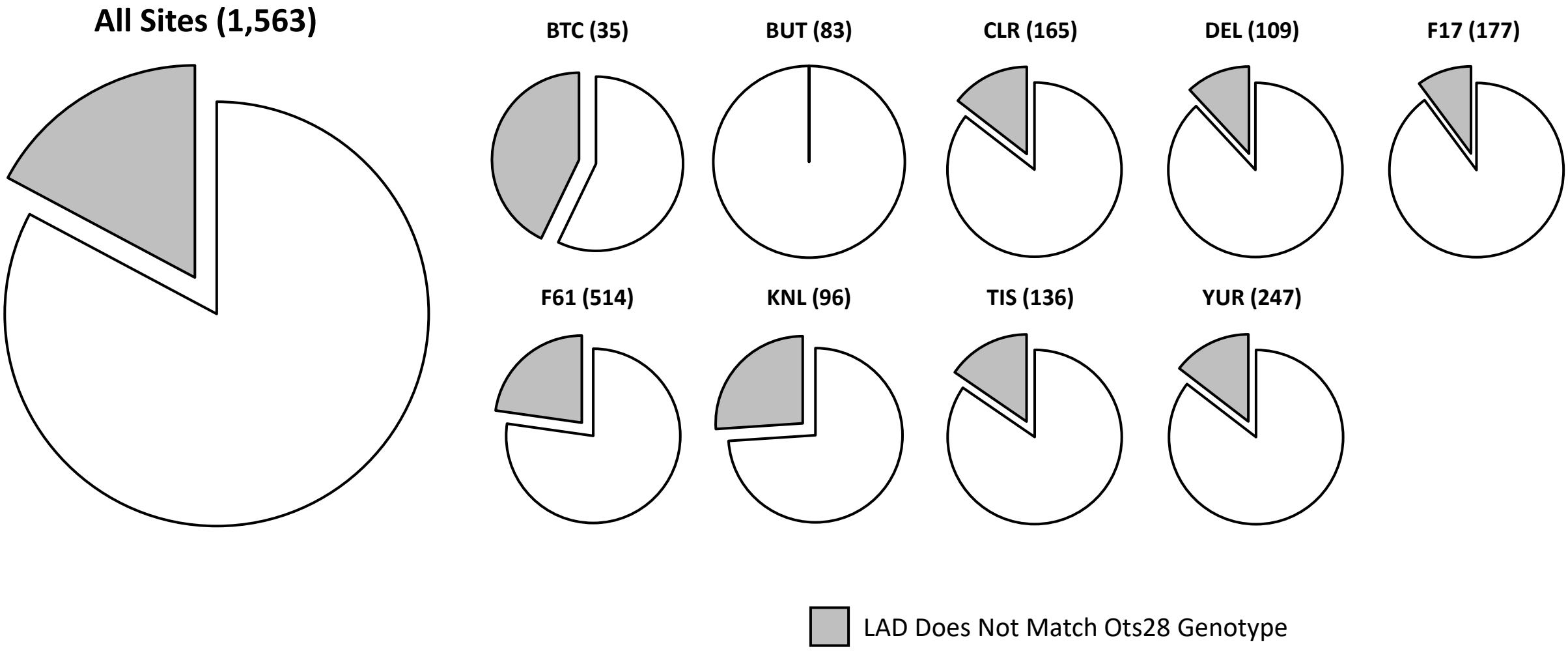
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2024 JPE: Genetics vs. Length-at-Date



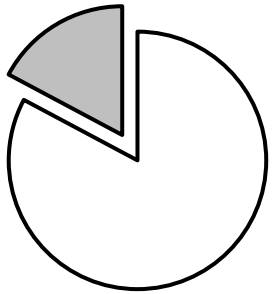
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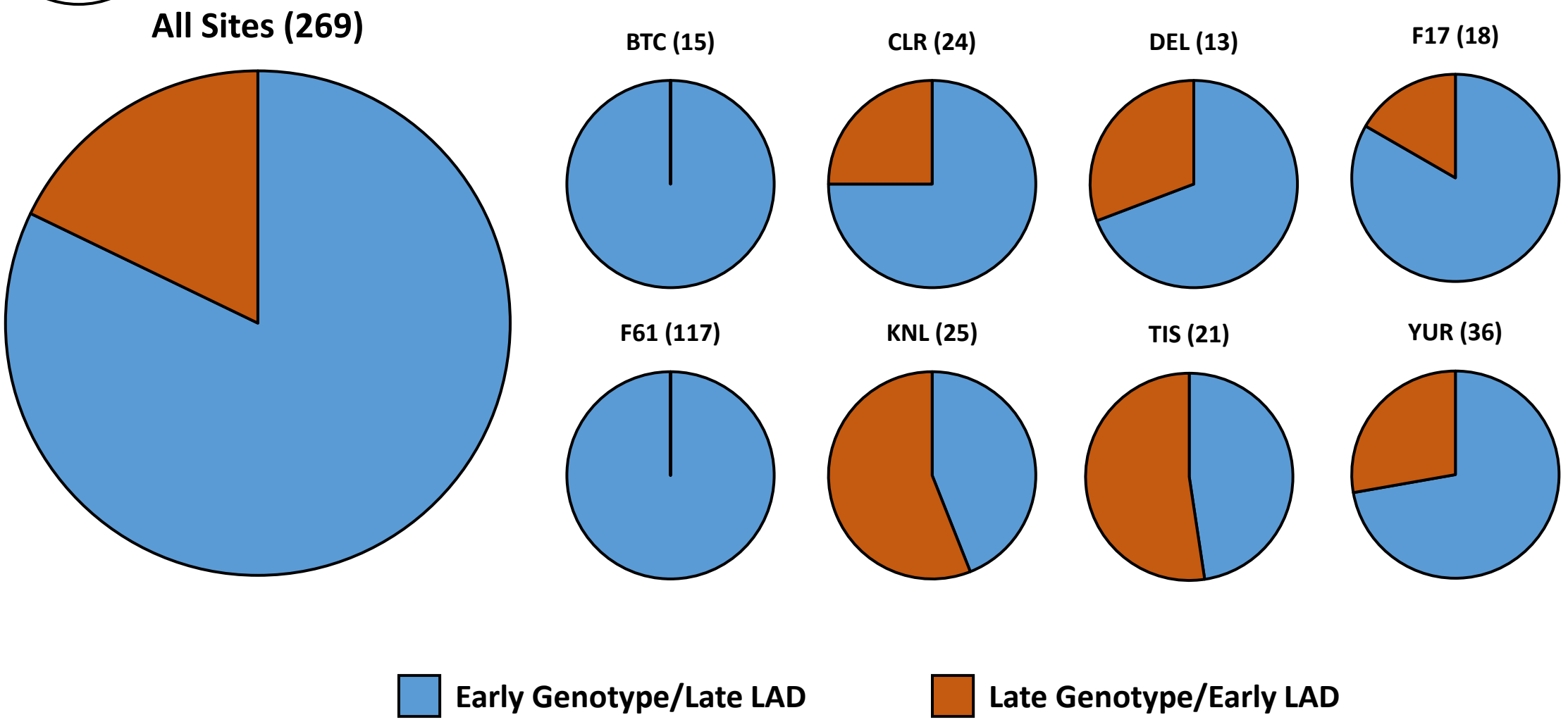
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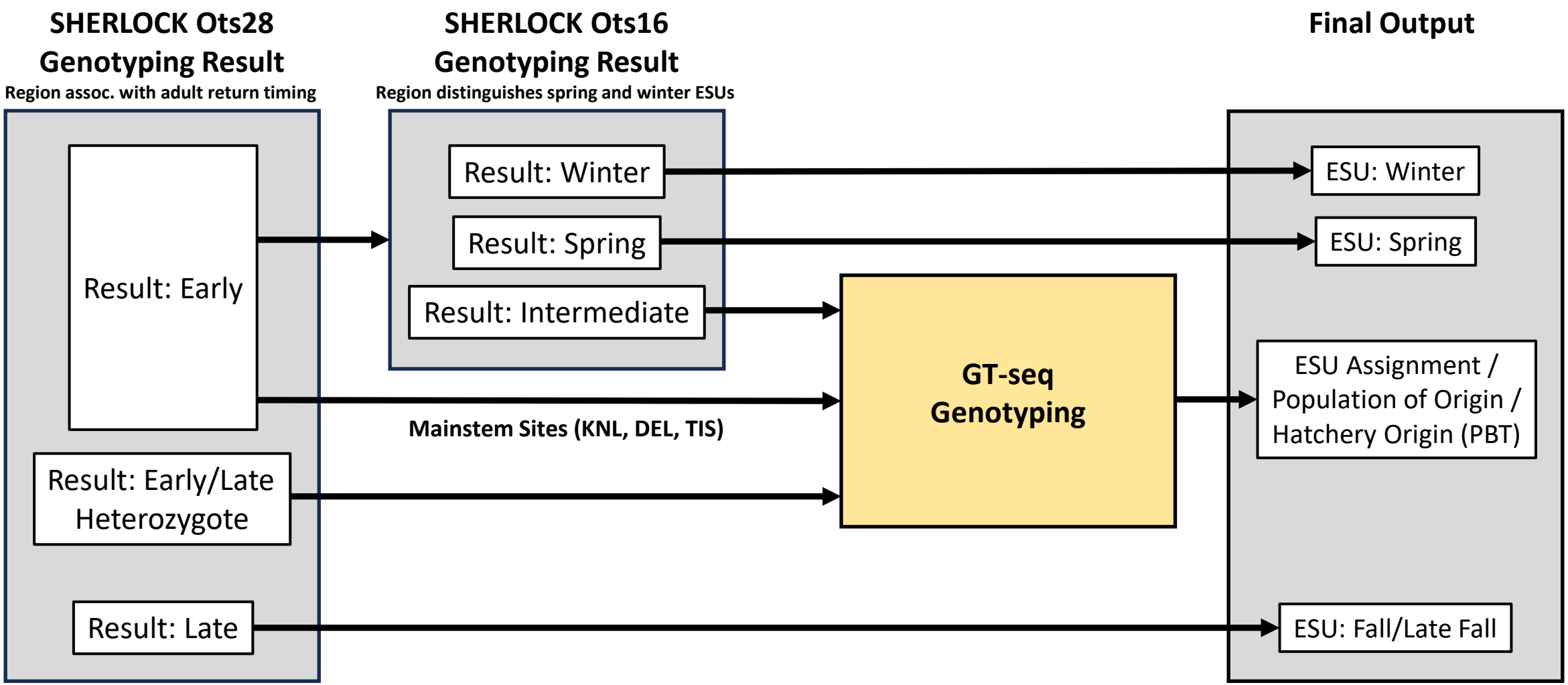
2024 JPE: Length-at-Date Bias



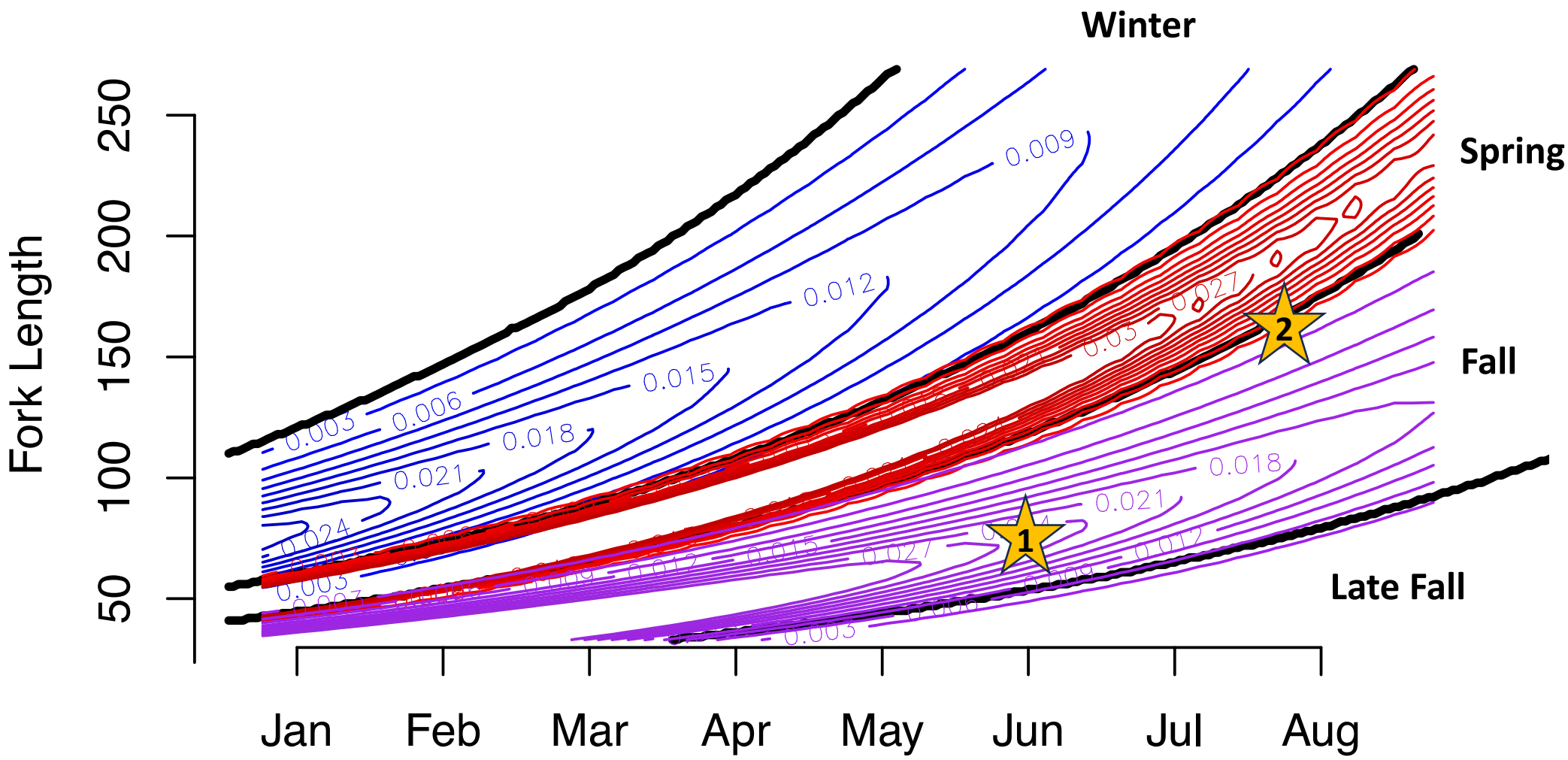


Preliminary Data – Do Not Cite

2025 JPE Genotyping Workflow



Probabilistic Length-At-Date (PLAD) Models



Probabilistic Length-At-Date (PLAD) Models

Continuous Data Feedback

Sampling

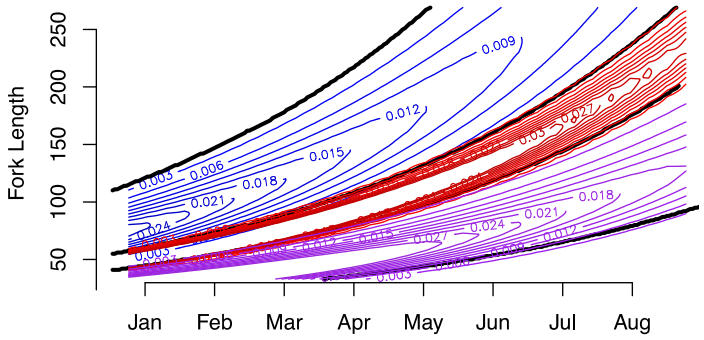
Collect Data
(e.g. location, length, date)

Collect Genetic Sample
(e.g. fin-clip and/or mucus)



PLAD

Use informed/updated model to determine run ID assignment probabilities



PLAD Assignment

Spring or Winter
OR
Uncertain Assignment

Genetics

Determine Run ID or verify PLAD assignment (as needed)

Genetic Assignment



Fall or Late Fall

No genetic verification needed

(May be subsampled for genetic analysis)

Acknowledgements

JPE Field Crews

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Ryan Revnak
Kassie Henley
Jeff Jenkins
Gabriel Loera
Nicolas Bauer
Grantton Henley
Natasha Wingerter
Lindsey Carson
Corey Fernandez
Andrew Huneycutt
Vanessa Costa
Casey Campos
...and many more!

JPE Collaborators

Pete Nelson
Nicole Kwan
Mallory Boro

Assay Development

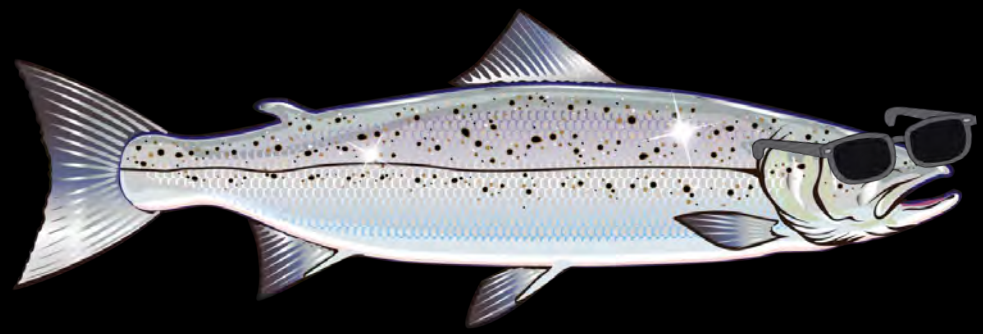
Alisha Goodbla
Matthew Campbell
Tasha Thompson
Mariah Meek
Emily Funk
Andrea Schreier

Lab Support

Daphne Gille
Sarah Stinson
Scott Meyer
Aviva Fiske
Pachia Lee
Emma Freedman
Ross Harper
Juan De La Torre

Other Support

FlowWest
CVTA (CDFW)
NMFS (NOAA)



Questions?

Forecasting the Timing and Abundance of Juvenile Spring-run Chinook Outmigrants from Sacramento River Tributaries
- Challenges and Progress -

SRF Conference – May 2nd, 2025

Josh Korman, **Brett Harvey,**
Flora Cordoleani, Ashley Vizek, Liz Stebbins

SR-JPE Program

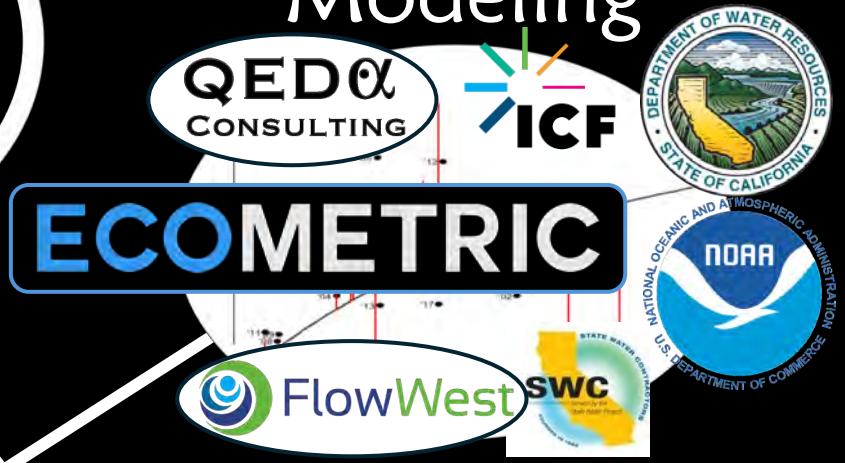
Data Management



Run Identification



Modeling



Monitoring

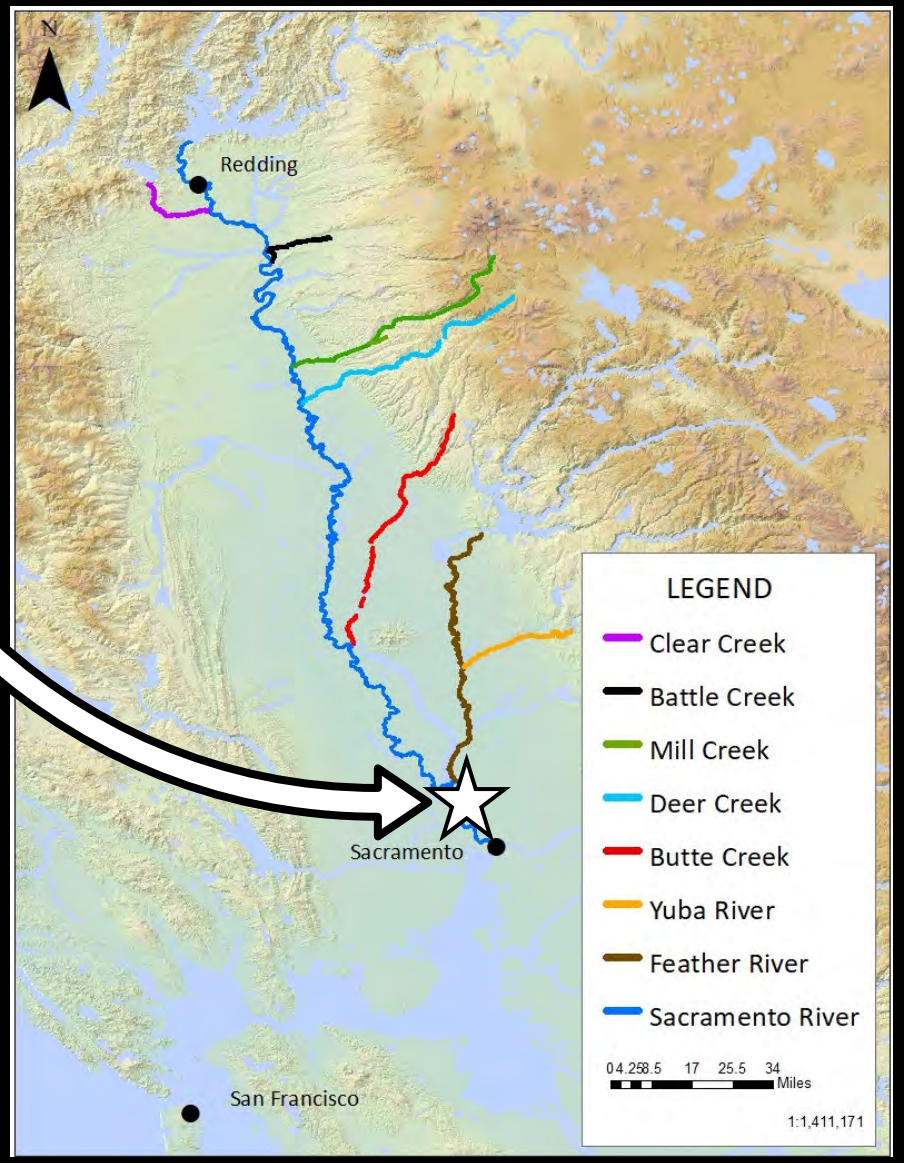


SDM Model Selection



The Challenge

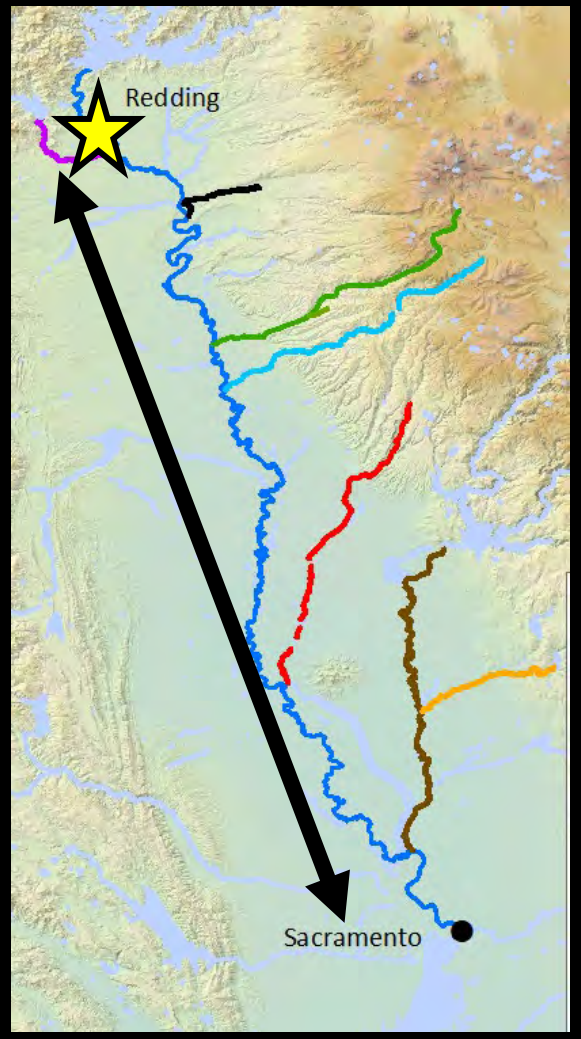
JPE = Forecast

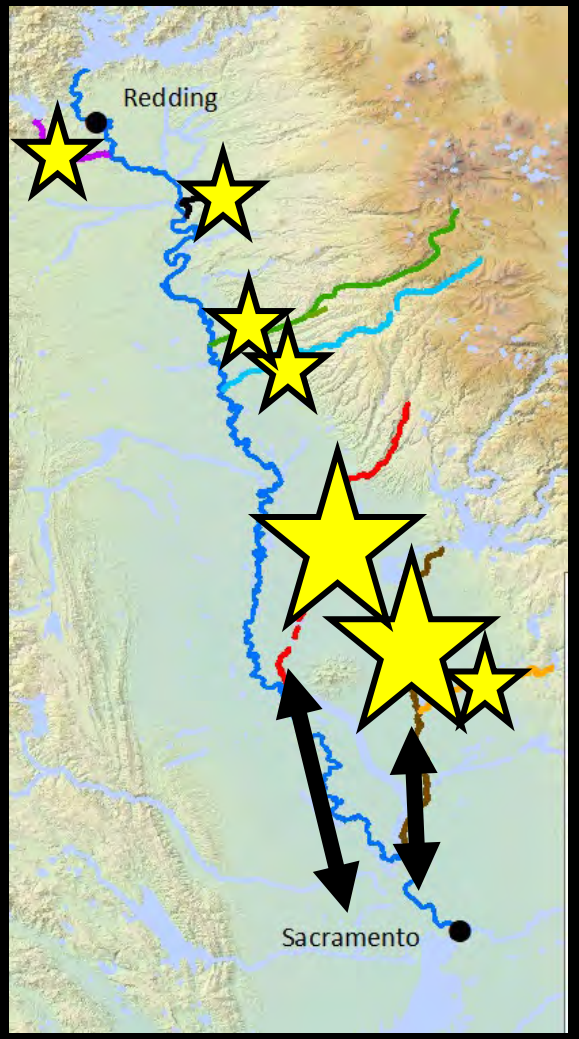


Map: Flora Cordoleani

Tributary Number and Geography

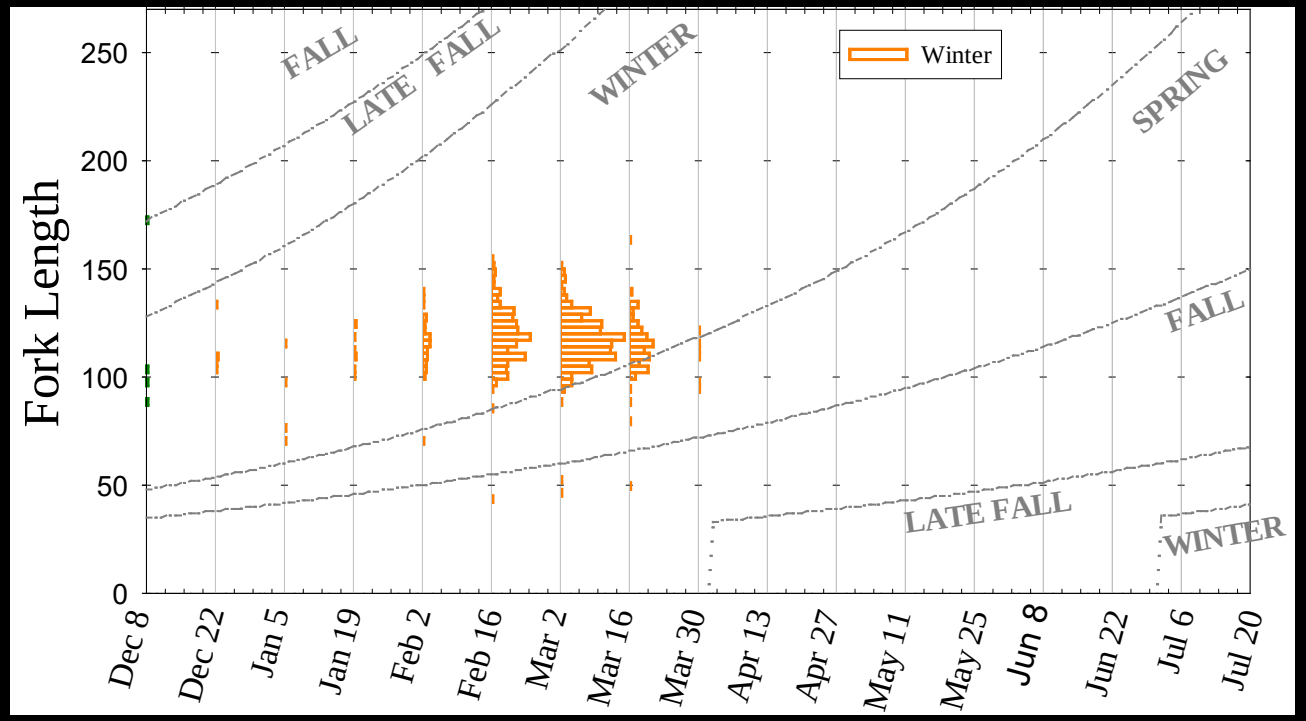
Winter JPE ≠ Spring JPE

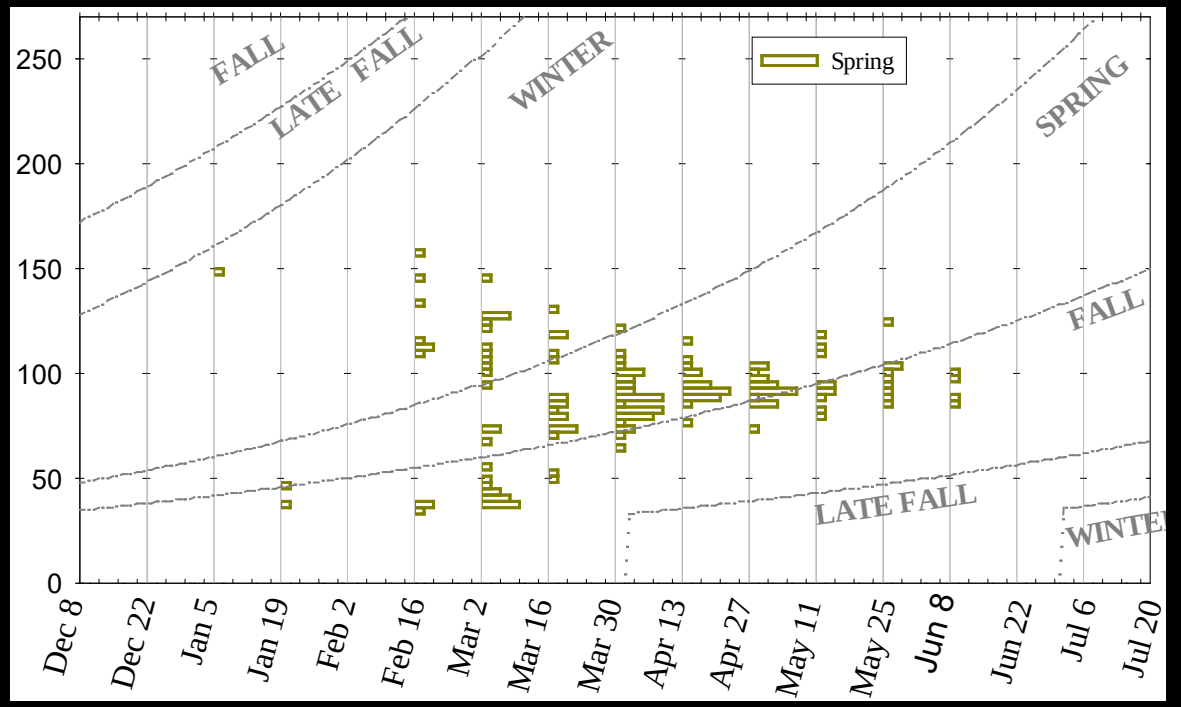




Migration Timing and Size

Winter JPE ≠ Spring JPE





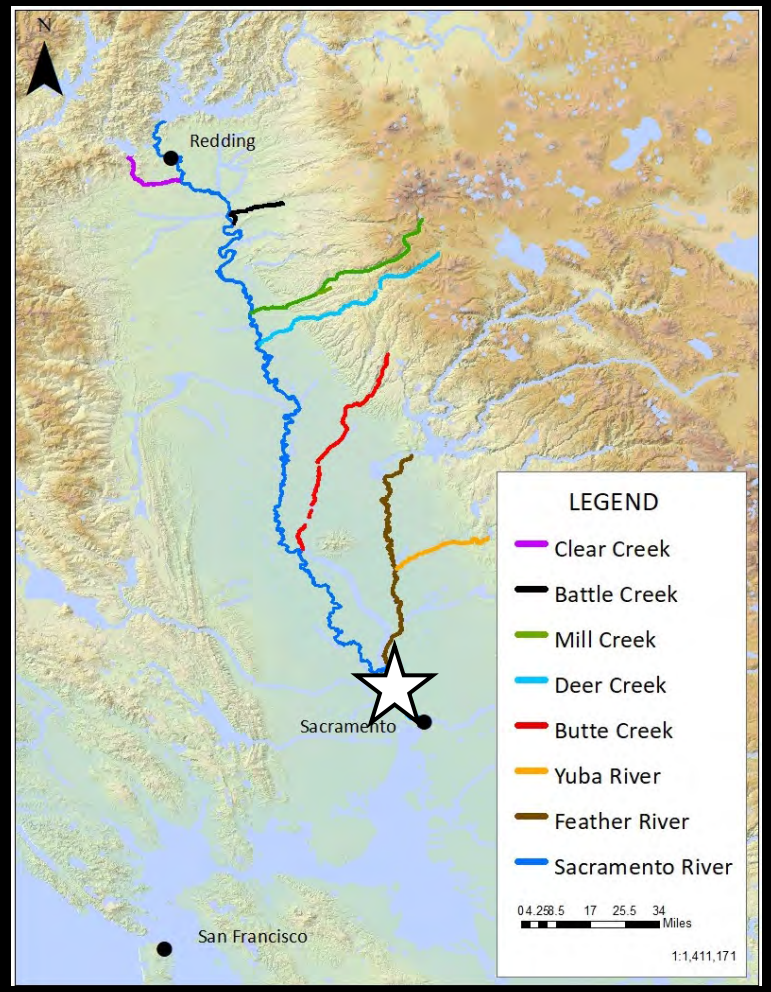
Migration Survival

Smolt ≠ Fry

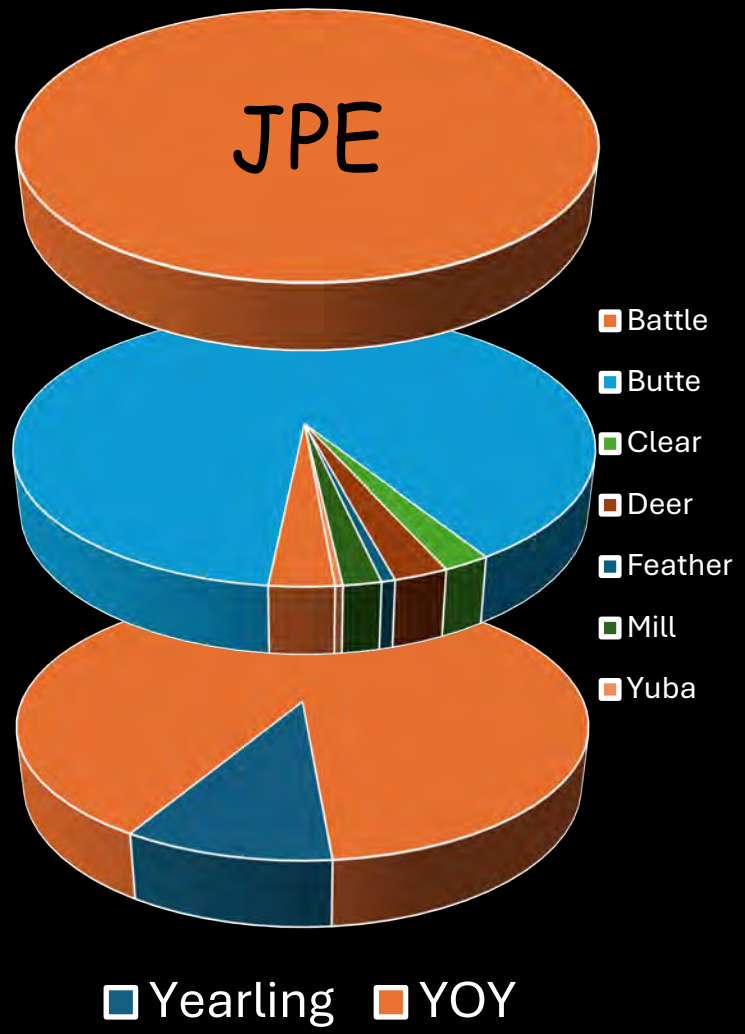


Photo: Naoaki Ikemiyagi

JPE Bells & Whistles

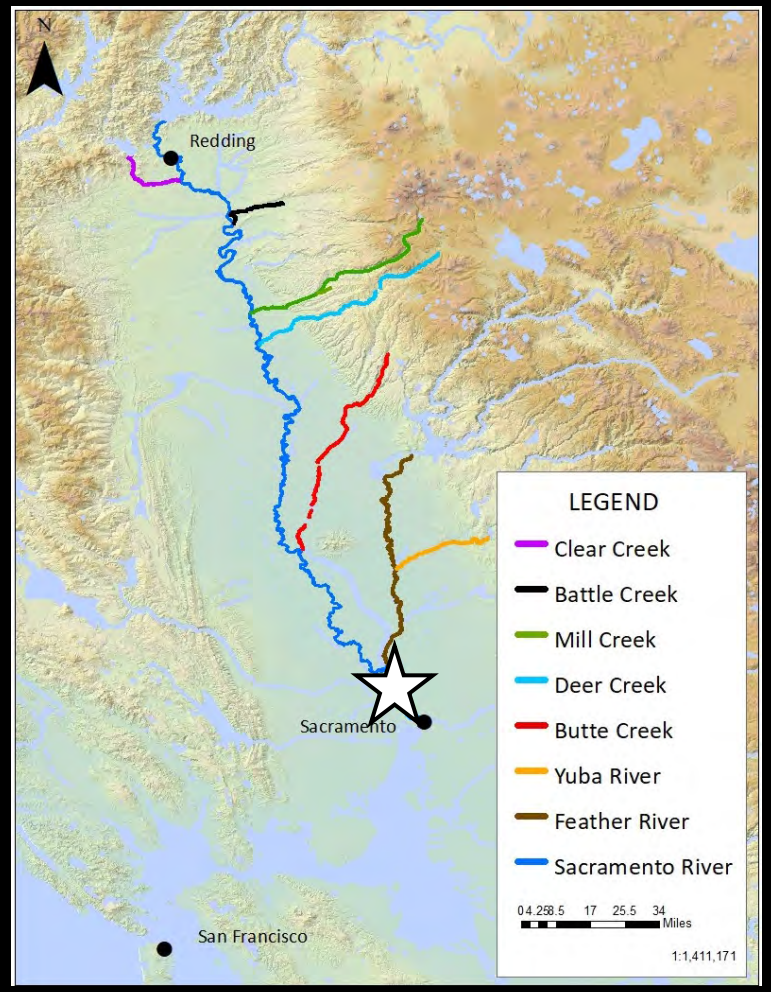


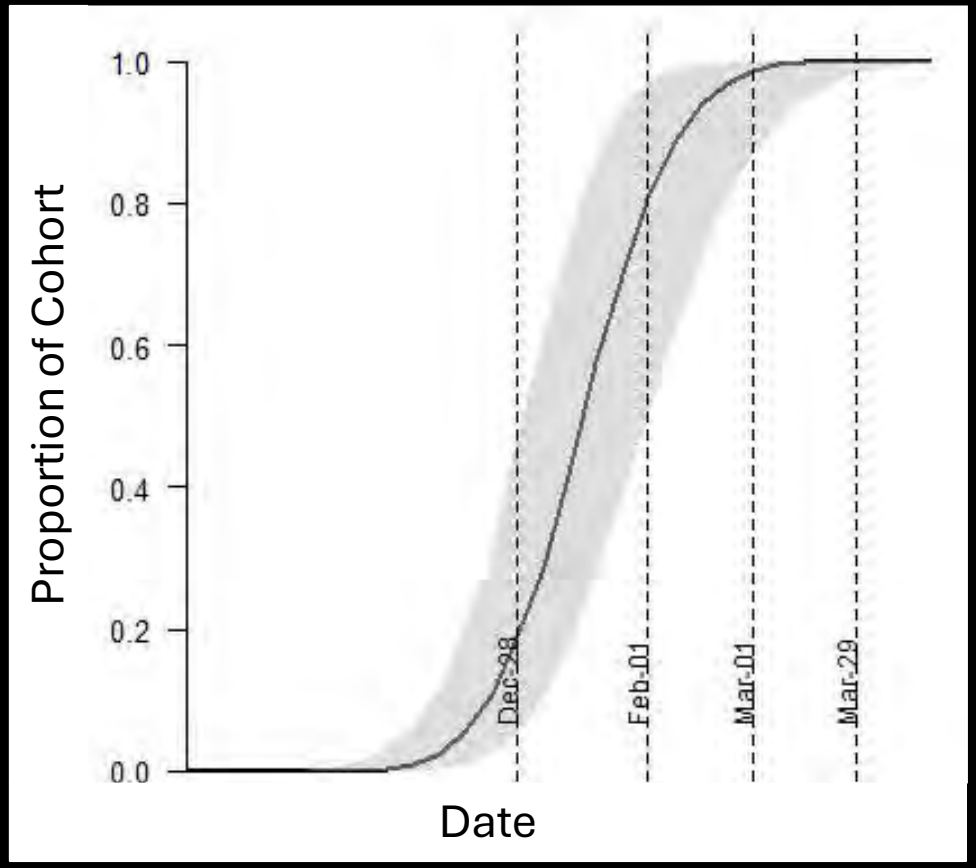
Spatial and Life History Diversity



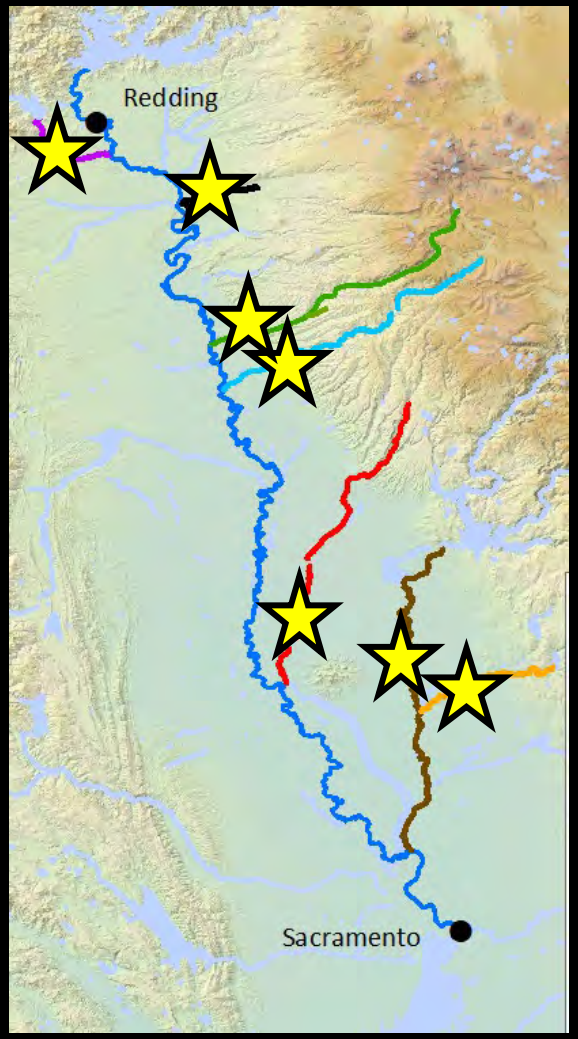
JPE Bells & Whistles

Delta Entry Timing

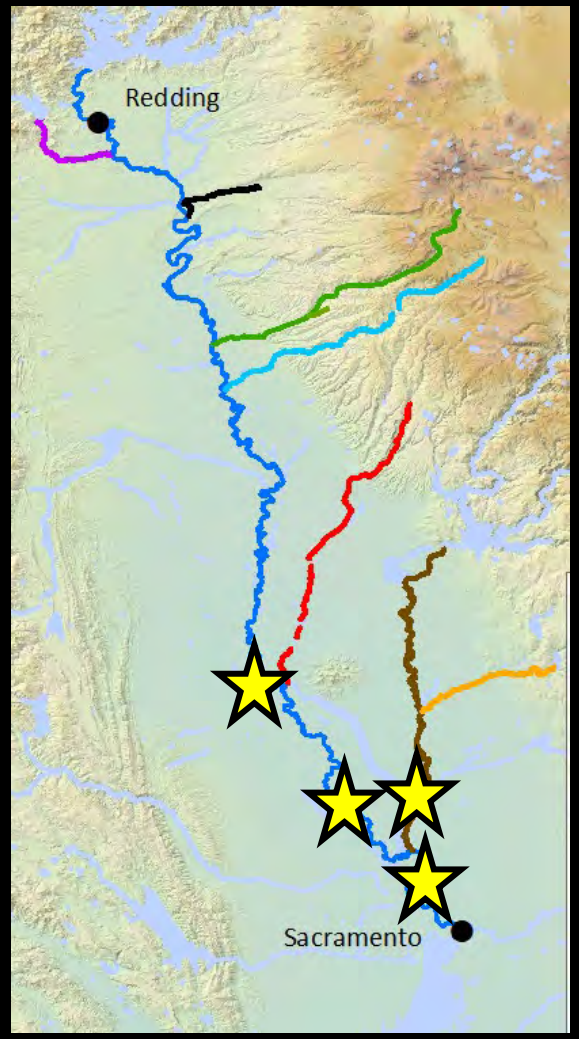




Tributary vs Mainstem Monitoring

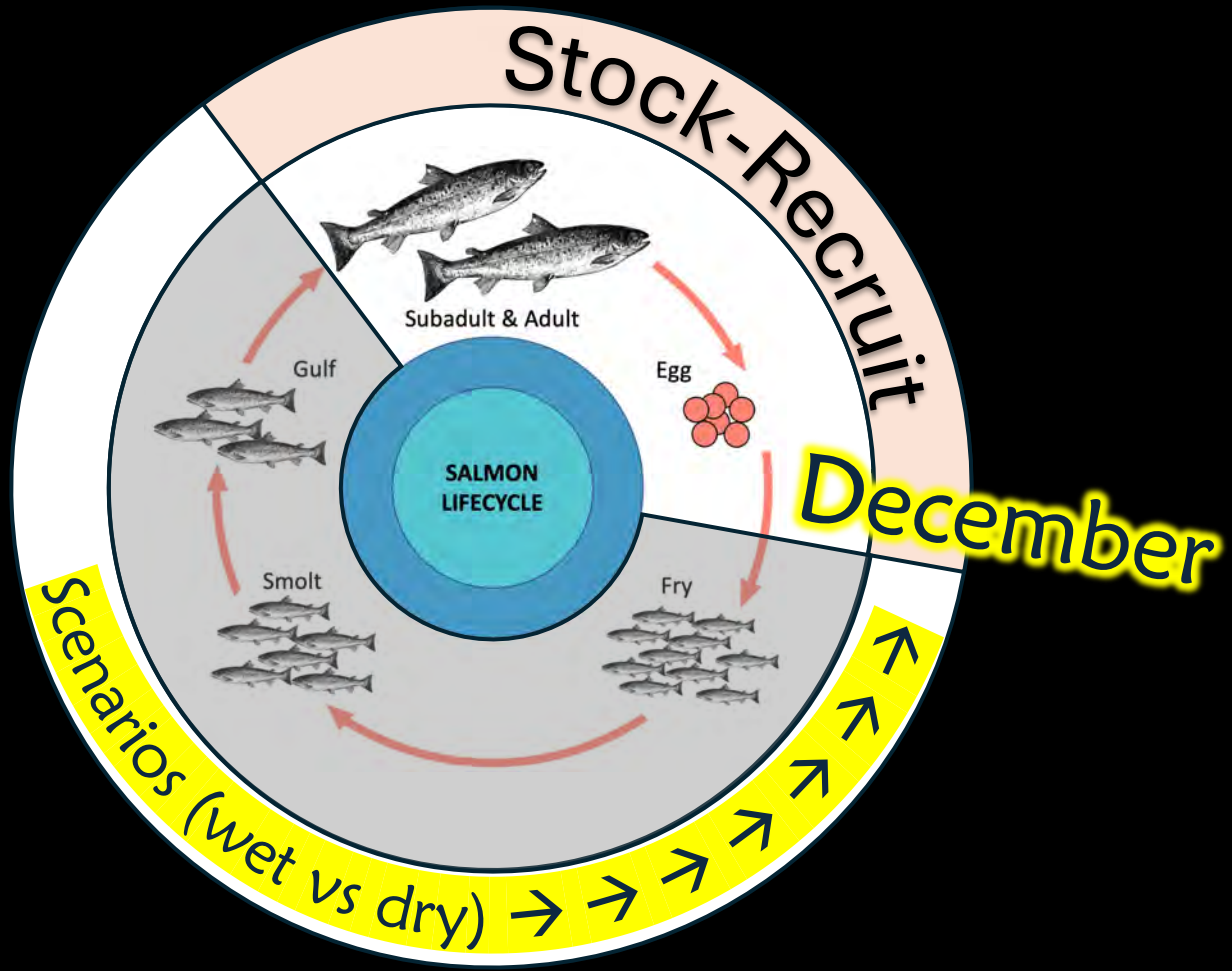


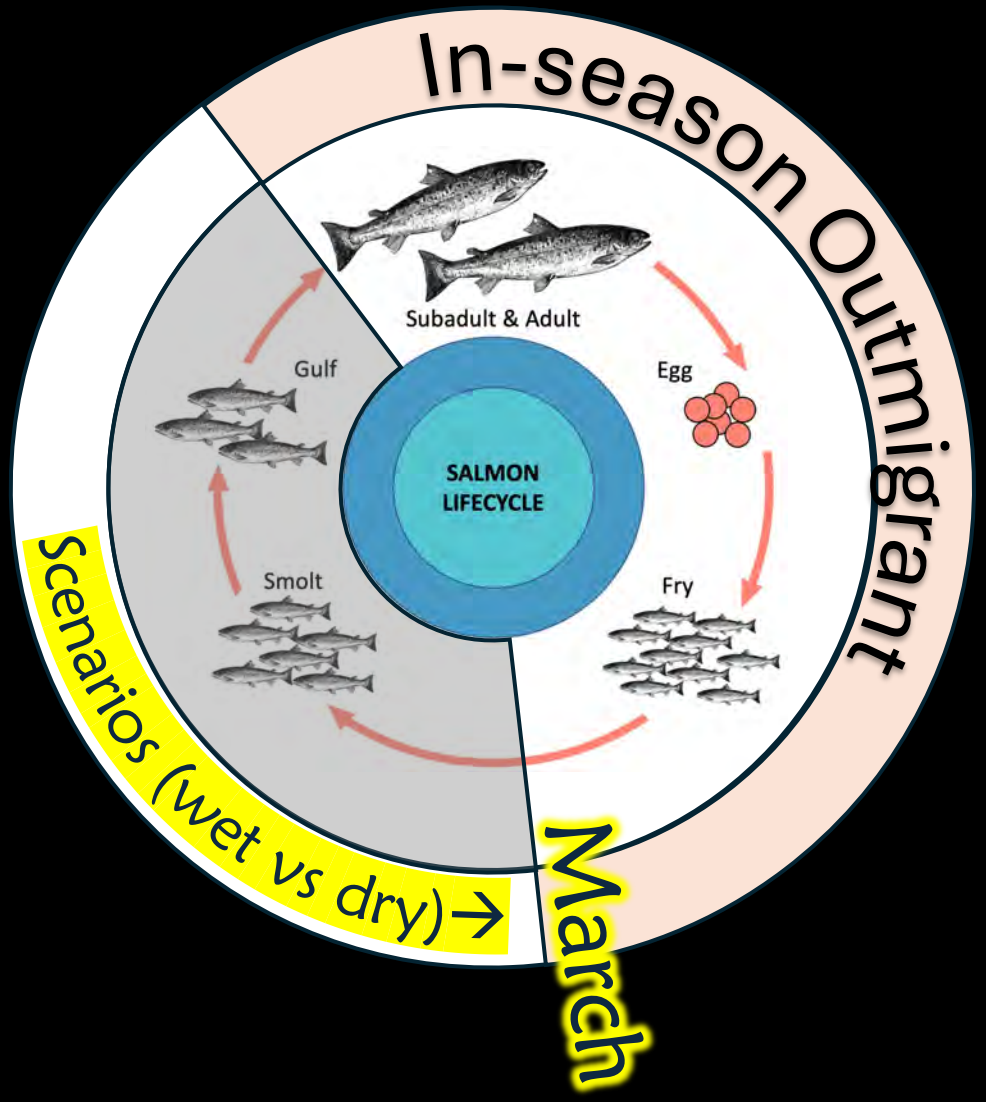
Redundancy



Model Progress

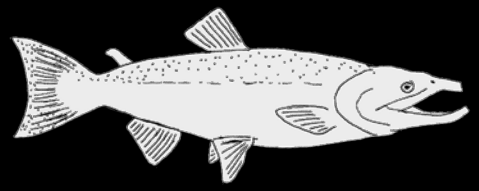
JPE Date defines the Data
Data defines the Model



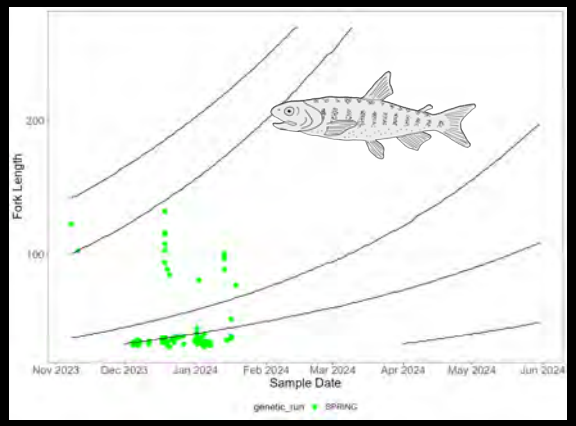


JPE Date and Prediction Uncertainty

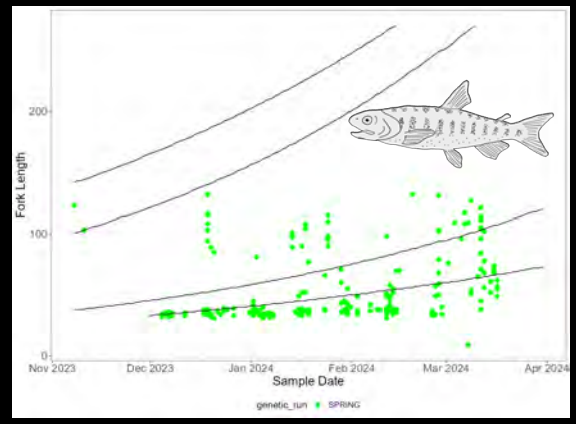
December

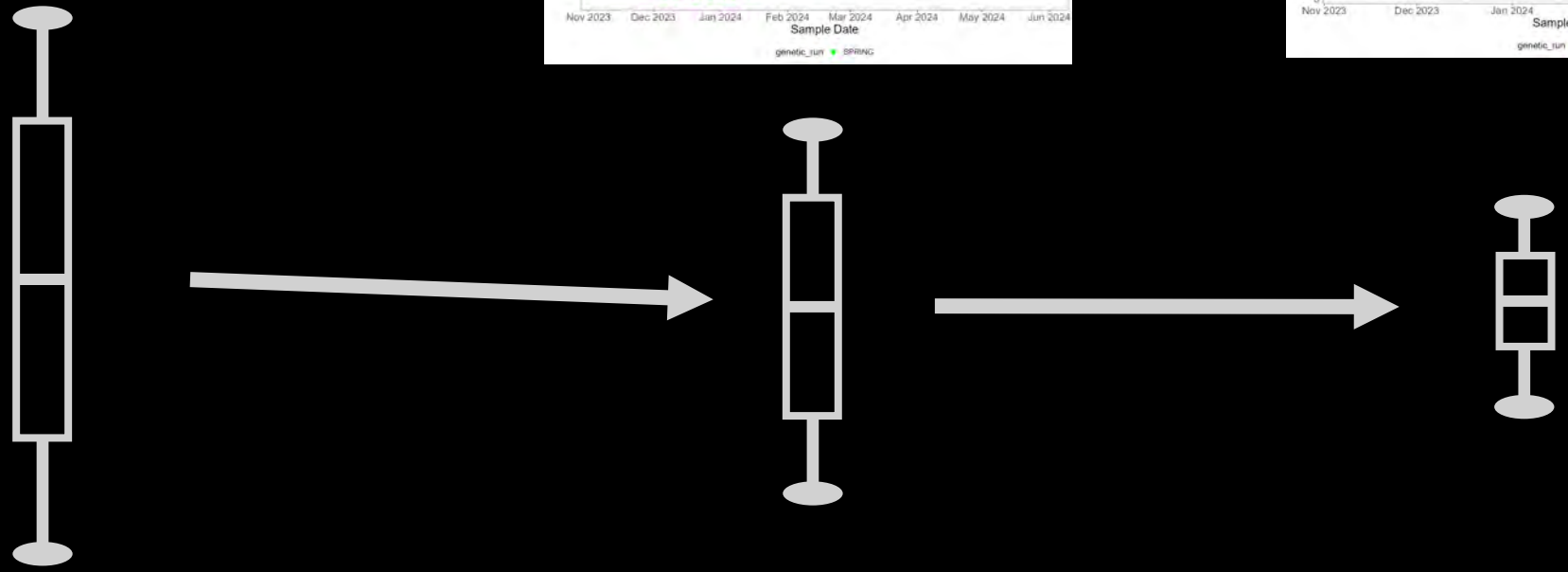


February



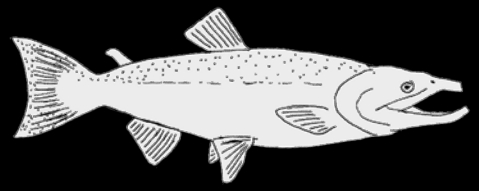
April



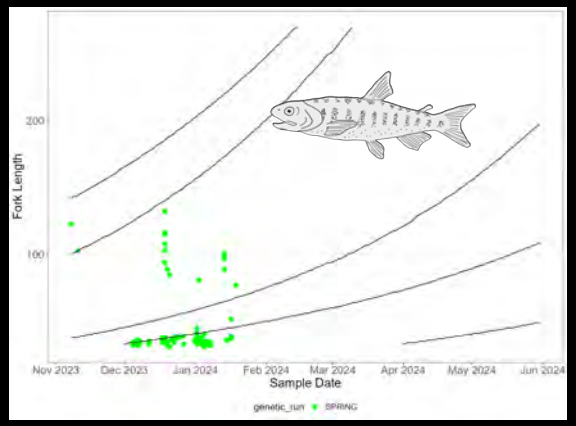


JPE Date and Prediction Uncertainty

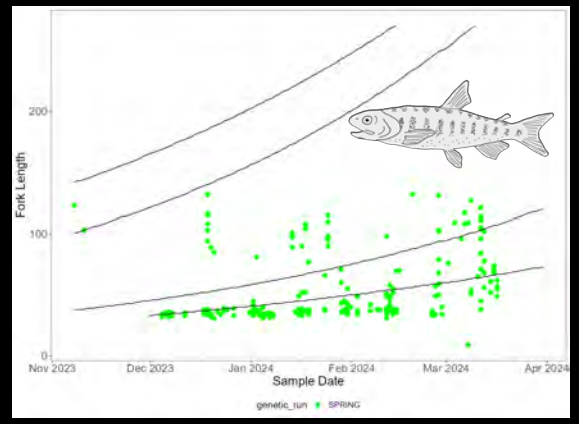
December

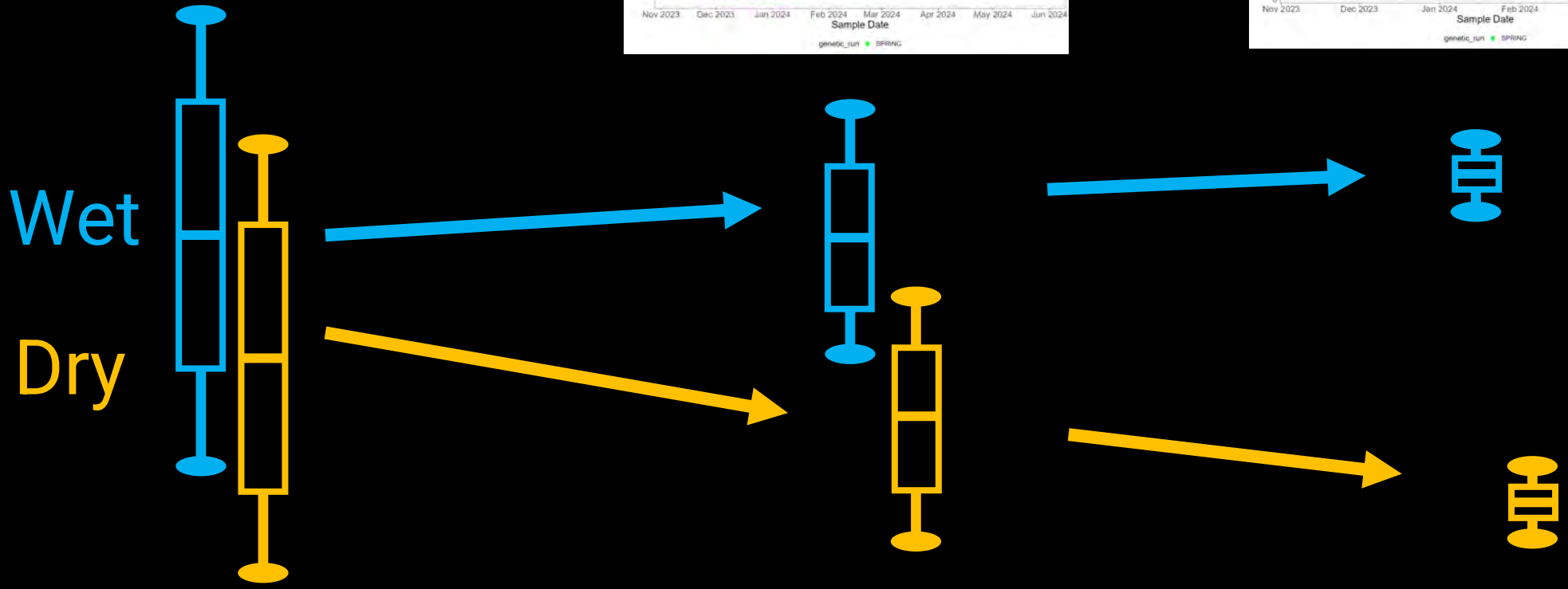


February



April





JPE ~ Stock Recruitment Approaches

Juvenile Production



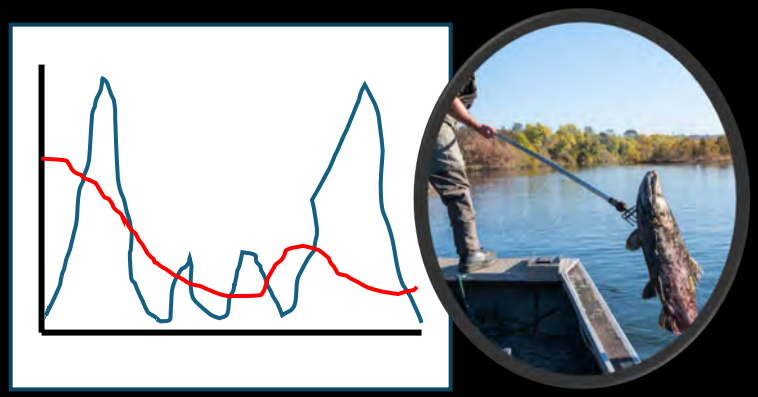
=

Adult Abundance



+

Covariates (flow, °C)



$$R_t = S_t \cdot e^{a+\beta \cdot S_t + \gamma \cdot X_t}$$

$$\log\left(\frac{\widehat{R_t}}{S_t}\right) = \propto + \beta \cdot S_t + \gamma \cdot X_t + \epsilon_t$$

JPE ~ InSeason Outmigrant proaches

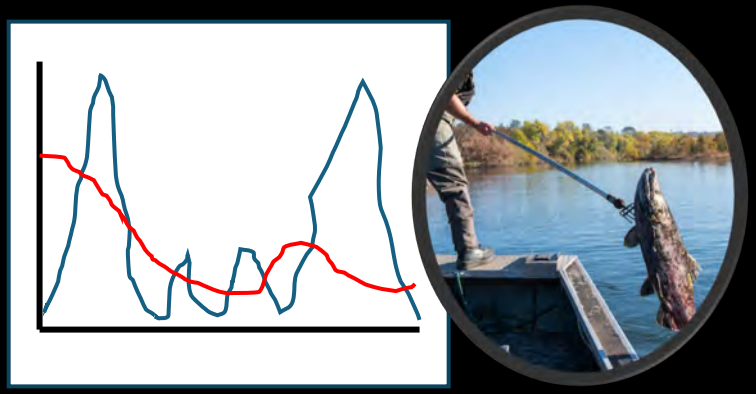
Juvenile Production = ~~Adult Abundance~~ Early-season Catch + Covariates (flow, °C)



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+



Need to Model
Abundance from Catch Data

Catch Efficiency is Key

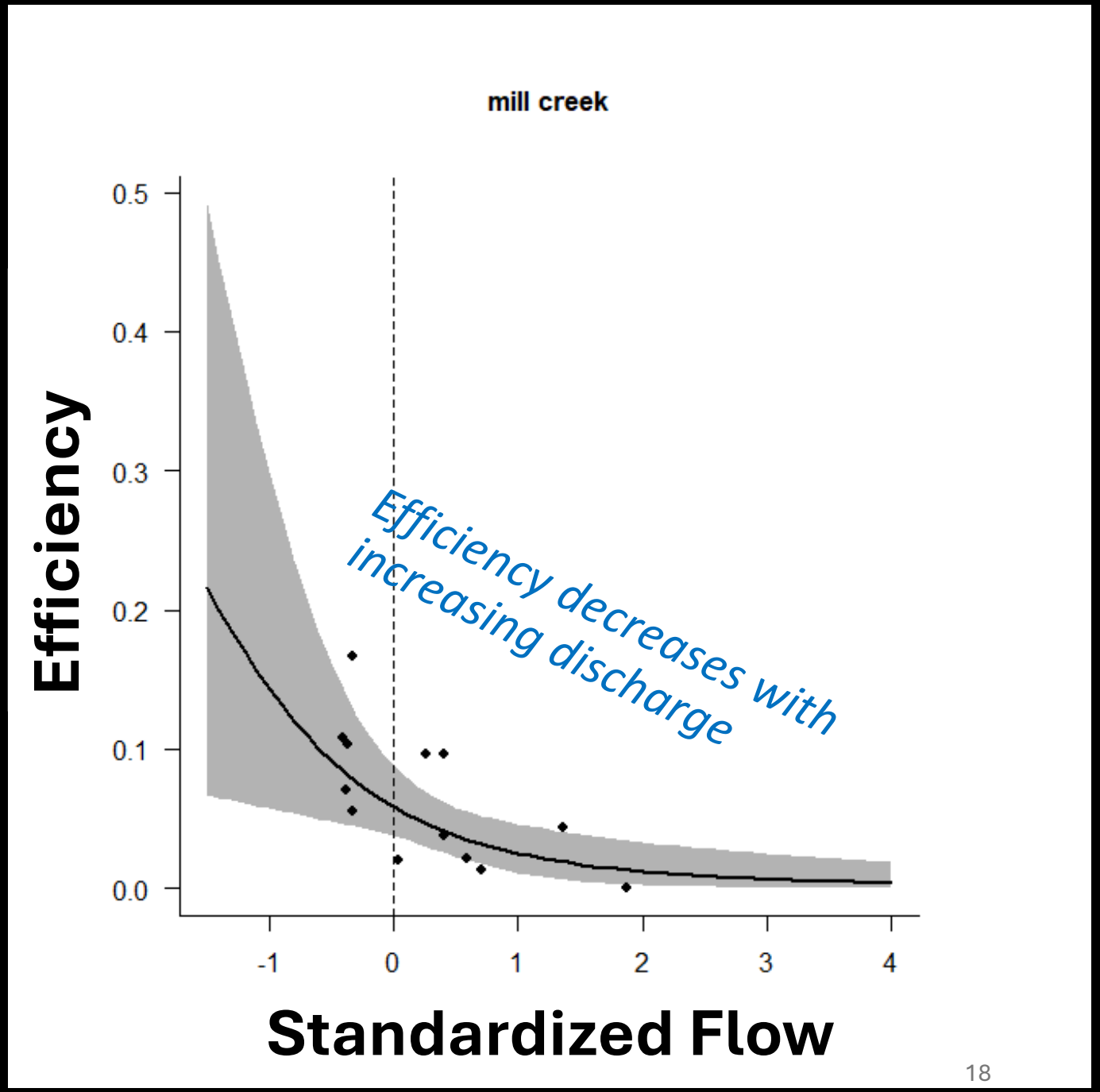
$$Outmigant\ Abundance = \frac{Catch}{Efficiency}$$



- Low precision of efficiency estimates
- Limited efficiency trials
- No sampling in some weeks

BTSPAS-X

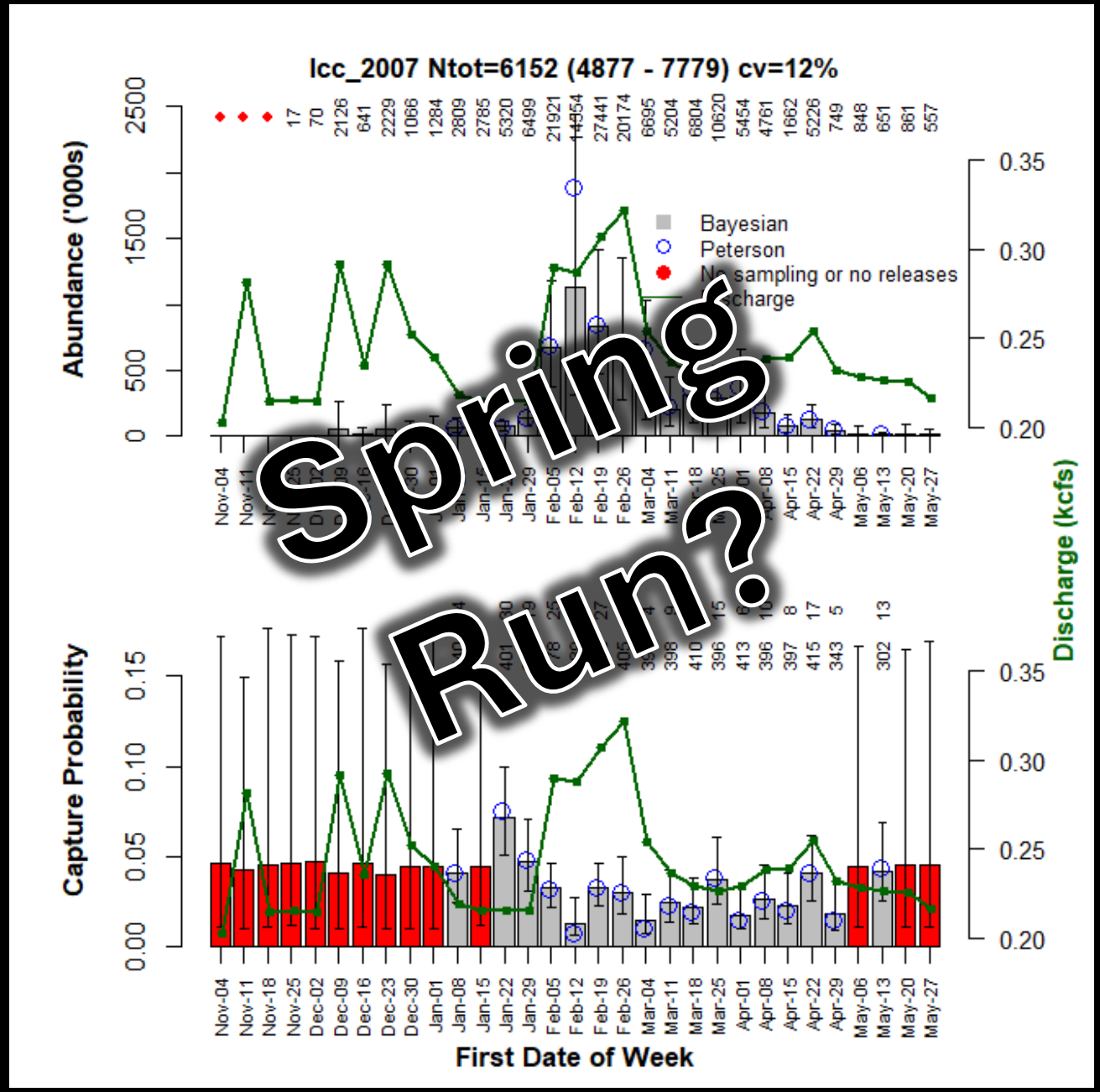
Predictors of efficiency



Preliminary results – do not cite

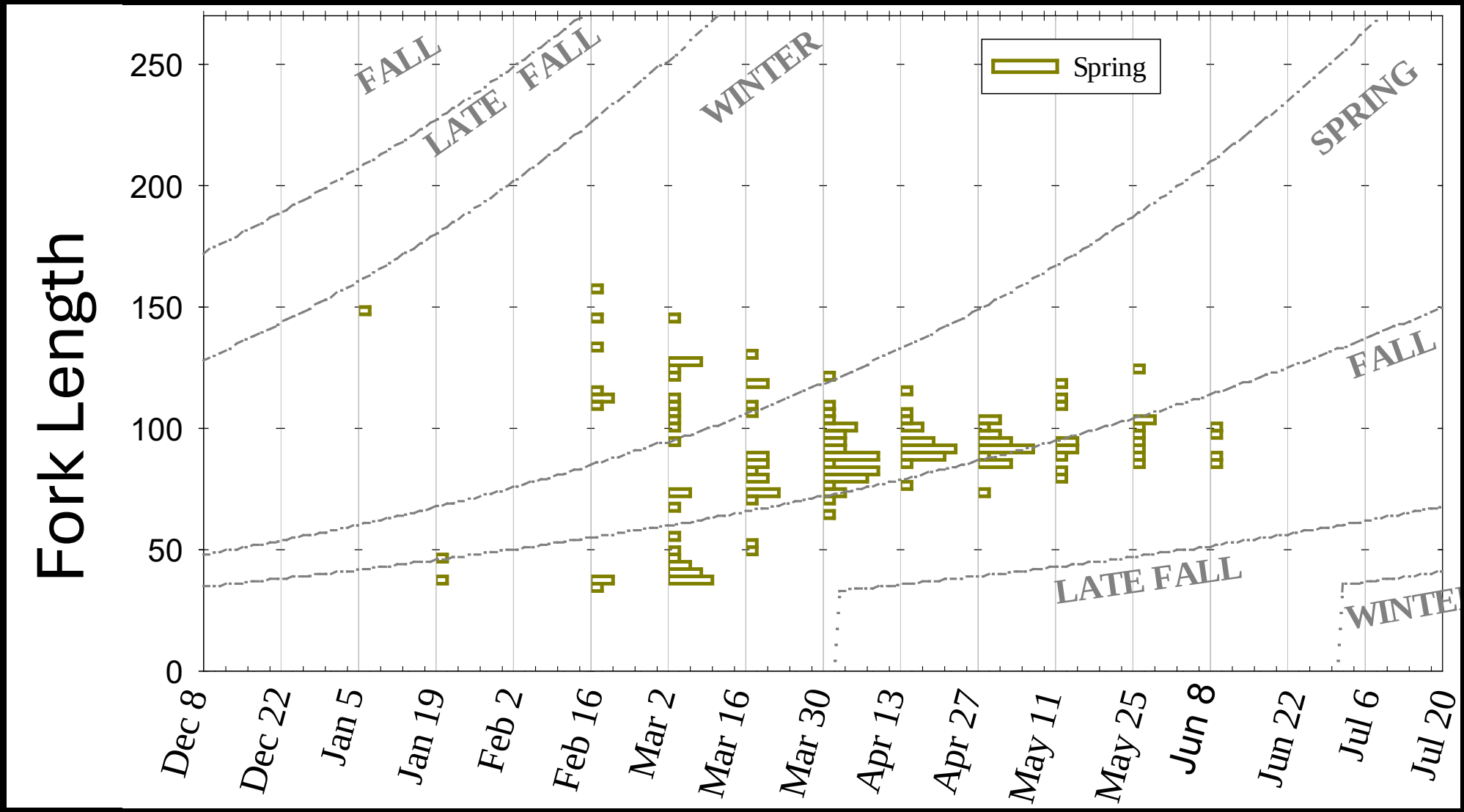
BTSPAS-X

Putting it together: Weekly Efficiency & Abundance

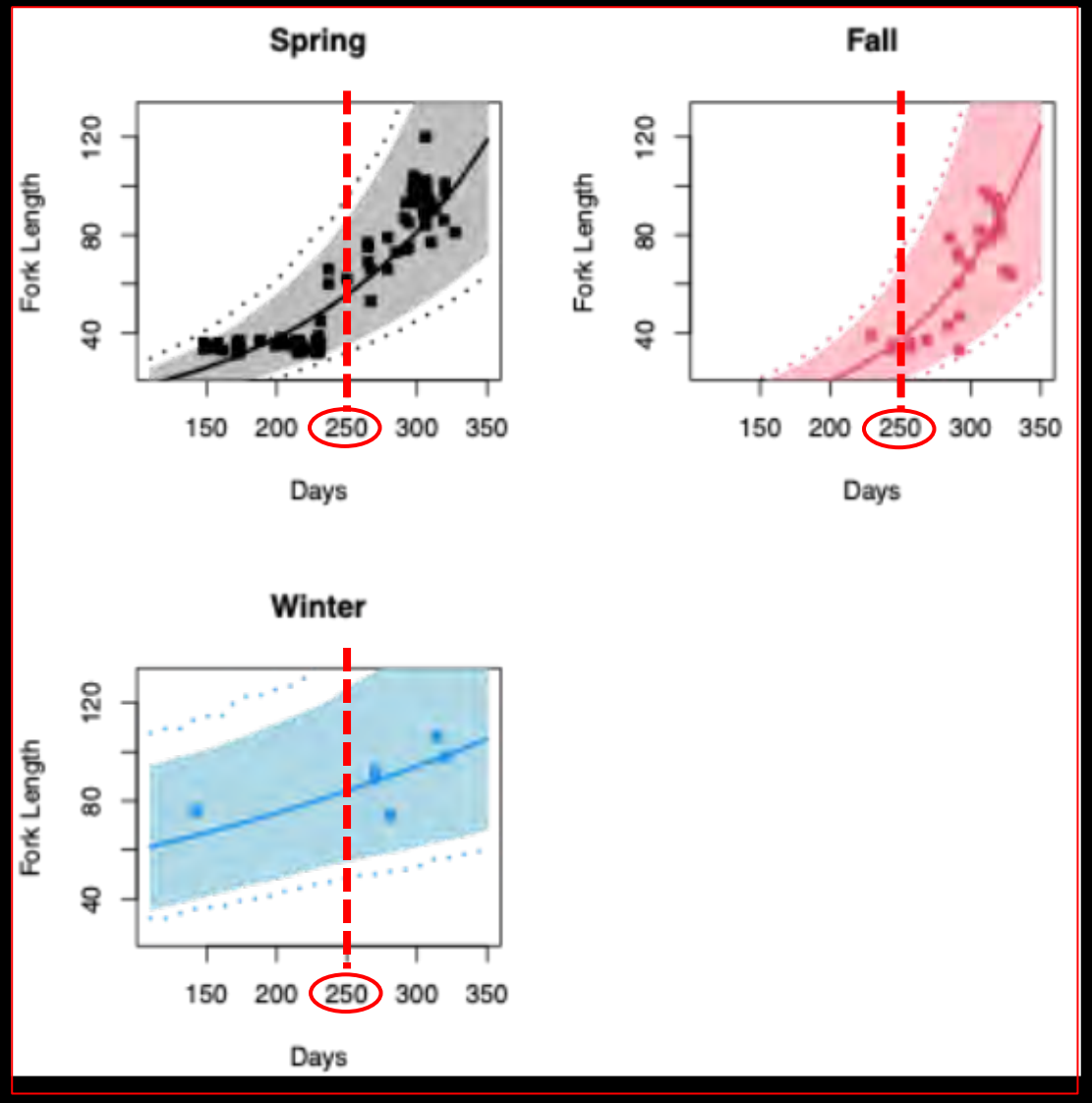


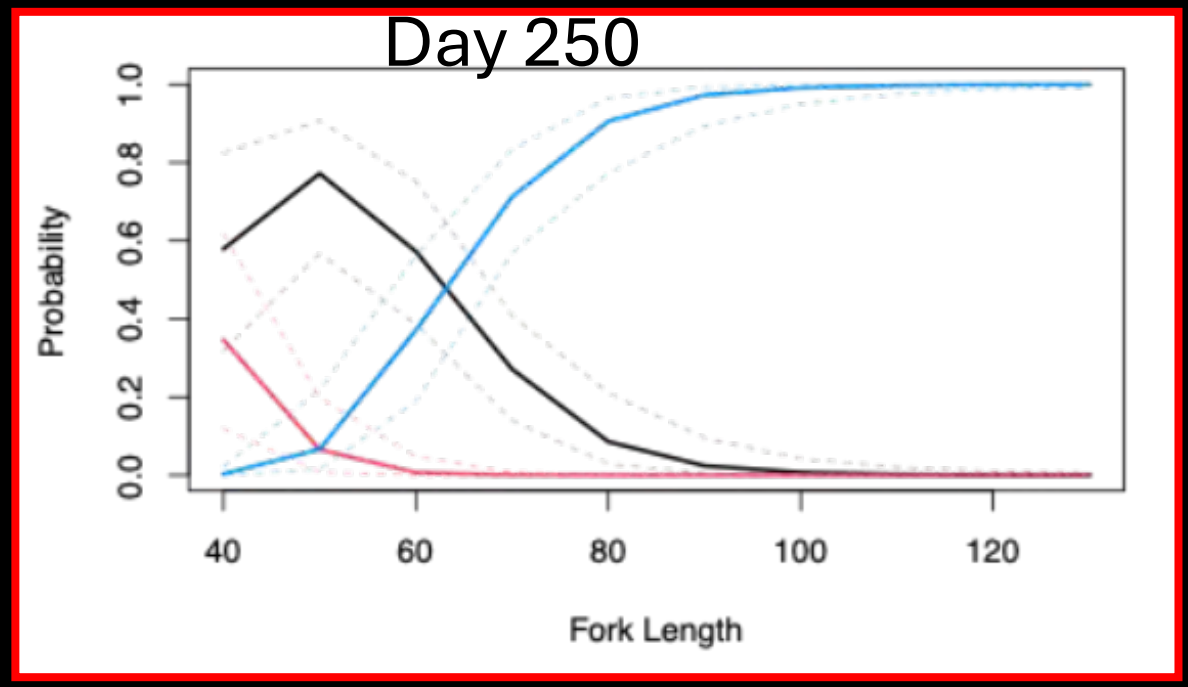
Preliminary results – do not cite

Length at Date: LAD



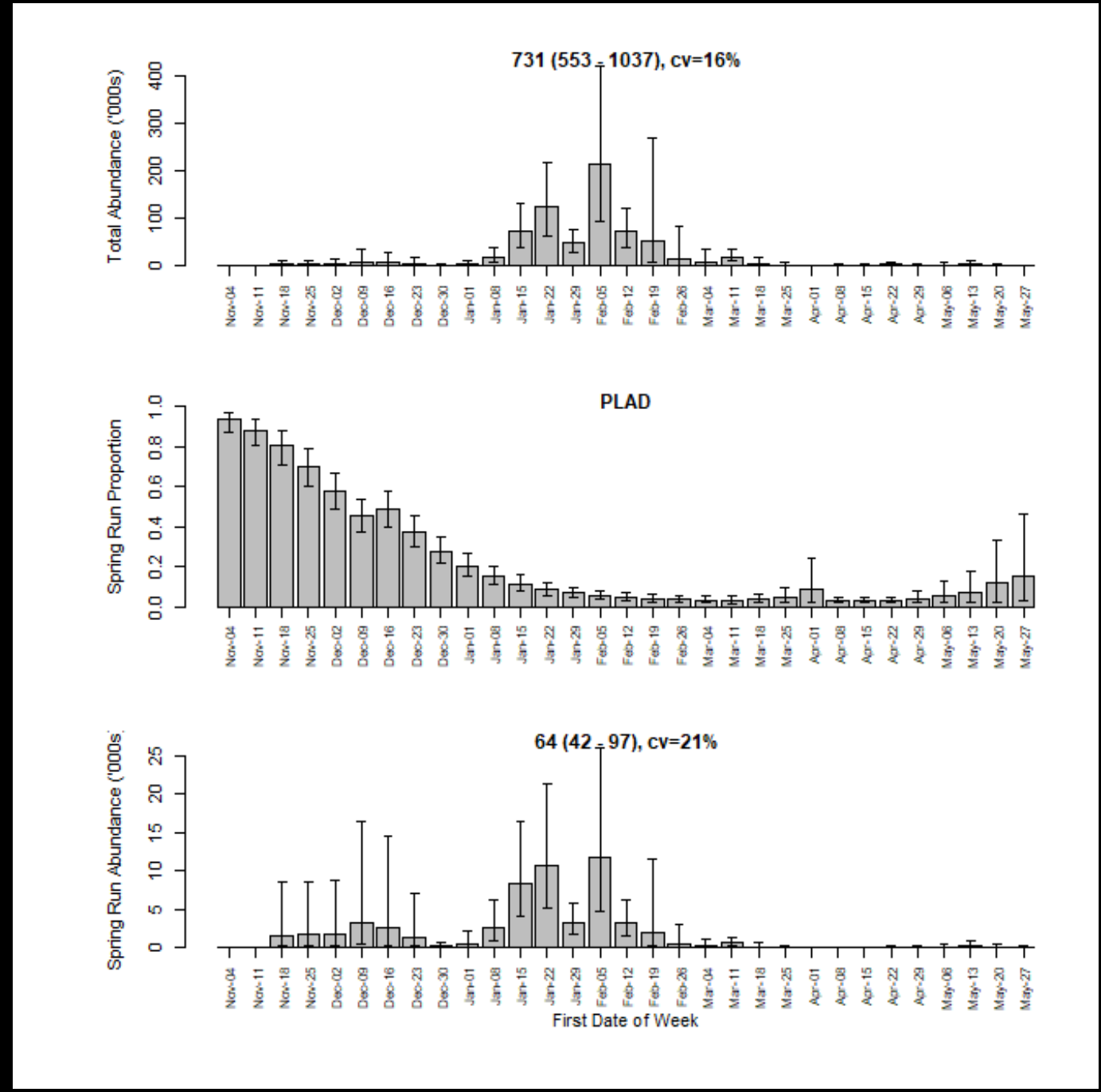
Probabilistic Length at Date: PLAD





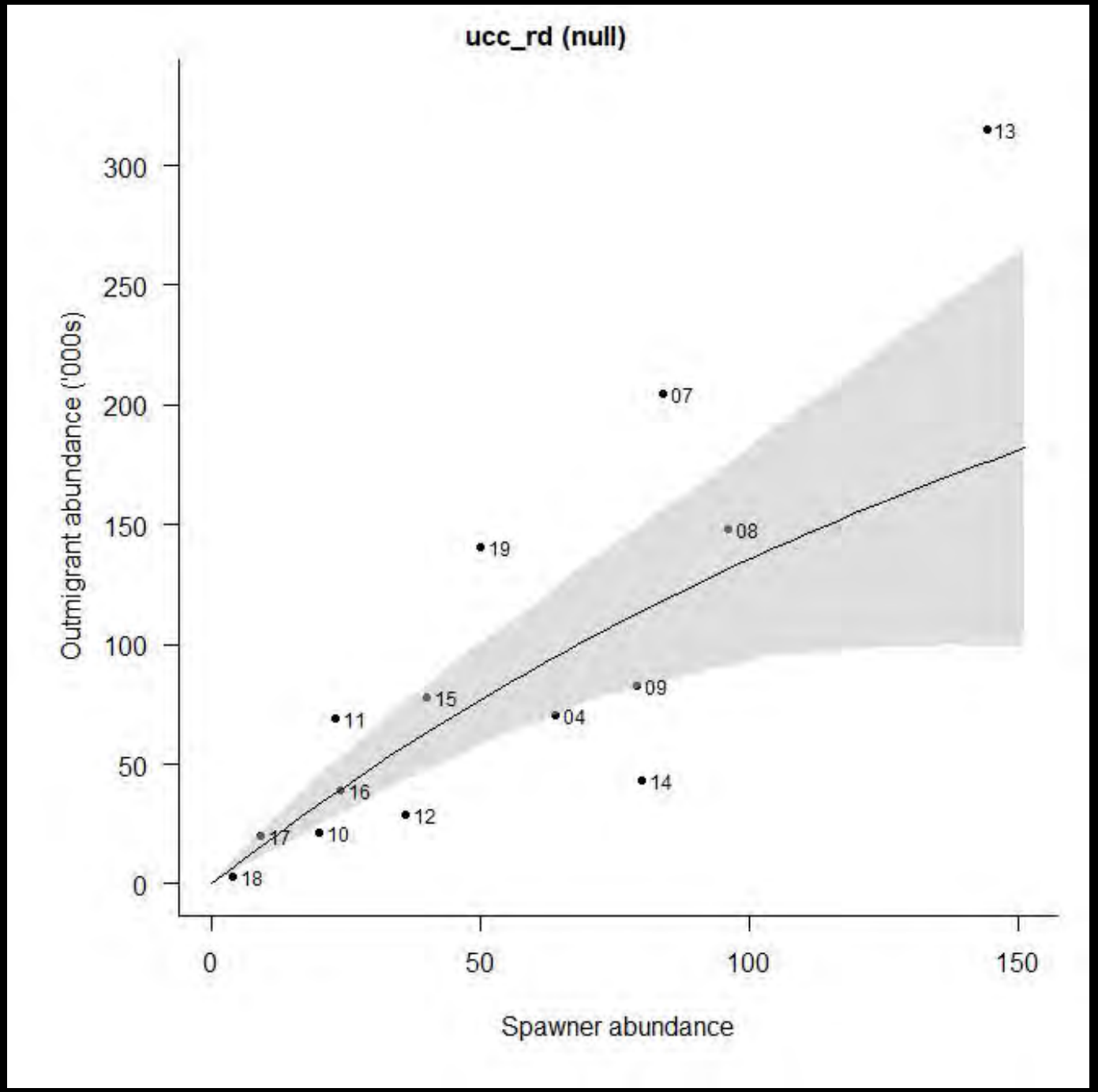
Preliminary results – do not cite

Putting it ALL Together



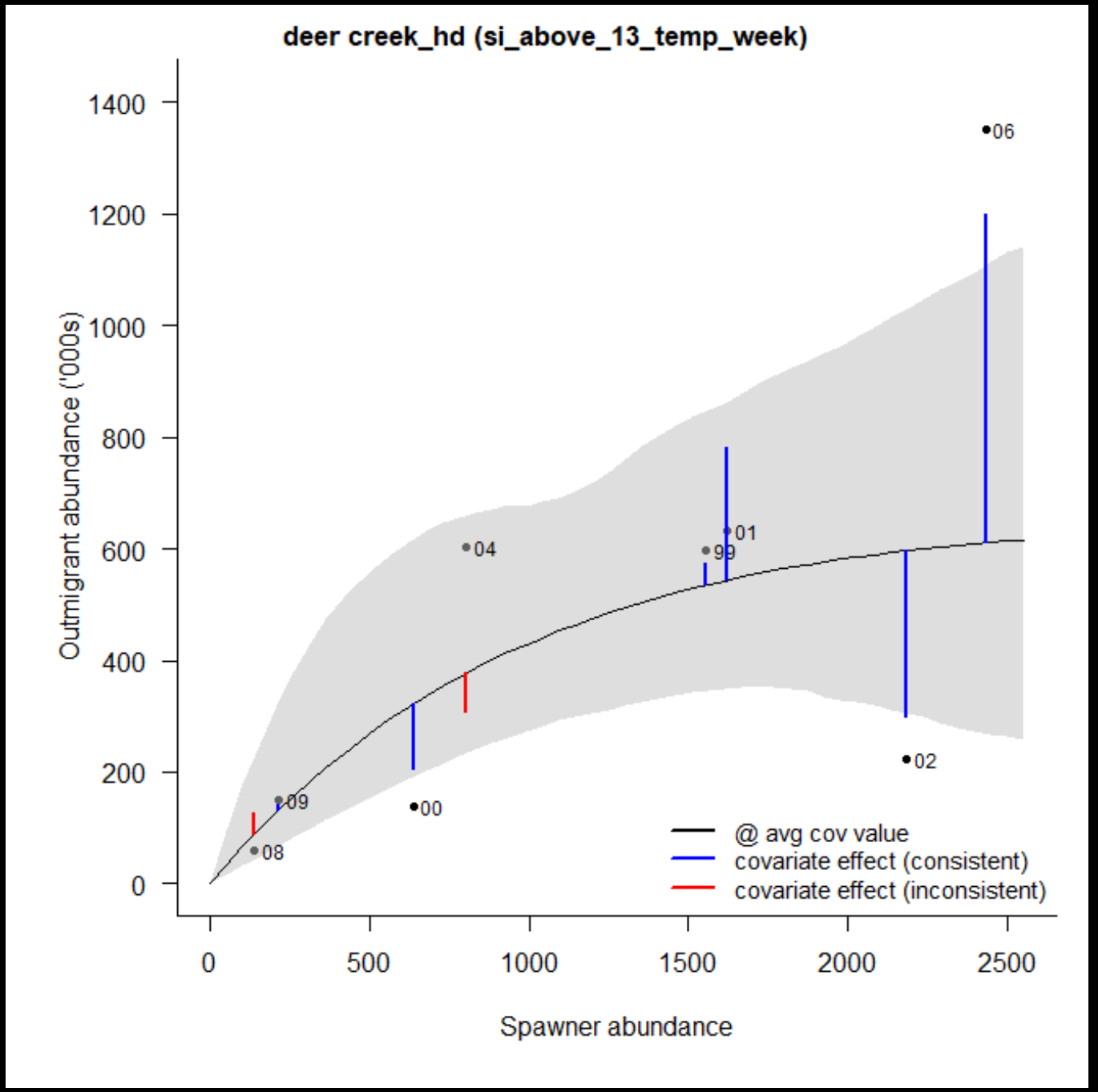
Preliminary results – do not cite

Stock-Recruit Example



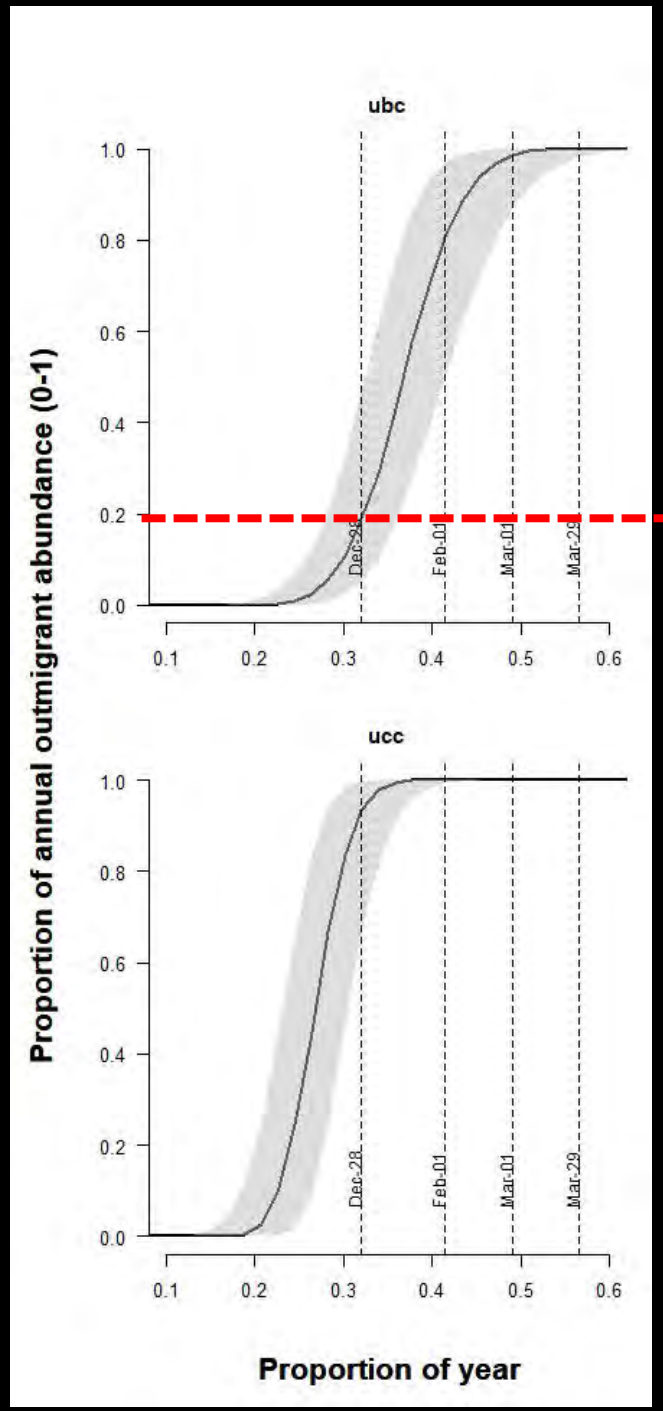
Preliminary results – do not cite

Stock-Recruit Example



Preliminary results – do not cite

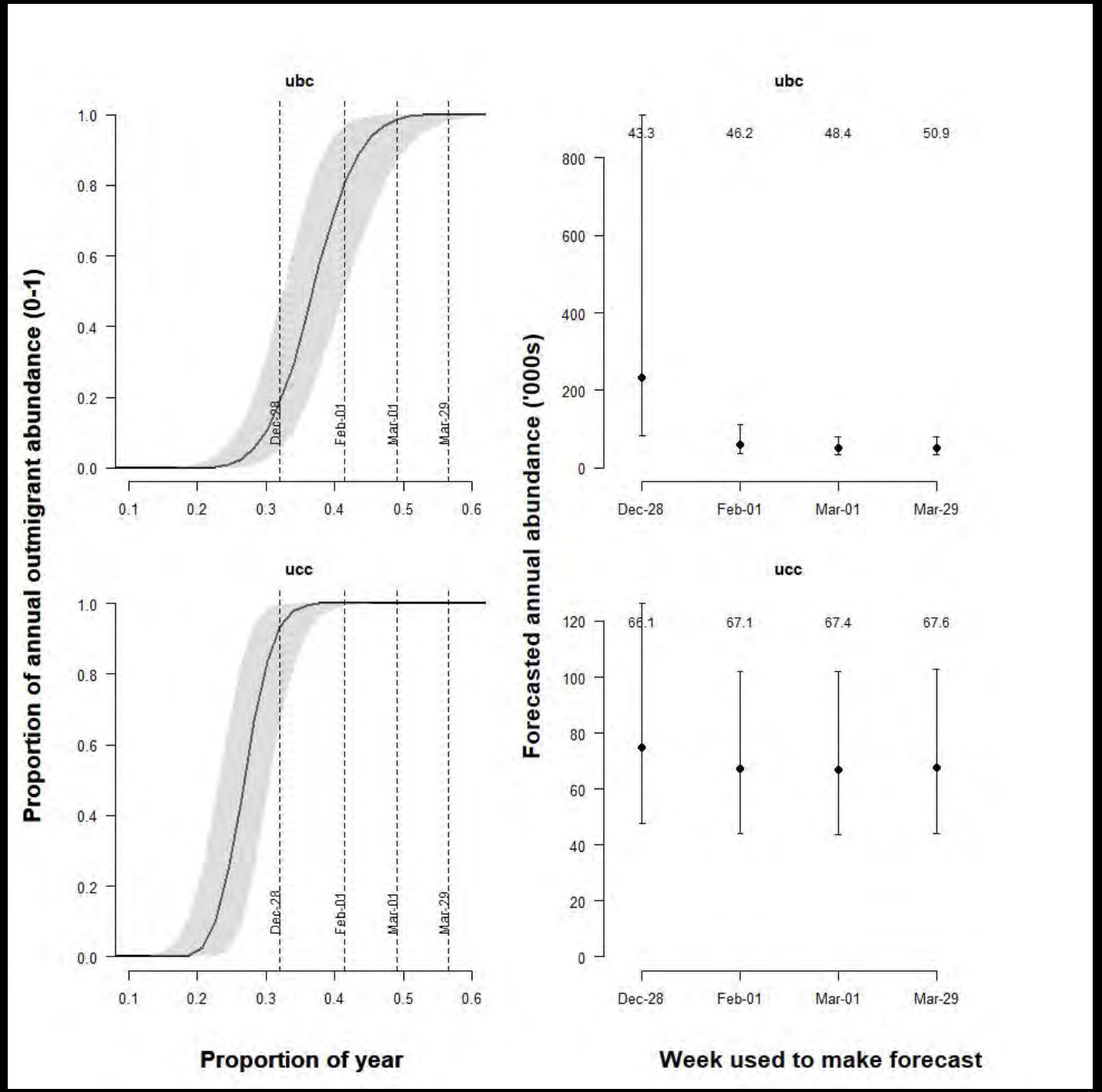
In-season Outmigrant Examples



$$\frac{Abund\ to\ date}{Proportion\ to\ date} = JPE$$

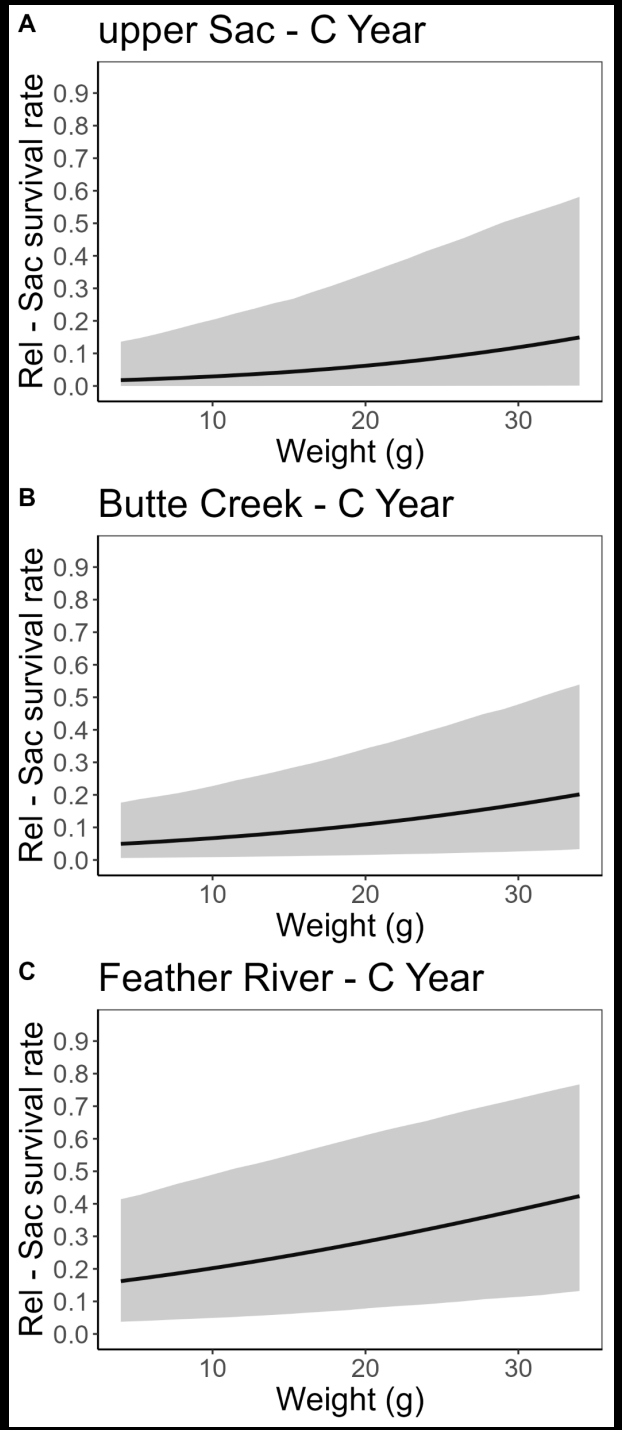
Preliminary results – do not cite

In-season Outmigrant Examples



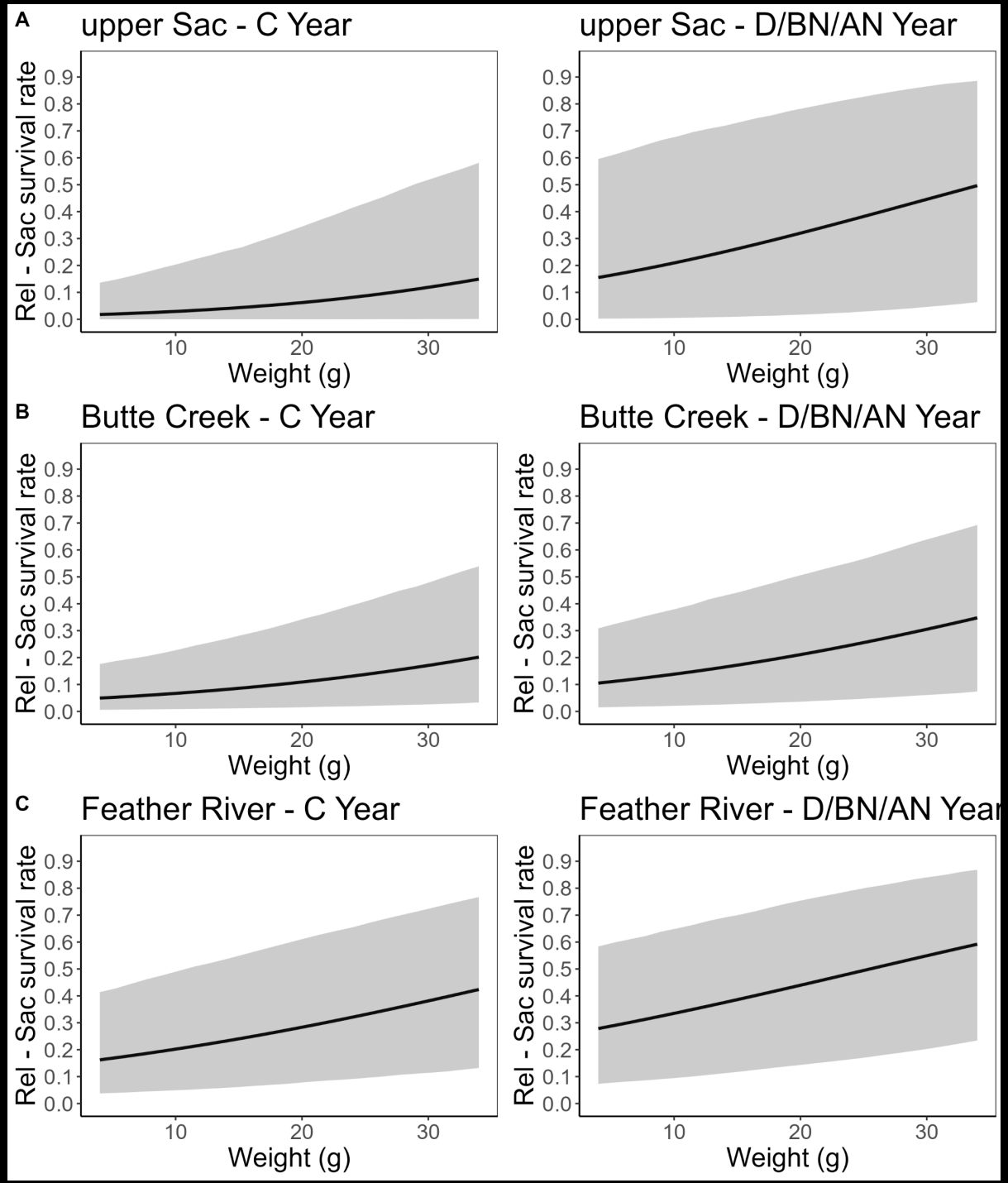
Preliminary results – do not cite

Survival forecasts



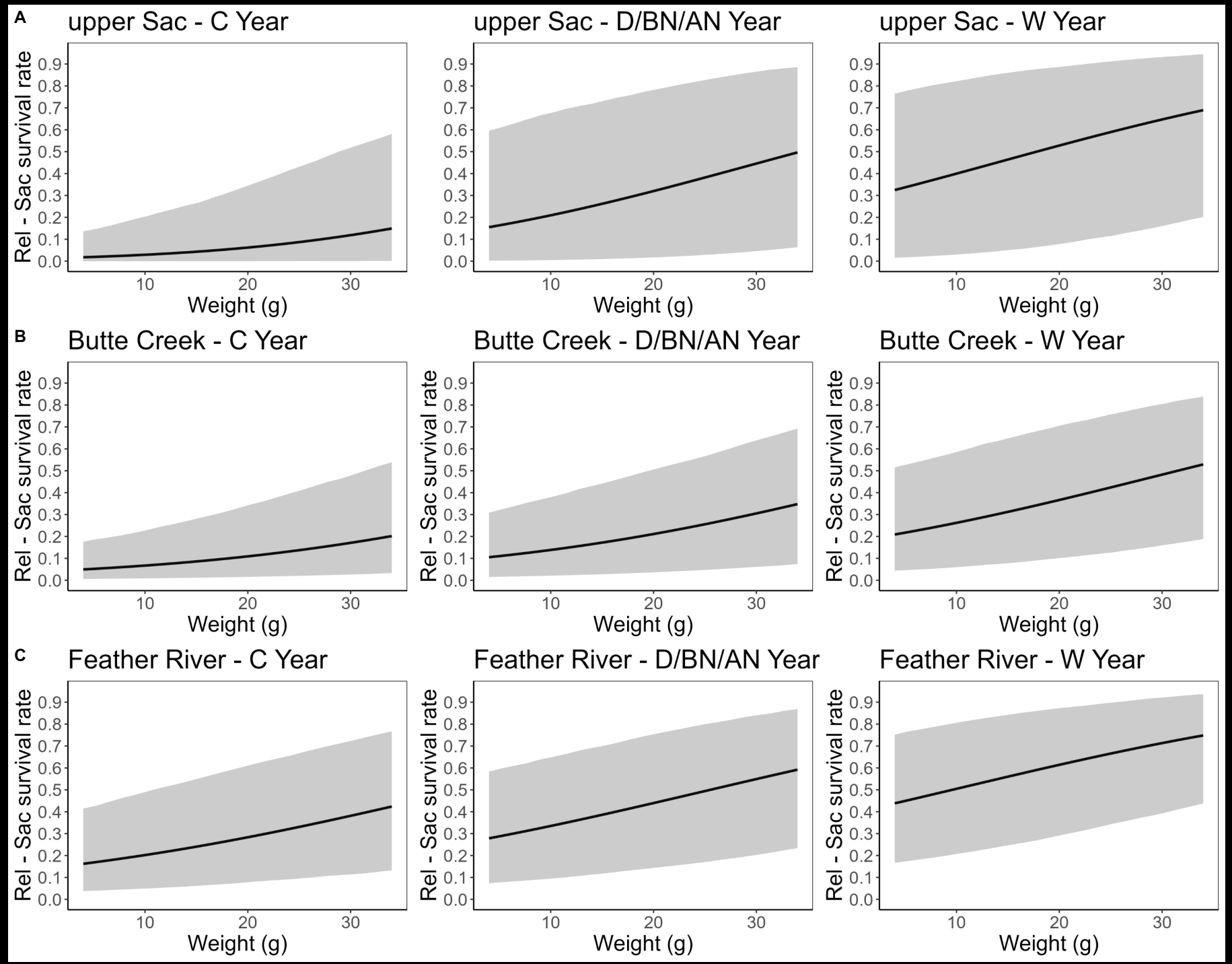
Preliminary results
do not cite

Survival forecasts



Preliminary results
do not cite

Survival forecasts



Preliminary results
do not cite

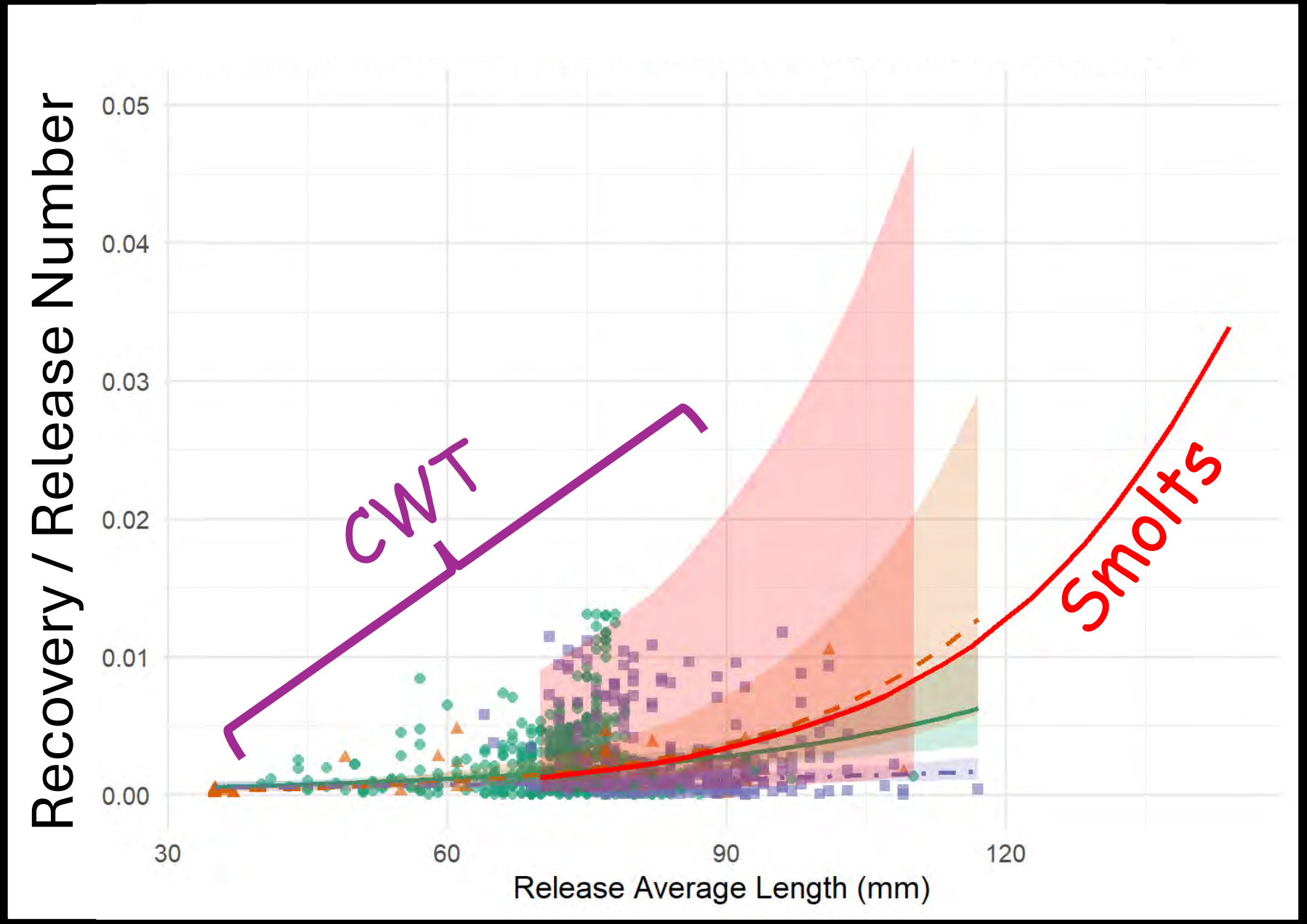
Migration Survival

Smolt ≠ Fry

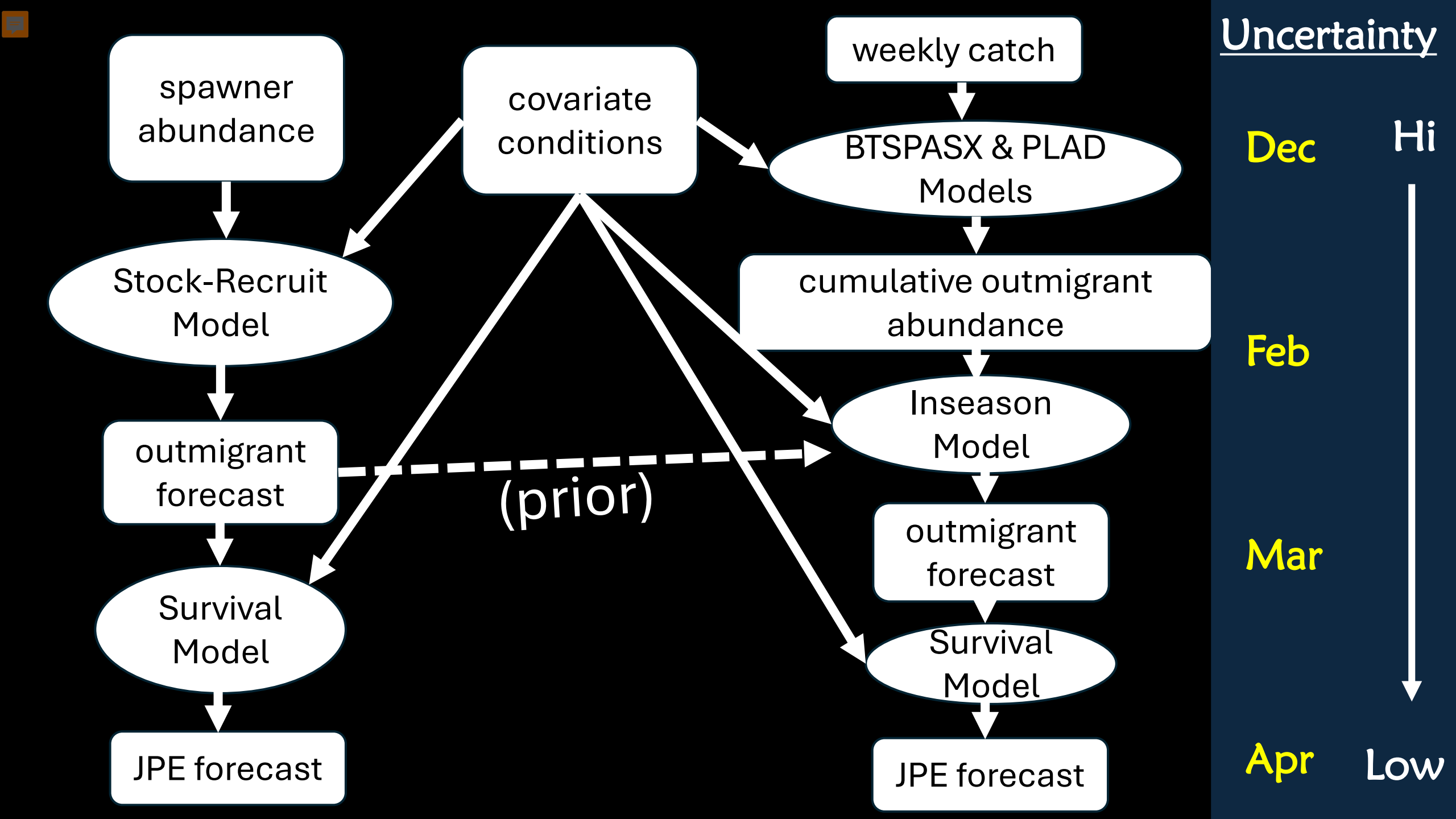


Photo: Naoaki Ikemiyagi

Fry Survival?



Preliminary results – do not cite


spawner abundance
covariate conditions
weekly catch
BTSPASX & PLAD Models
Stock-Recruit Model
cumulative outmigrant abundance
Inseason Model
outmigrant forecast
(prior)
outmigrant forecast
Survival Model
Survival Model
JPE forecast
JPE forecast
Uncertainty
Dec
Hi
Feb
Mar
Apr
Low

Thank You

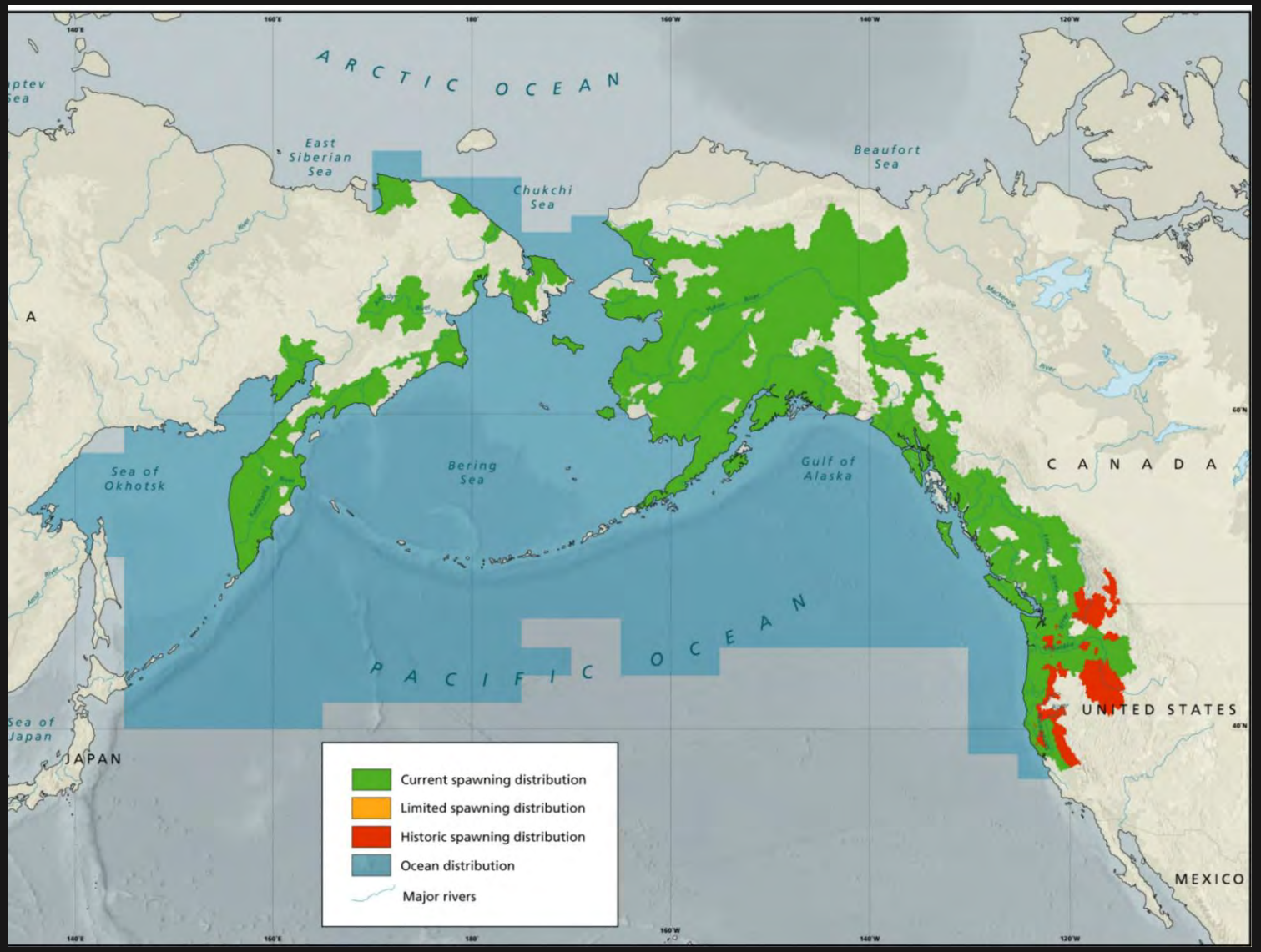


Uncovering genetic and life history resilience in spring-run Chinook salmon

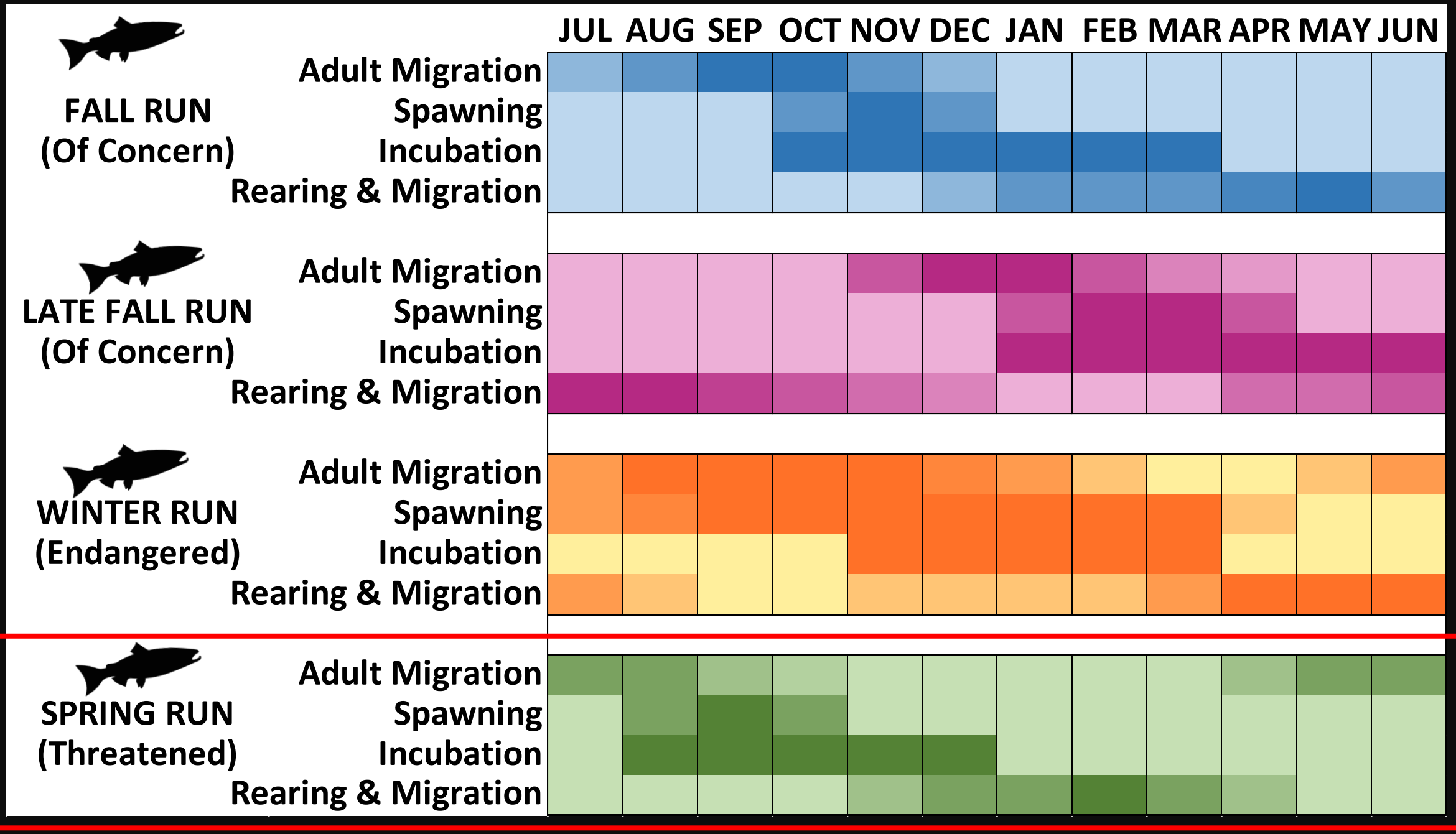
Flora Cordoleani, Malte Willmes, Anna Sturrock, George Whitman, Mariah Meek, Sarah Hugentobler, Carson Jeffres, Rachel Johnson

UC SANTA CRUZ NINA UCDAVIS CENTER FOR WATERSHED SCIENCES MICHIGAN STATE UNIVERSITY

CV Chinook Salmon at the southern end of their range



Wild Salmon Center


JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
FALL RUN
(Of Concern)
Adult Migration
Spawning
Incubation
Rearing & Migration
LATE FALL RUN
(Of Concern)
Adult Migration
Spawning
Incubation
Rearing & Migration
WINTER RUN
(Endangered)
Adult Migration
Spawning
Incubation
Rearing & Migration
SPRING RUN
(Threatened)
Adult Migration
Spawning
Incubation
Rearing & Migration

Spring-run Chinook life cycle

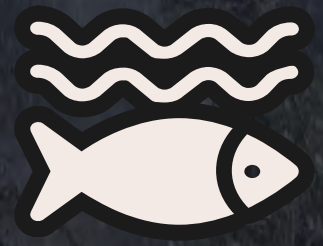
Freshwater entry

April - July



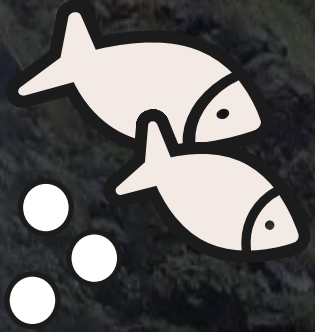
Over-summering

Summer



Spawning

August - November



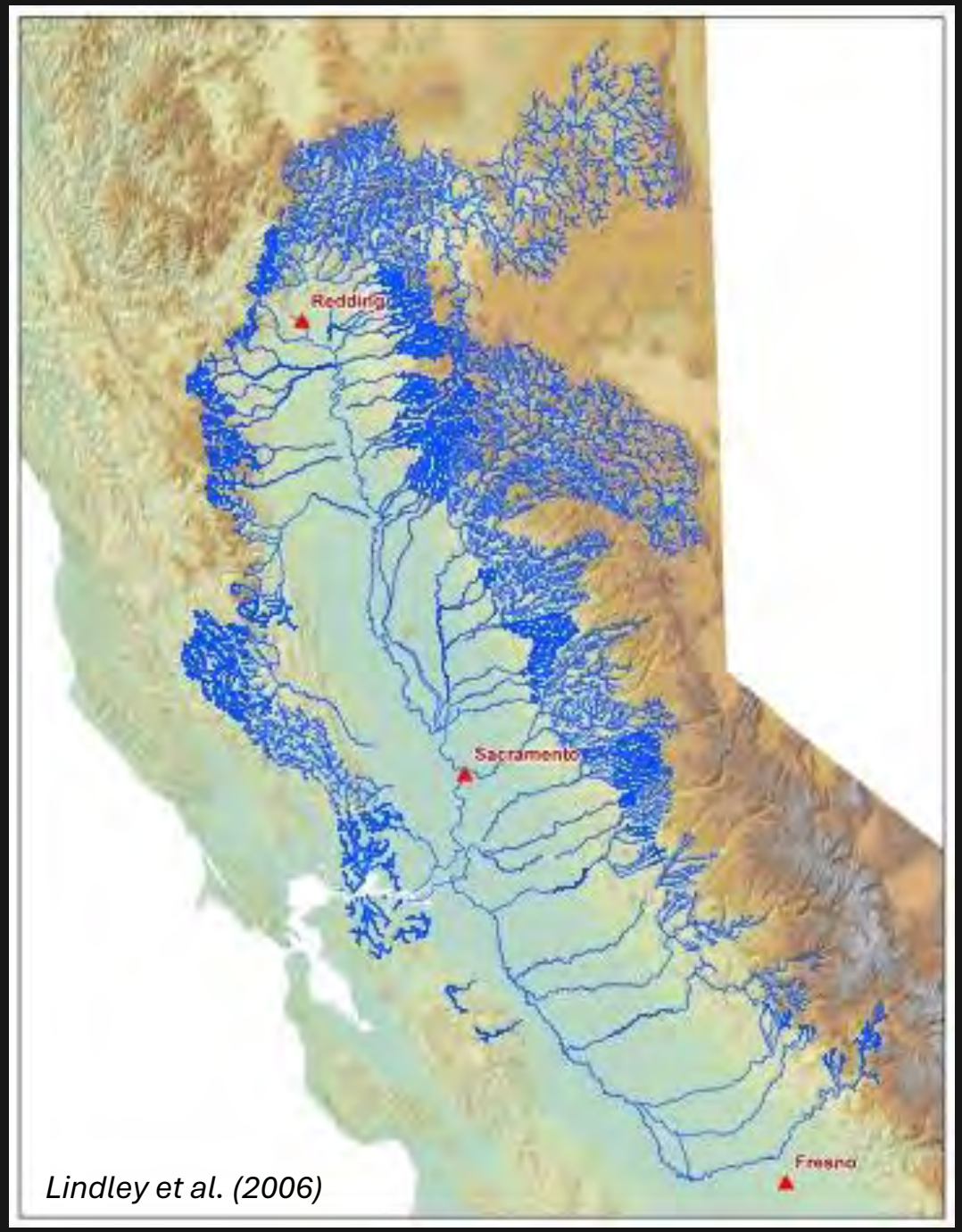
Fry Emergence

Fall



NOAA Fisheries

Before: diverse habitat mosaic



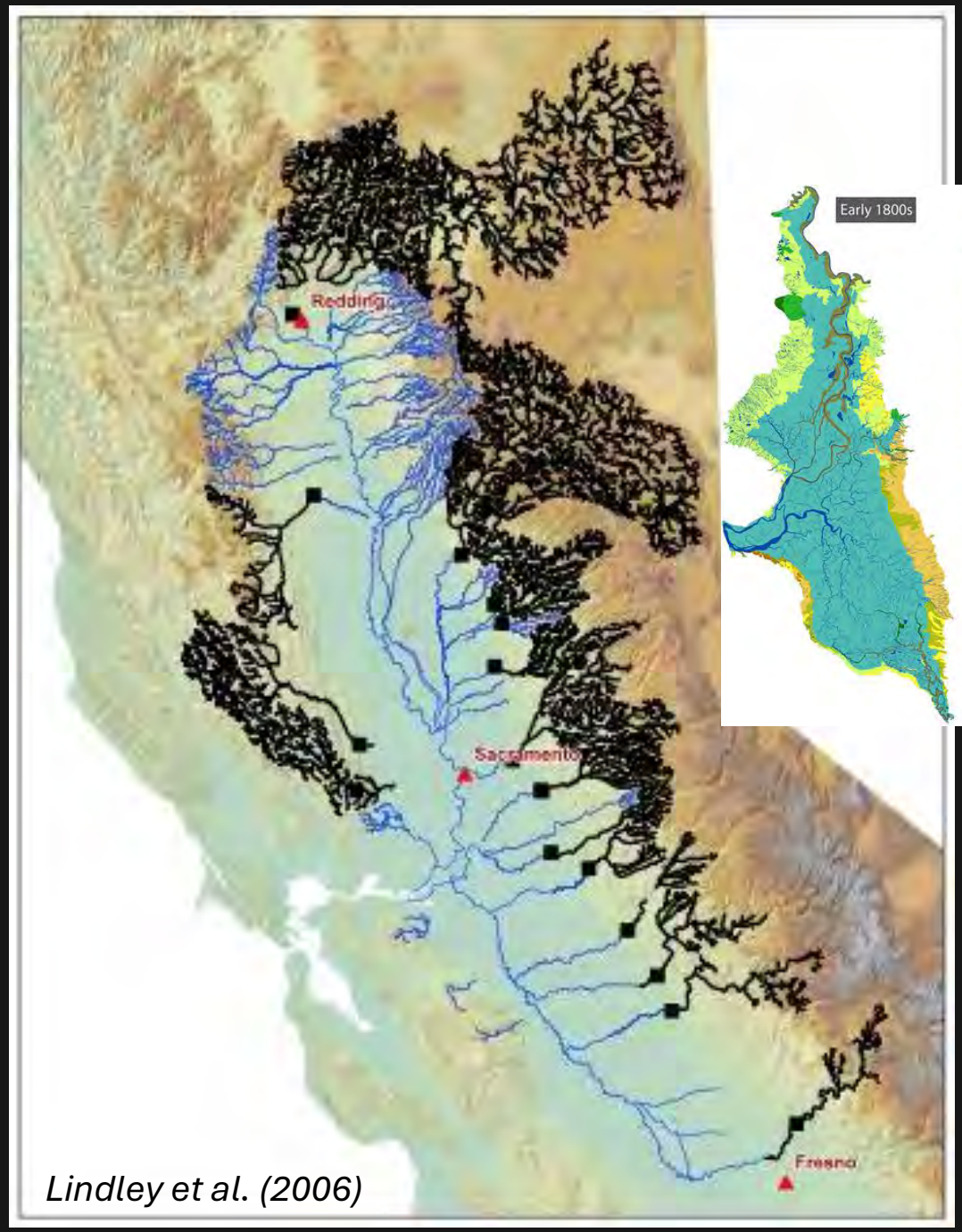
Lindley et al. (2006)



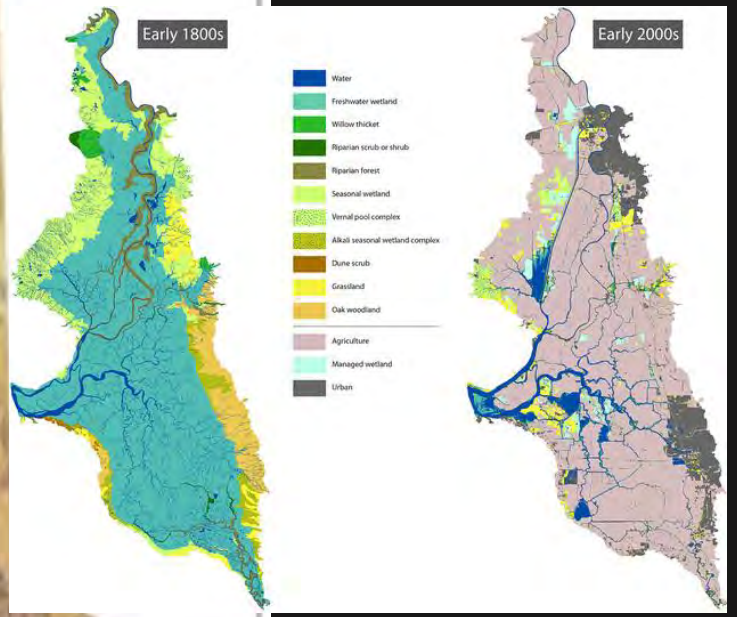




Now: highly altered and disconnected landscape



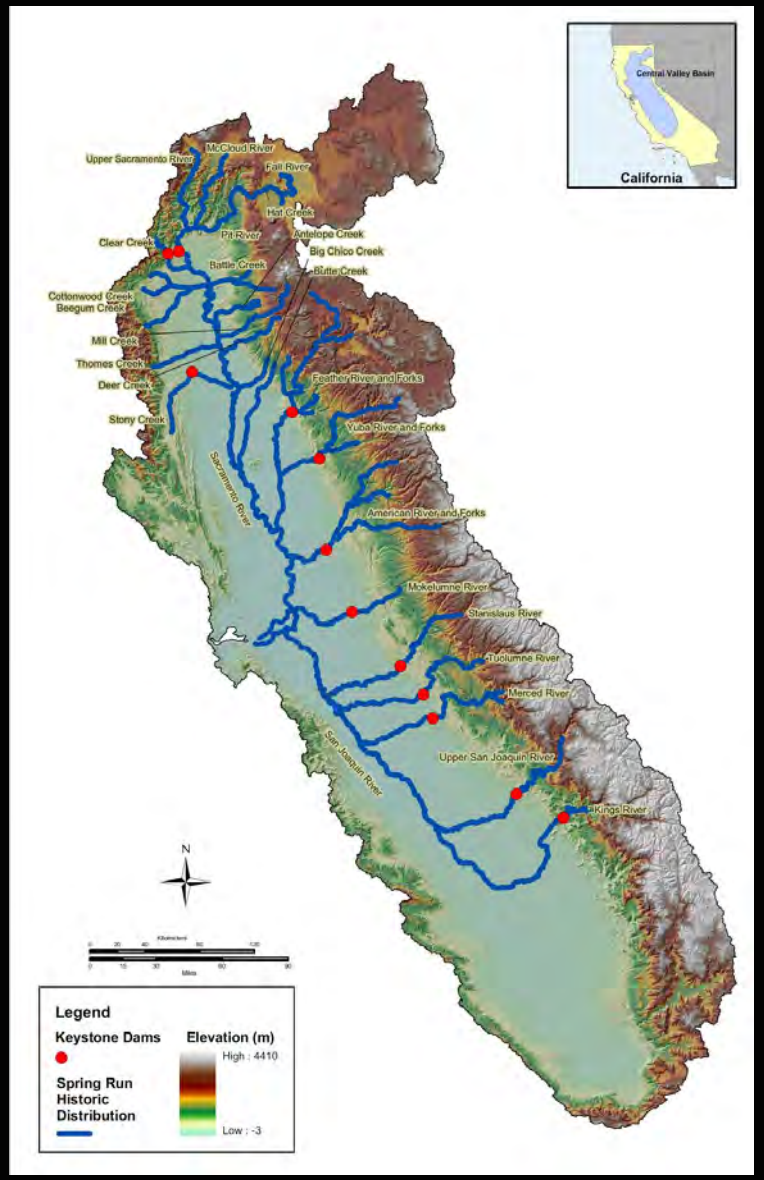
Lindley et al. (2006)







Before: vast distribution of spring-run Chinook



Lindley et al. 2006

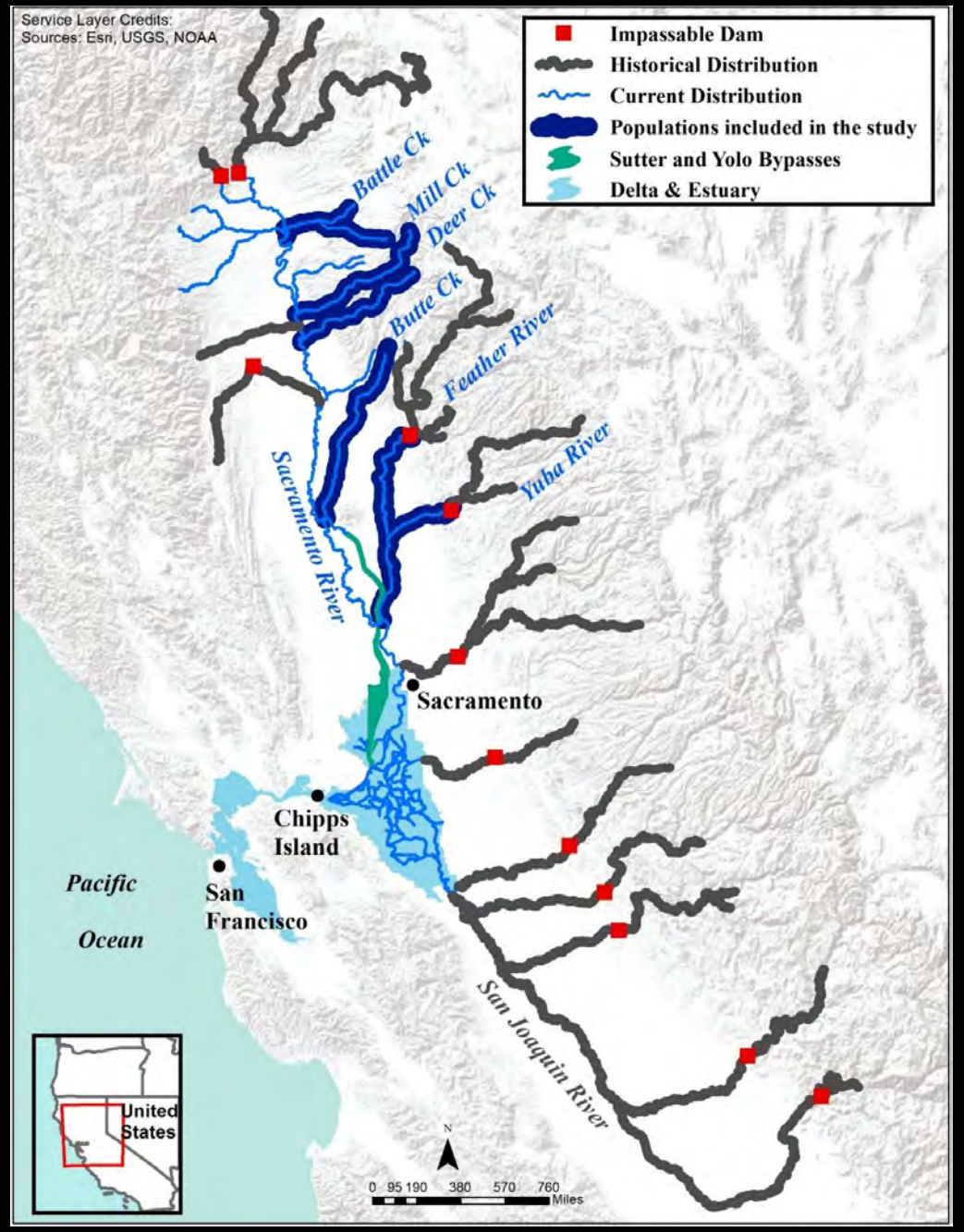


A Maidu village on the Feather River during the spring and fall salmon run, 1850 (Killackey illustration and design)

Now: threatened stock with limited spatial distribution

Remaining populations

- Mill/Deer Creek
- Butte Creek
- Battle Creek
- Yuba River
- Feather River (hatchery)

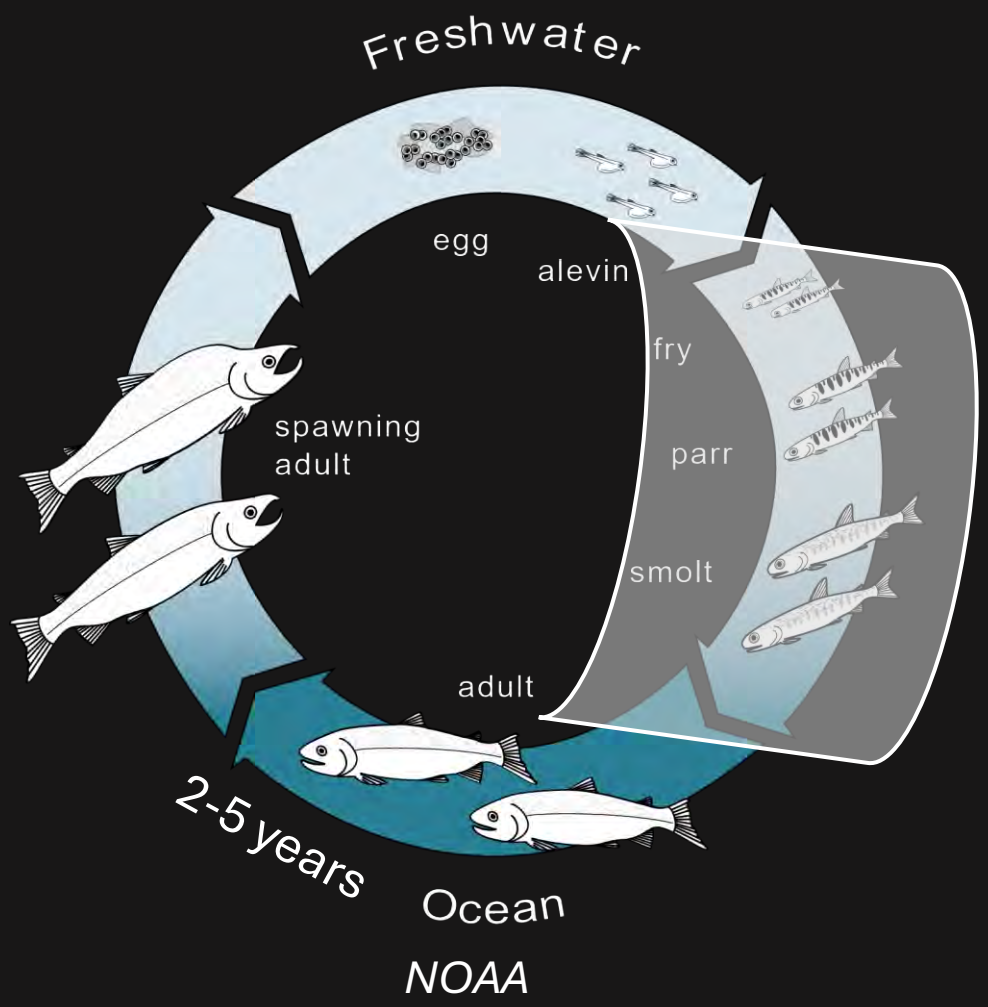


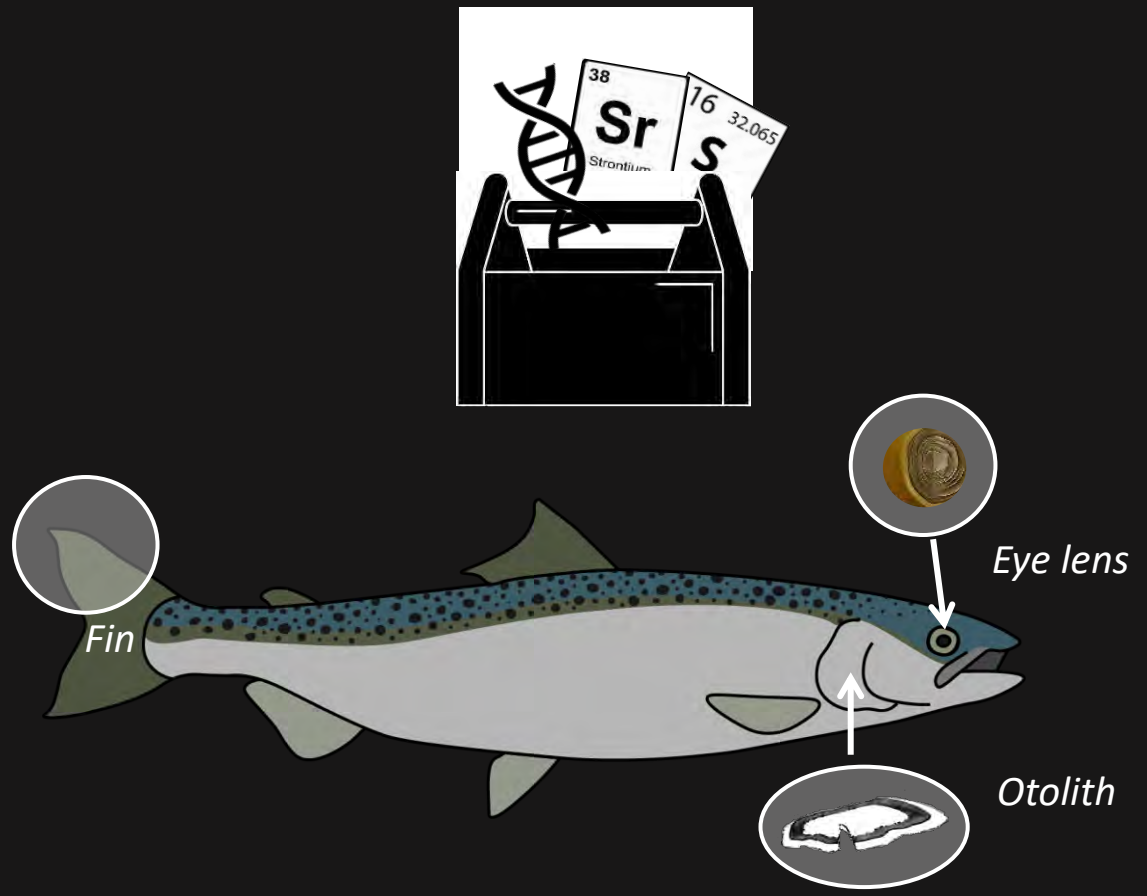
How does life history diversity help spring-run populations cope with the California warming climate and altered landscape?





Salmon Natural Tag Toolbox





Carcass surveys





Photo credit: Matt Johnson, CDFW



Studying the survivors



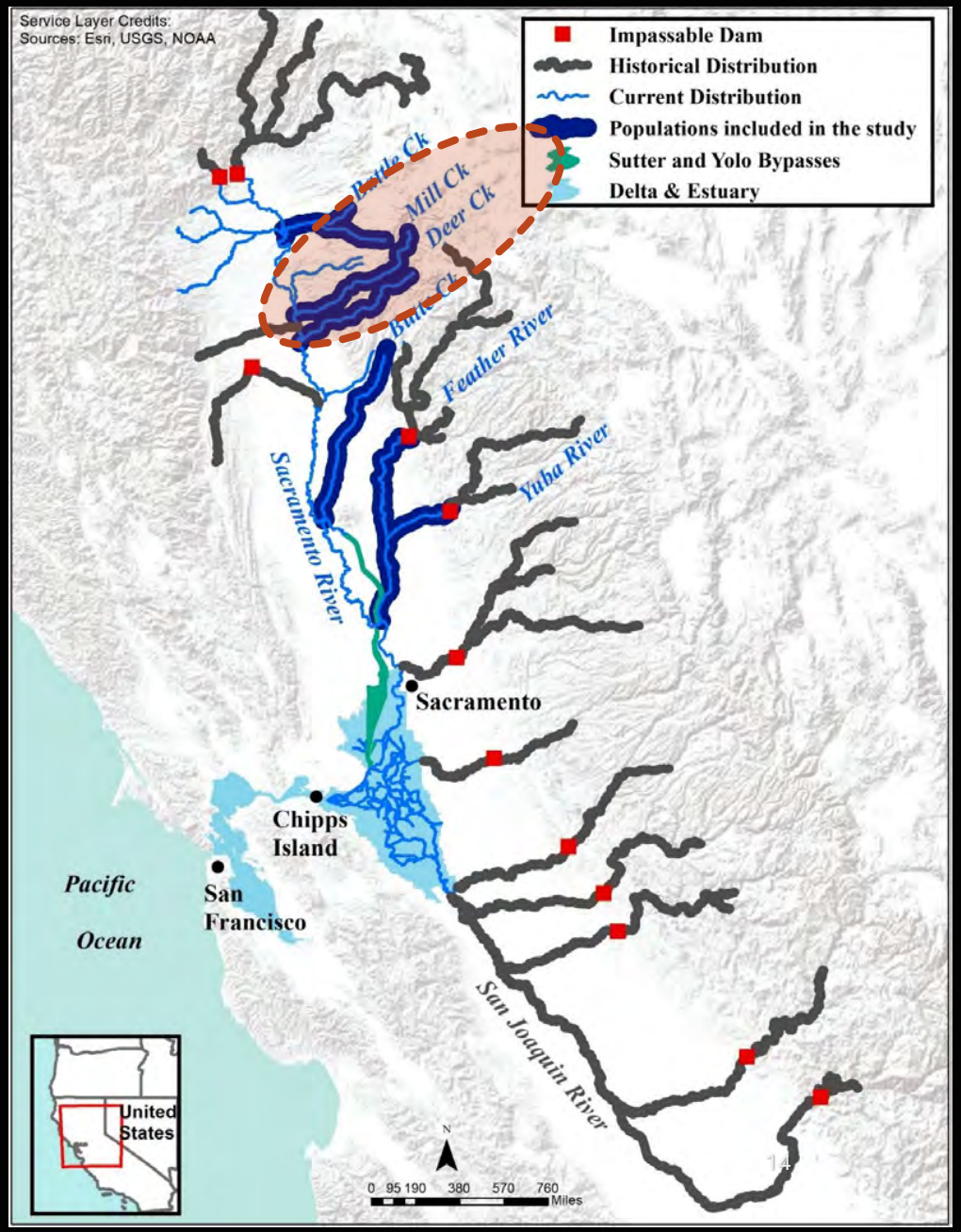
Studying the survivors





Spring-run populations

- Mill/Deer Creek
- Butte Creek
- Battle Creek
- Yuba River
- Feather River

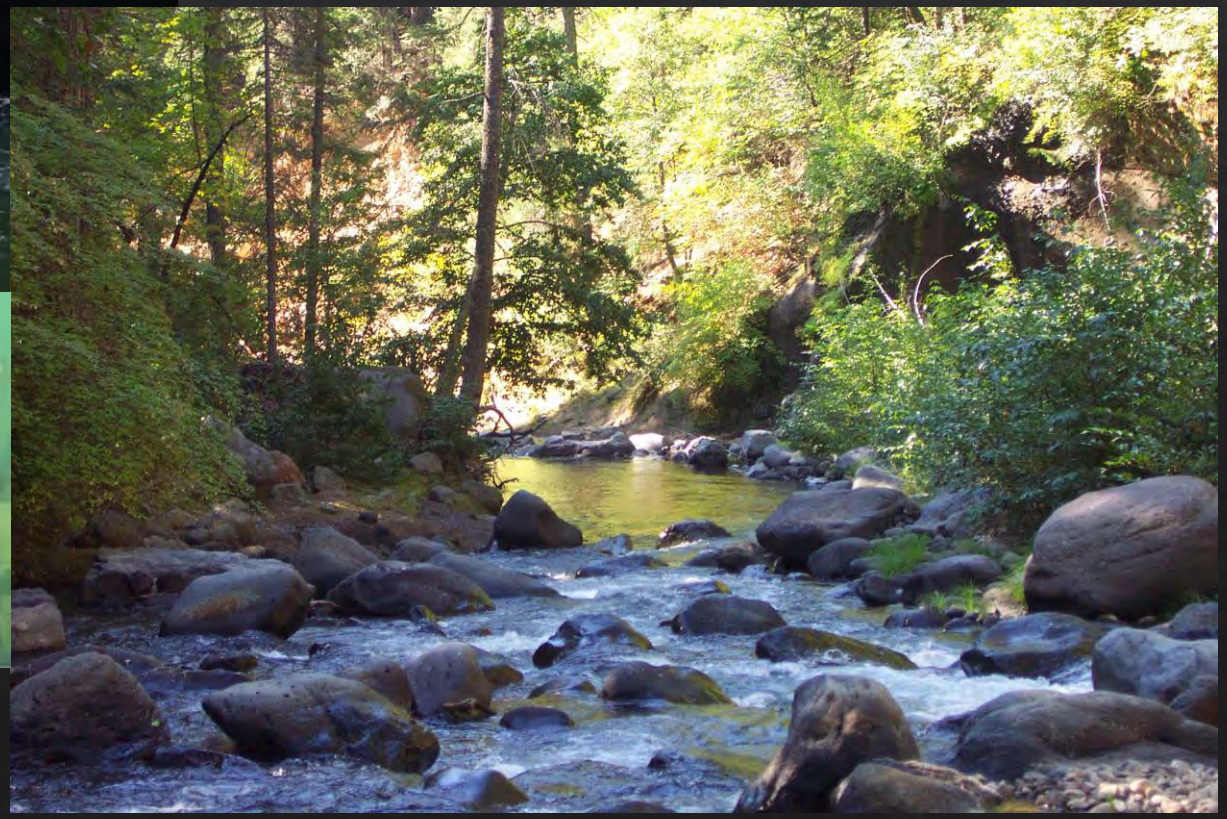


Pristine habitat





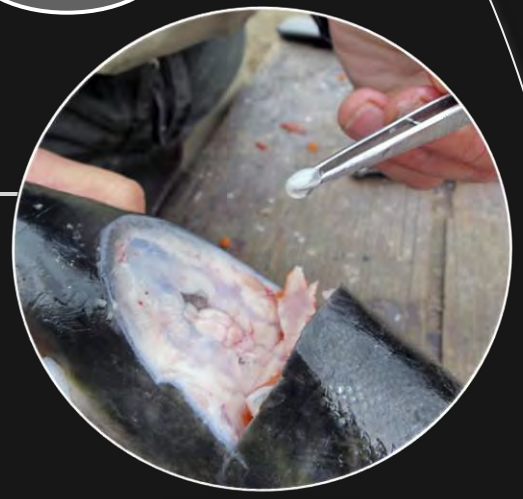
Holding pool in upper Deer Creek - CDFW



National Fish Habitat Partnership

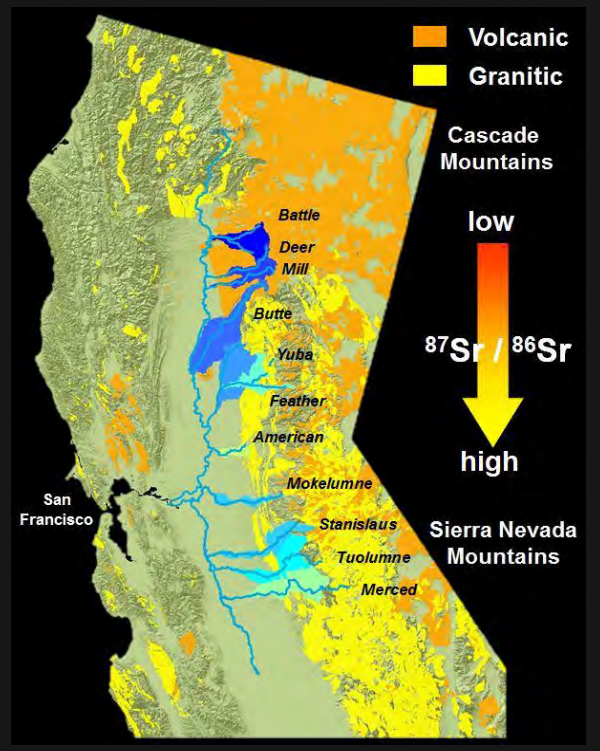
Otolith tools





- Non-natal (freshwater) rearing
- Juvenile migration timing/size
- Habitat specific growth rates
- Natal origins

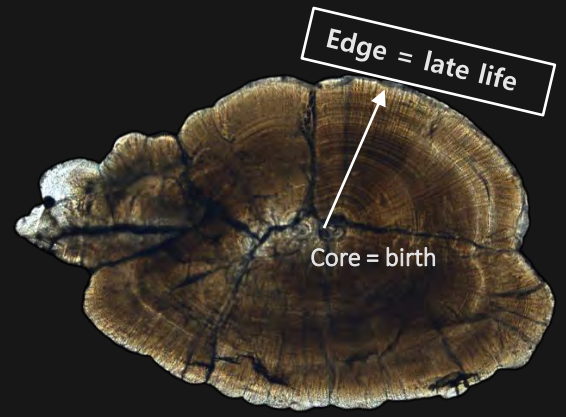
$^{87}Sr/^{86}Sr$ ISOSCAPE



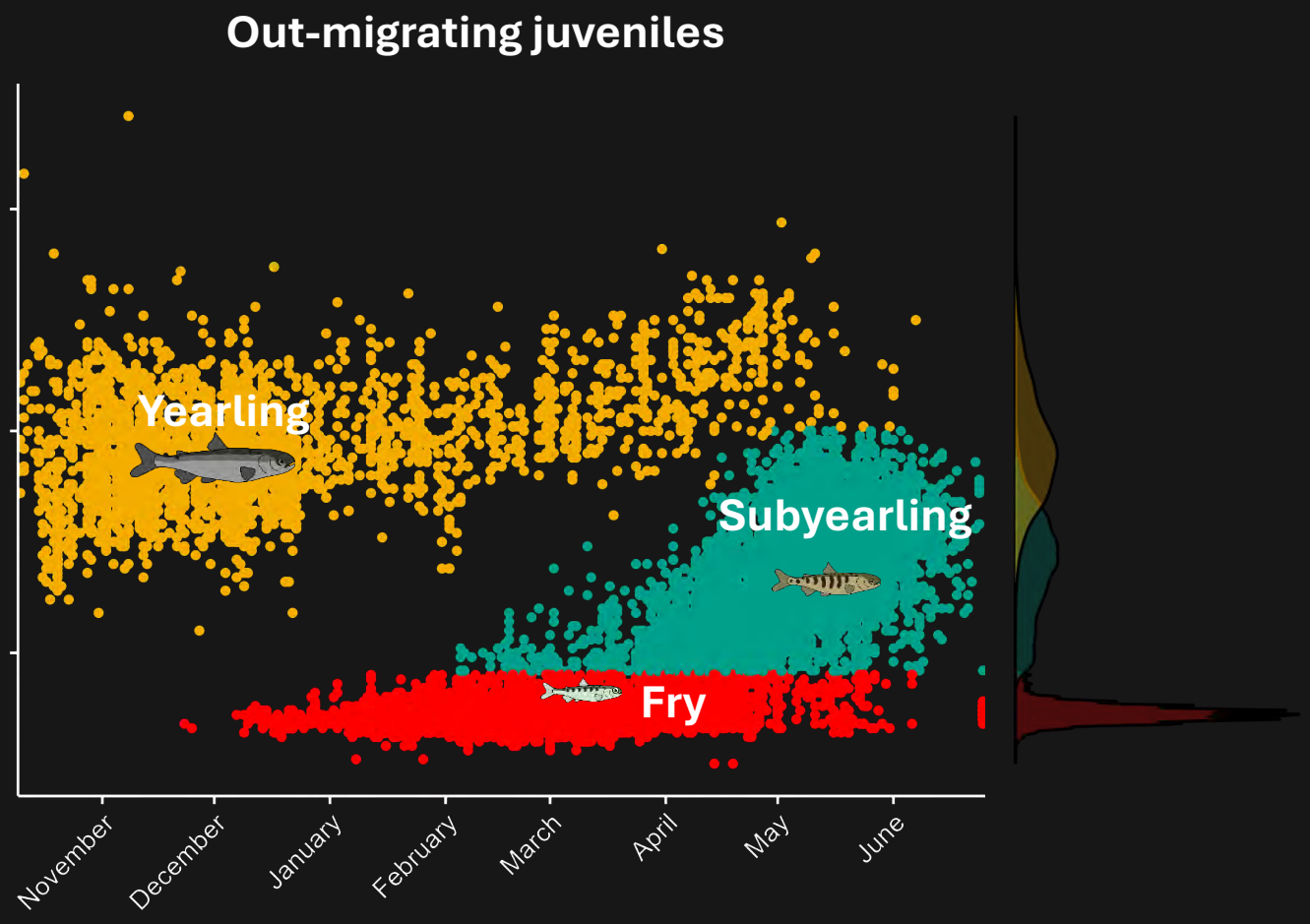
Hobson, Barnett-Johnson and Cerling, 2009

Geochemical analyses





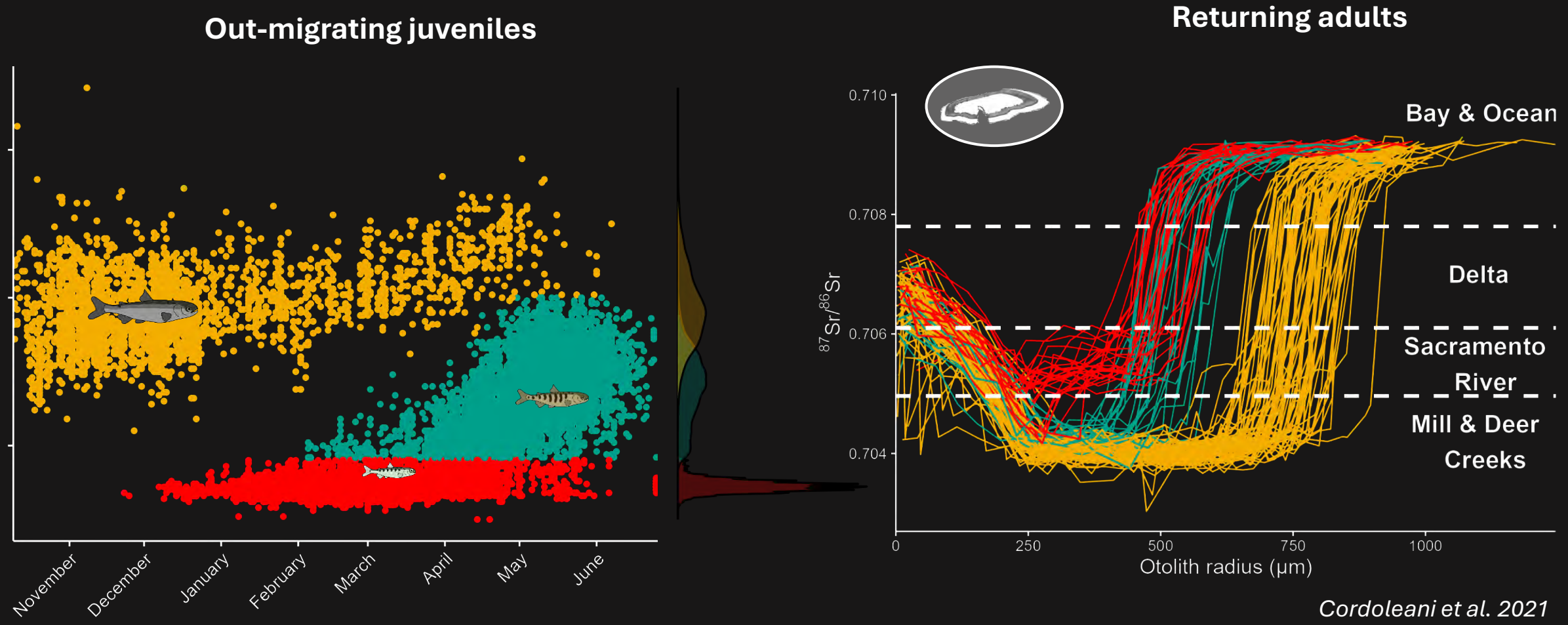
RST information



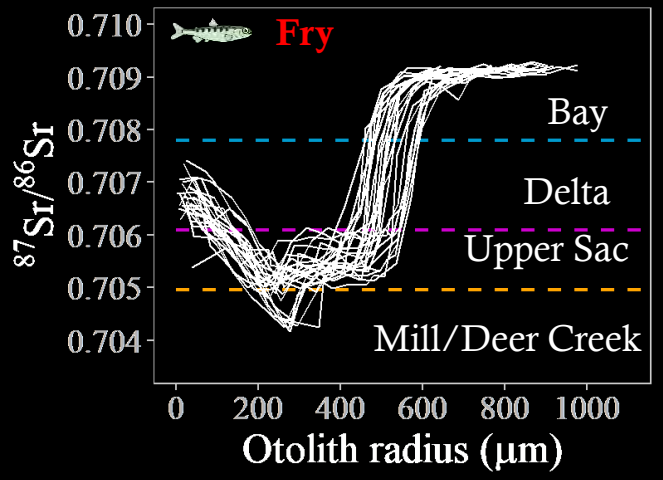


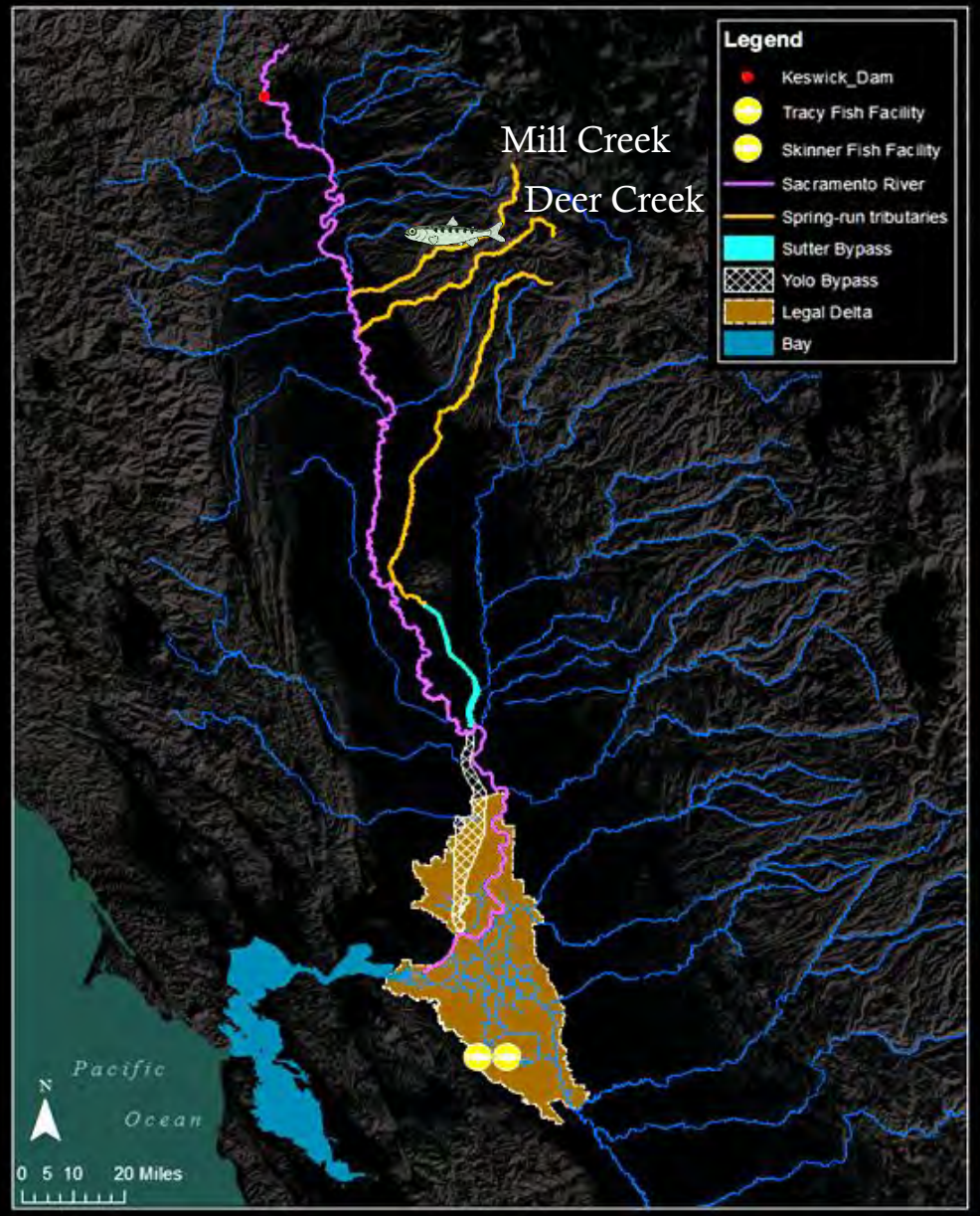
Rotary screw trap (USFWS 2010)

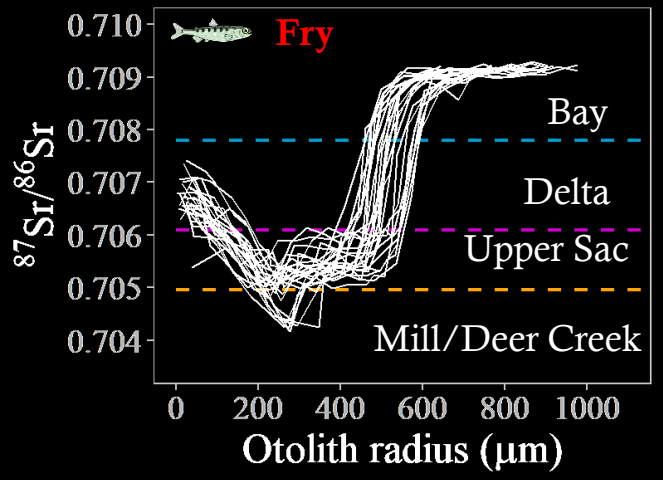
Multiple juvenile strategies among adults

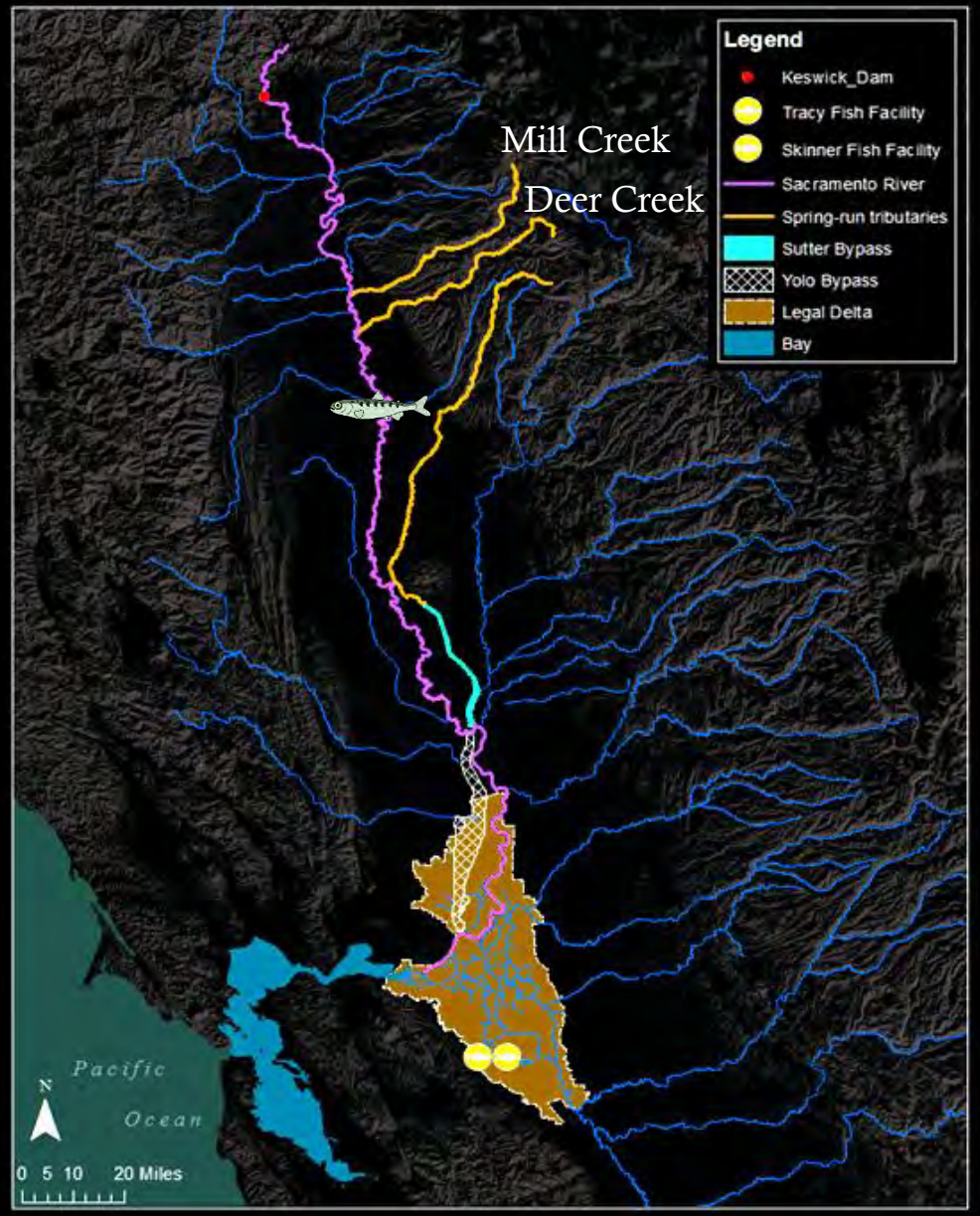


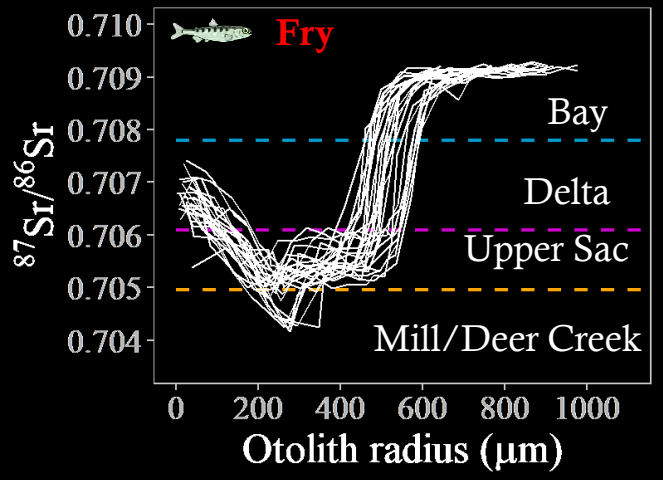
Cordoleani et al. 2021

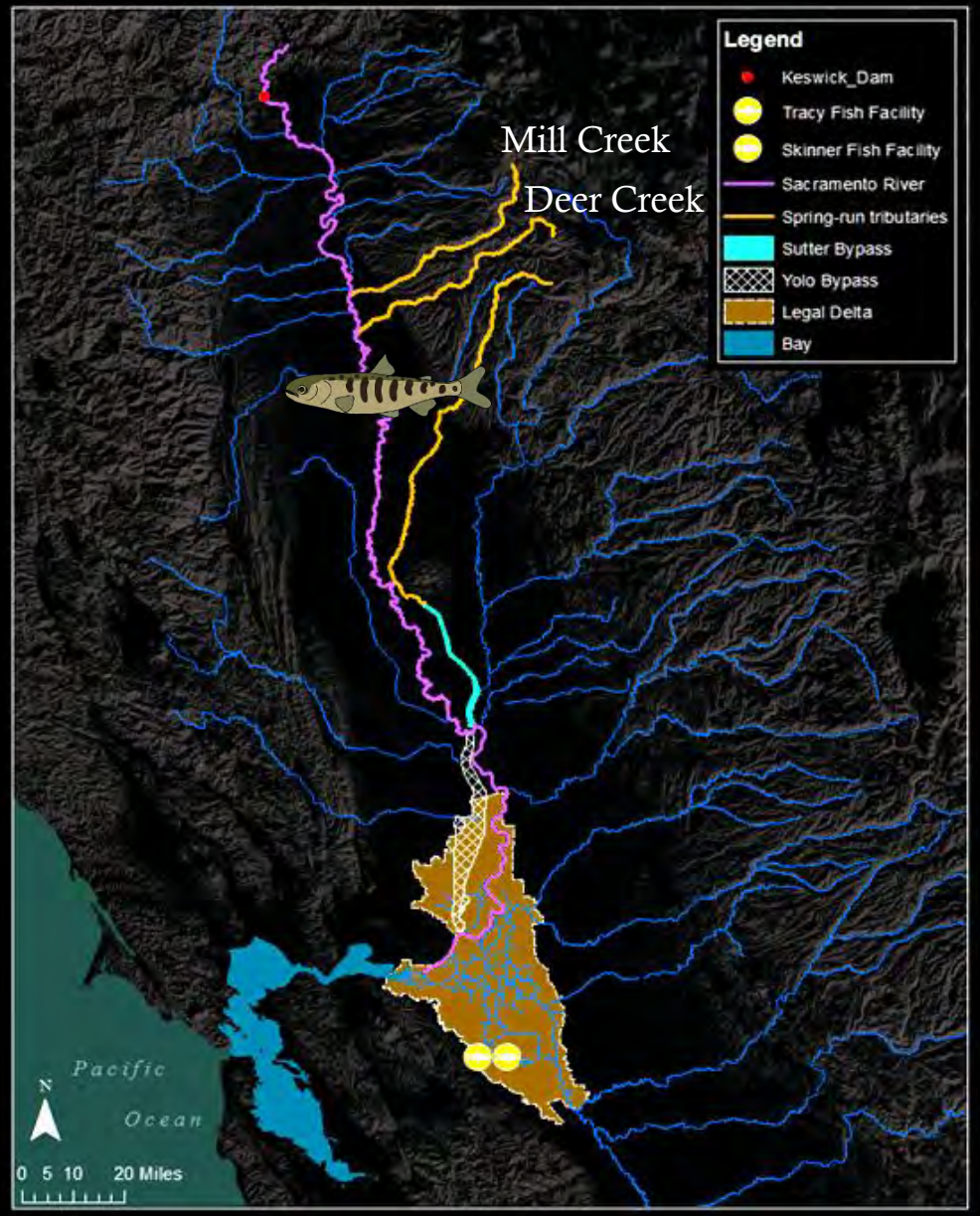

Fry
Bay
Delta
Upper Sac
Mill/Deer Creek
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$^{87}Sr/^{86}Sr$
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Otolith radius (μm)

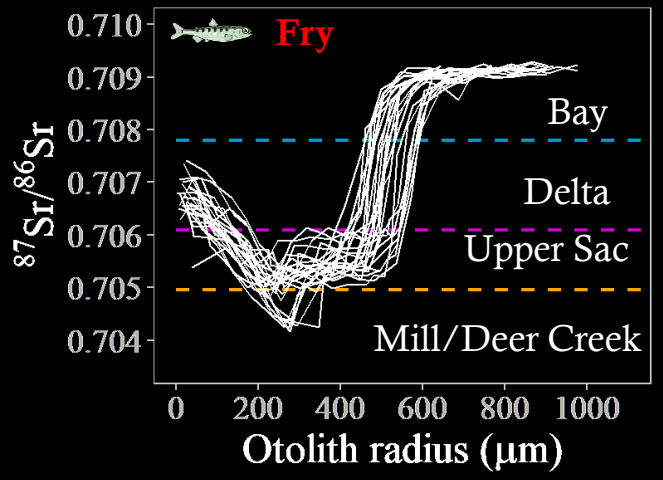

Legend
Keswick_Dam
Tracy Fish Facility
Skinner Fish Facility
Sacramento River
Spring-run tributaries
Sutter Bypass
Yolo Bypass
Legal Delta
Bay
Mill Creek
Deer Creek
Pacific
Ocean
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0 5 10 20 Miles

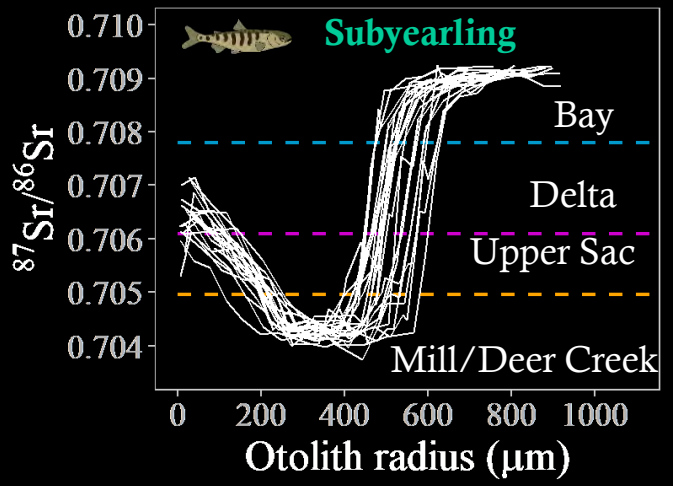

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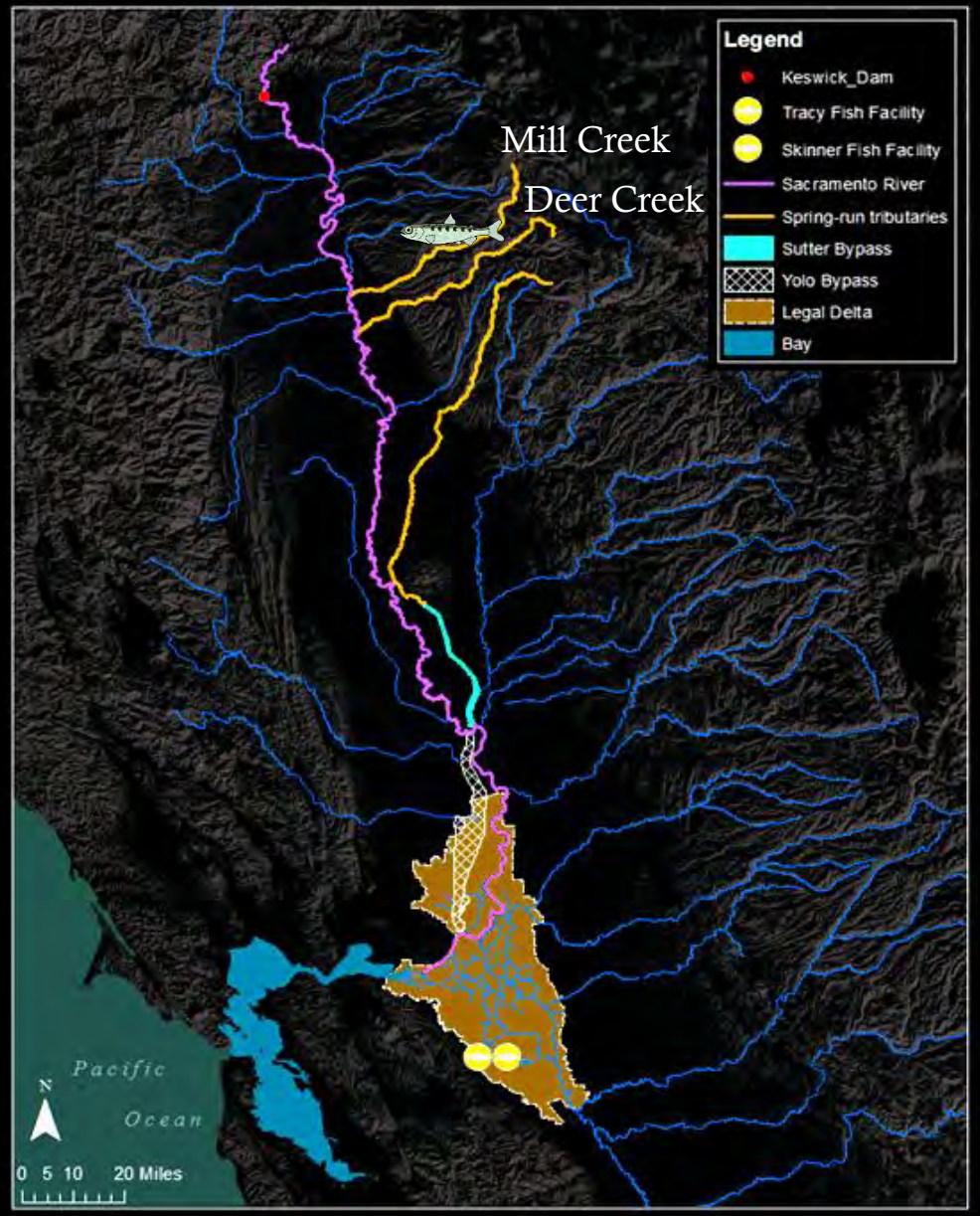

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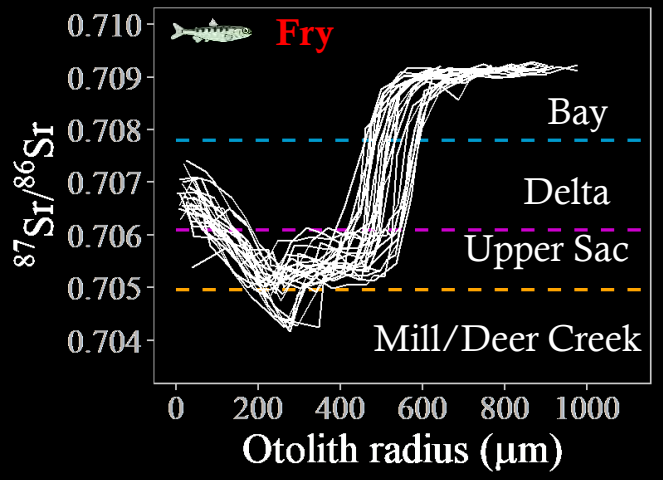

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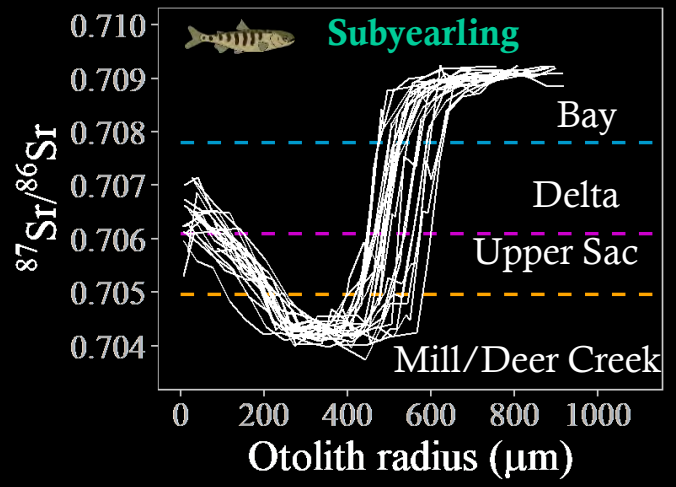

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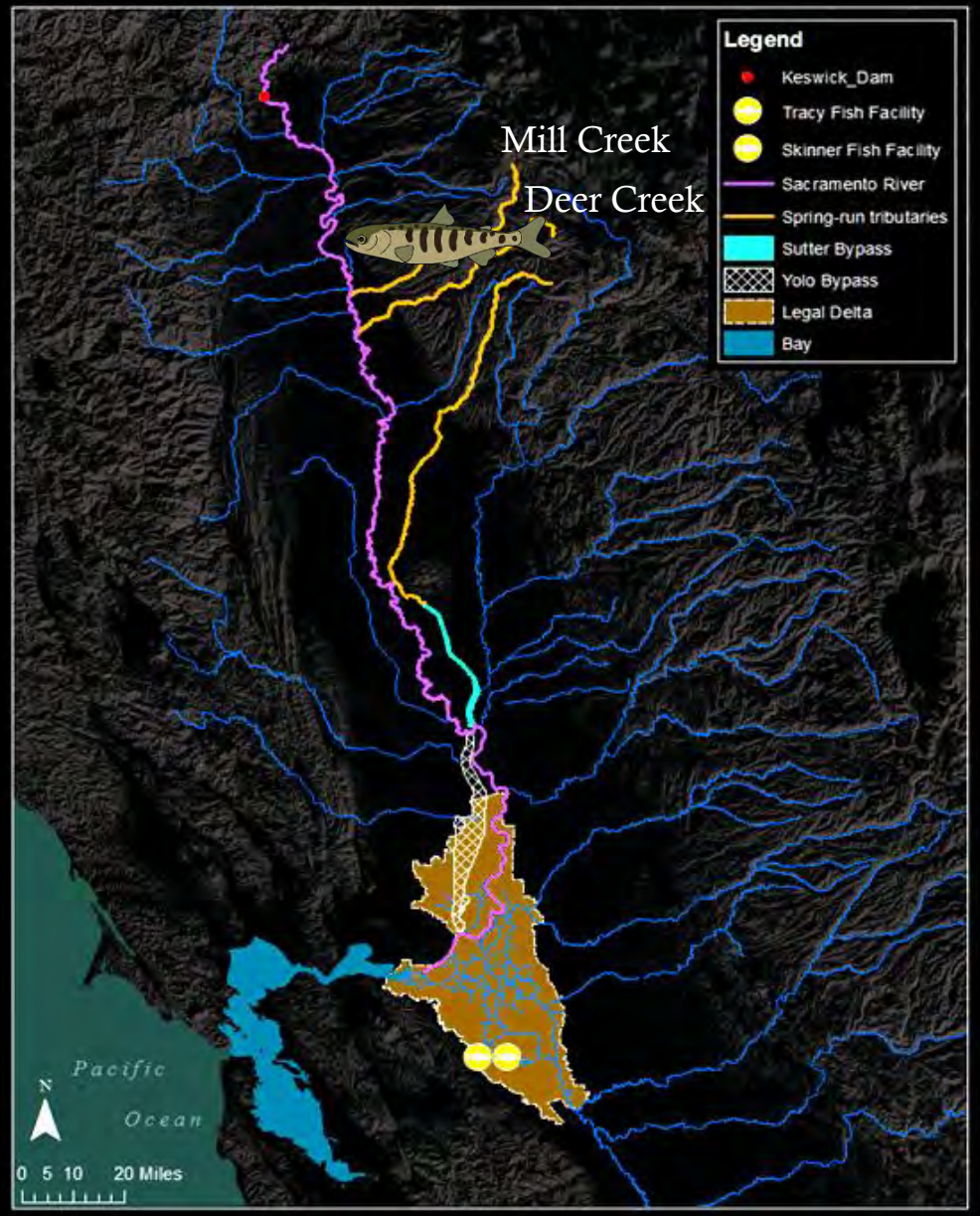

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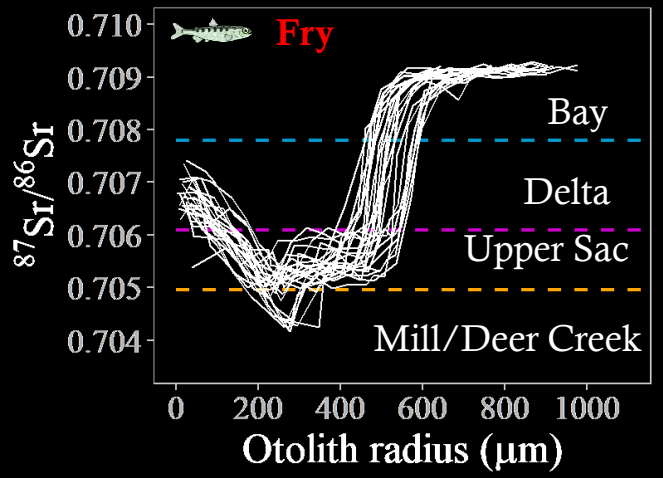

Subyearling
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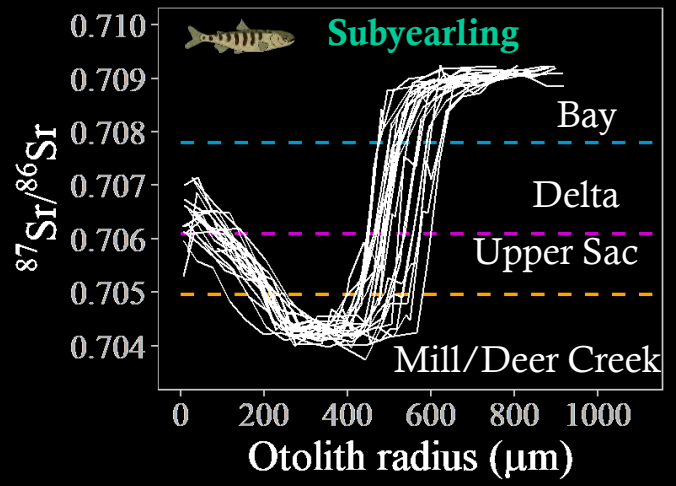

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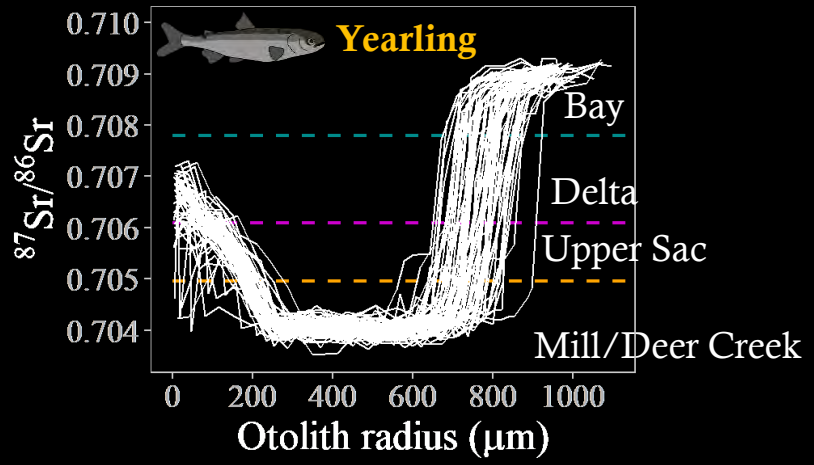

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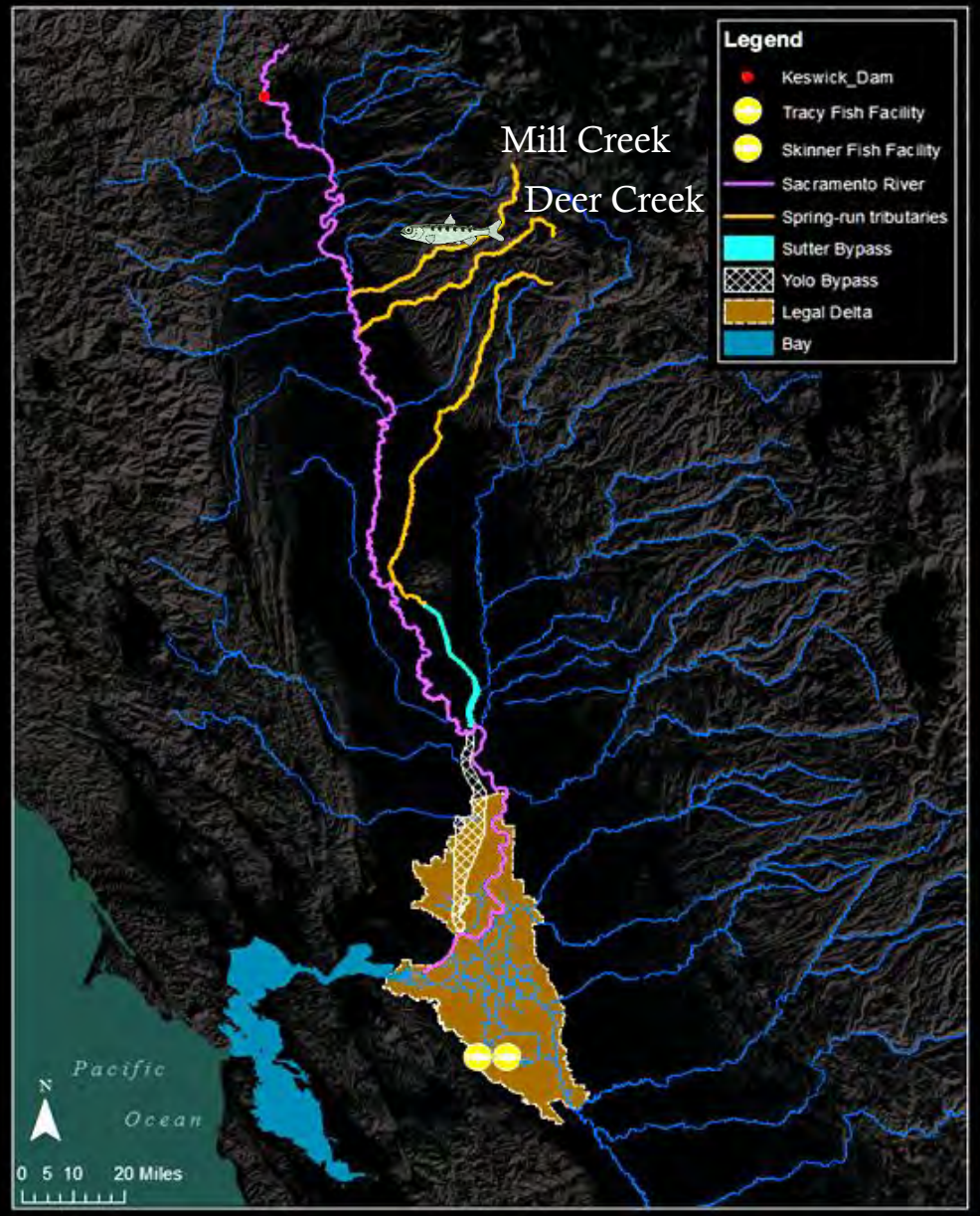

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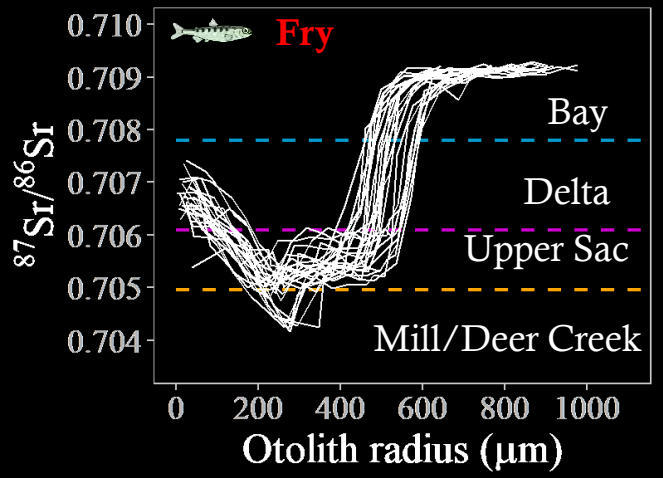

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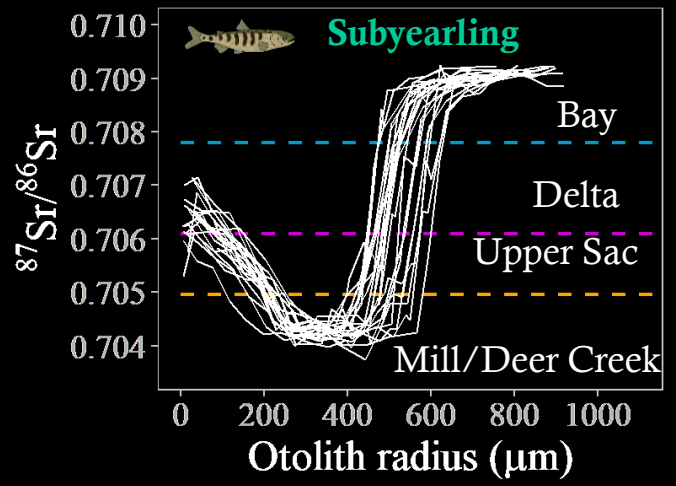

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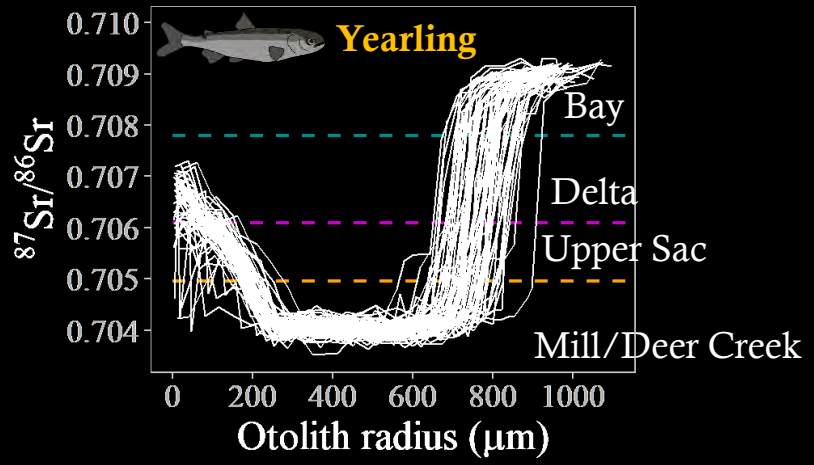

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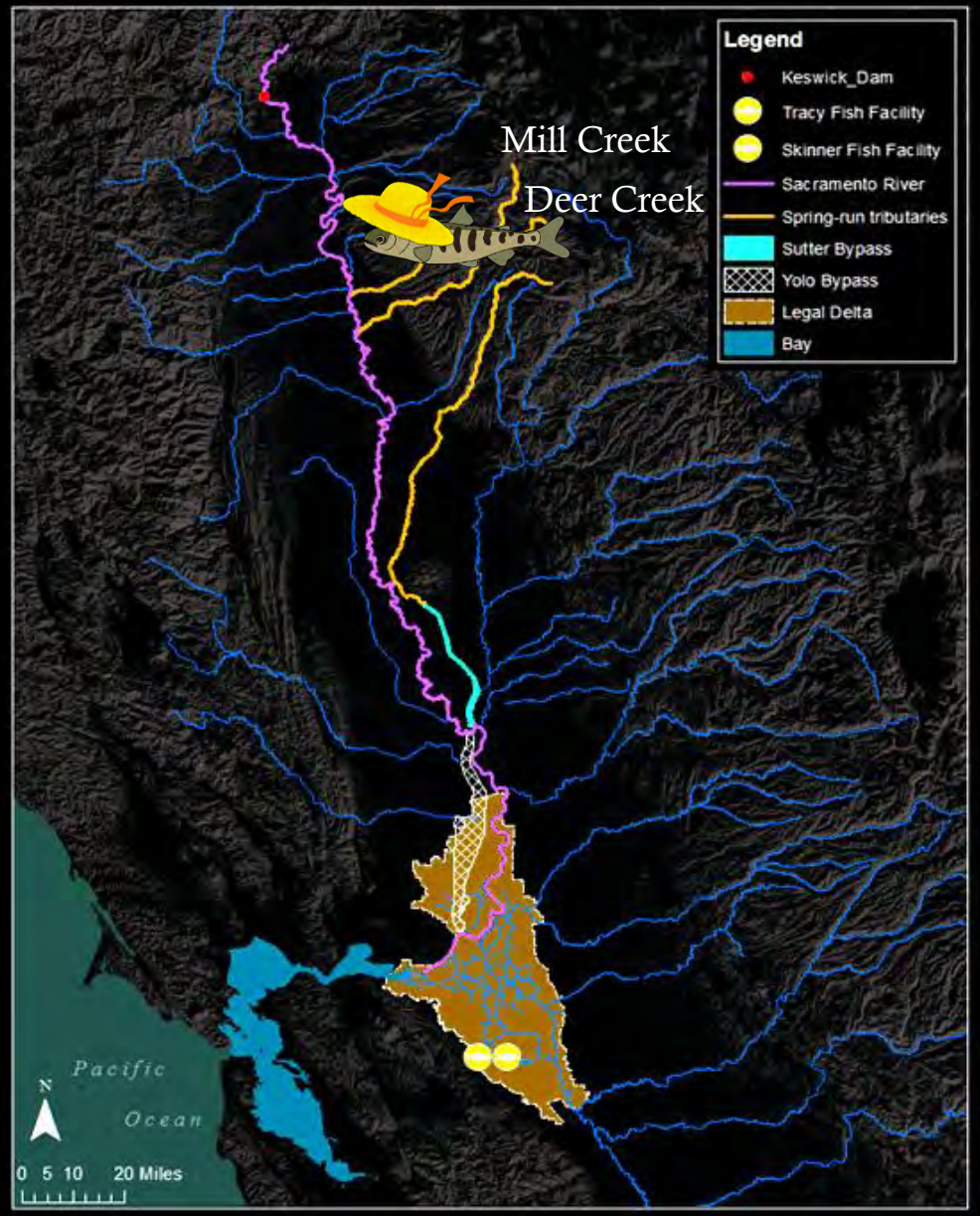

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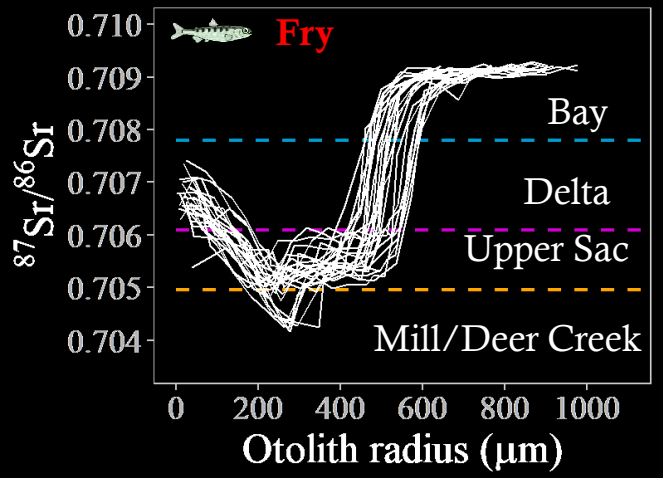

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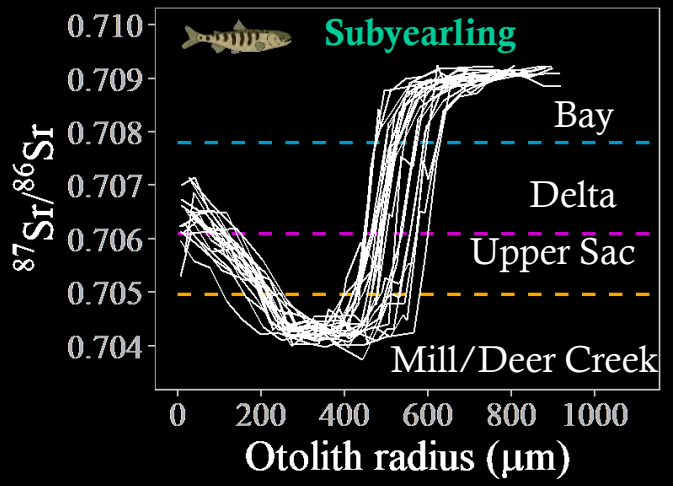

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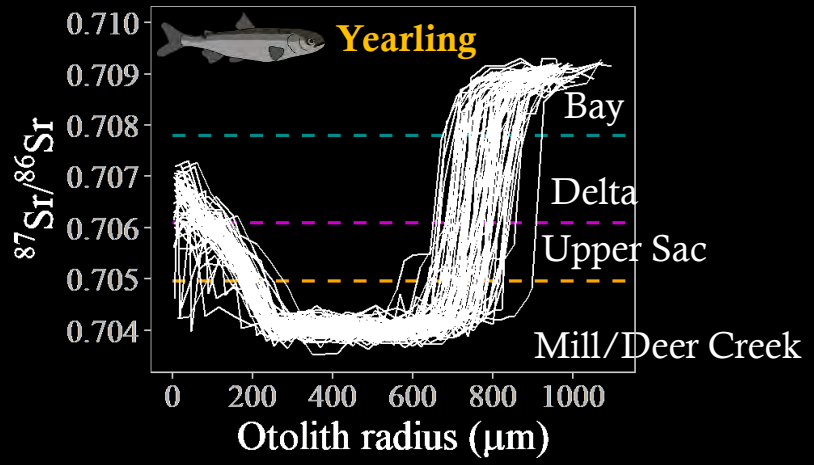

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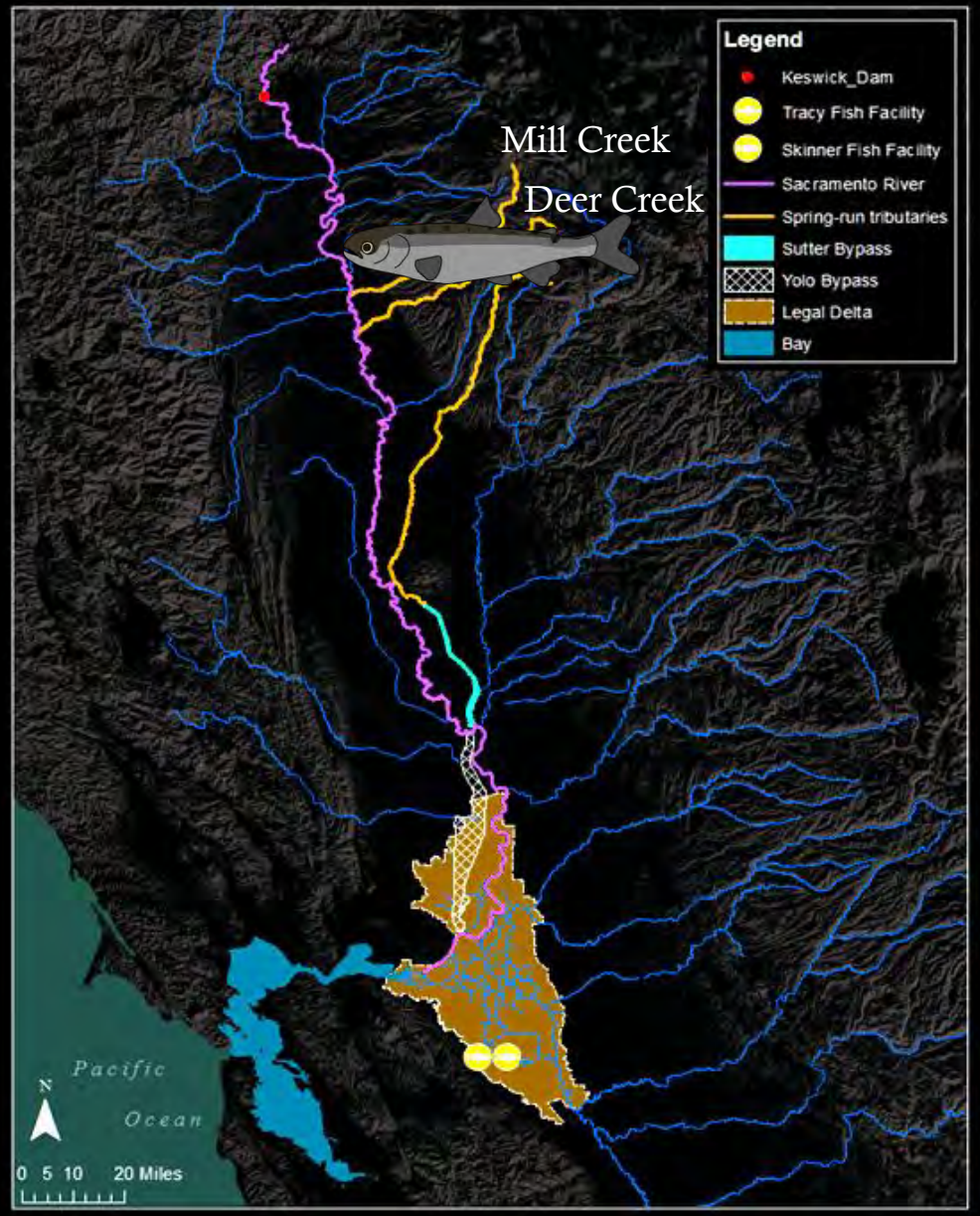

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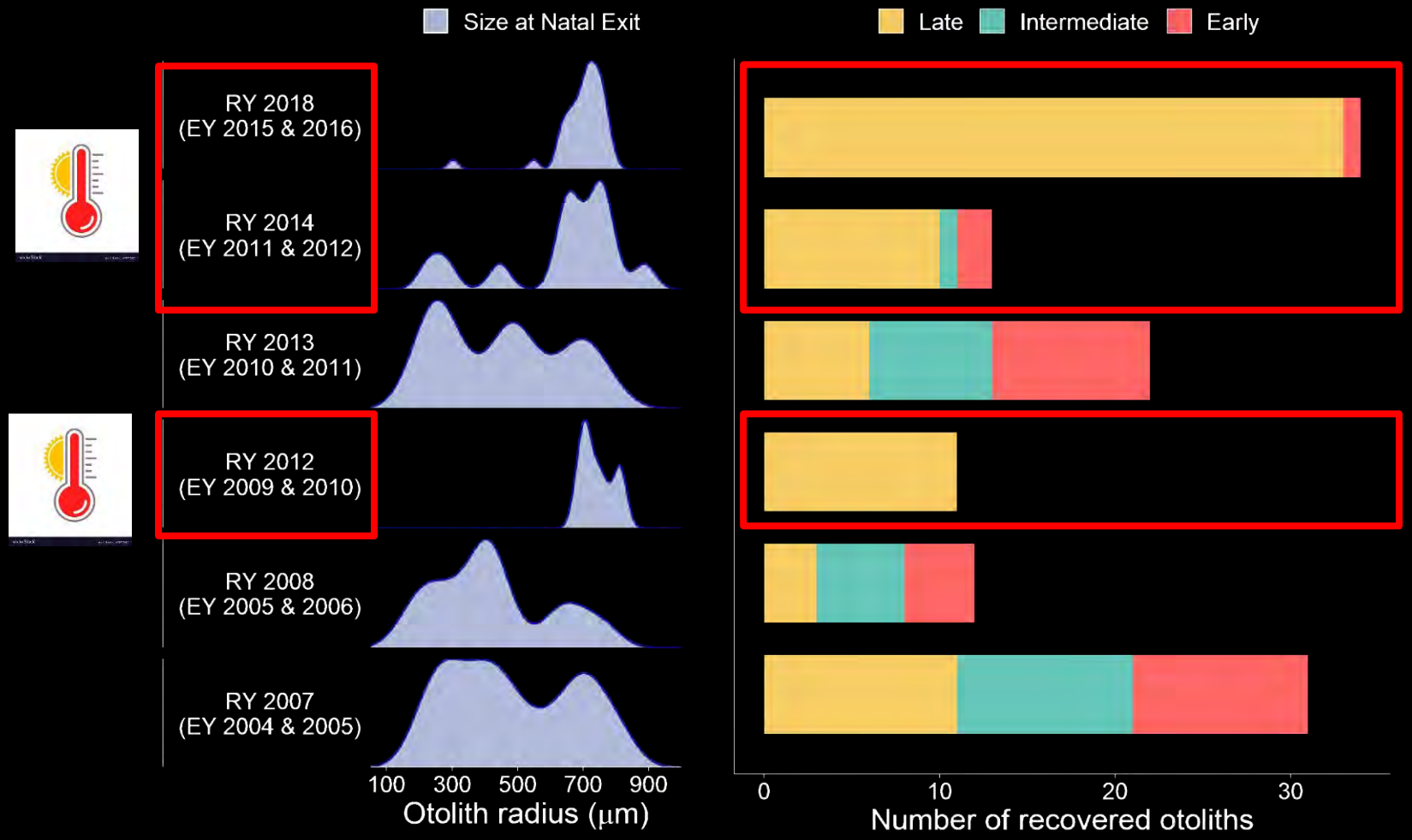

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Yearling strategy dominant during dry years

nature climate change
ARTICLES
https://doi.org/10.1038/s41558-021-01186-4
Check for updates

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

F. Cordoleani[1,2]✉, C. C. Phillis[3], A. M. Sturrock[4], A. M. FitzGerald[1,2], A. Malkassian[5], G. E. Whitman[6], P. K. Weber[7] and R. C. Johnson[2,6]



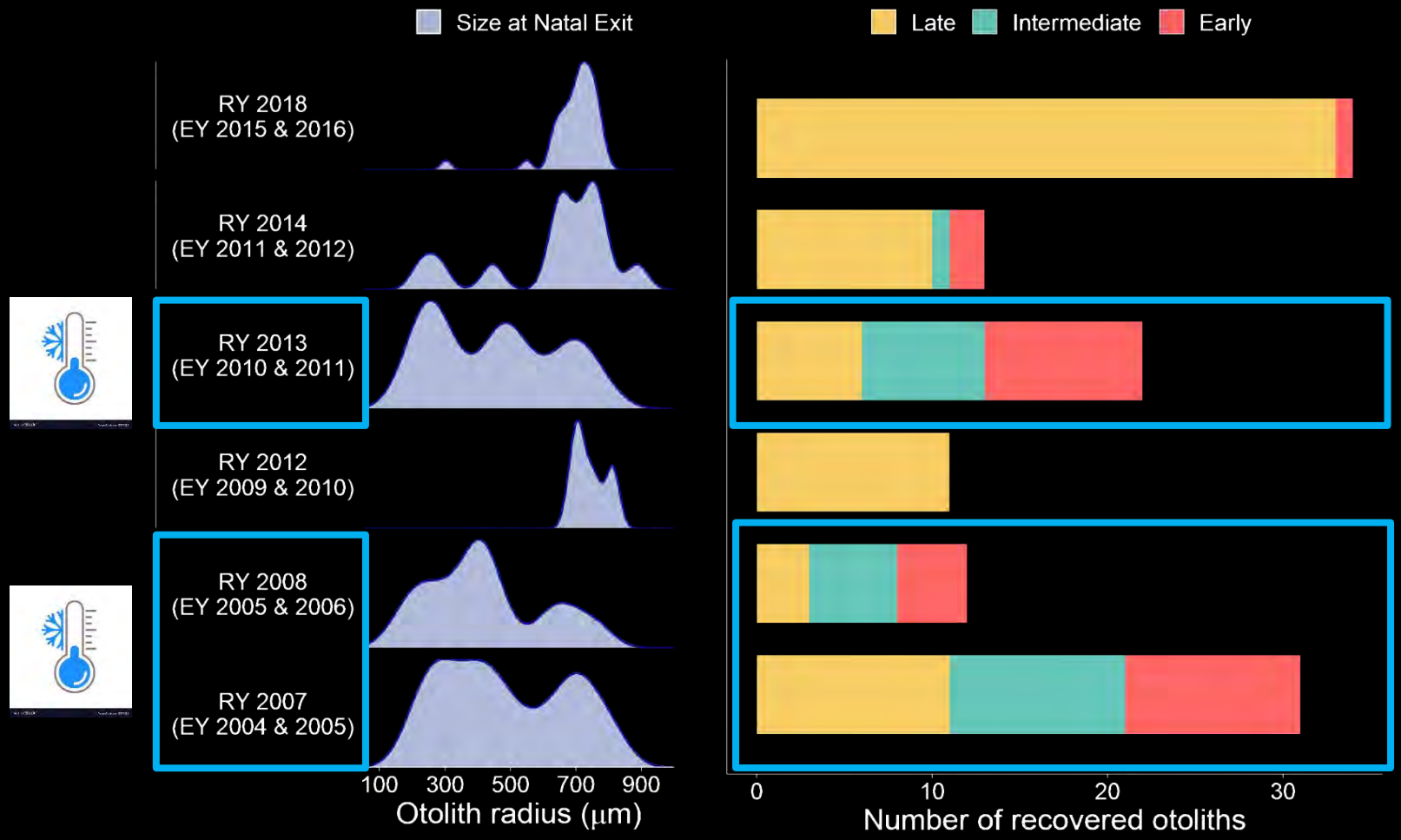
Cordoleani et al. 2021

Mix of the three strategies during wetter years

nature climate change
ARTICLES
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Threatened salmon rely on a rare life history strategy in a warming landscape

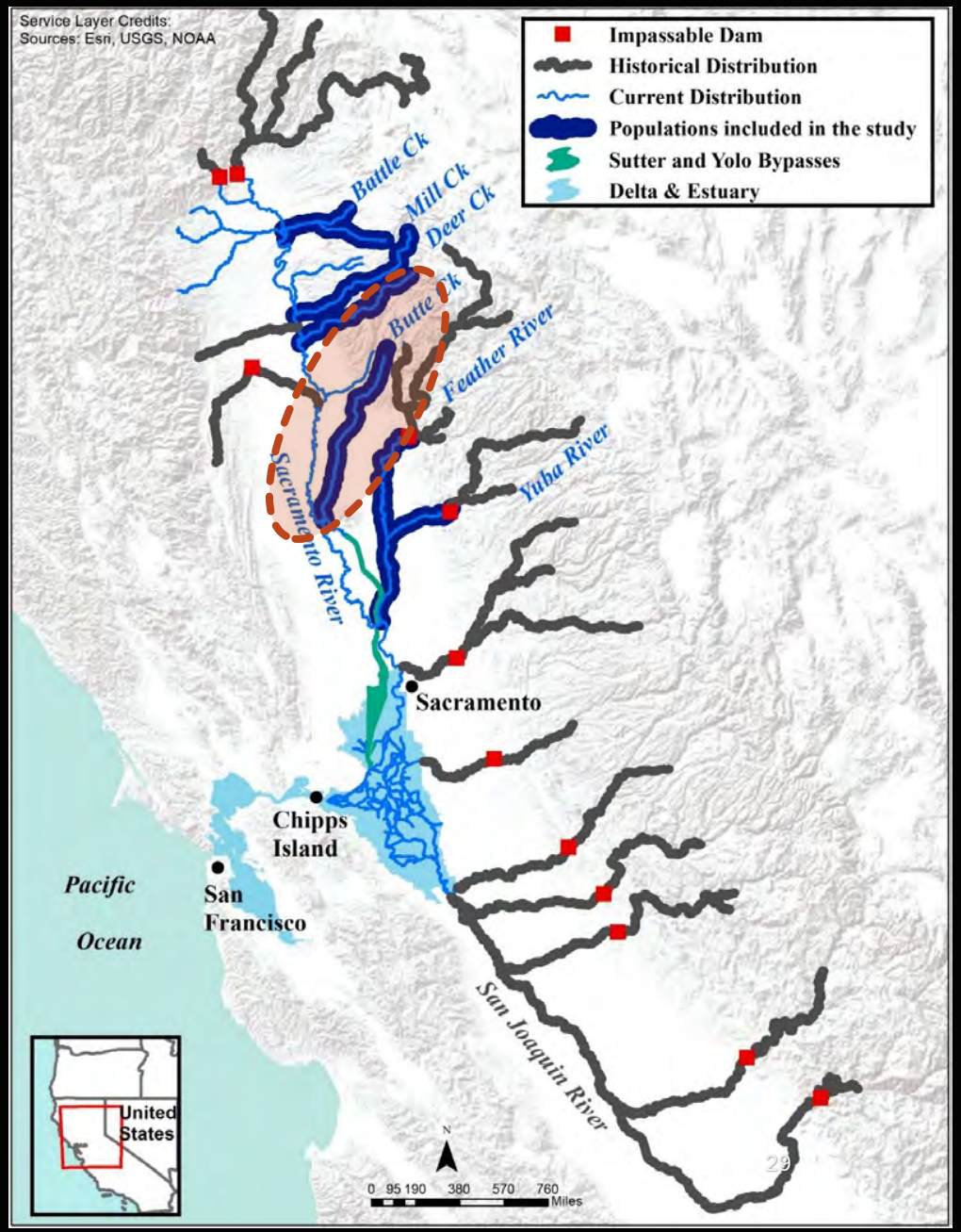
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Cordoleani et al. 2021

Spring-run populations

- Mill/Deer Creek
- Butte Creek
- Battle Creek
- Yuba River
- Feather River



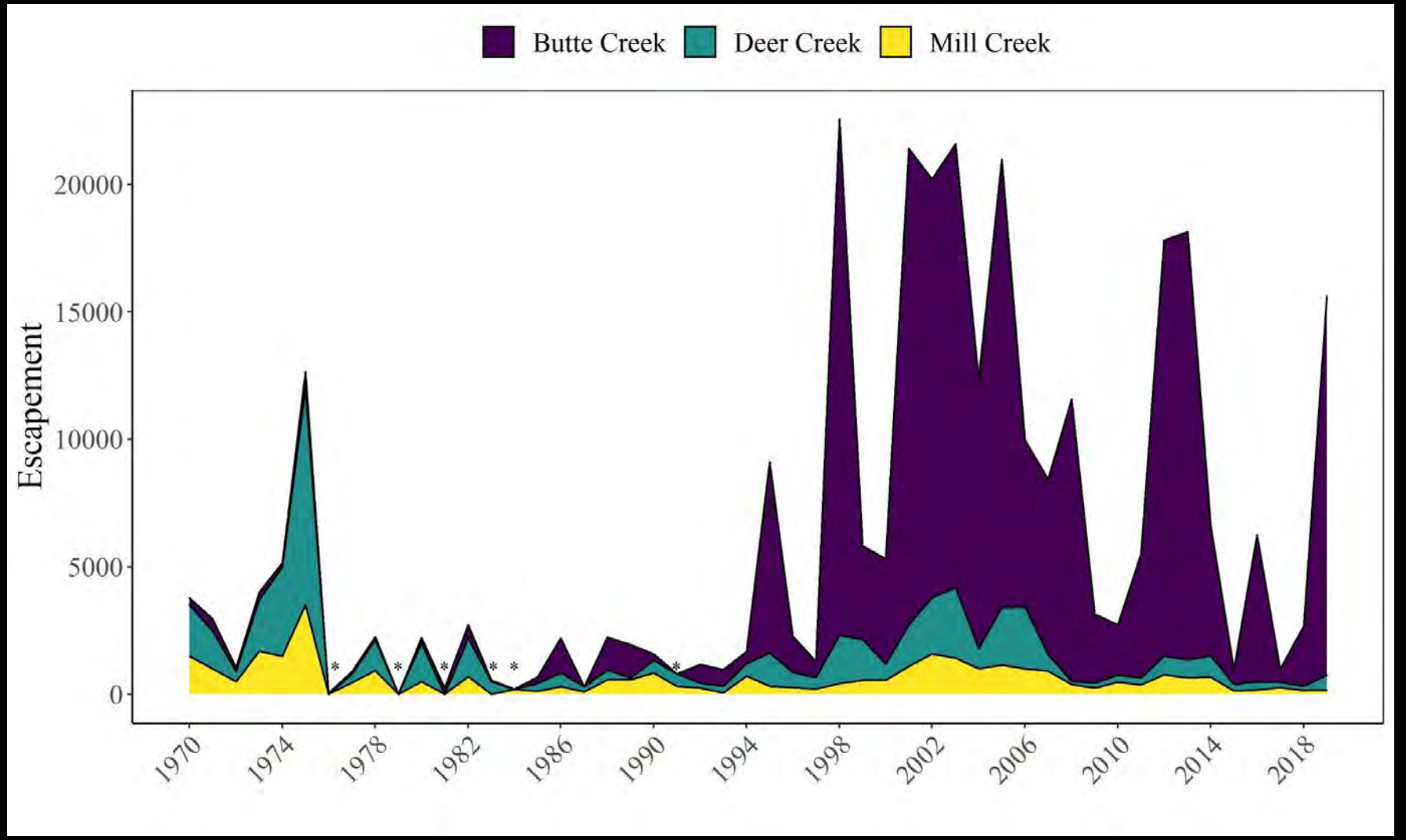
Large holding pools



Photo Credit: Carson Jeffres

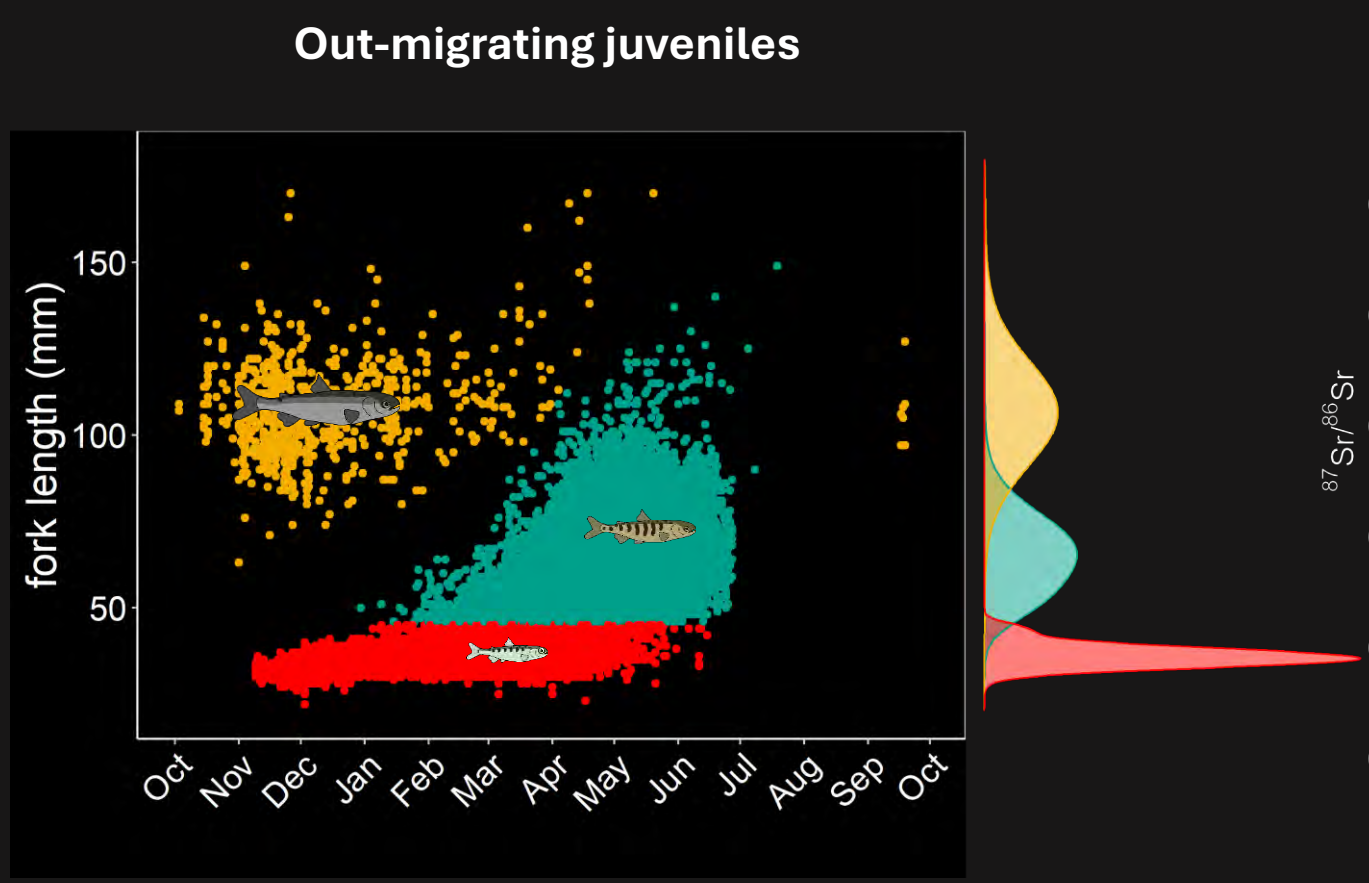


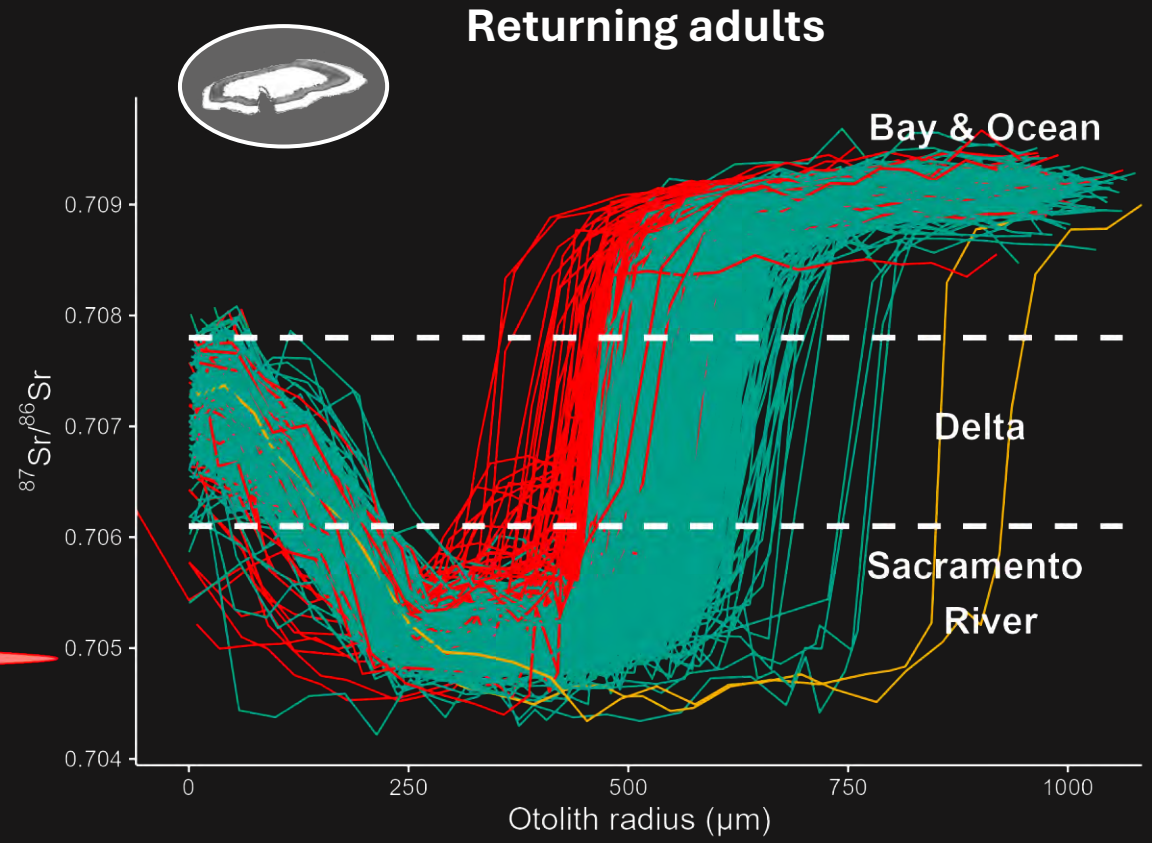
Largest modern spring-run population



Cordoleani et al. 2024a

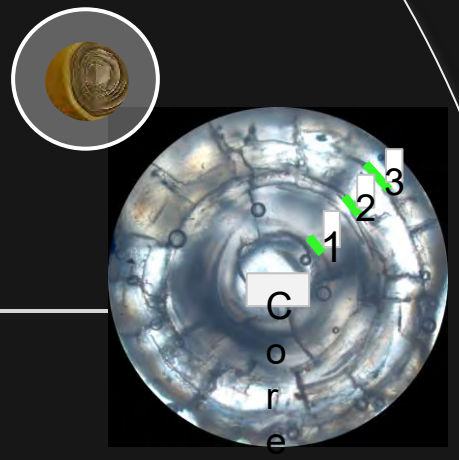
Subyearling migrants dominate across all years





Cordoleani et al. 2024a

Eye lens tools



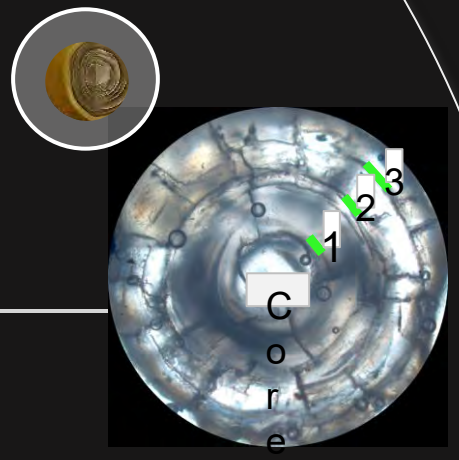
Lenses grow like an onion



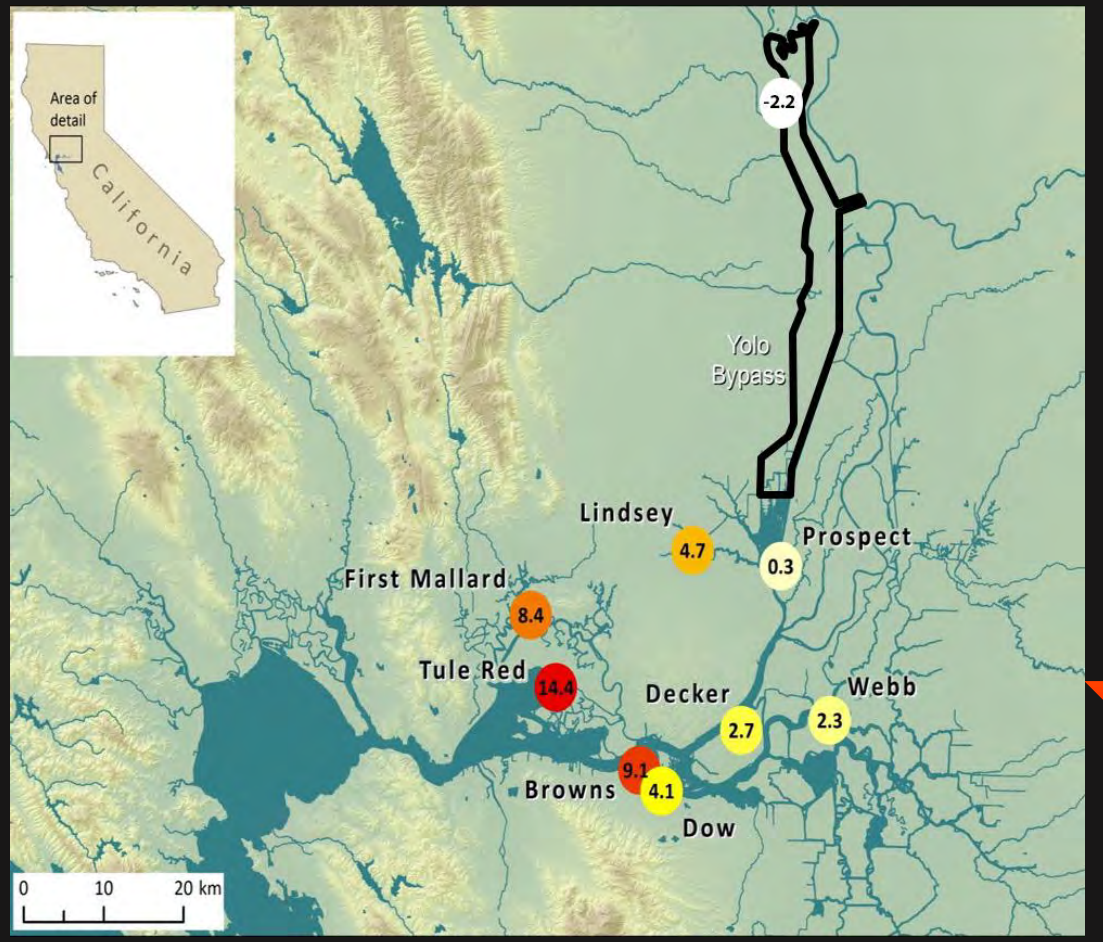
Peeling processed for isotope analysis



Eye lens tools



- Channel vs off-channel habitat use

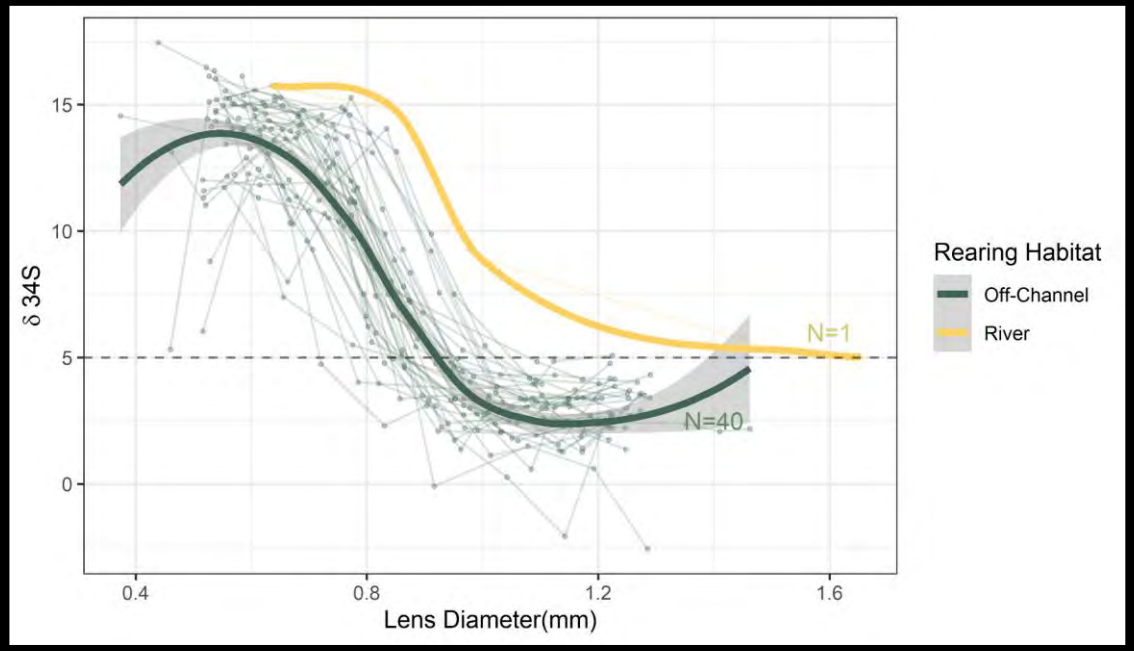


Map courtesy of Dr. Amber Manfree

Butte Creek juveniles used off-channel habitats

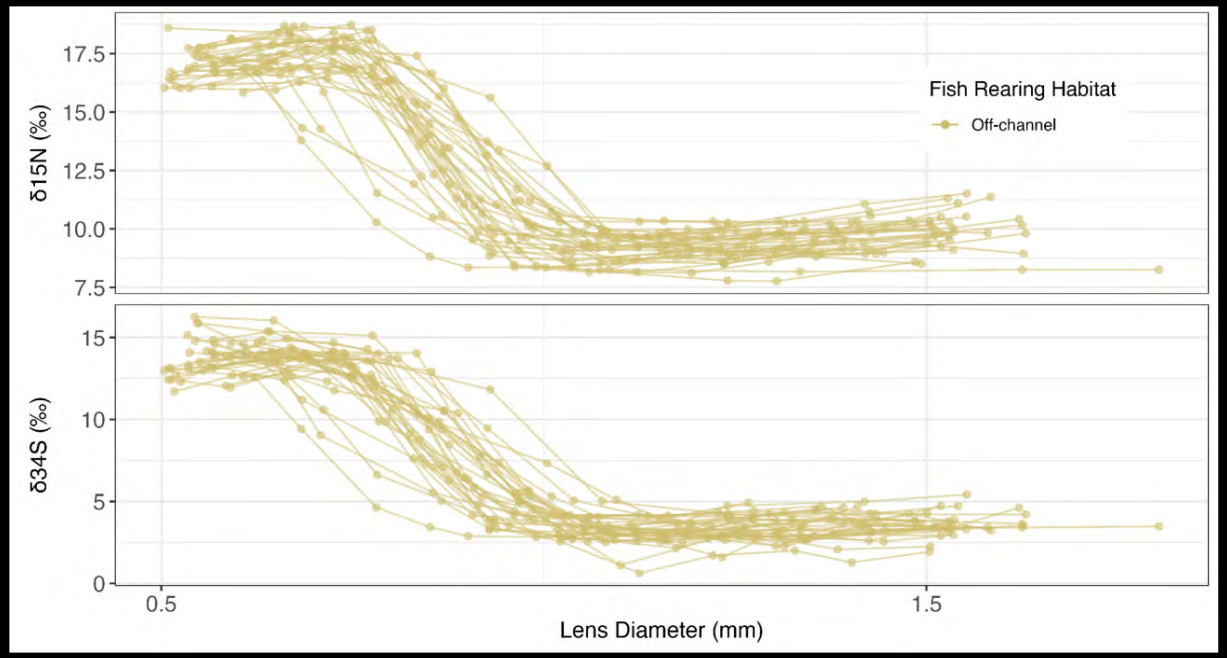


2021



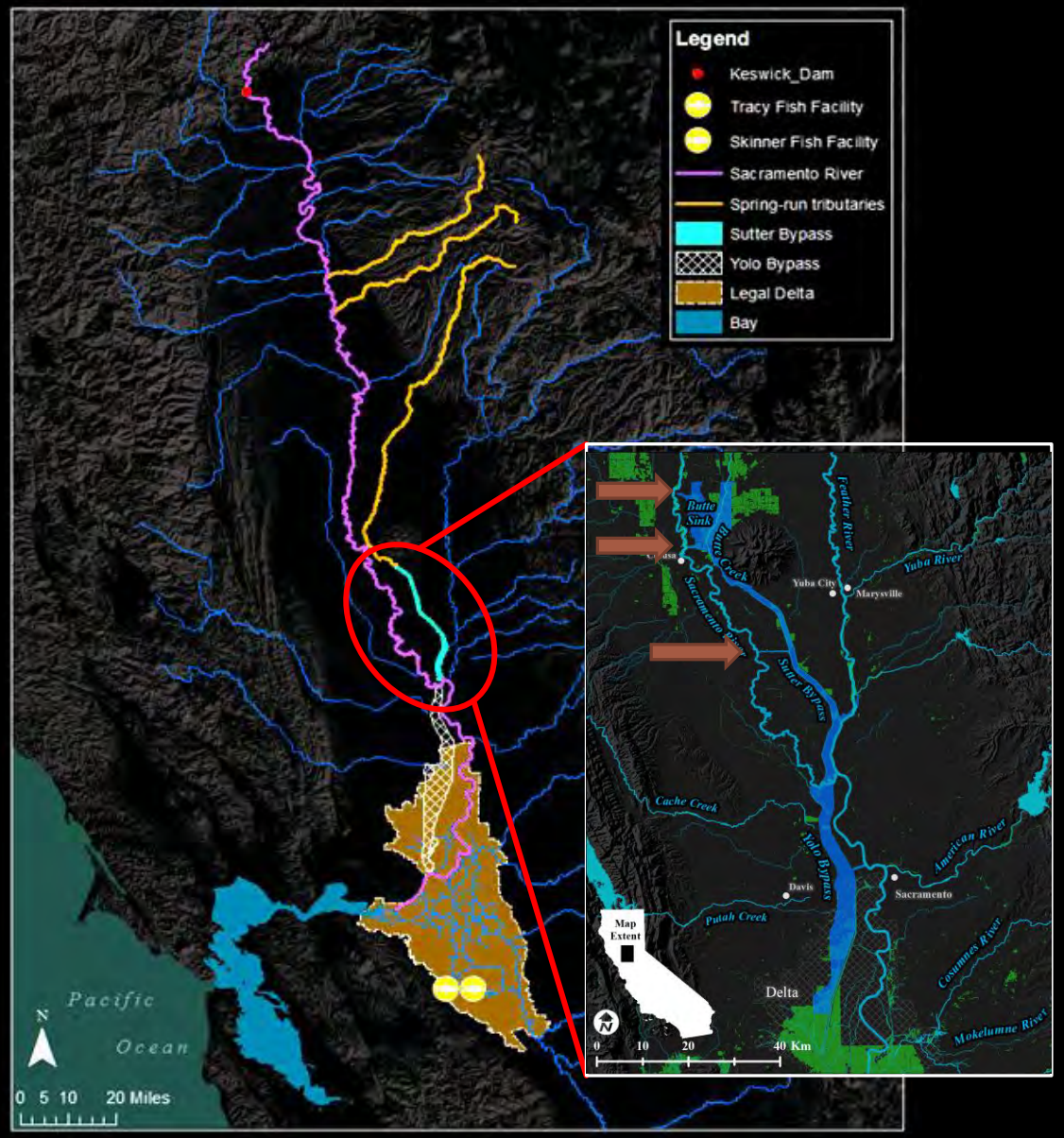
Cordoleani et al. 2023

2022



Cordoleani et al. 2024b

Butte Sink and Sutter Bypass floodplains







Floodplain provides high growth opportunities

March 25, 2016





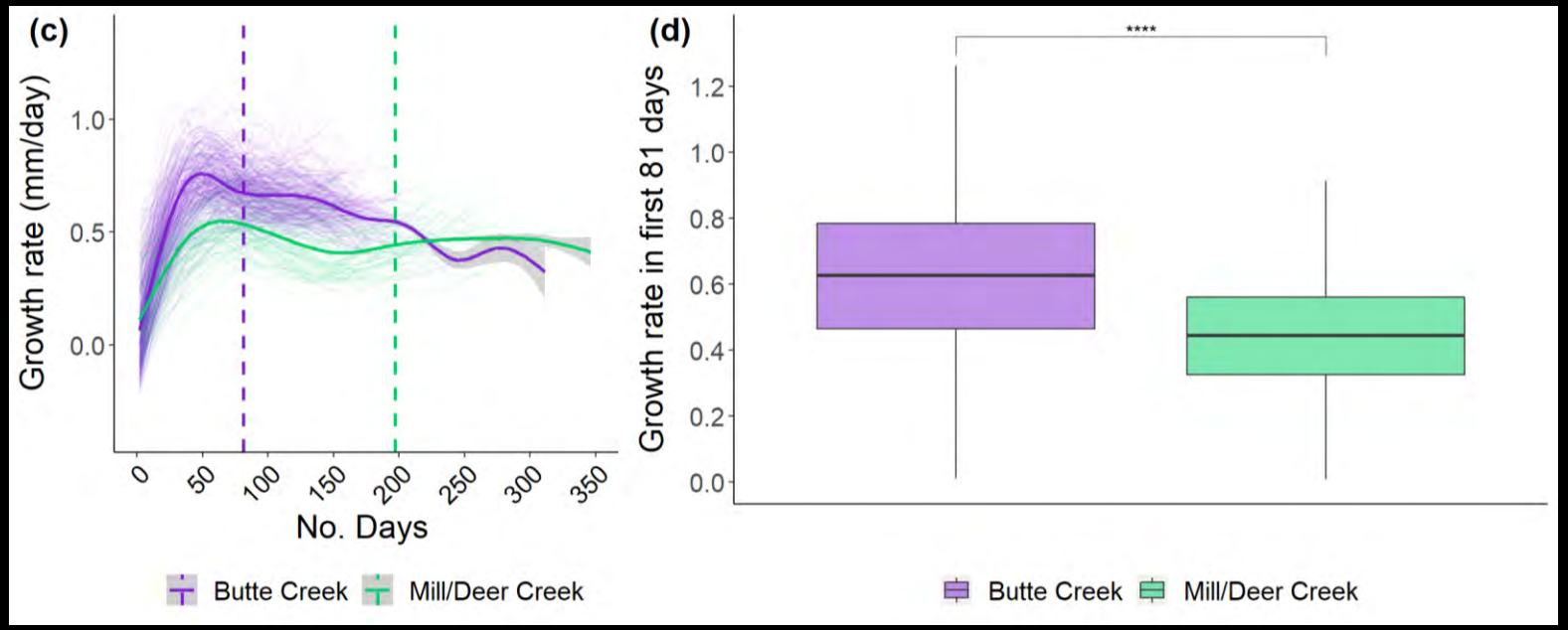
Carson Jeffres



Received: 22 June 2023 | Revised: 6 December 2023 | Accepted: 29 December 2023
DOI: 10.1002/ecs2.4803
ECOSPHERE
AN ESA OPEN ACCESS JOURNAL
ARTICLE
Freshwater Ecology

Restoring freshwater habitat mosaics to promote resilience of vulnerable salmon populations

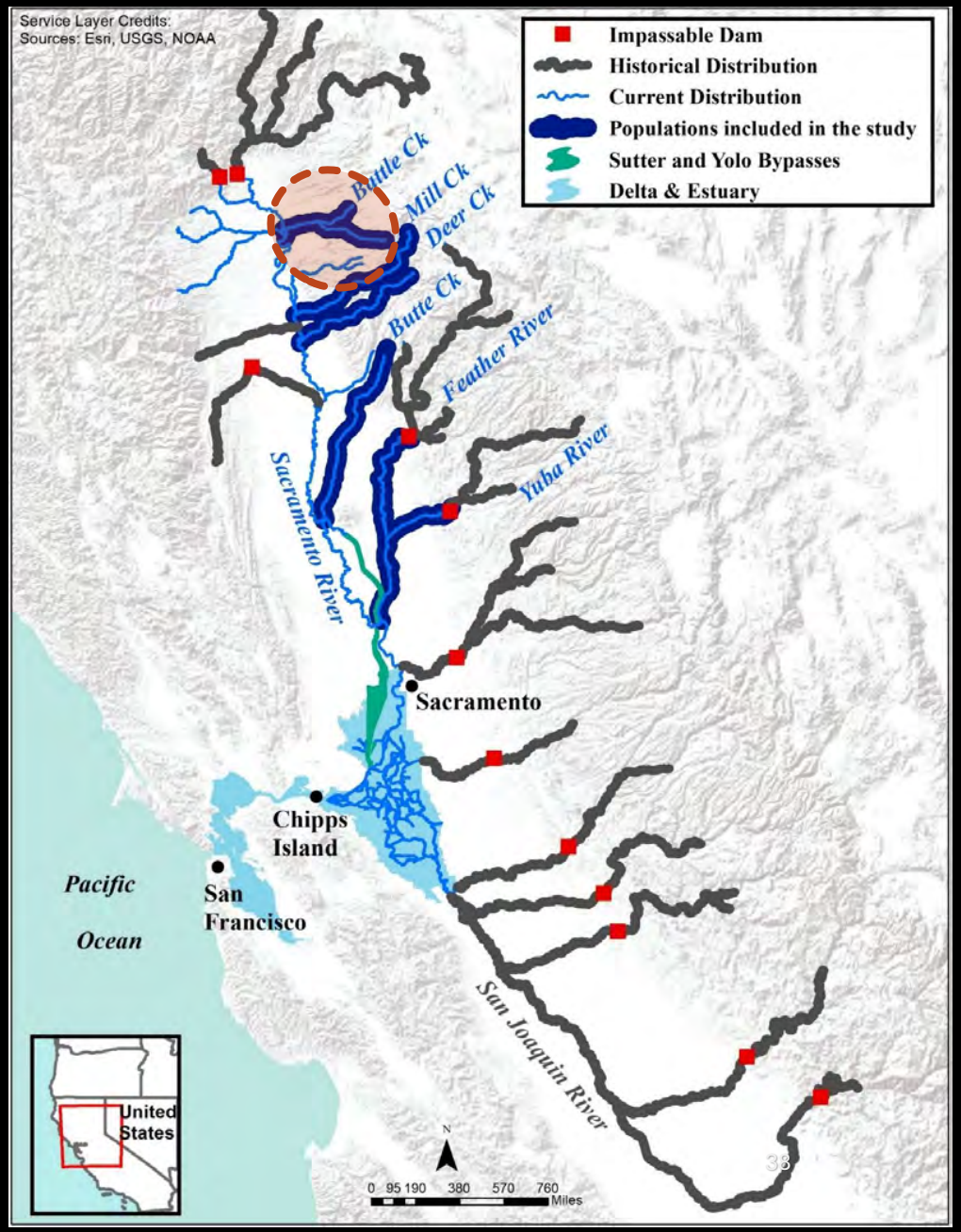
Flora Cordoleani[1,2] | Corey C. Phillis[3] | Anna M. Sturrock[4] | Malte Willmes[1,5] | George Whitman[6] | Eric Holmes[6] | Peter K. Weber[7] | Carson Jeffres[6] | Rachel C. Johnson[2,6]



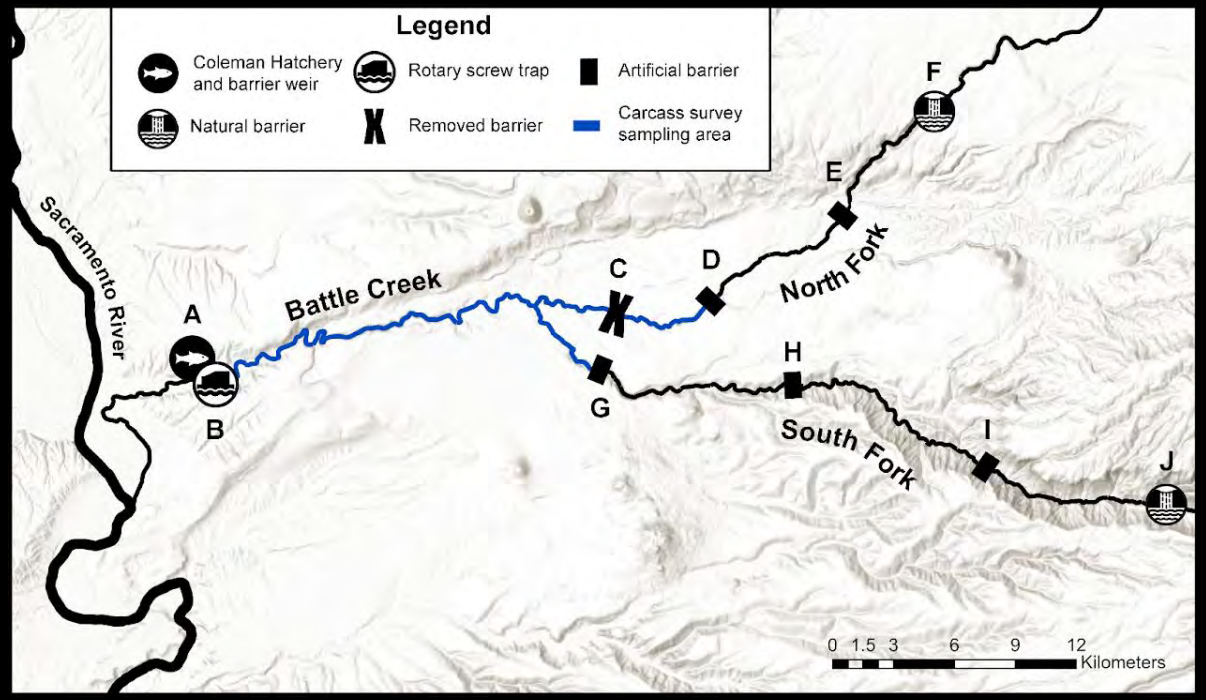
Cordoleani et al. 2024a

Spring-run populations

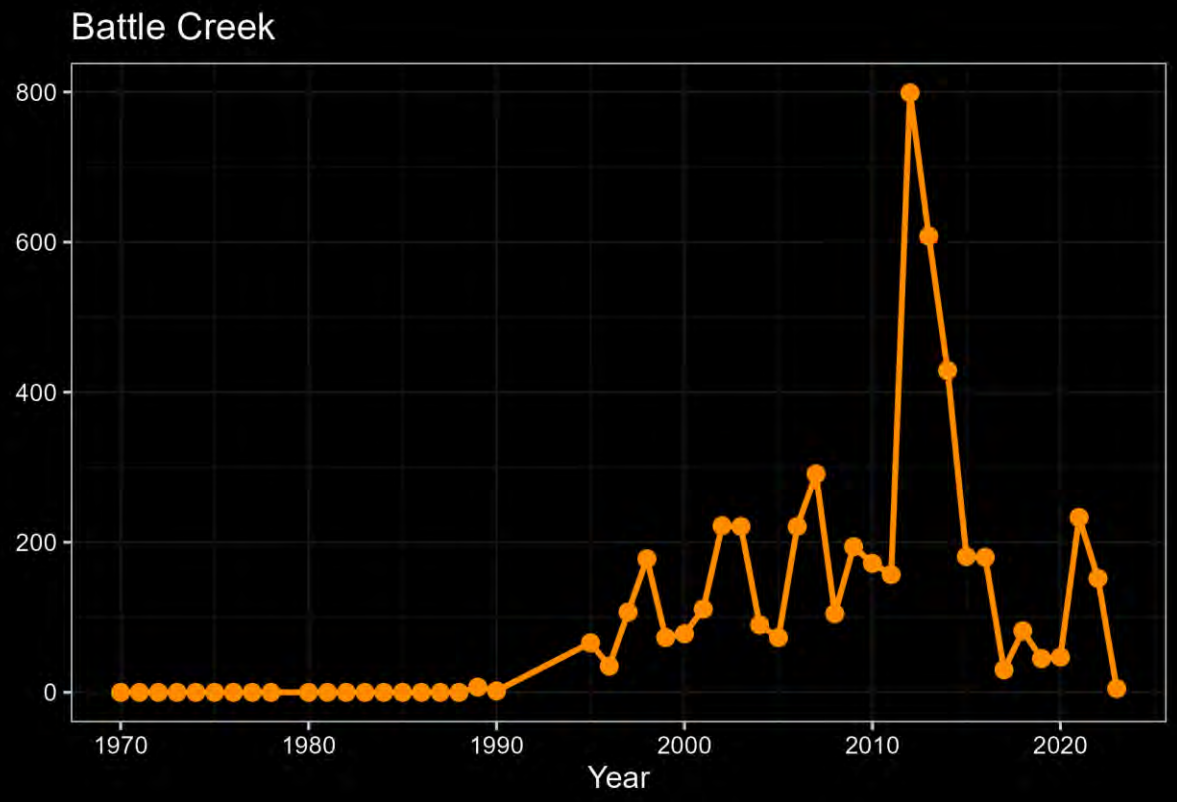
- Mill/Deer Creek
- Butte Creek
- Battle Creek
- Yuba River
- Feather River



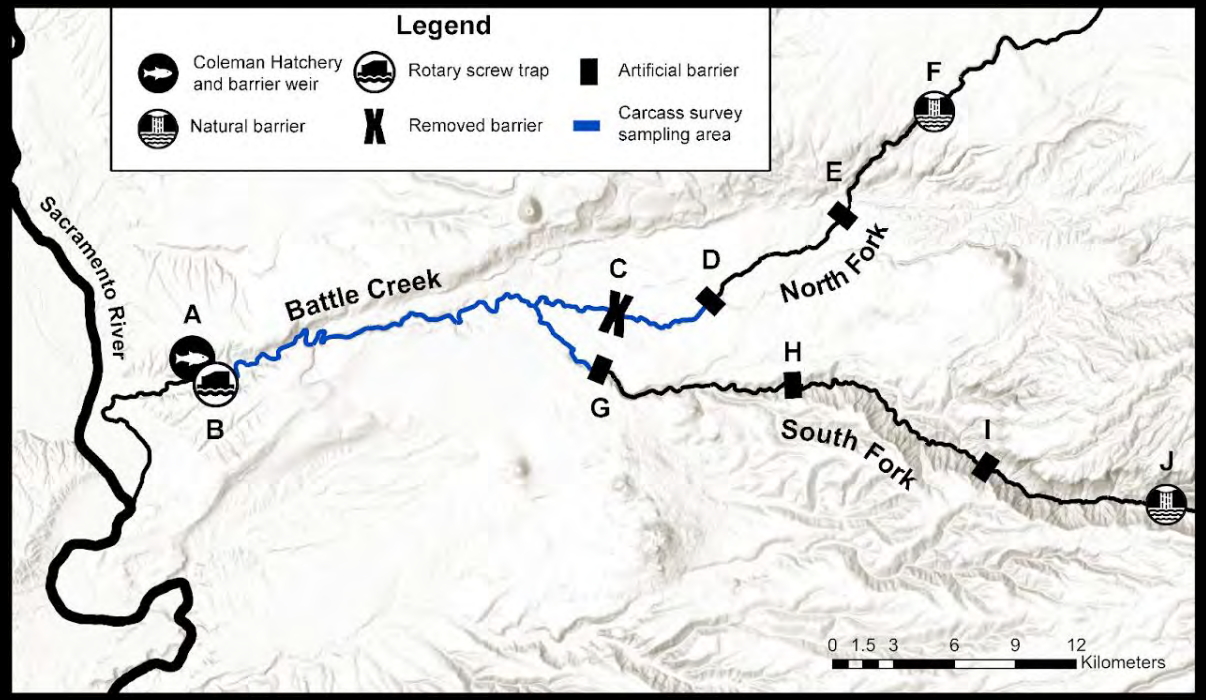
Spring-run passive reintroduction



George Whitman, UC Davis



Spring-run passive reintroduction



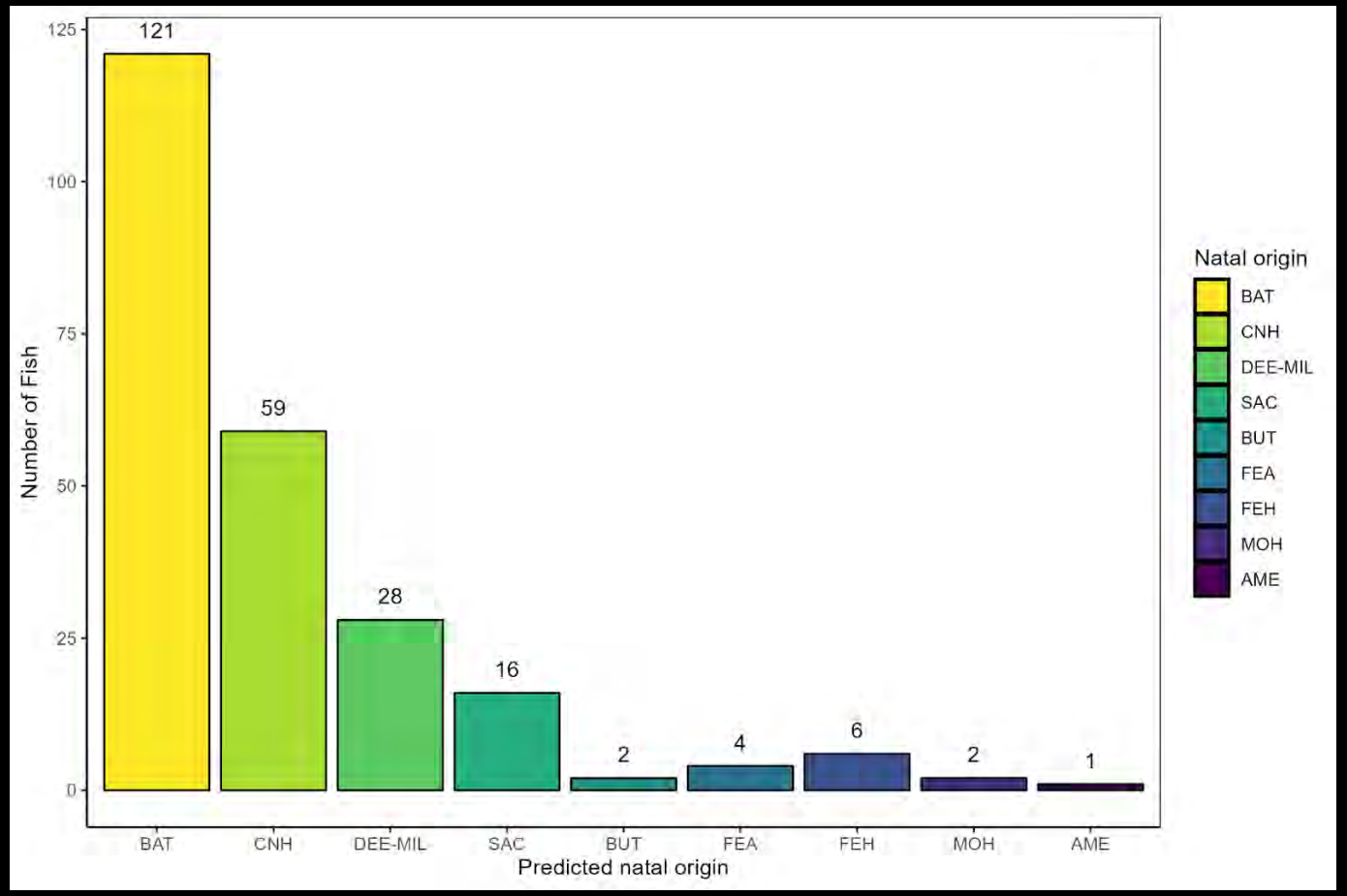
George Whitman, UC Davis



Laurie Earley, USWFS

Natal and non-natal adults returning

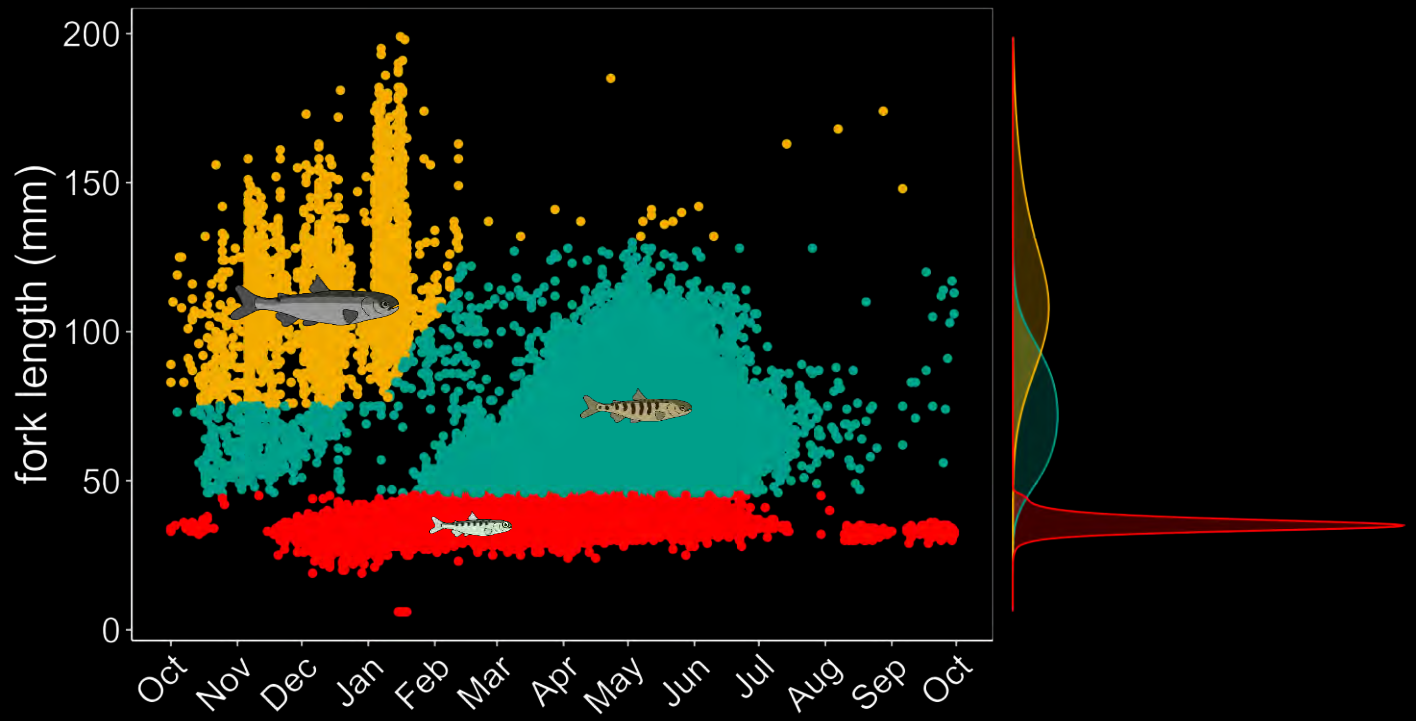




Preliminary data – do not cite

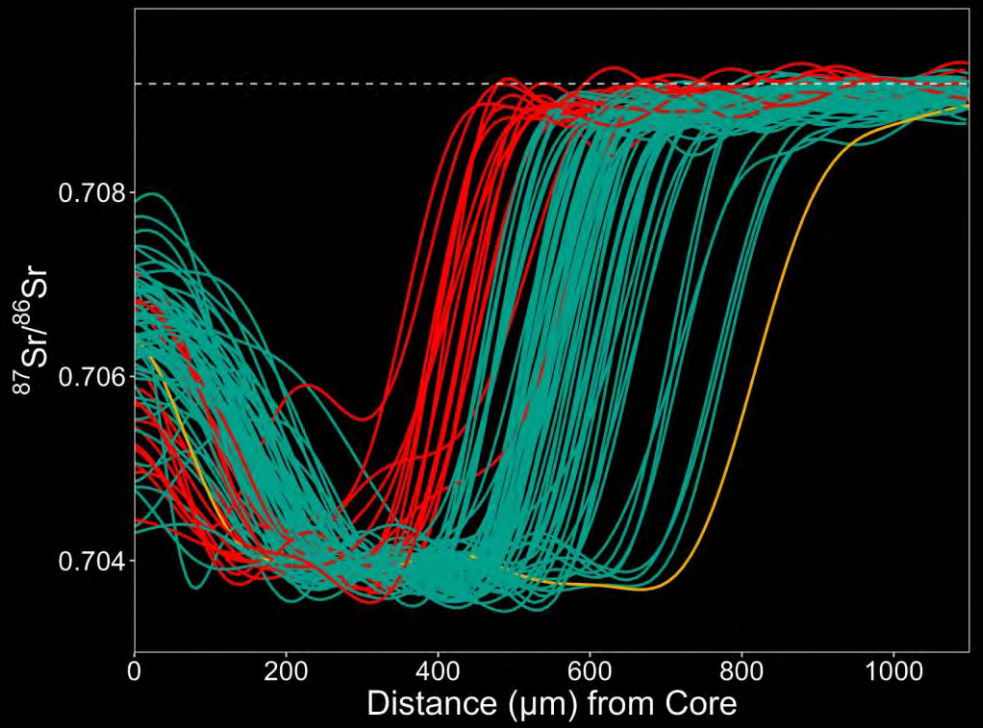
Subyearling migrants dominate in adult returns

Out-migrating juveniles



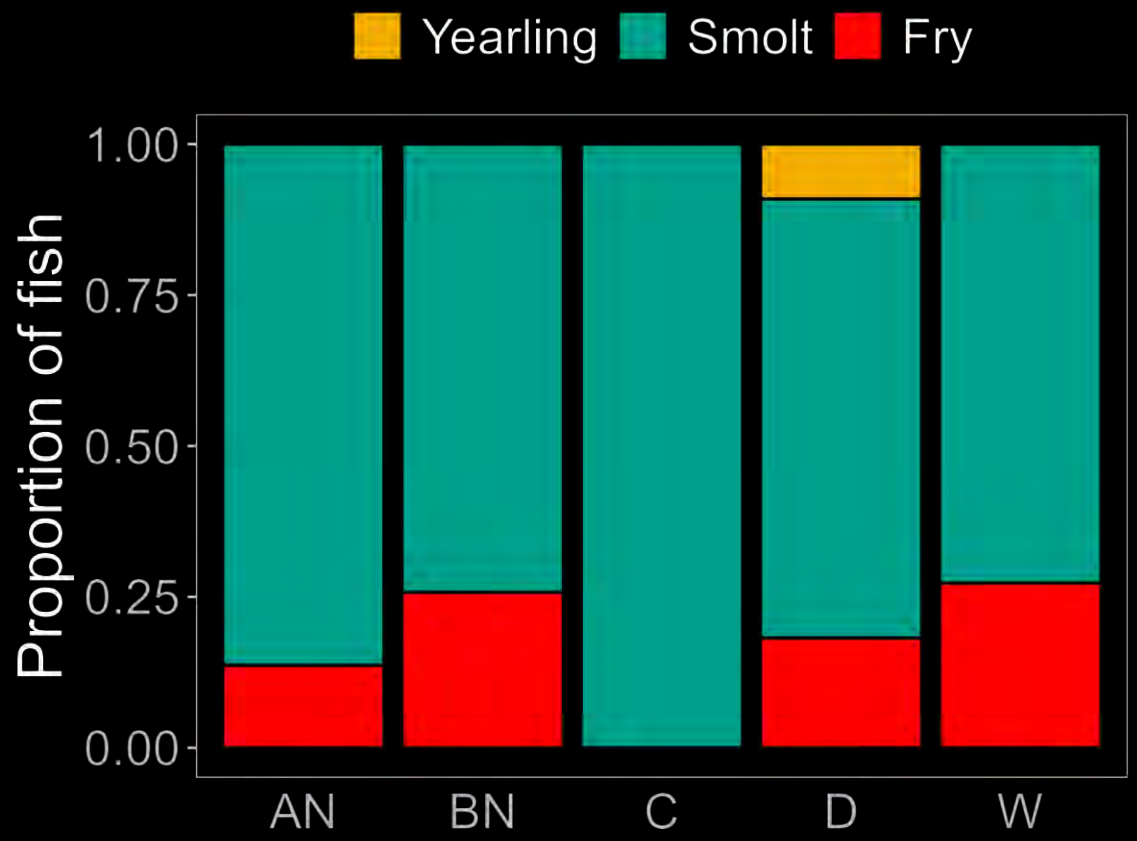


Returning adults



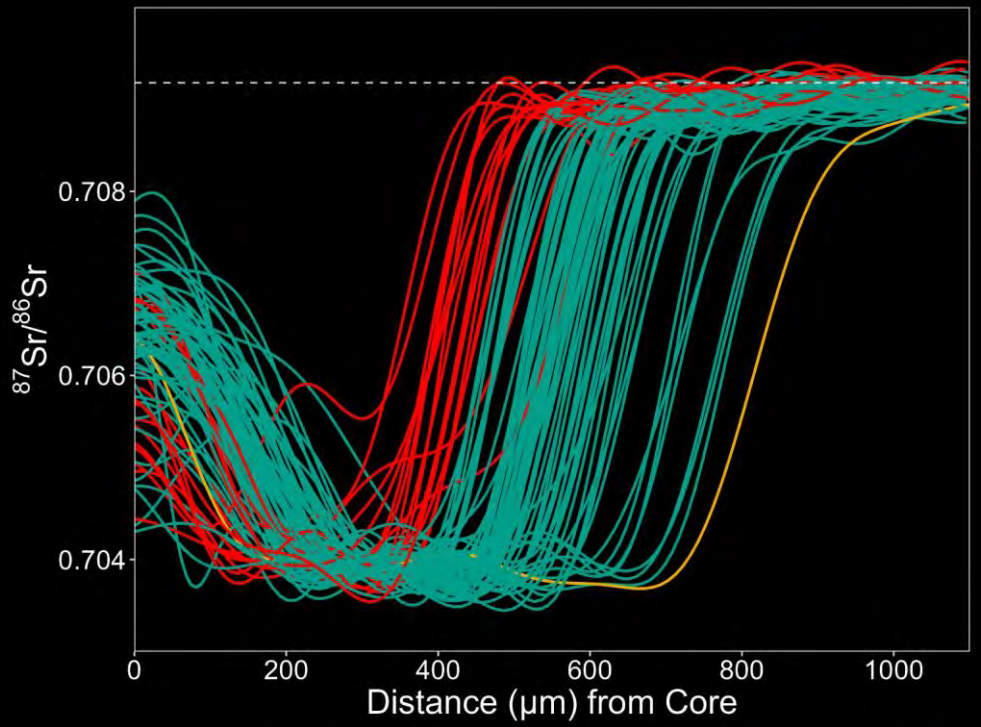
Preliminary data – do not cite

Subyearling migrants dominate across all years





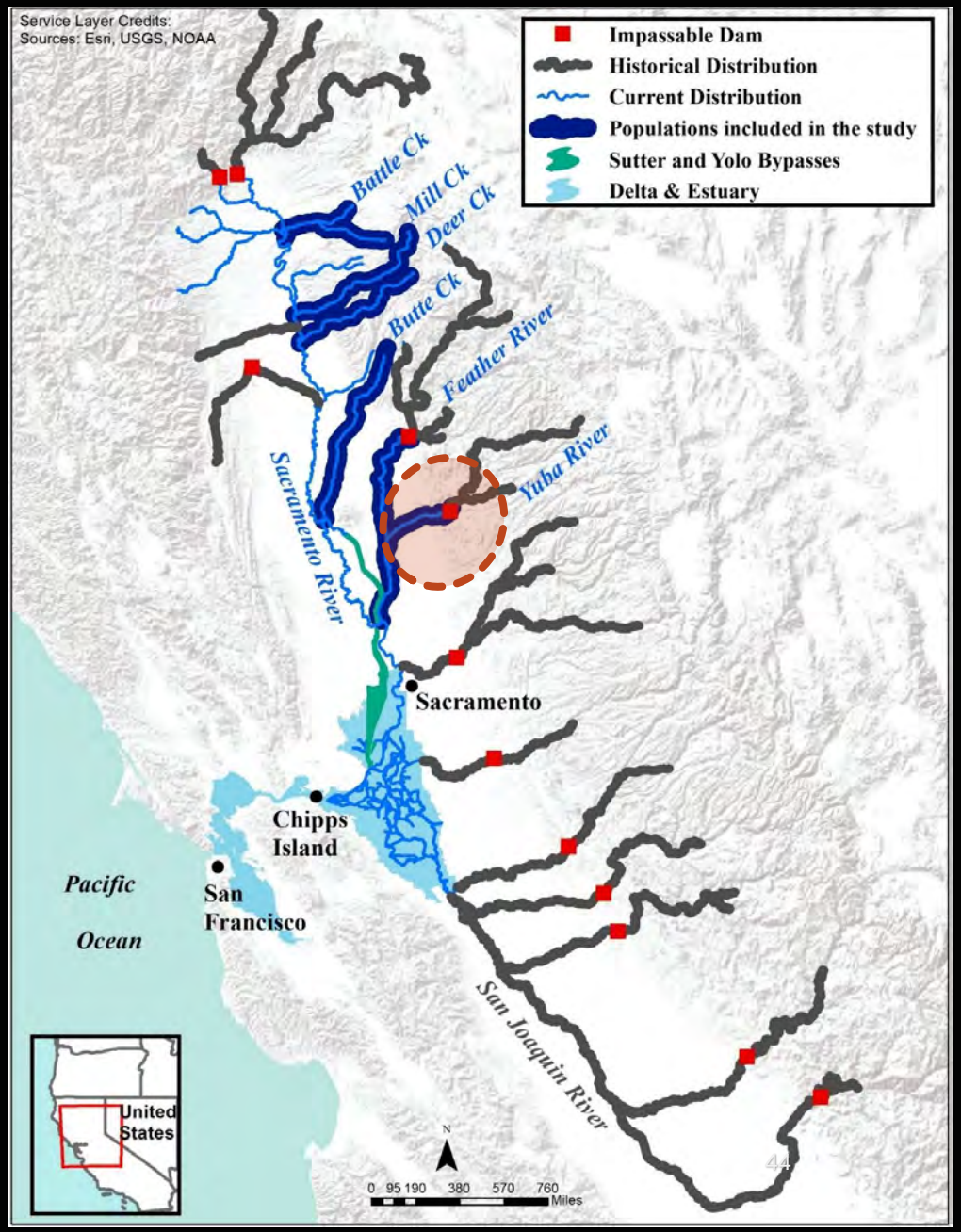
Returning adults



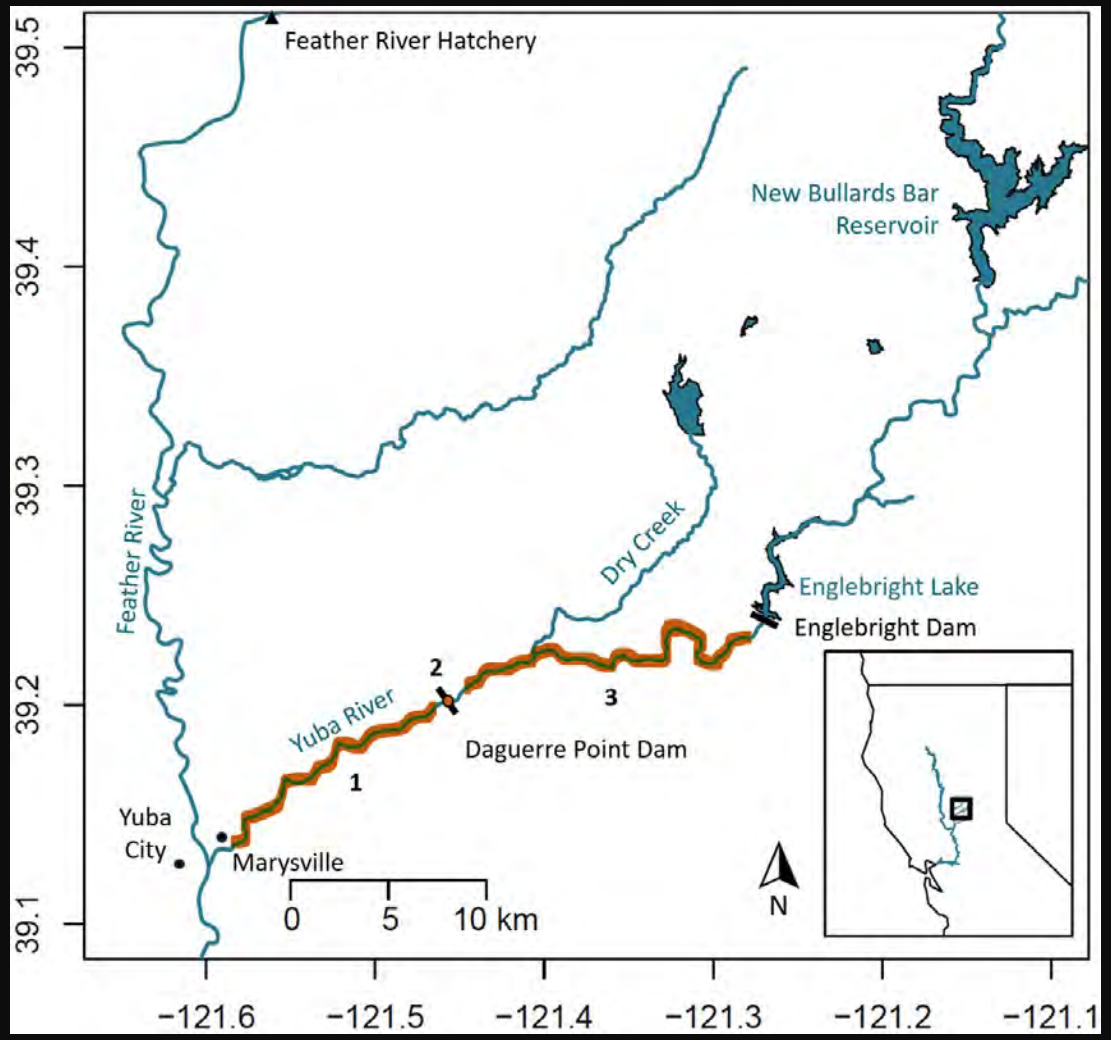
Preliminary data – do not cite

Spring-run populations

- Mill/Deer Creek
- Butte Creek
- Battle Creek
- Yuba River
- Feather River



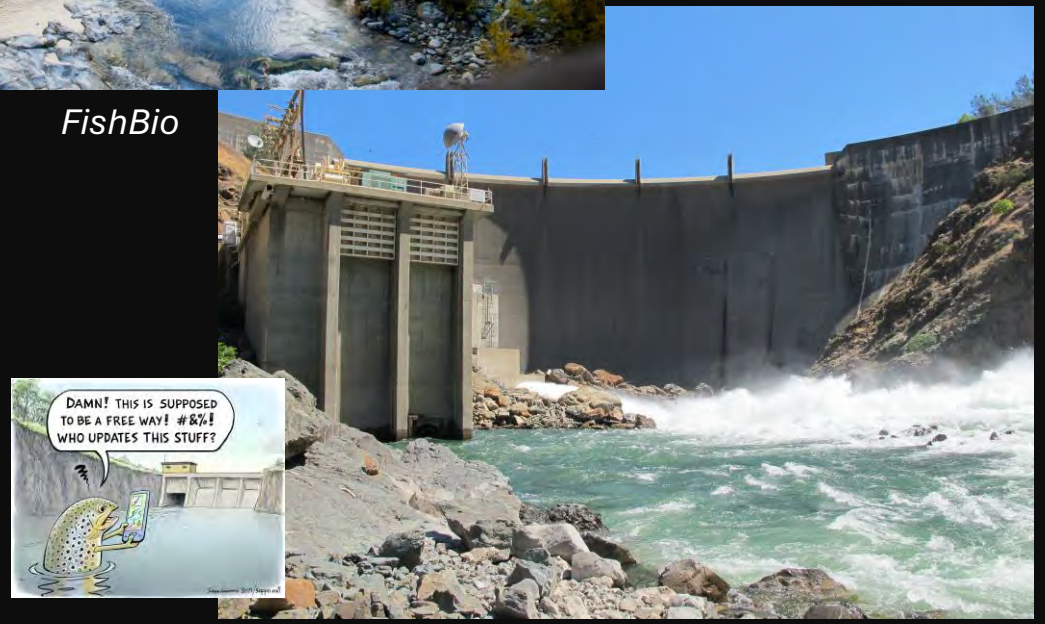
Long lasting anthropogenic legacy



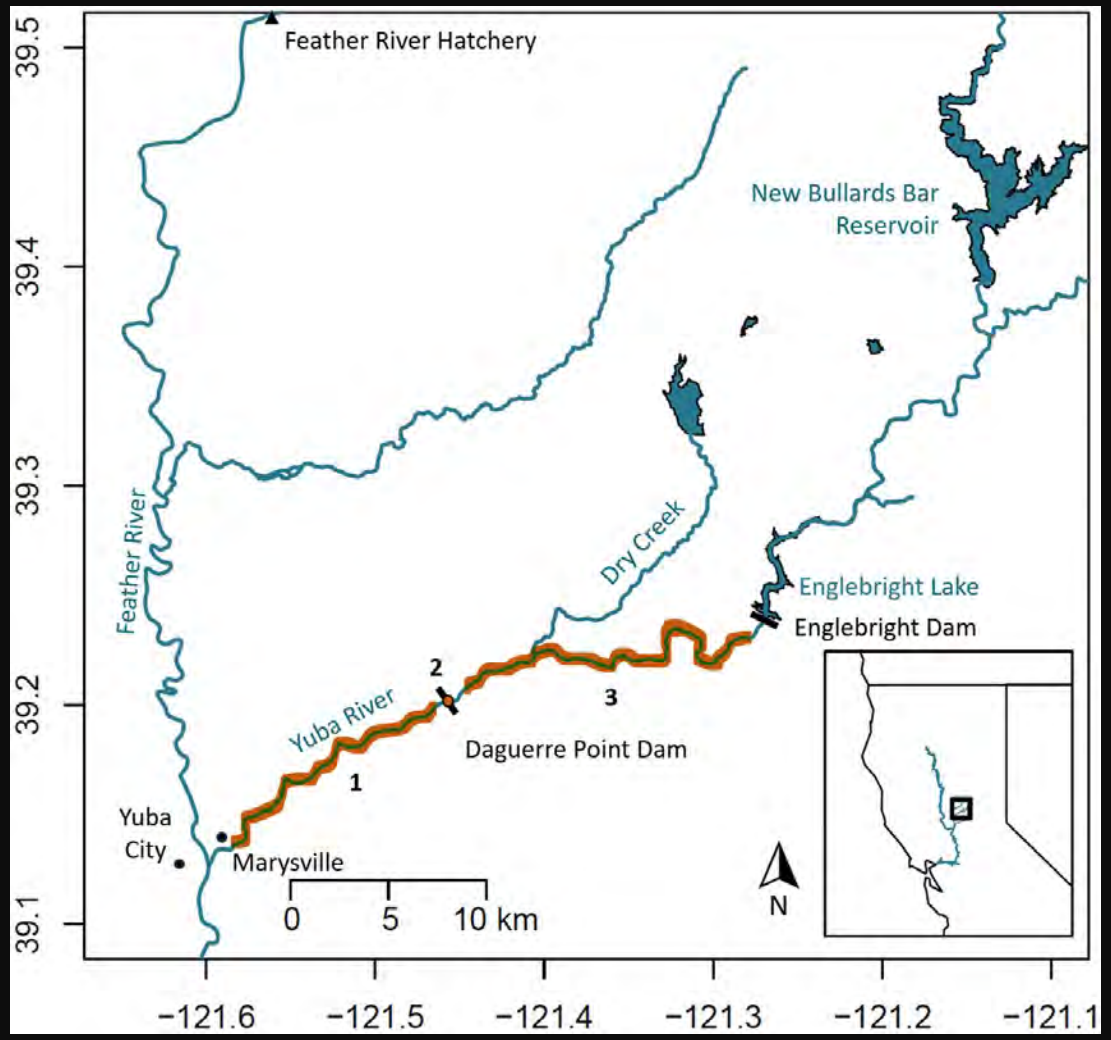
Hugentobler et al., 2024



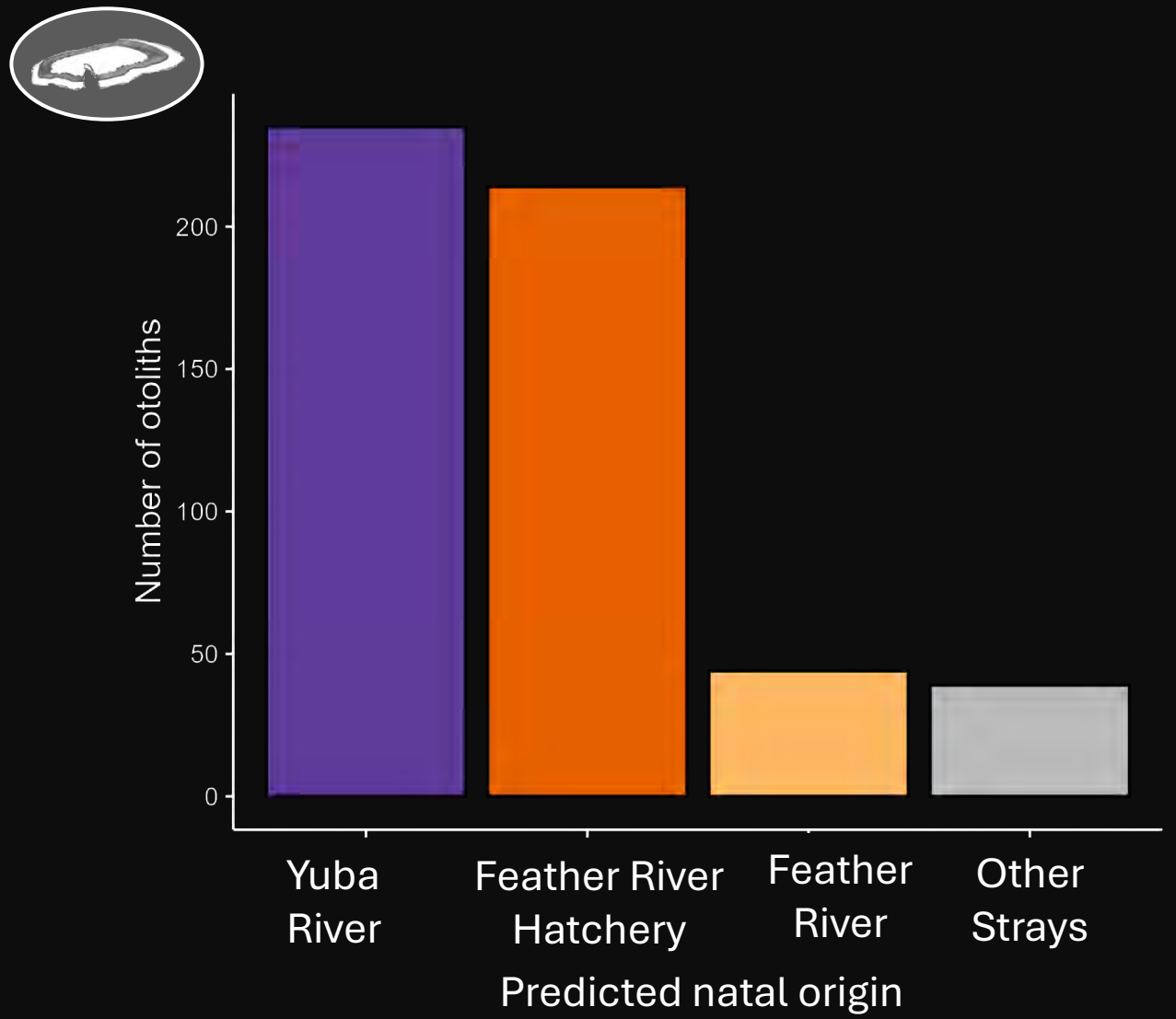
FishBio



Wild and hatchery adult returns



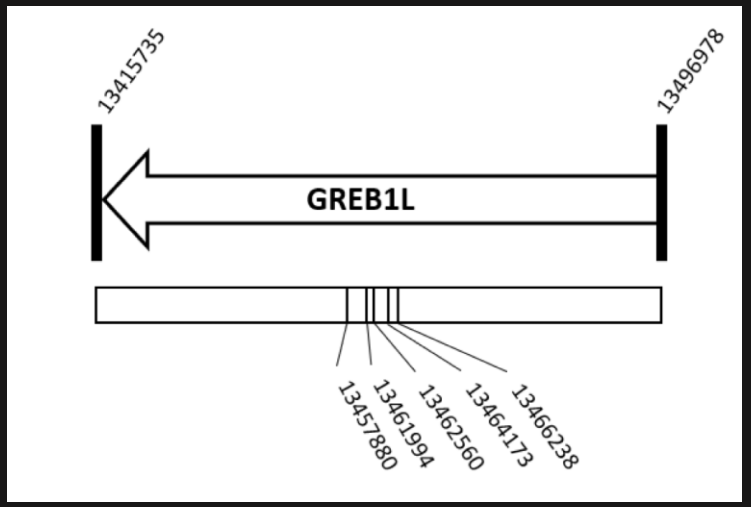
Hugentobler et al., 2024



Willmes et al., 2024

DNA tools

- Identify run assignment
- Spawner migration phenotype
- Fall and spring-run hybridization



Hugentobler et al. 2024

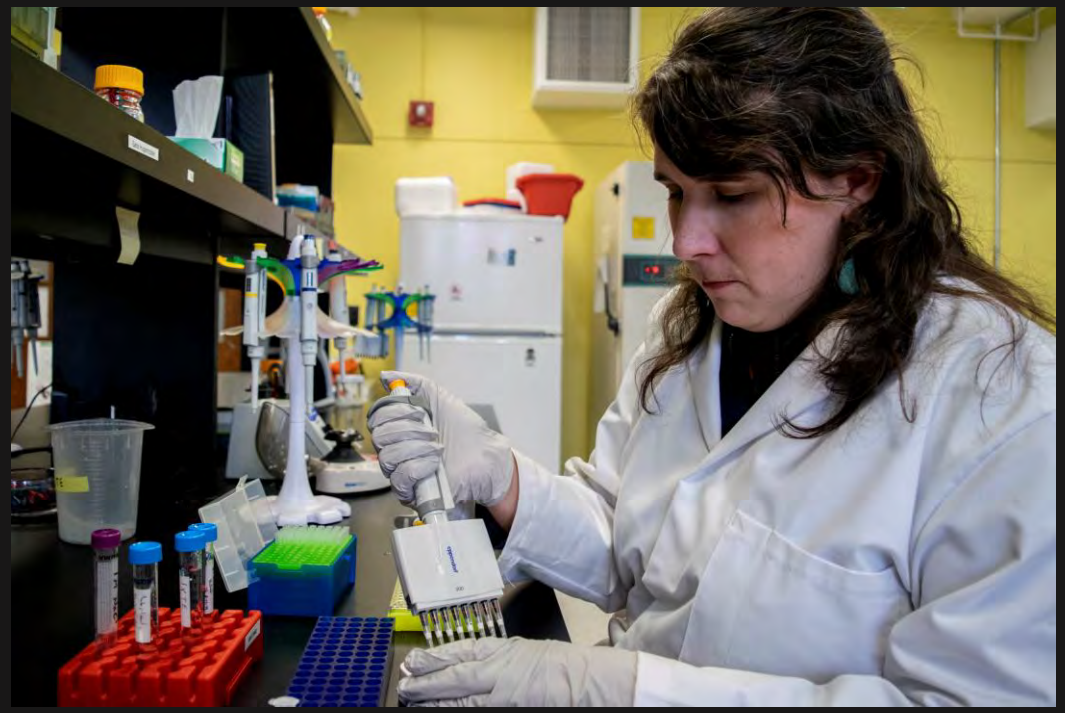


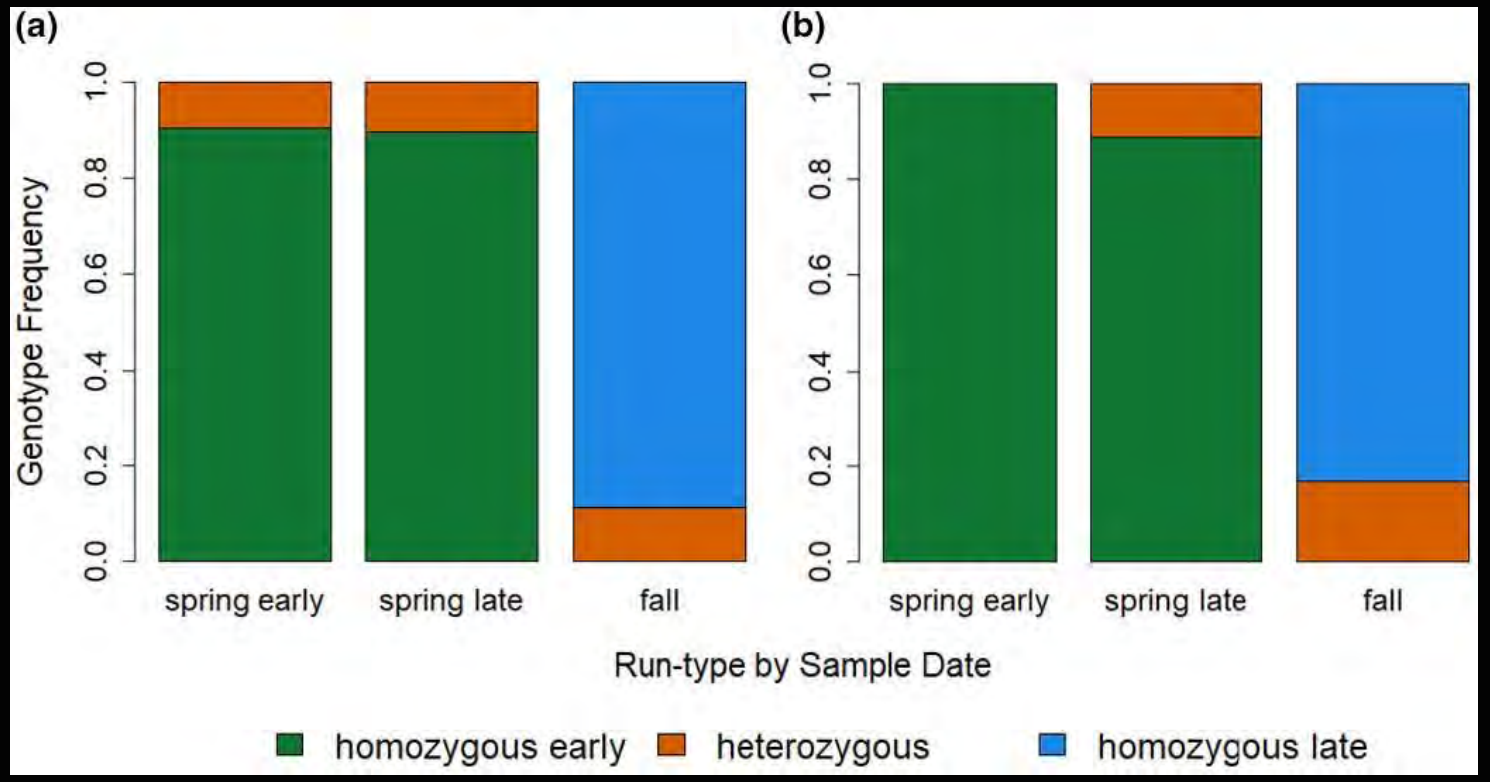
Photo Credit: Mariah Meek, MSU

Genetic spring-run fish confirmation

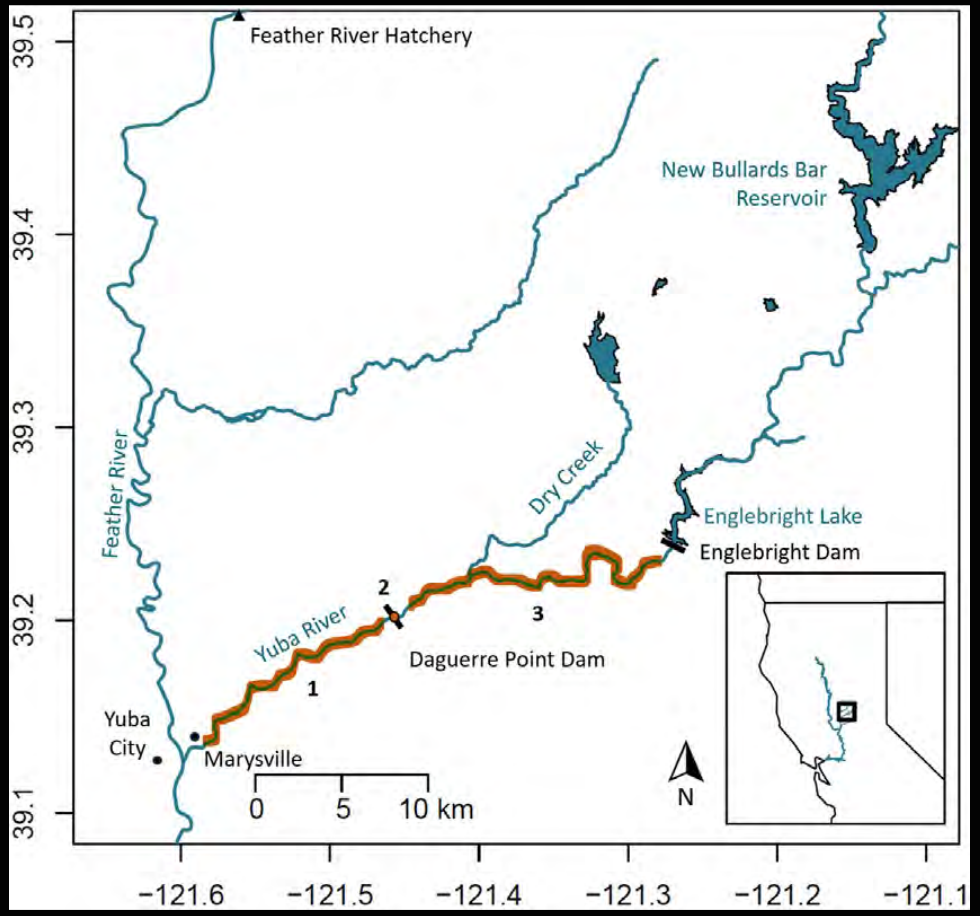
Received: 31 August 2023 | Revised: 28 May 2024 | Accepted: 29 May 2024
DOI: 10.1111/eva.13741
ORIGINAL ARTICLE
Evolutionary Applications WILEY

Remnant salmon life history diversity rediscovered in a highly compressed habitat

Sara A. Hugentobler[1] | Anna M. Sturrock[2,3] | Malte Willmes[4,5] | Tasha Q. Thompson[1,6] | Rachel C. Johnson[2,7] | Flora Cordoleani[4,7] | Natalie J. Stauffer-Olsen[8] | George Whitman[2] | Mariah H. Meek[1]



Hugentobler et al., 2024



Fall and spring-run temporal segregation

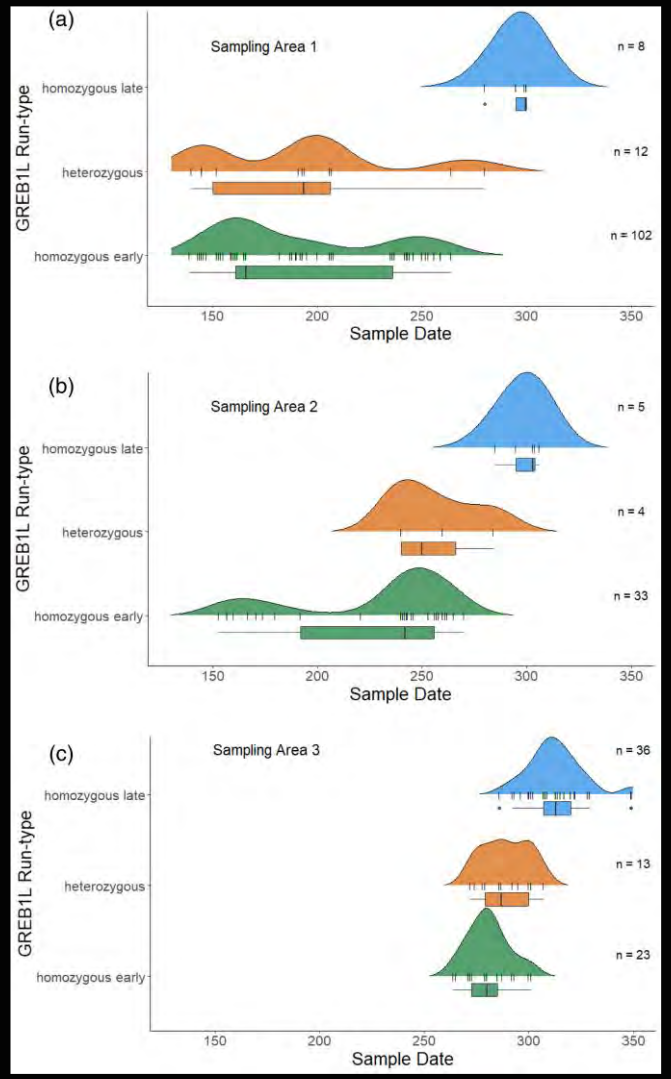
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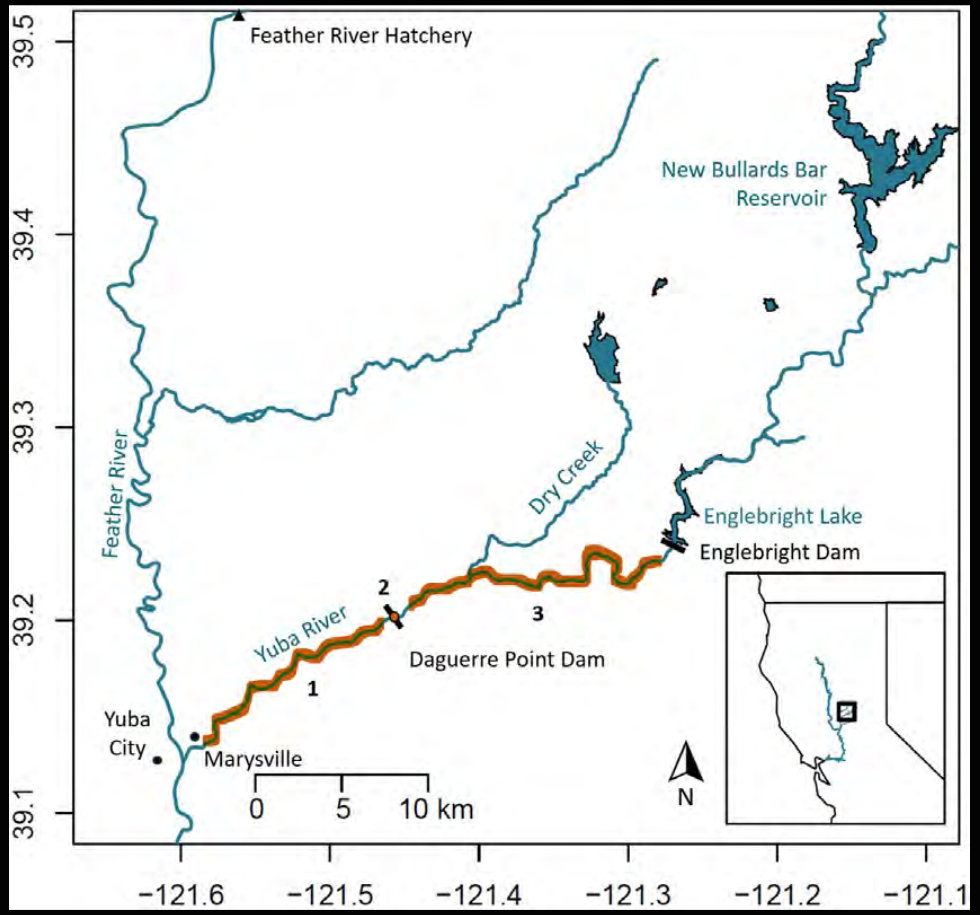
Evolutionary Applications WILEY

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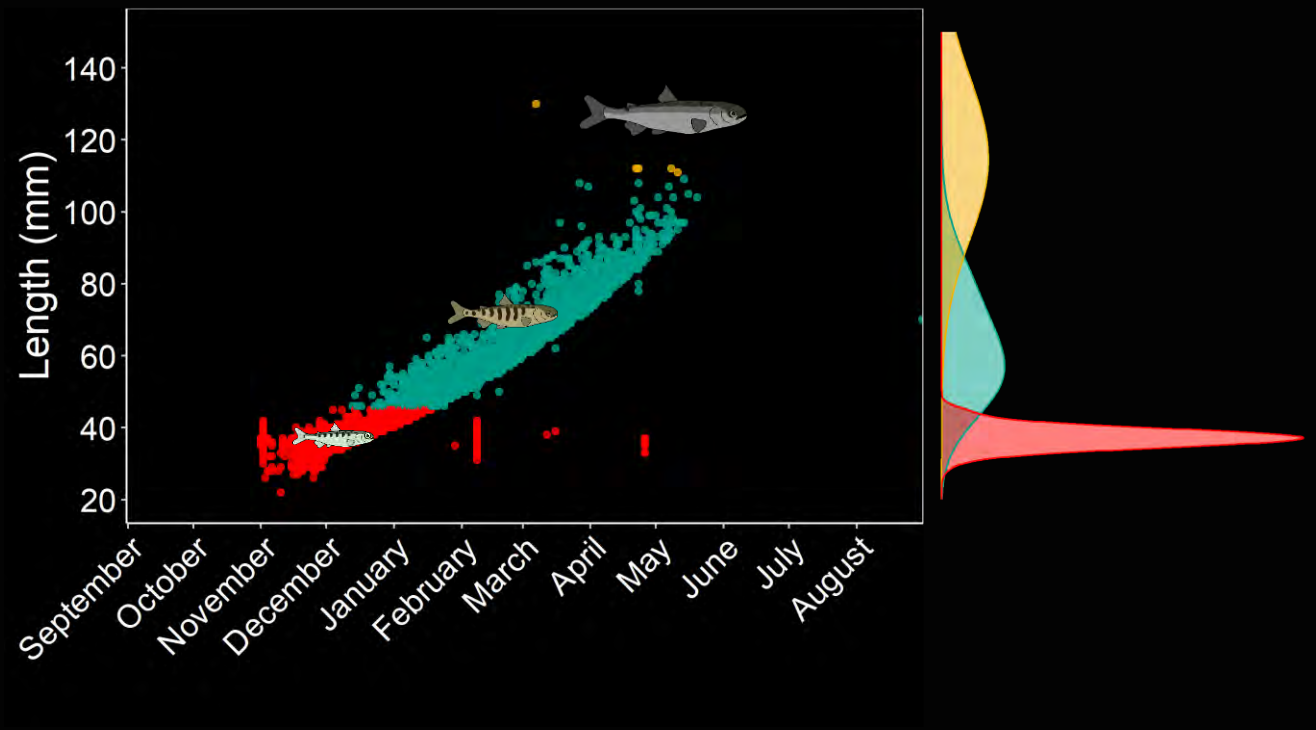
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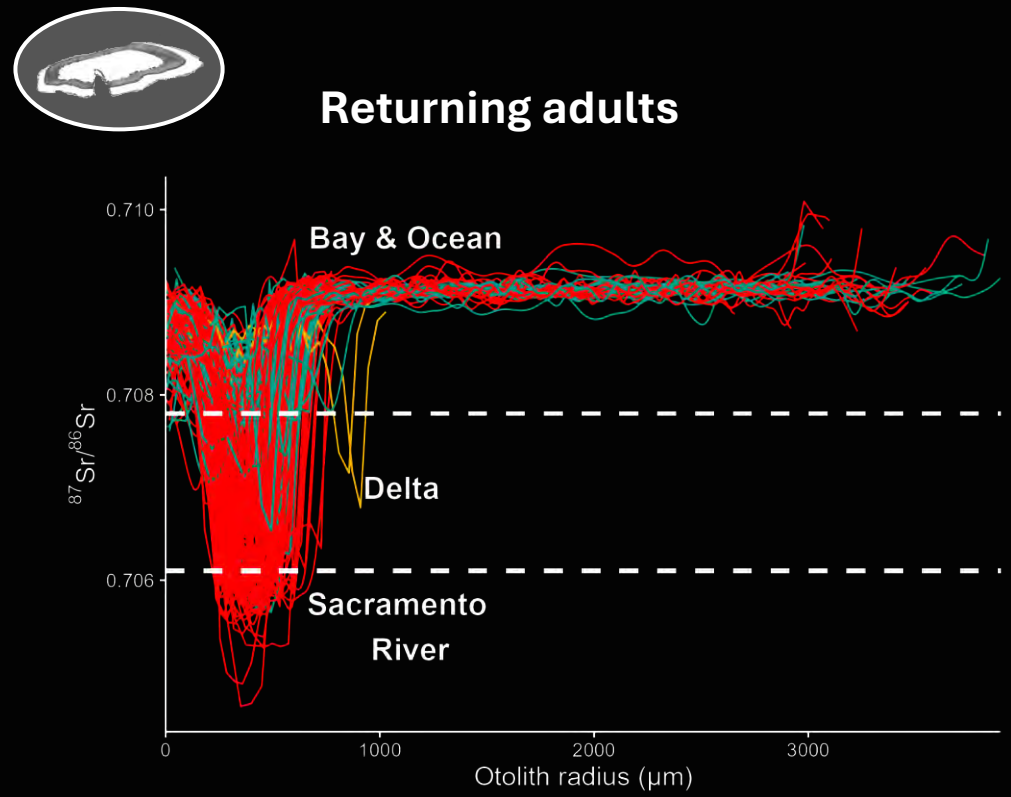


Hugentobler et al., 2024



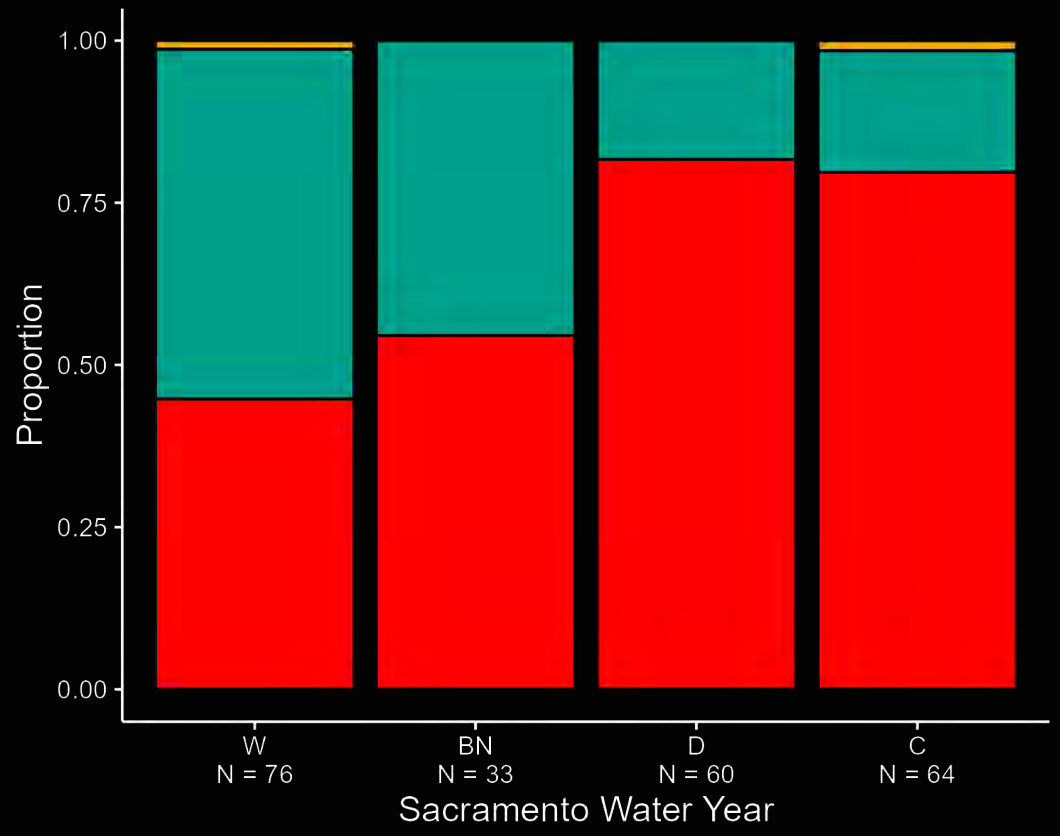
Fry dominate in adult returns





Willmes et al., 2024

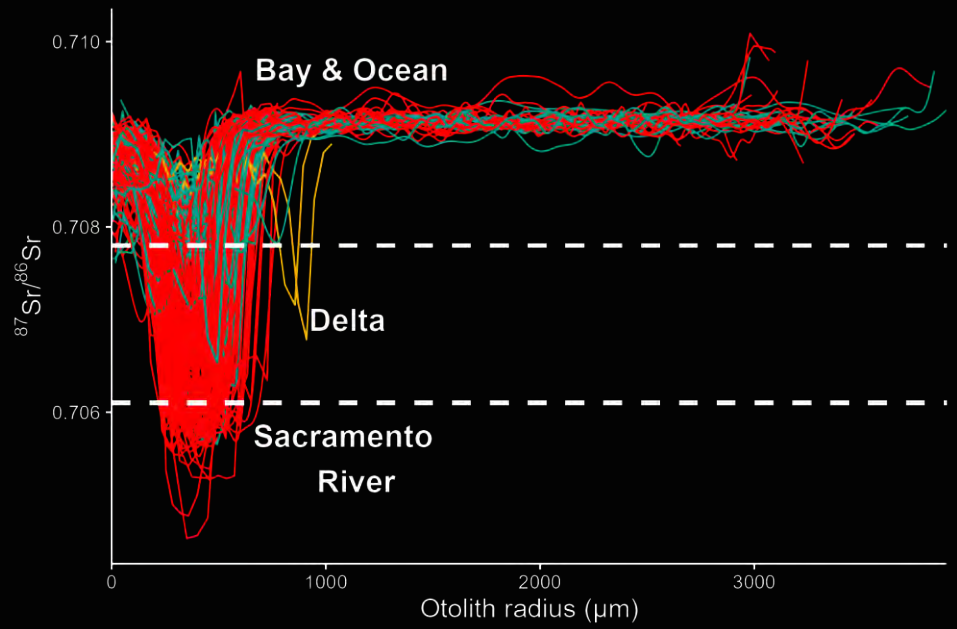
Fry dominate across all years



Willmes et al., 2024



Returning adults





Journal of Fish Biology

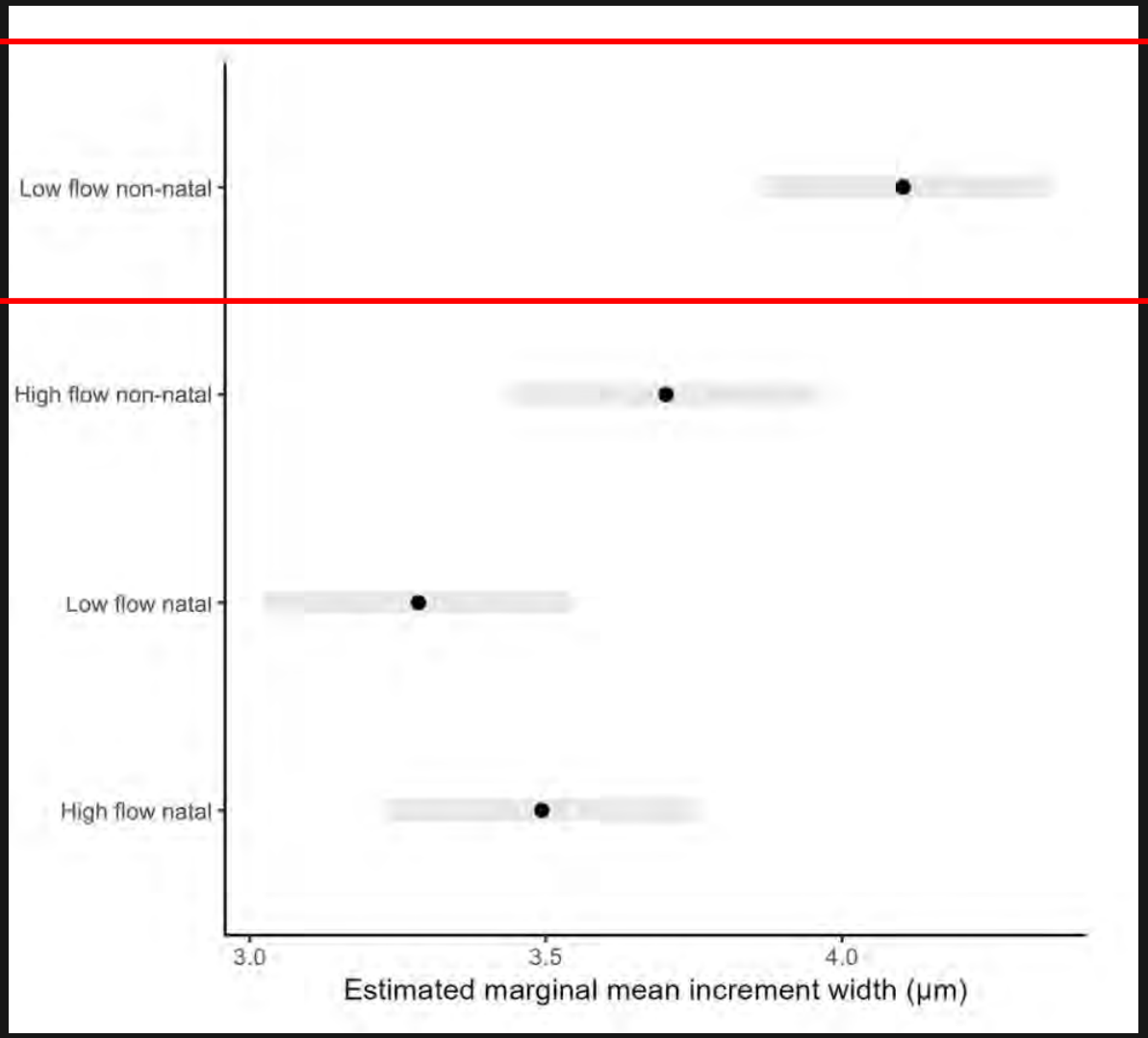
Integrating otolith and genetic tools to reveal intraspecific biodiversity in a highly impacted salmon population.

DOI: 10.1111/jfb.15847

Status: In Production

Larger growth for fry in non-natal habitat and dry years







Journal of Fish Biology

Integrating otolith and genetic tools to reveal intraspecific biodiversity in a highly impacted salmon population.

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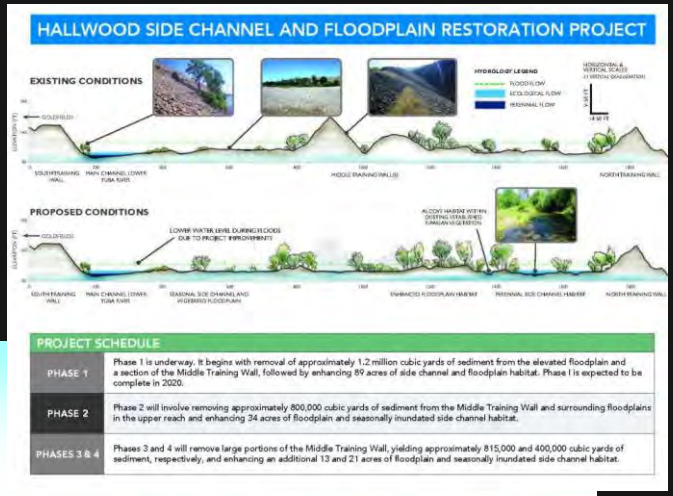
Status: In Production

Willmes et al., 2024

Long lasting anthropogenic legacy



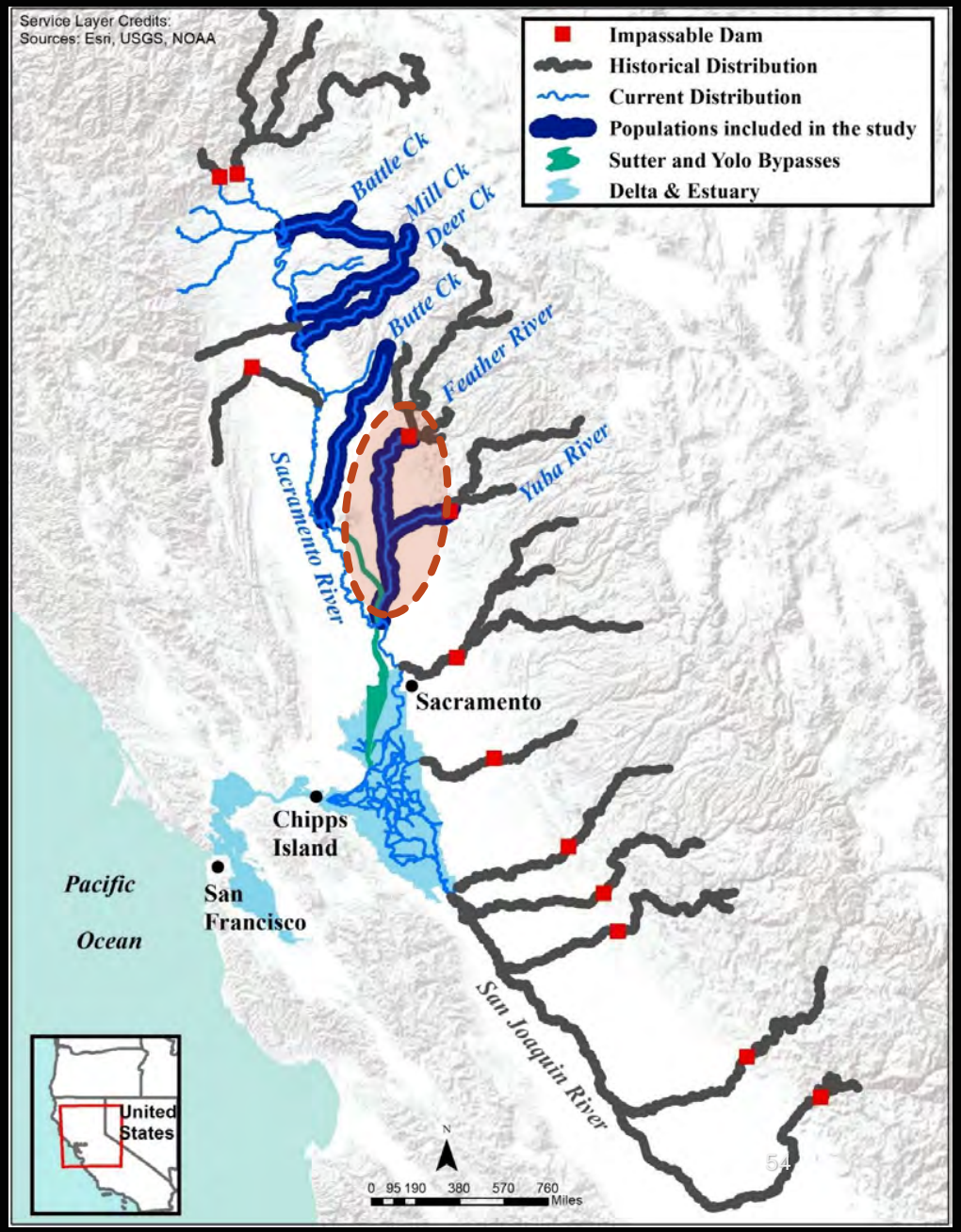
Historic hydraulic pit areas represent attractive mining sites for both the metal detectorist and small miner. North Bloomfield MD, Nevada Co., California. (Photo credit: Carlton Watkins Collection, Bancroft Library.)



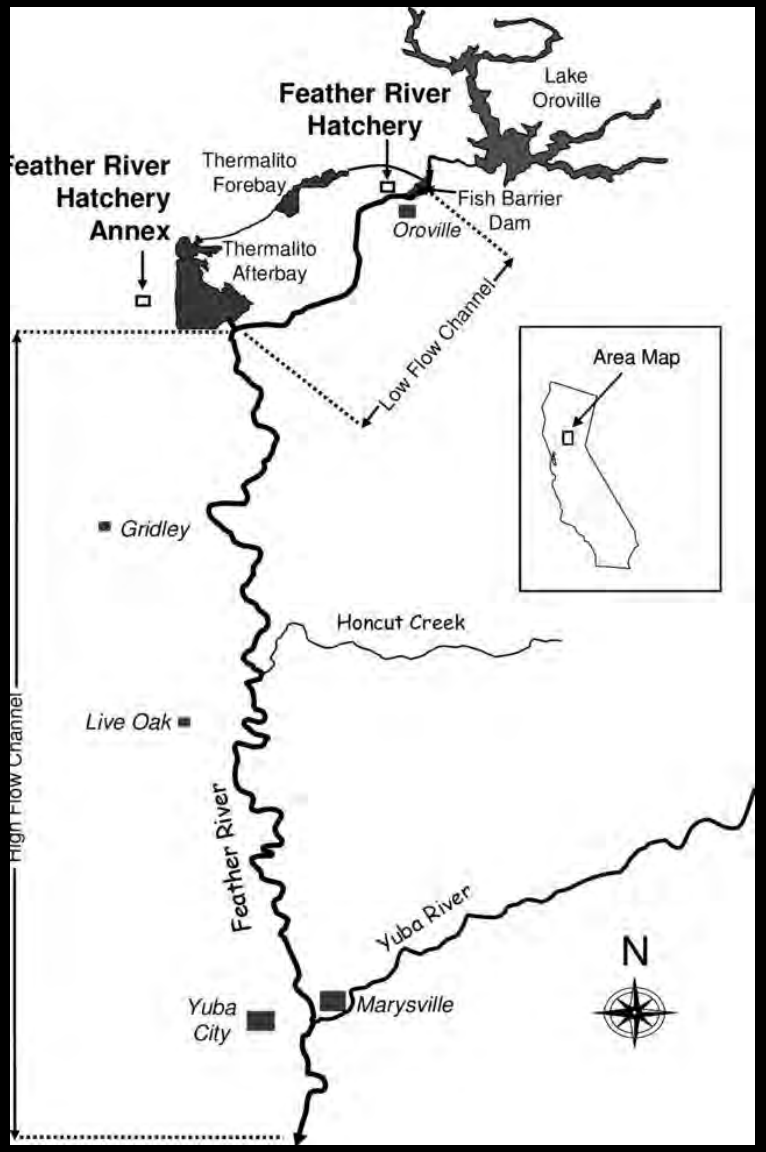


Spring-run populations

- Mill/Deer Creek
- Butte Creek
- Battle Creek
- Yuba River
- Feather River



Hatchery influence?



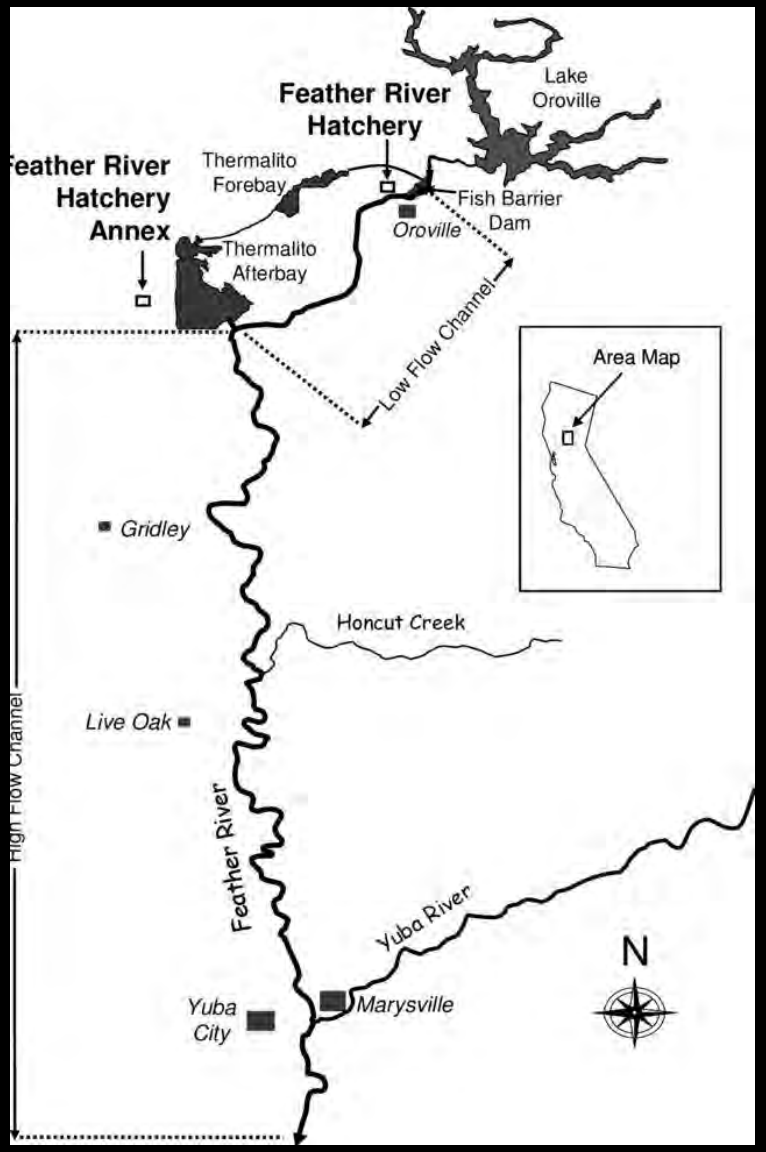
Cavallo et al., 2009





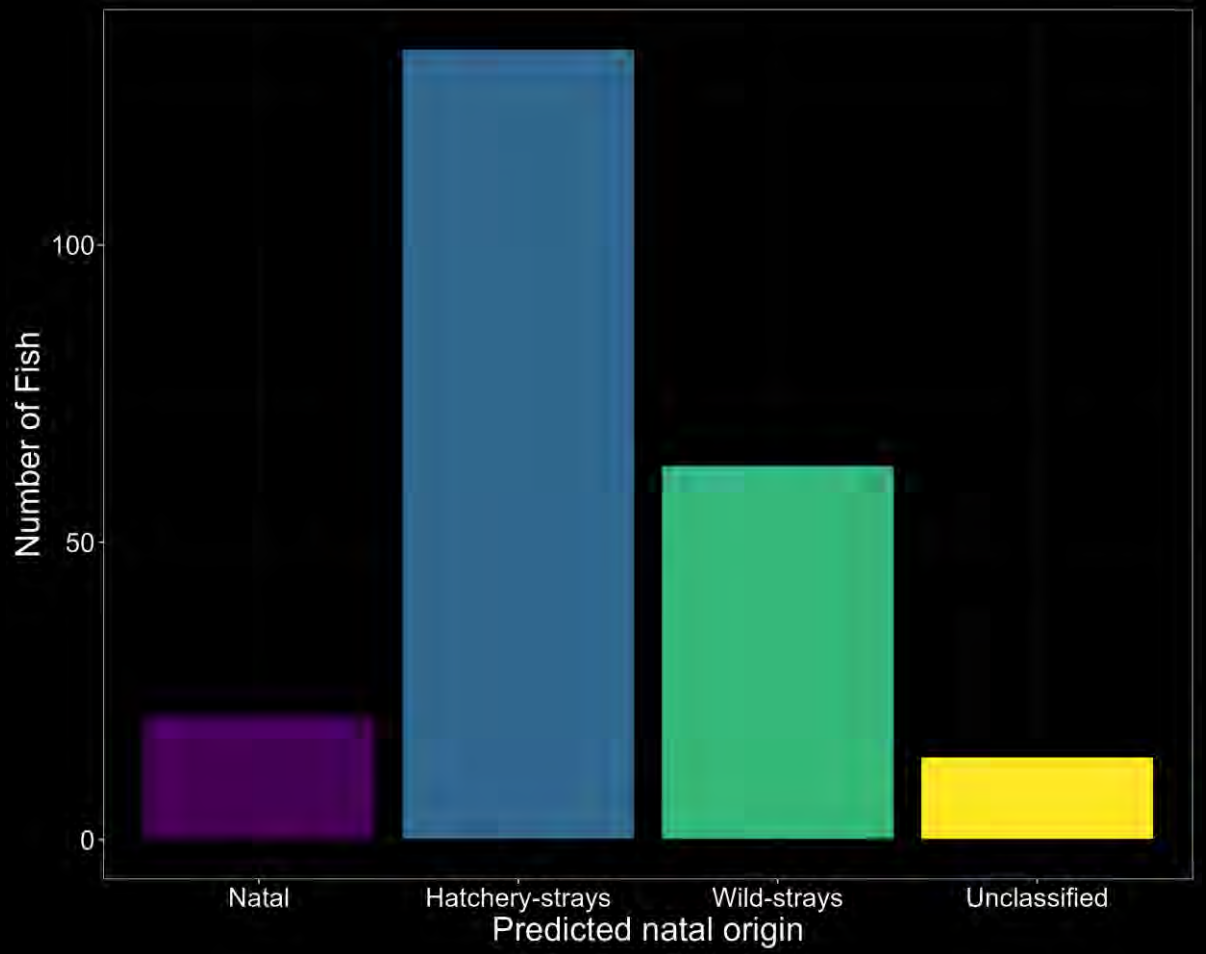
CDFW

Strong hatchery component in natal spawning grounds



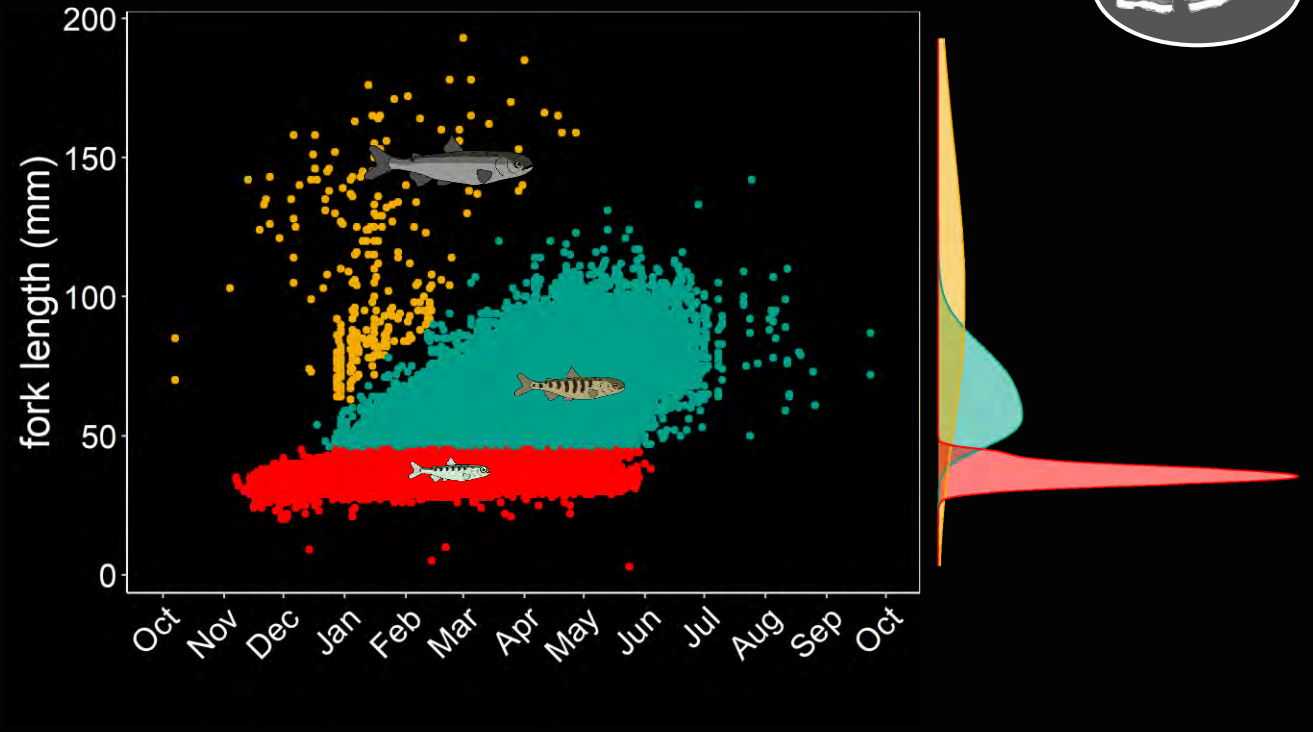
Cavallo et al., 2009



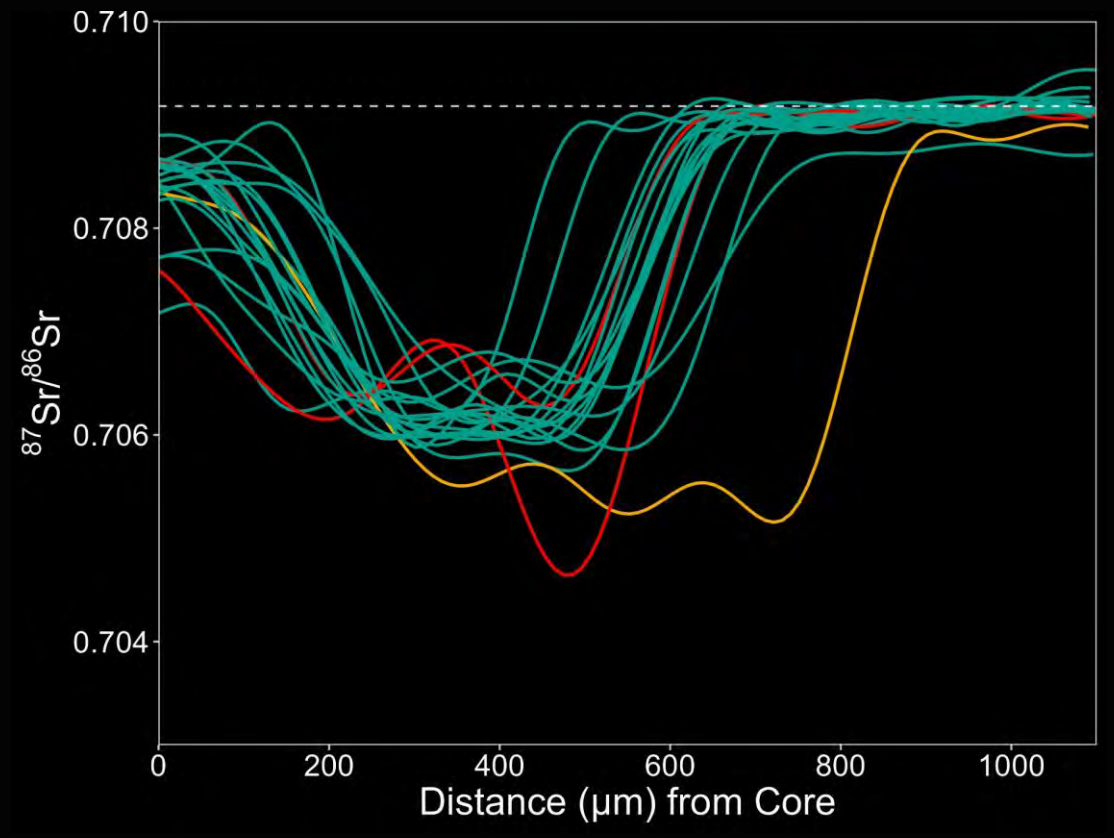


Preliminary data – do not cite

Subyearling migrants dominate in adult returns





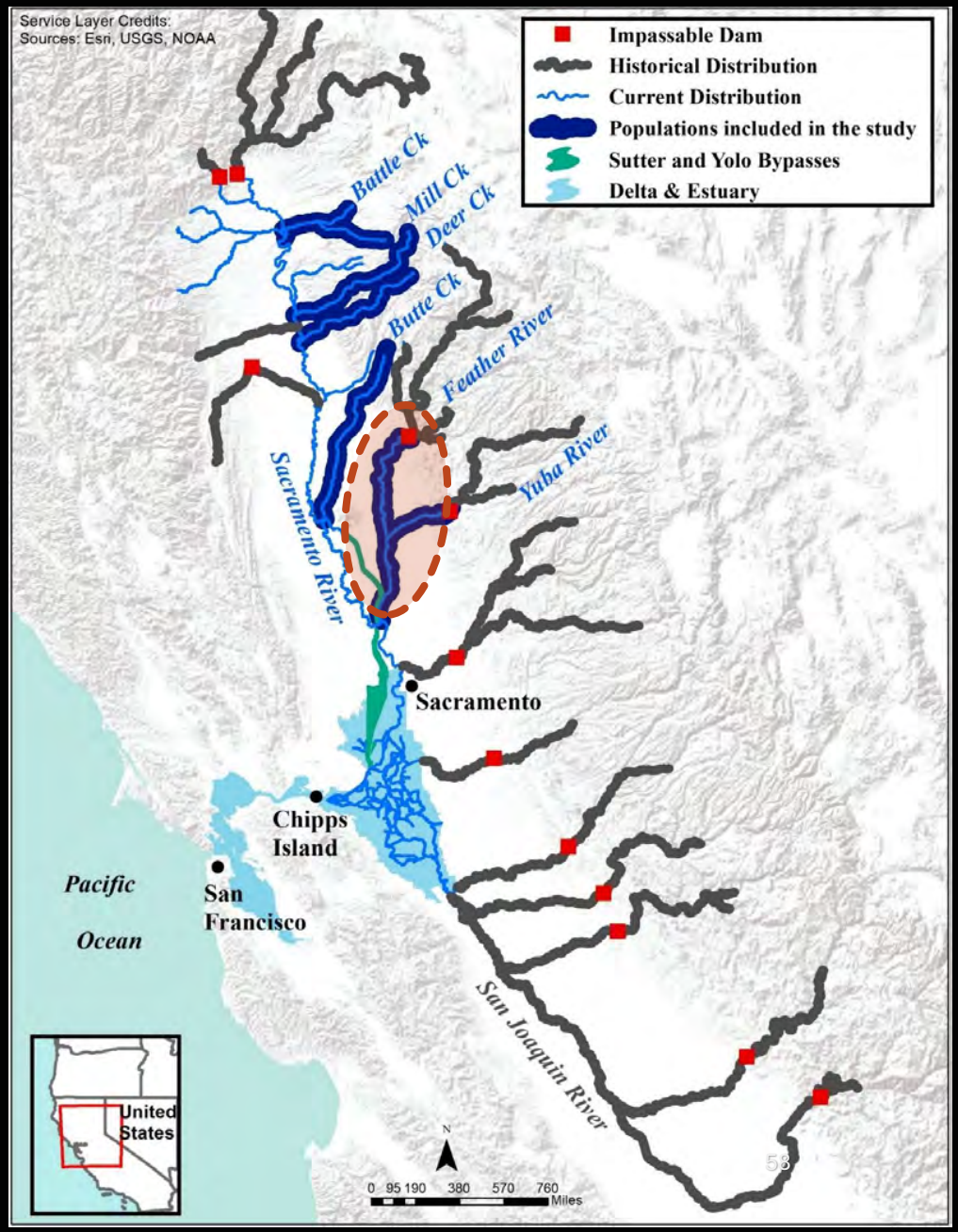


Preliminary data – do not cite

Spring-run populations

- Mill/Deer Creek
- Butte Creek
- Battle Creek
- Yuba River
- Feather River

But what about time?













ENTERPRISE RANCHERIA
EST. 1915
ESTOM YUMEKA MAIDU

- Feather River West levee project (Sutter Butte Flood Control Agency)
- 18 archaeological sites along a 20 mile stretch of the Feather River
- Range in age from 1870s to 6000 cal. BP (Droughts and Floods).

Archaeologic fish collections

- Snapshot in time
- Fishing behavior
- Preservation and diagenesis



Chinook salmon phenotypes through time

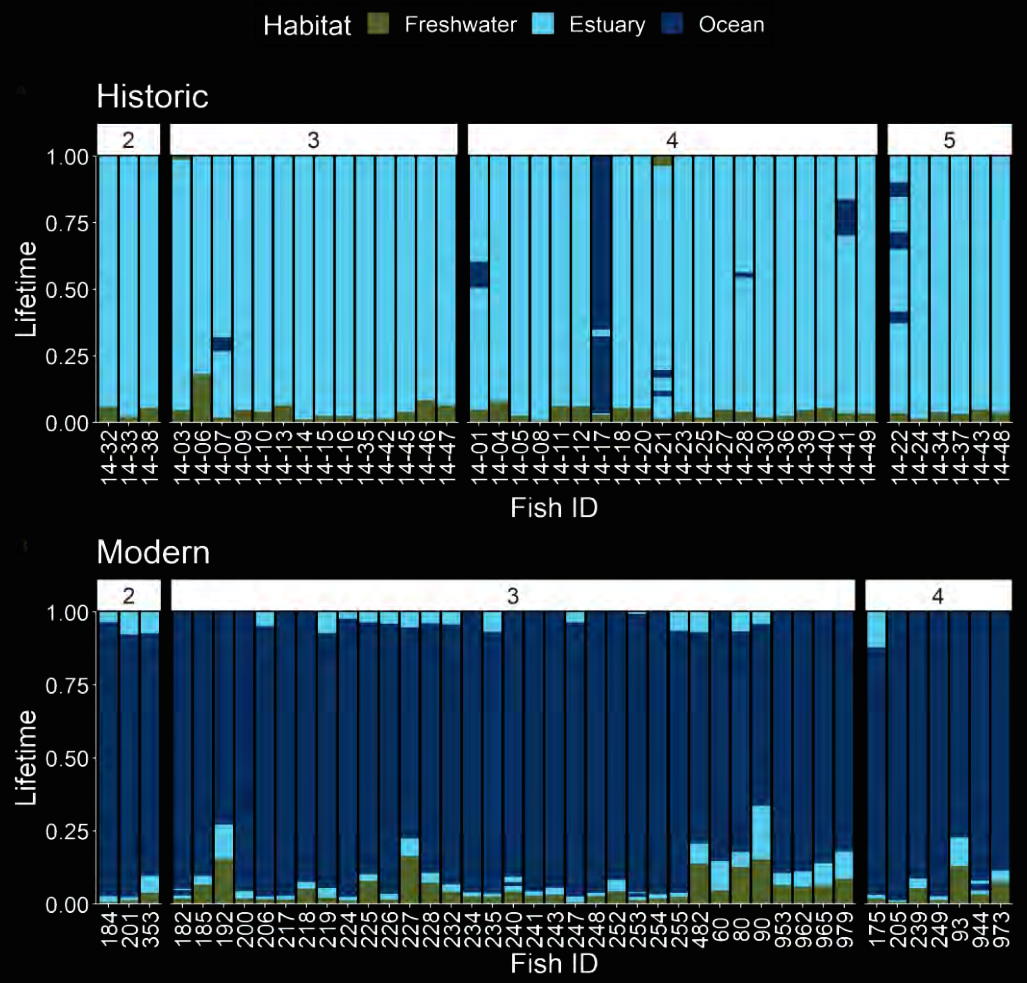


Preliminary data – do not cite

Archaeologic fish collections



Habitat use



Preliminary data – do not cite

Good news !

- CV spring-run Chinook Salmon still display a large phenotypic and genetic diversity and each life history strategy success varies among watersheds and in response to climate conditions

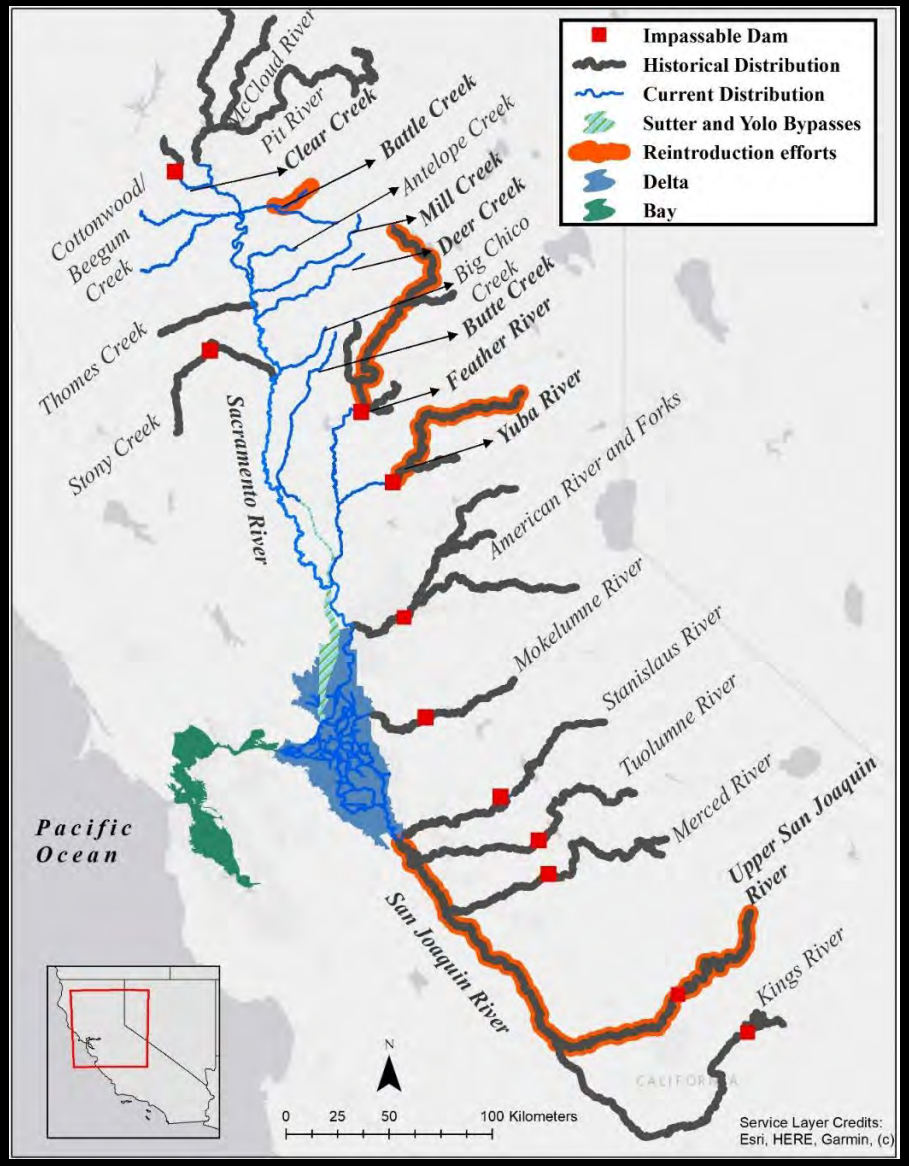
Bad news !

- Spring-run population abundances are dropping to dangerous lows because of multiple environmental stressors (e.g., wildfires, canal breach, droughts)

Conclusions

- Track life history diversity metrics in addition to abundance targets to evaluate resiliency
- Provide access to a mosaic of connected habitats supporting the different migratory types (e.g. cold water pools, floodplains and other natal and non natal off channel habitats)
- Listen to the past - indigenous records to get a snapshot of the long-term baseline and uncover “lost” life histories

Some hope? Reintroduction Efforts



Many thanks to
























Questions?
fcordole@ucsc.edu
© Carson Jeffres

References

- Cordoleani et al. 2021. https://www.nature.com/articles/s41558-021-01186-4
- Cordoleani et al. 2023. DOI: 10.13140/RG.2.2.30985.62562
- Cordoleani et al. 2024a. https://onlinelibrary.wiley.com/doi/abs/10.1002/ecs2.4803
- Cordoleani et al. 2024b. DOI: 10.13140/RG.2.2.31400.79363
- Hugentobler et al. 2024. https://onlinelibrary.wiley.com/doi/full/10.1111/eva.13741
- Willmes et al. 2024. https://onlinelibrary.wiley.com/doi/full/10.1111/jfb.15847

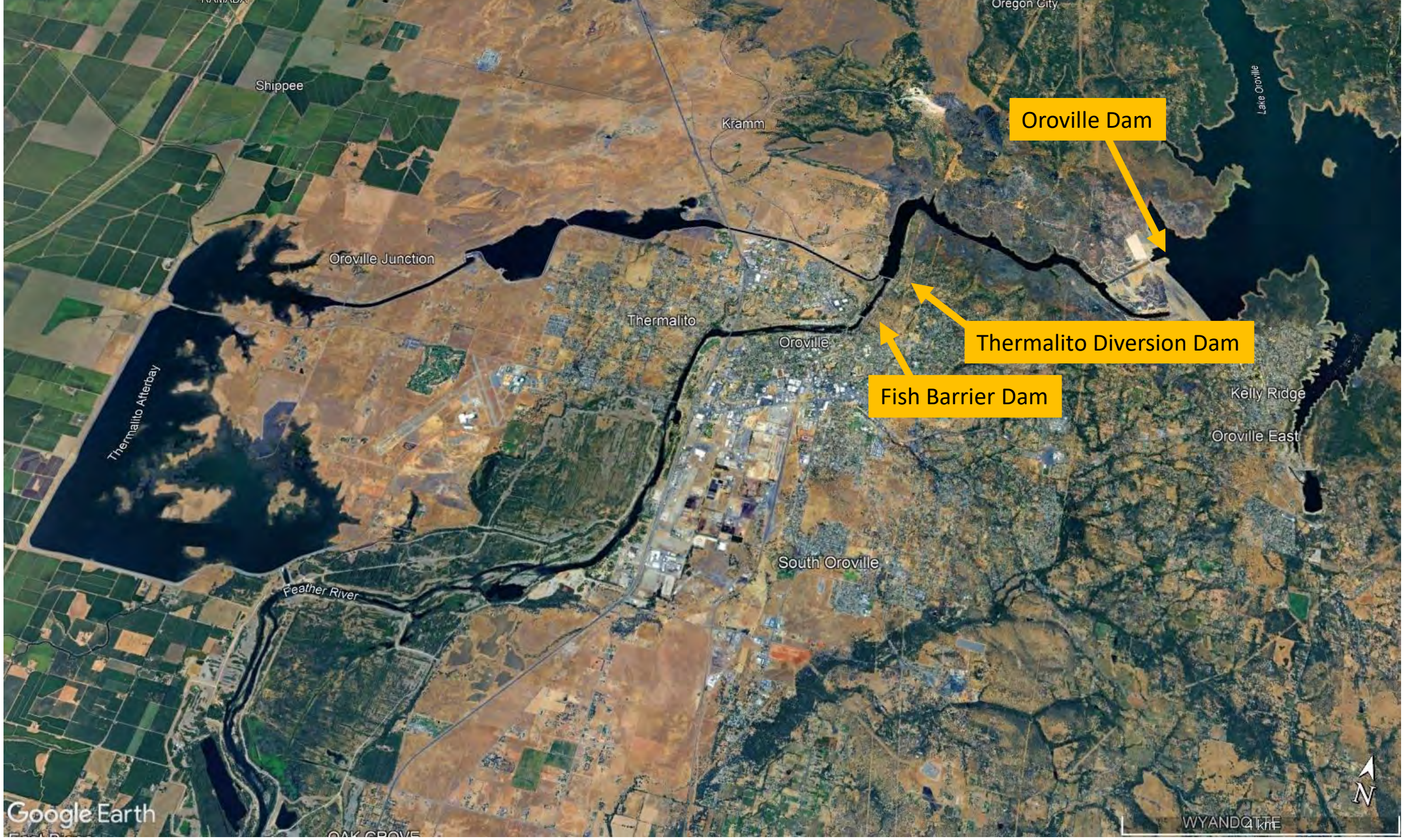
Movement and survival of acoustic tagged hatchery spring-run Chinook salmon from the Feather River.

Arnold Ammann[1], Jason Kindopp[2], Ryon Kurth[2],
Jeremy Notch[3], Flora Cordoleani[3]
Grant Henley[4], Claire Bryant[4], and Anna Allison[4]
1 – Presenter. National Marine Fisheries Service
2 –California Department of Water Resources
3 – NOAA affiliate, University of California Santa Cruz
4 – California Dept. of Fish and Wildlife

Overview

- Background on Feather River Hatchery Spring-run
- Methodology
- Total outmigration times and survival
- Outmigration through four habitats or ‘regions’
- Relationships with flow, temperature and turbidity
- Conclusions




Oroville Dam
Thermalito Diversion Dam
Fish Barrier Dam
Shippee
Kramm
Oroville Junction
Thermalito
Oroville
Thermalito Afterbay
Feather River
South Oroville
Kelly Ridge
Oroville East
Lake Oroville
Oregon City
Google Earth
4 km
N


Feather River State Fish Hatchery
Fish Barrier Dam
Feather River
Google Earth
200 m
N









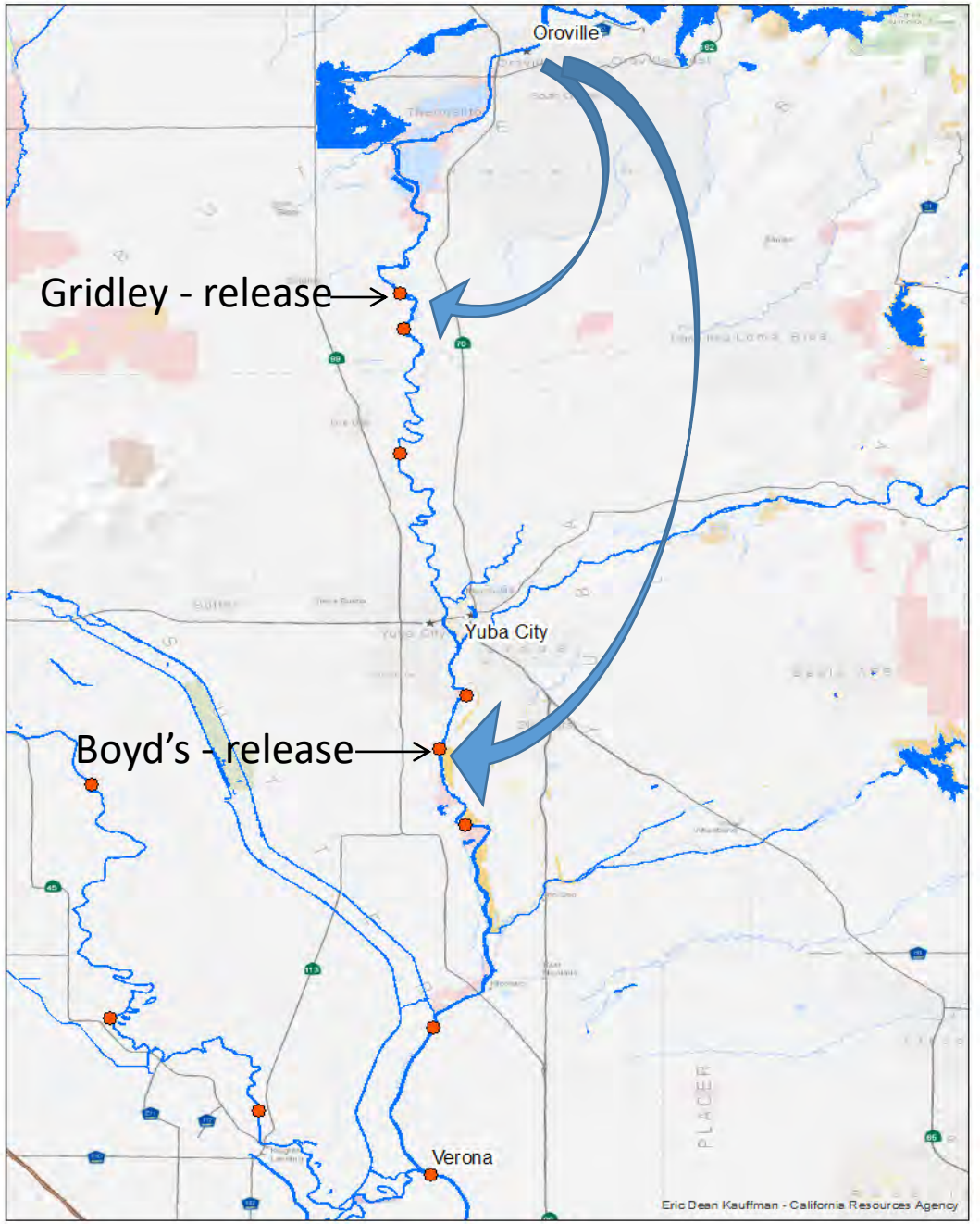











Oroville
Gridley - release
Yuba City
Boyd's - release
Verona
PLACER
Eric Dean Kauffman - California Resources Agency

Methods: Acoustic telemetry

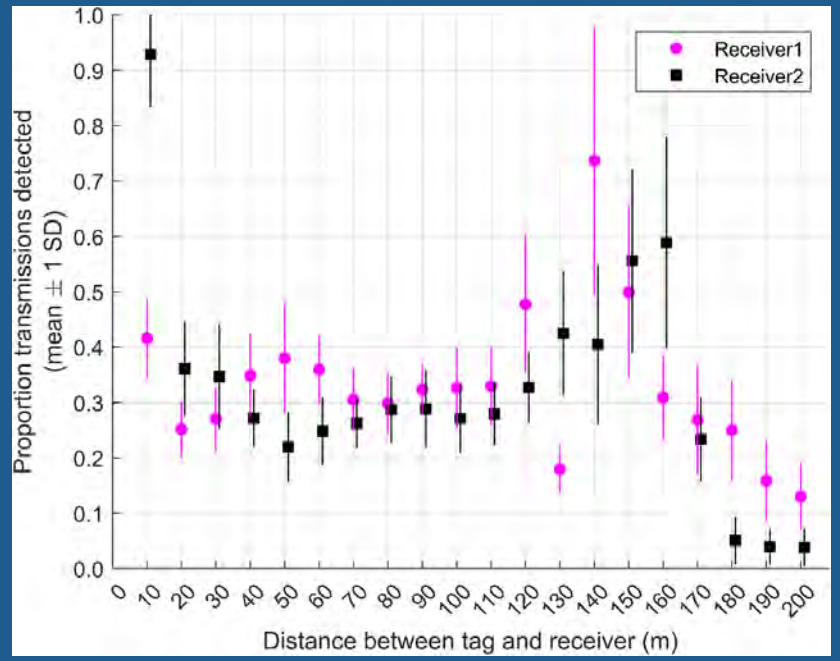
Receiver



Transmitter (tag)



Max Range 50 to 200m



Ammann, A.J. Factors affecting detection probability and range of transmitters and receivers designed for the Juvenile Salmon Acoustic Telemetry System. *Environ Biol Fish* **103**, 625–634 (2020). https://doi.org/10.1007/s10641-020-00987-4

Methods: Acoustic telemetry - Tags

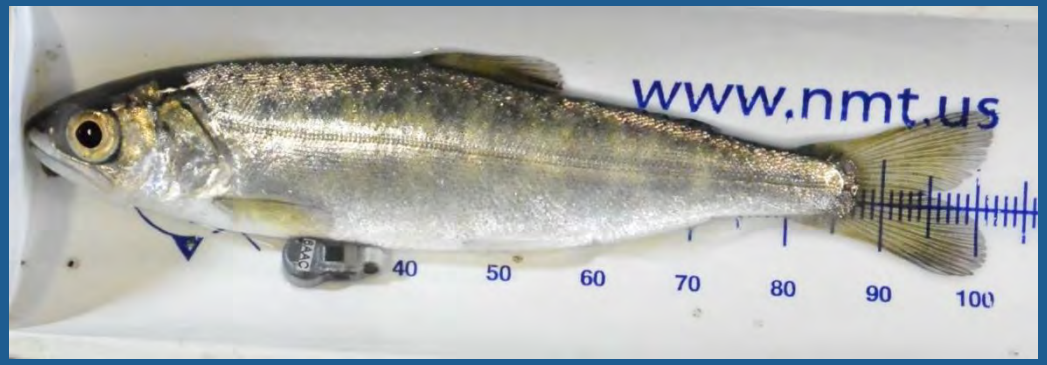
JSATS – Juvenile Salmon Acoustic Telemetry System

Very small size

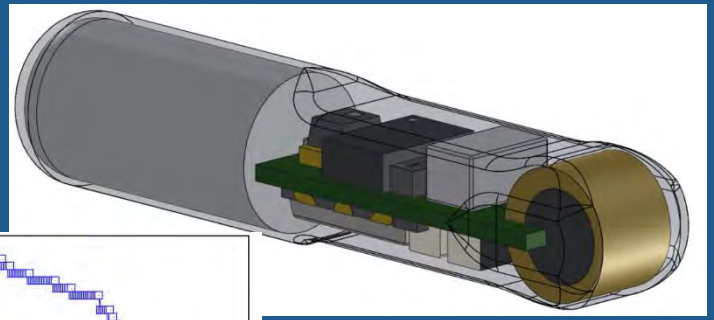
Fast ping rate

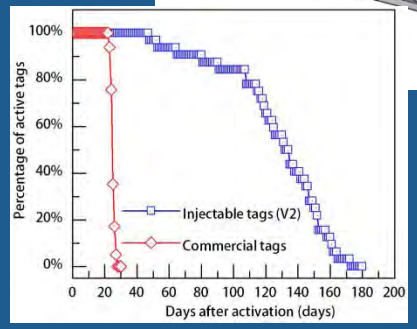
Detect many tags

Non-proprietary

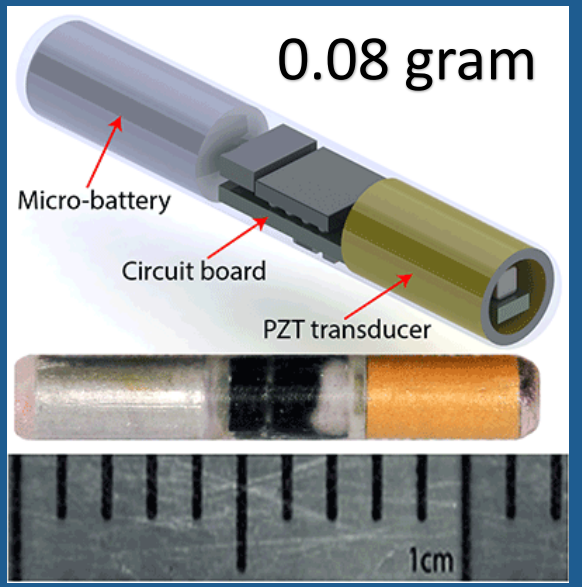








0.24 gram
"injectable"



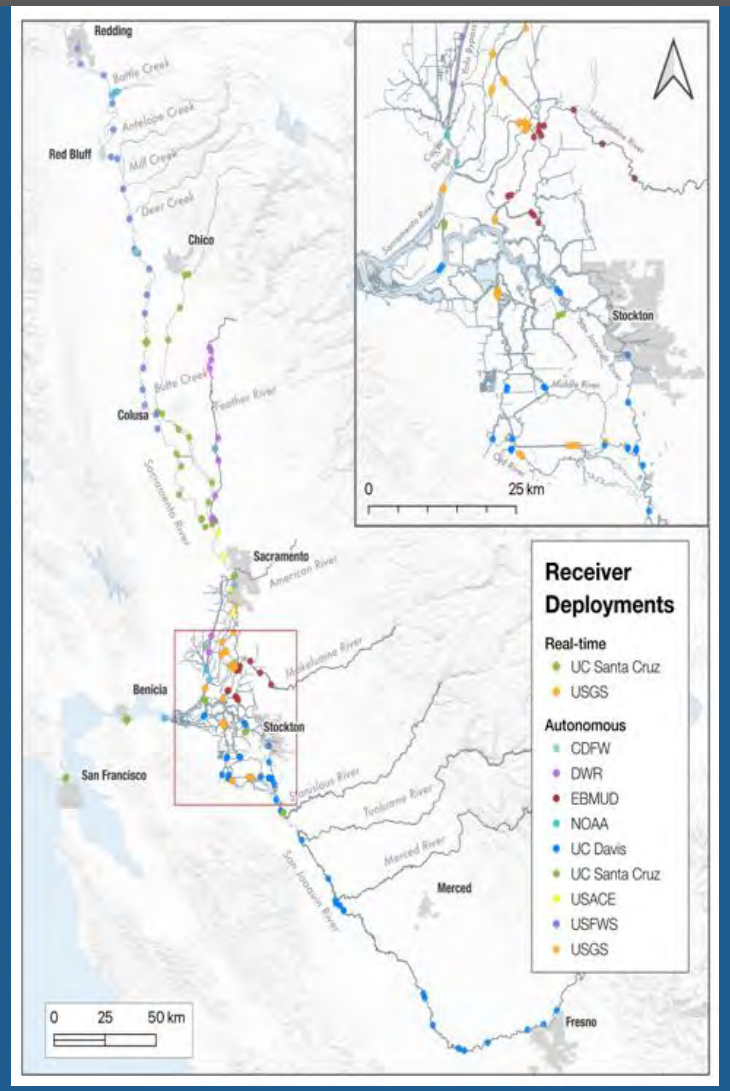
Methods: Acoustic telemetry - Receivers

- Multi agency effort
- Array has 130 locations with 350 receivers and over 600 deployments for the year
- Many reaches allow fine scale estimates of survival and movement









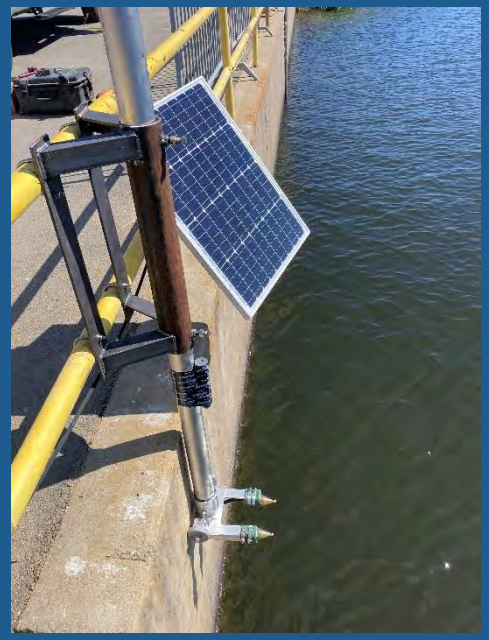
Map by Jessica Frey

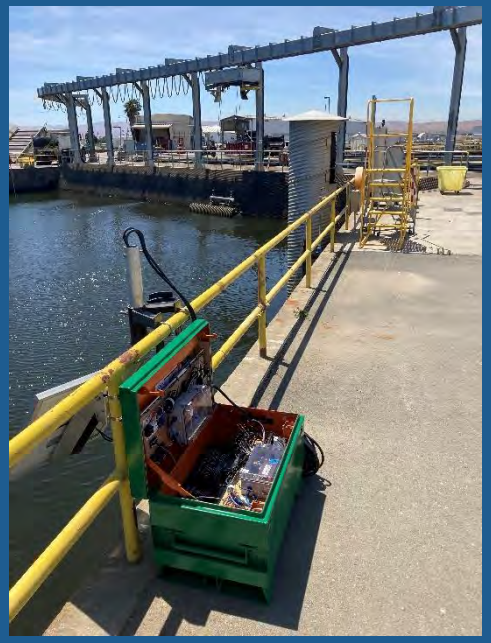
Real time receivers

Data uploaded to CalFishTrack website every hour.
https://oceanview.pfeg.noaa.gov/CalFishTrack/

54 receivers at 18 locations below Red Bluff, Meridian Bridge, Sacramento Tower and I80-50 Bridges, south Delta, CVP Trash Rack, Tanks and Benicia Bridge.







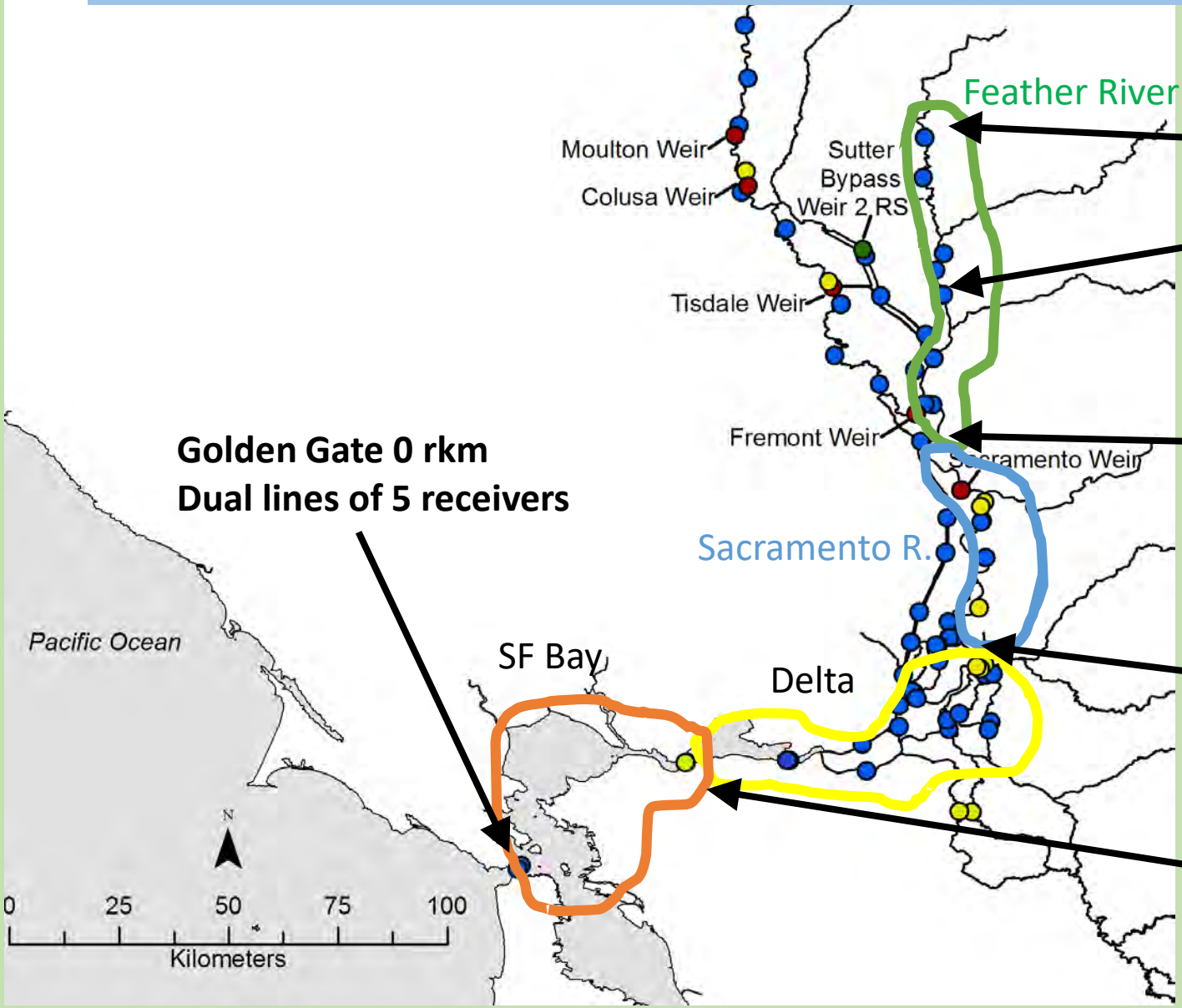
Study groups of acoustic tagged Feather River Hatchery Spring-run juveniles								
Grp#	**Year**	**Release Location**	**Release Day**	**Count**	**Weight**	**FL**	**Tag Model**	**PRI sec**
1	2013	Boyds	4/18/2013	151	8.8	93	SS300	5
2	2013	Gridley	4/17/2013	151	8.0	90	SS300	5
3	2014	Boyds	4/11/2014	150	7.1	85	SS300	5
4	2014	Gridley	4/10/2014	150	6.8	84	SS300	5
5	2015	Boyds	3/18/2015	75	7.2	87	SS300	5
6	2015	Boyds	4/2/2015	75	7.4	86	SS300	5
7	2015	Gridley	3/18/2015	75	7.2	86	SS300	5
8	2015	Gridley	4/2/2015	75	7.4	87	SS300	5
9	2019	Boyds	4/22/2019	300	8.1	89	SS300	5
10	2019	Gridley	4/22/2019	300	8.4	90	SS300	5
11	2020	Boyds	4/7/2020	252	7.9	87	SS300	5
12	2020	Gridley	4/7/2020	256	7.9	87	SS300	5
13	2021	Boyds	3/19/2021	300	7.8	88	SS300	5
14	2021	Boyds	4/1/2021	290	8.8	91	SS300	5
15	2023	Gridley	4/11/2023	490	7.2	86	SS300	10
16	2024	Gridley	4/23/2024	498	7.9	88	SS300	10







Breaking up the migration by regions



Gridley 287 rkm

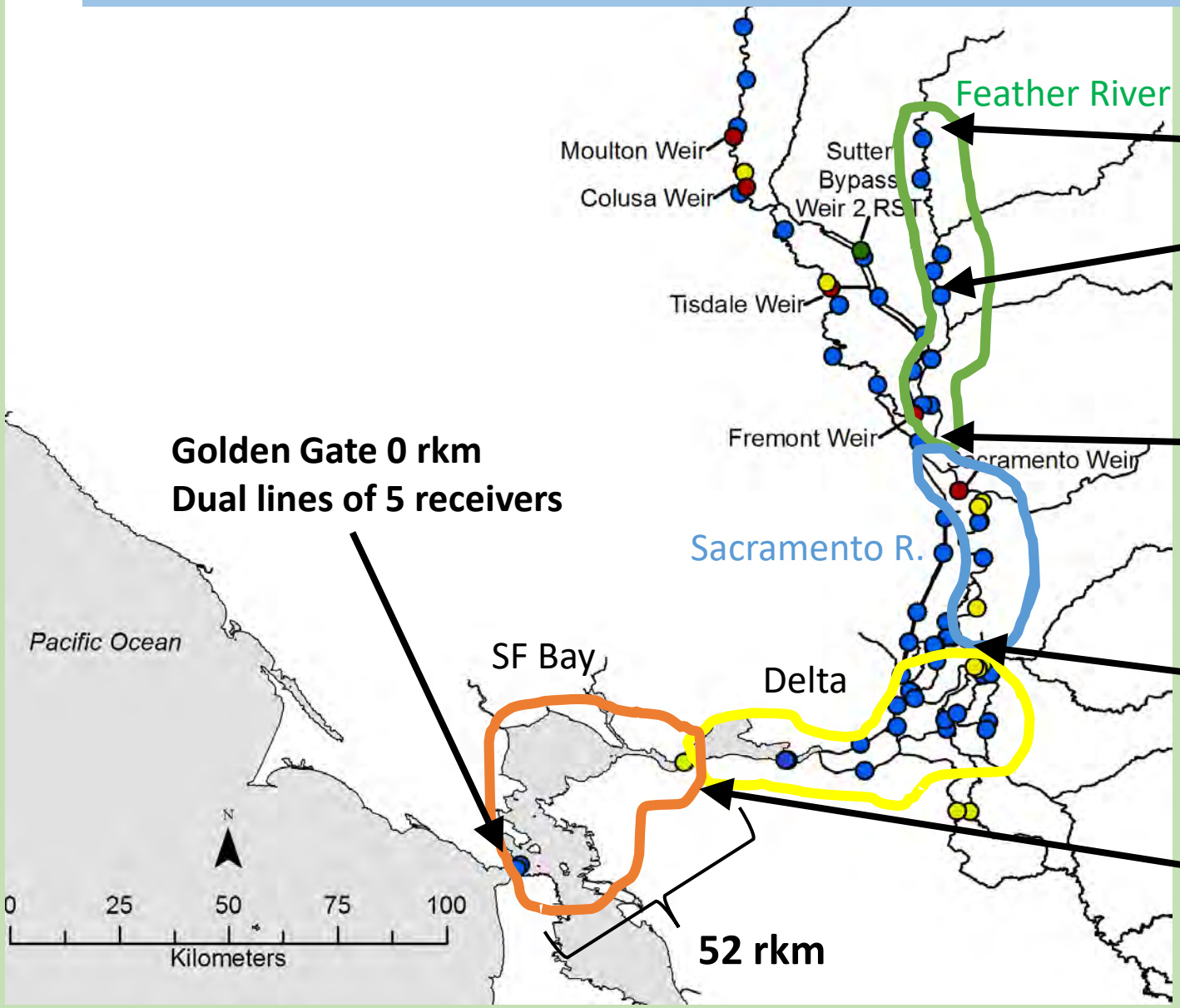
Boyds 241 rkm

FR Confluence (Verona) 203 rkm
Pooled 2-4 receivers

Freeport 152 rkm
Pooled 2-4 receivers

Benicia Bridge 52 rkm
Pooled 8-16 receivers

Breaking up the migration by regions



Gridley 287 rkm

Boyds 241 rkm

84/38 rkm

FR Confluence (Verona) 203 rkm
Pooled 2-4 receivers

51 rkm

Freeport 152 rkm
Pooled 2-4 receivers

100 rkm

Benicia Bridge 52 rkm
Pooled 8-16 receivers

Golden Gate 0 rkm
Dual lines of 5 receivers

52 rkm

Methods: Acoustic Data

1. Detection Filter – multiple hits of correct PRI in time window
2. False detect algorithm – remove false positives
3. Visually inspect plots for each fish for incongruent patterns – manually remove false detects
4. Select subset Receiver Locations to define the four regions
5. Take first detection at each location
6. Create capture history (1s and 0s) for each fish.
7. Program Mark/Rmark run Cormack-Jolly-Seber models
8. Use “Release Group” x “Region” (reach) model to estimate Survival
9. Examine correlations between regional survival estimates and covariates

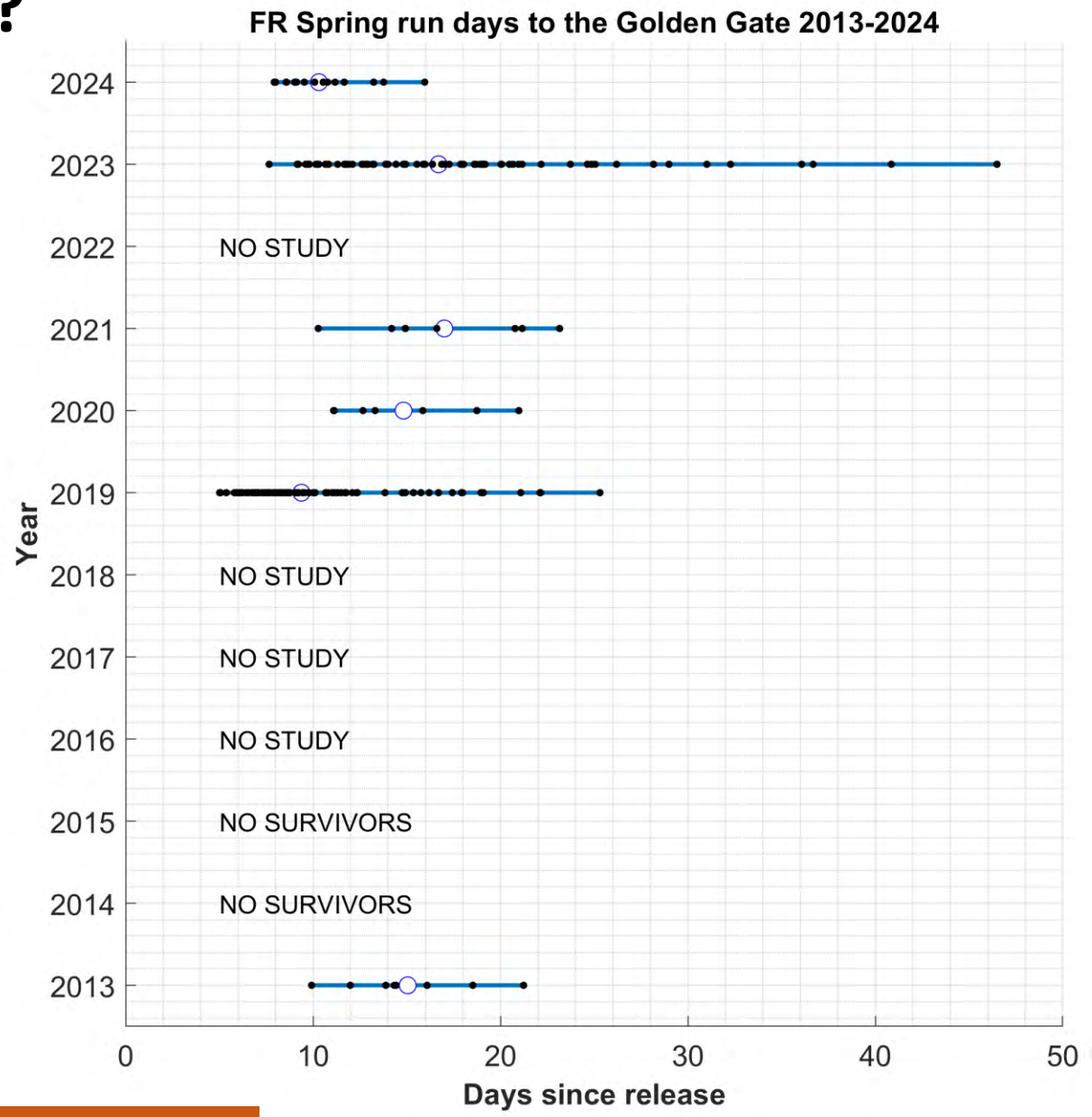
RESULTS: How long does it take?



To the Golden Gate and to the ocean
Gridley to Golden Gate: 287 rkm
Boyds to Golden Gate: 241 rkm

Annual mean: 9.3 to 17 days

All years: mean 12.7 days (SD 6.4) range 5-46 days



Preliminary data – do not cite

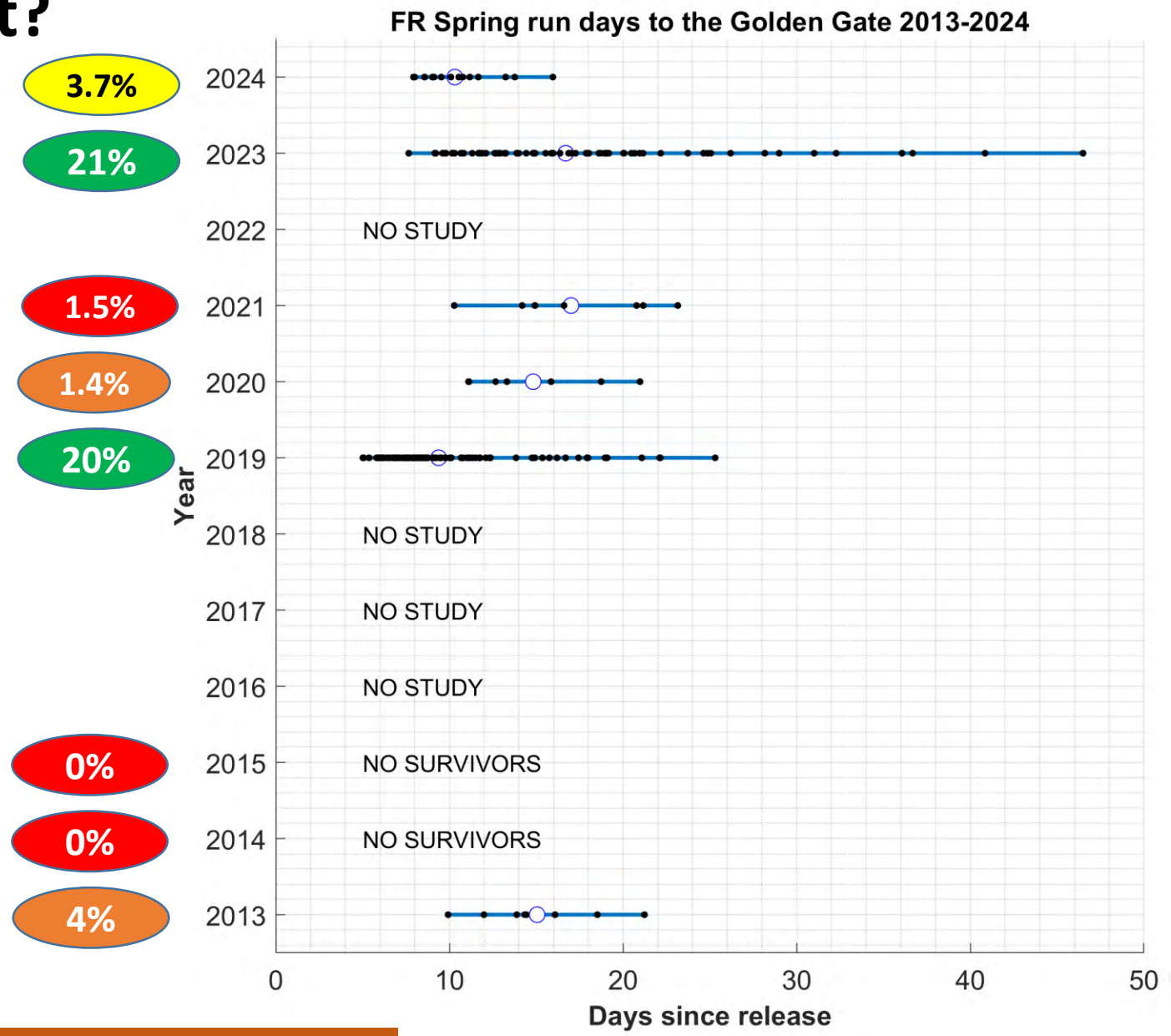
RESULTS: How many made it?



To the Golden Gate and to the ocean
Gridley to Golden Gate: 287 rkm
Boyds to Golden Gate: 241 rkm

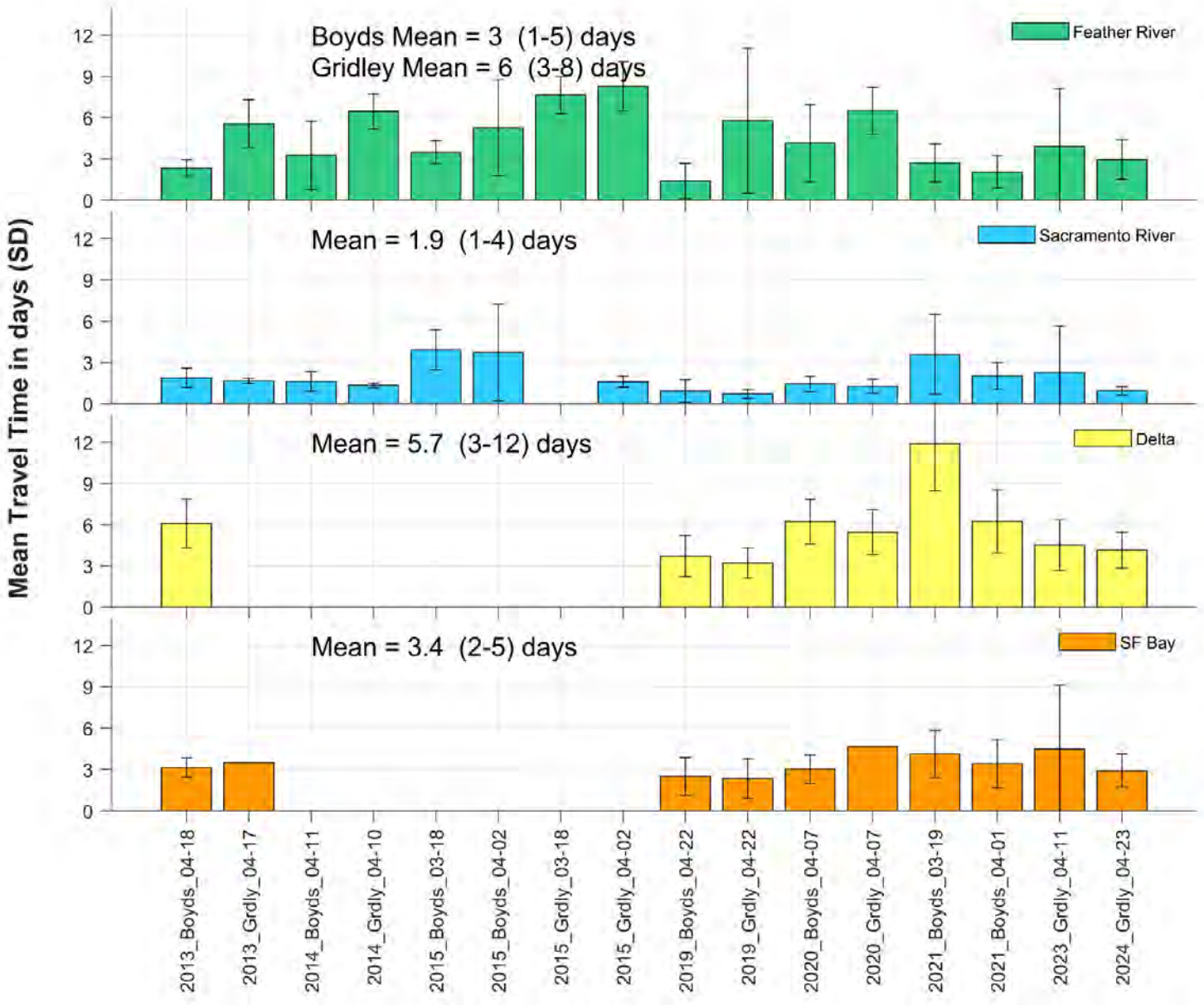
Water Year Types

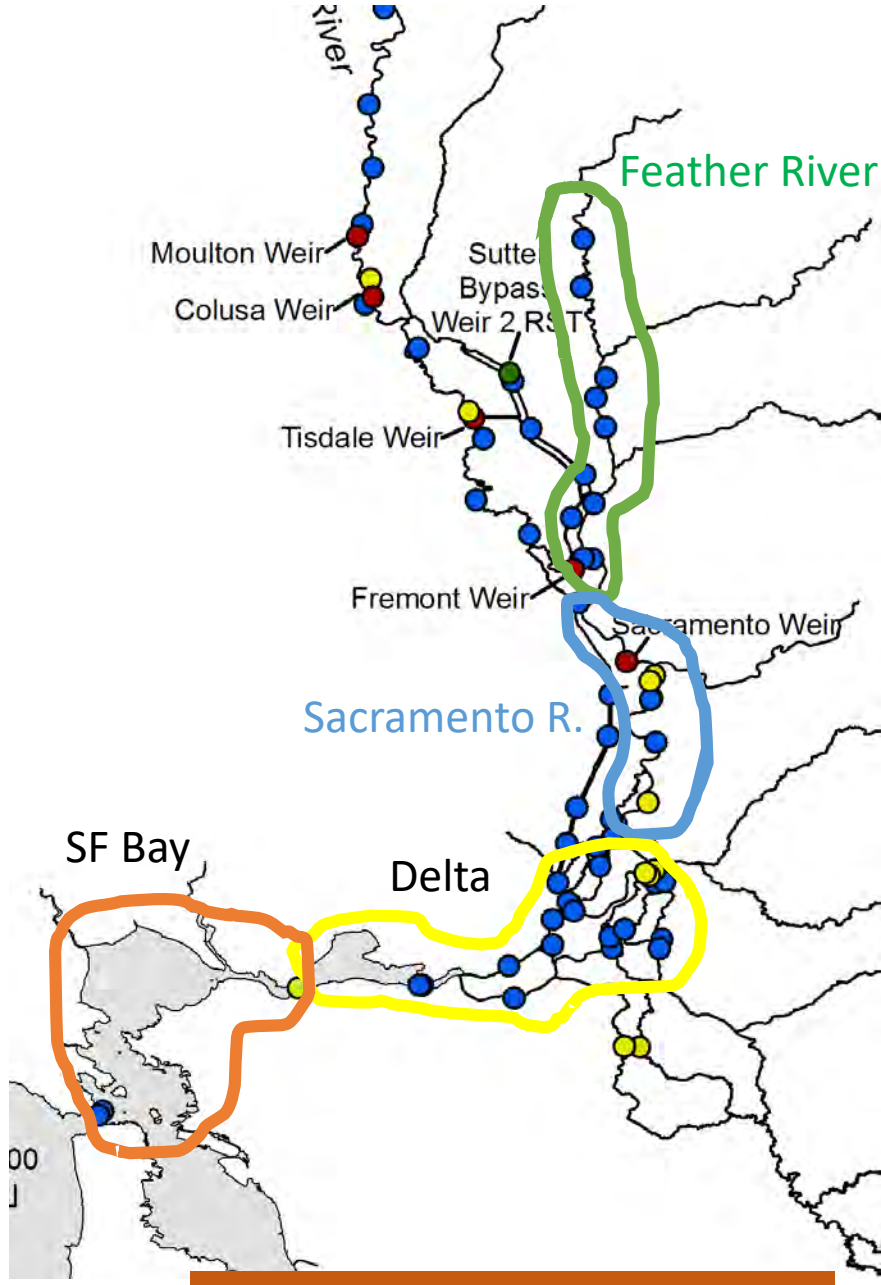
CD DRY NOR WET



Preliminary data – do not cite

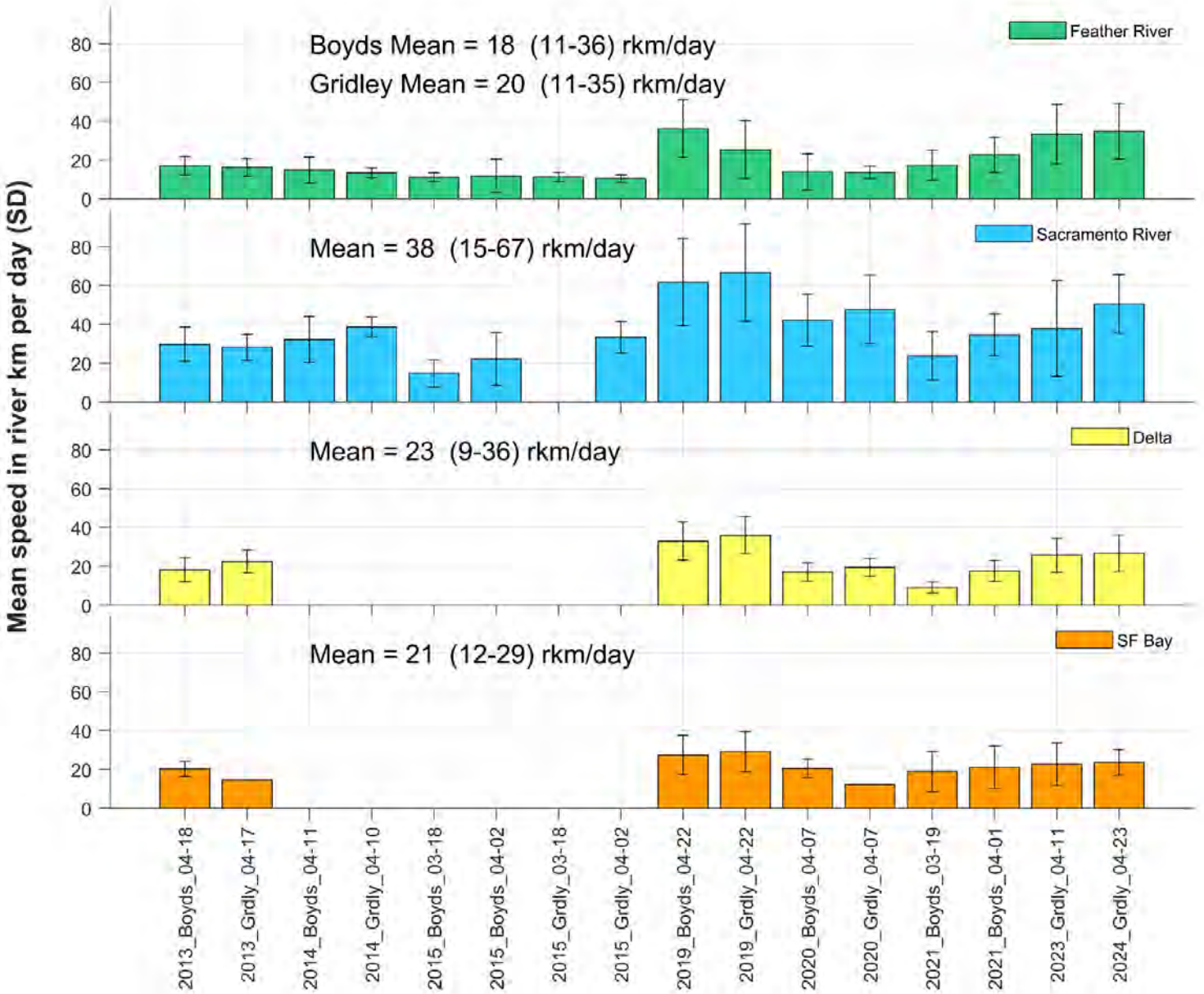
RESULTS: TRAVEL TIME

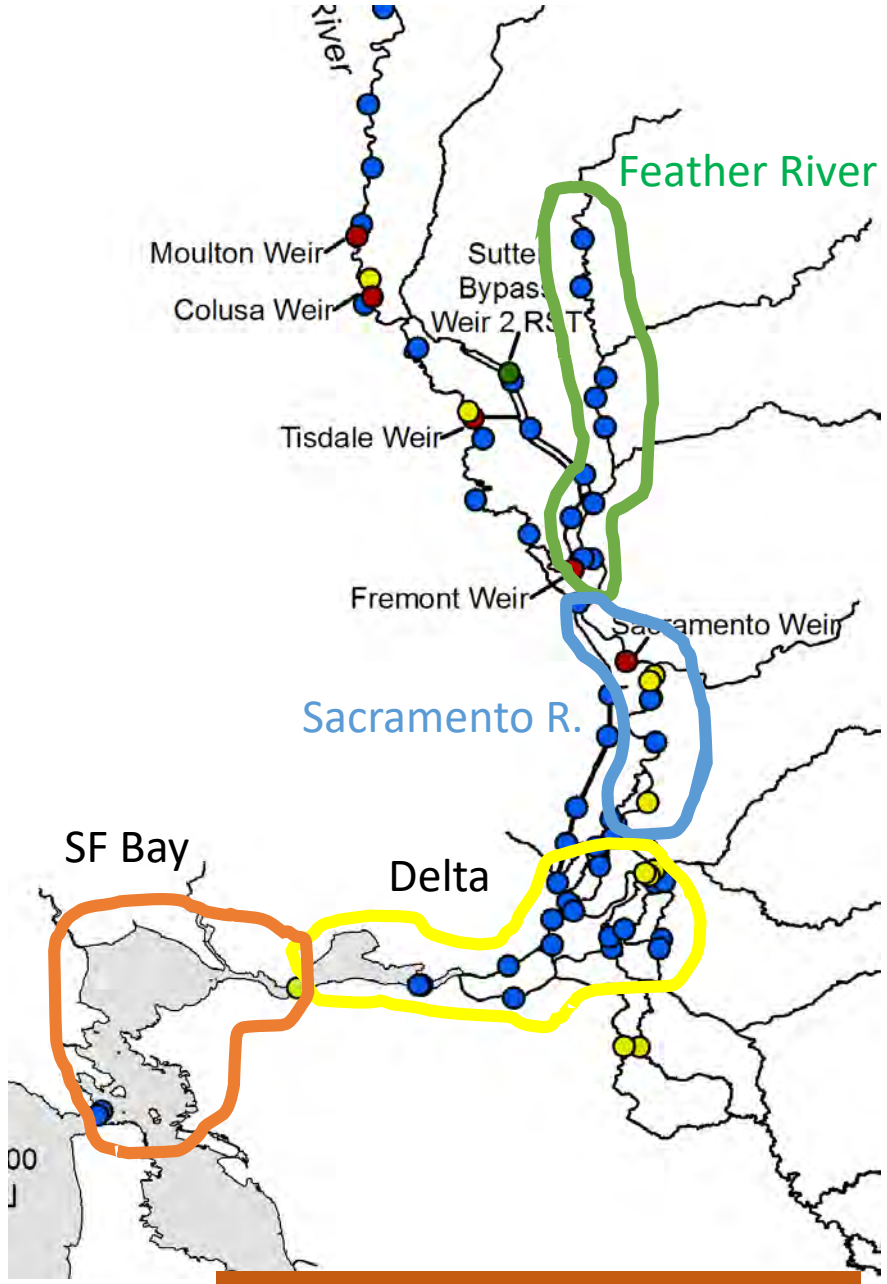




Preliminary data – do not cite

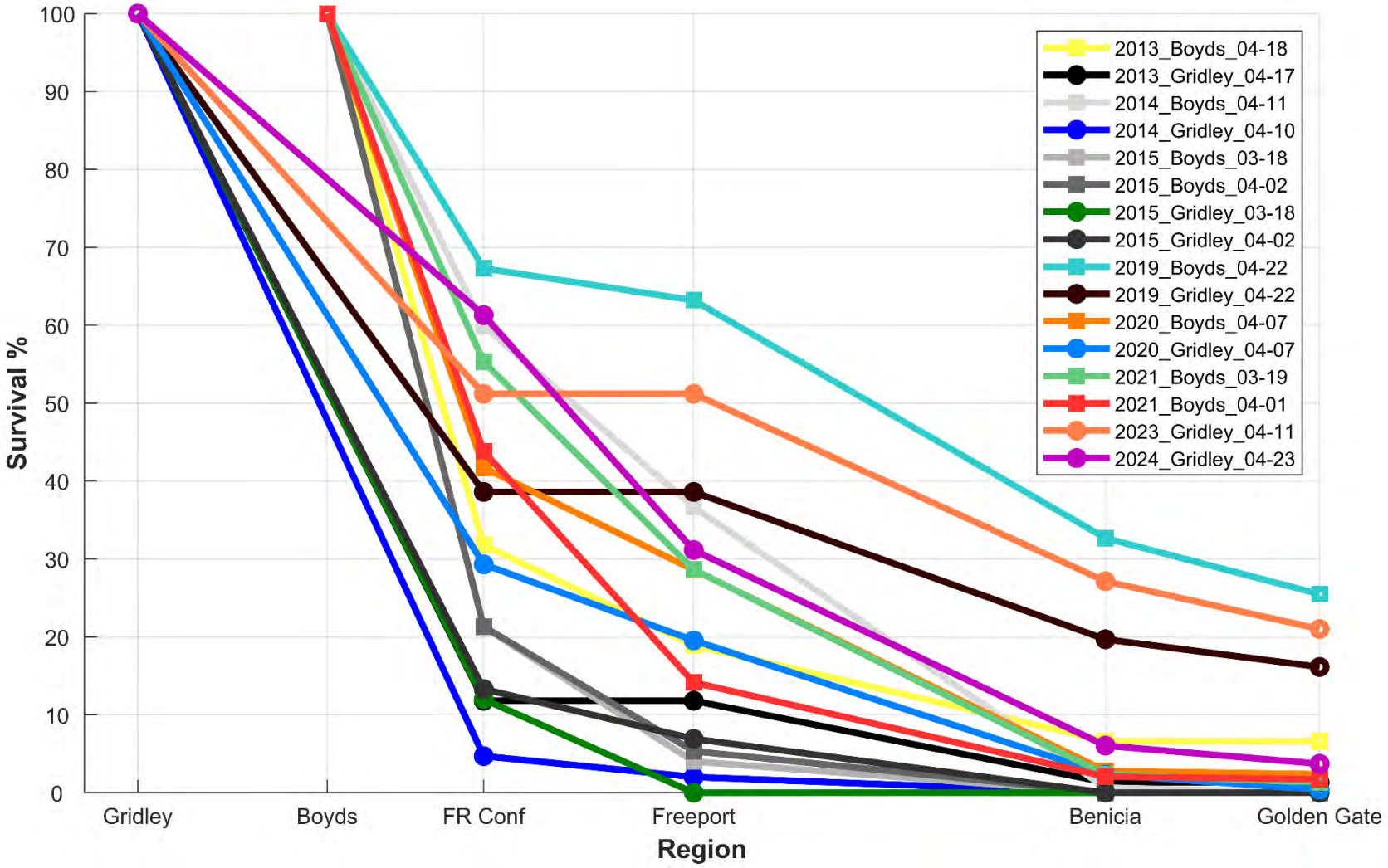
RESULTS: SPEED





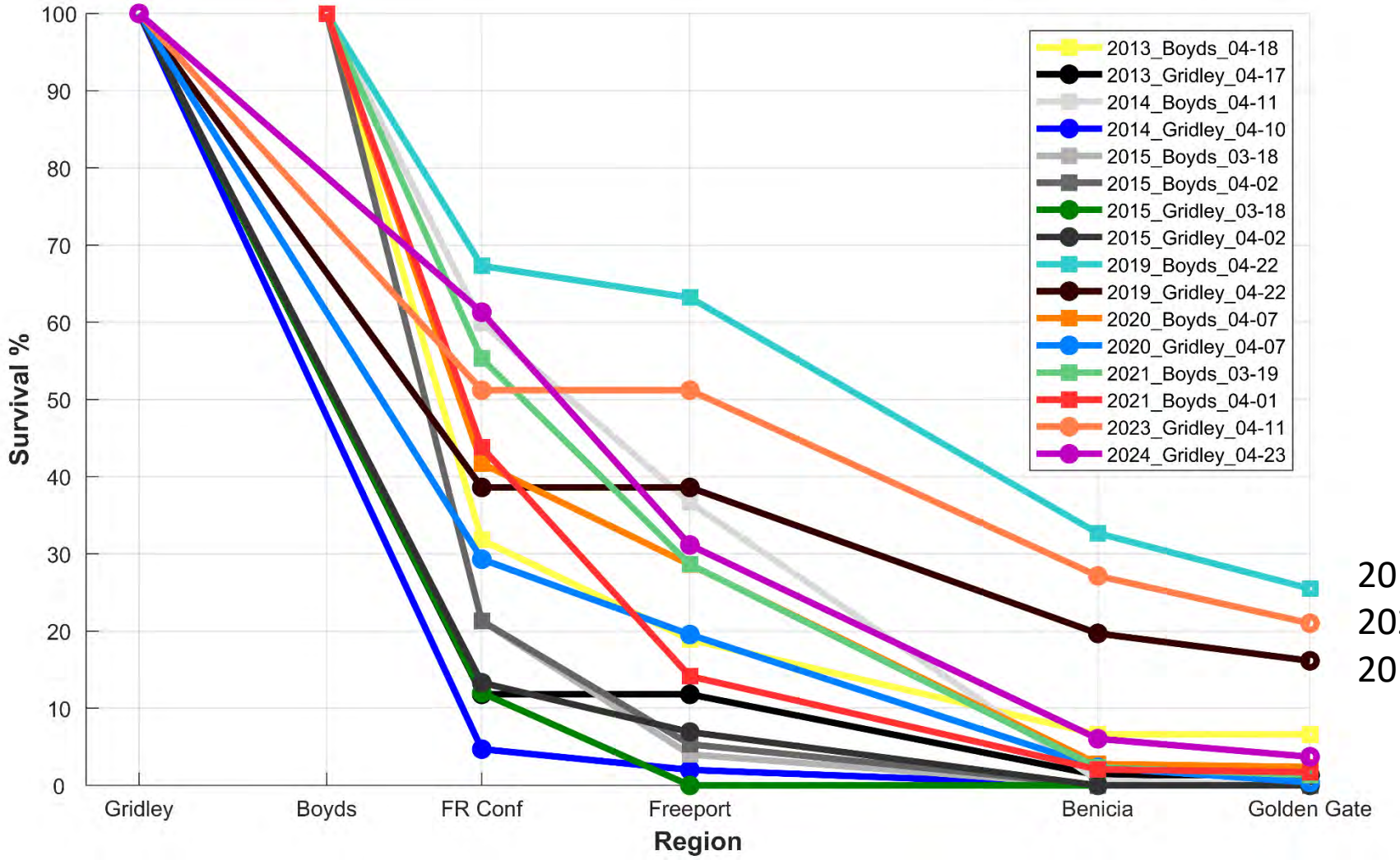
Preliminary data – do not cite

RESULTS: CUMULATIVE SURVIVAL



Preliminary data – do not cite

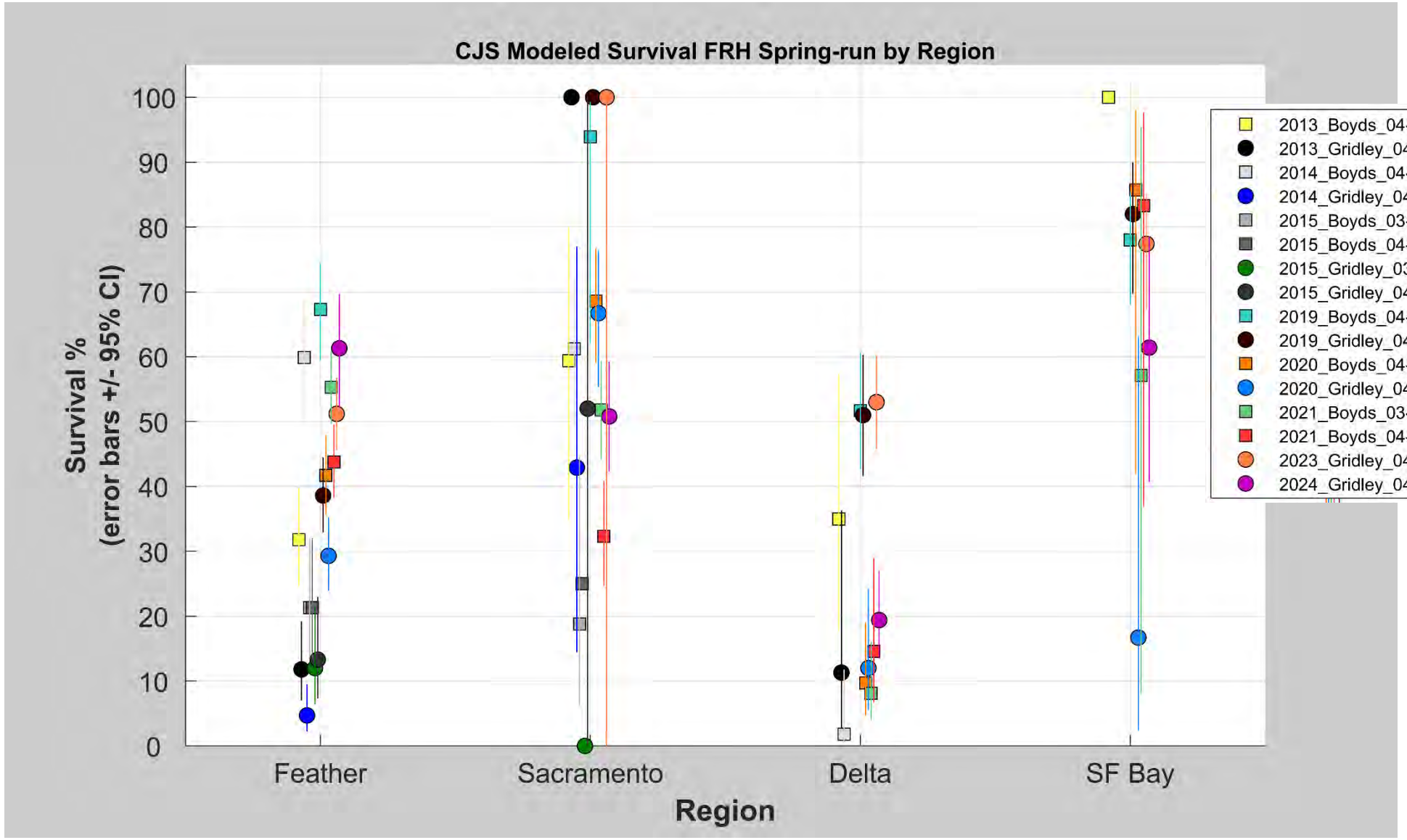
RESULTS: CUMULATIVE SURVIVAL



2019 Boyds
2023 Gridley
2019 Gridley

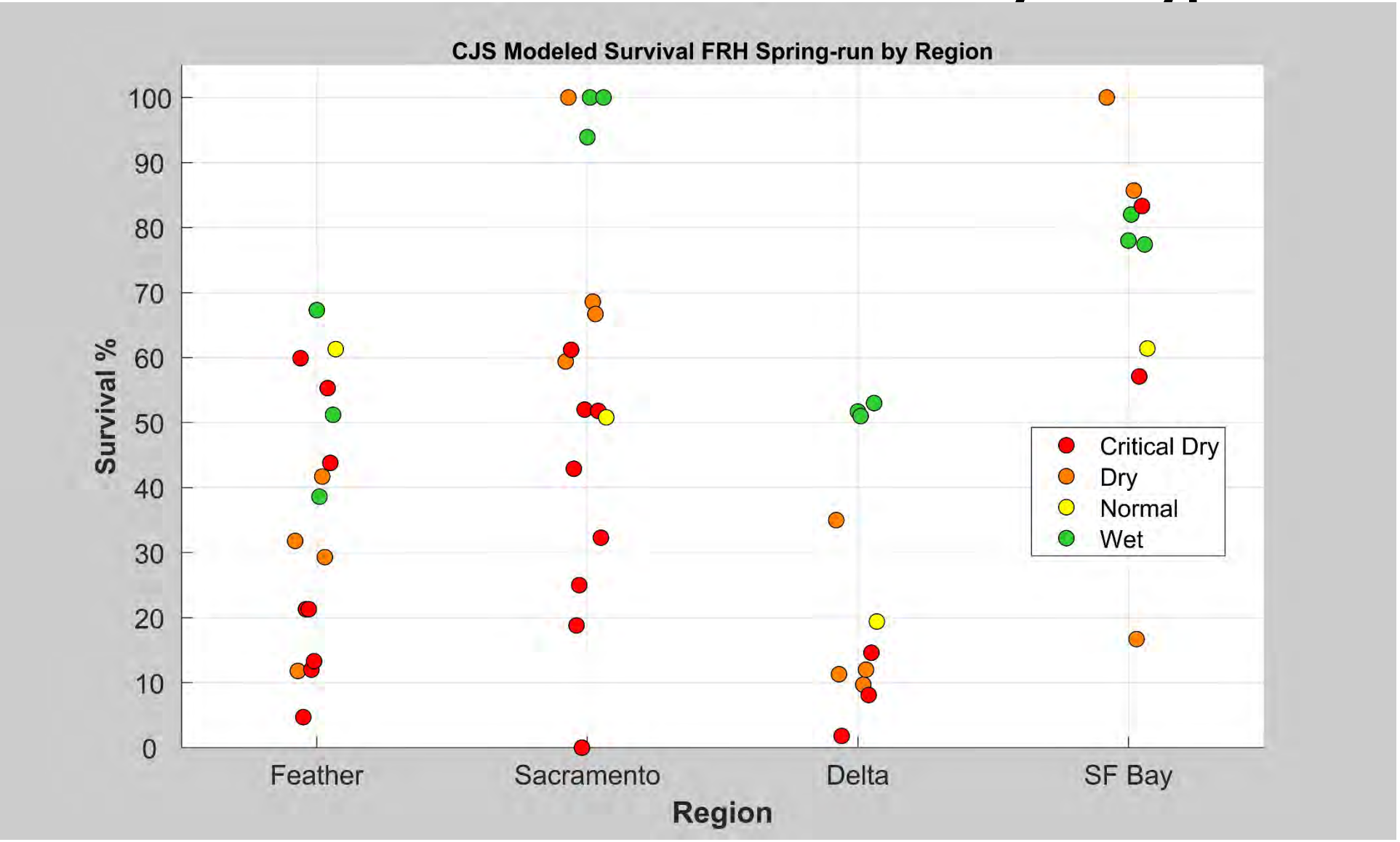
Preliminary data – do not cite

RESULTS: % SURVIVAL BY REGION



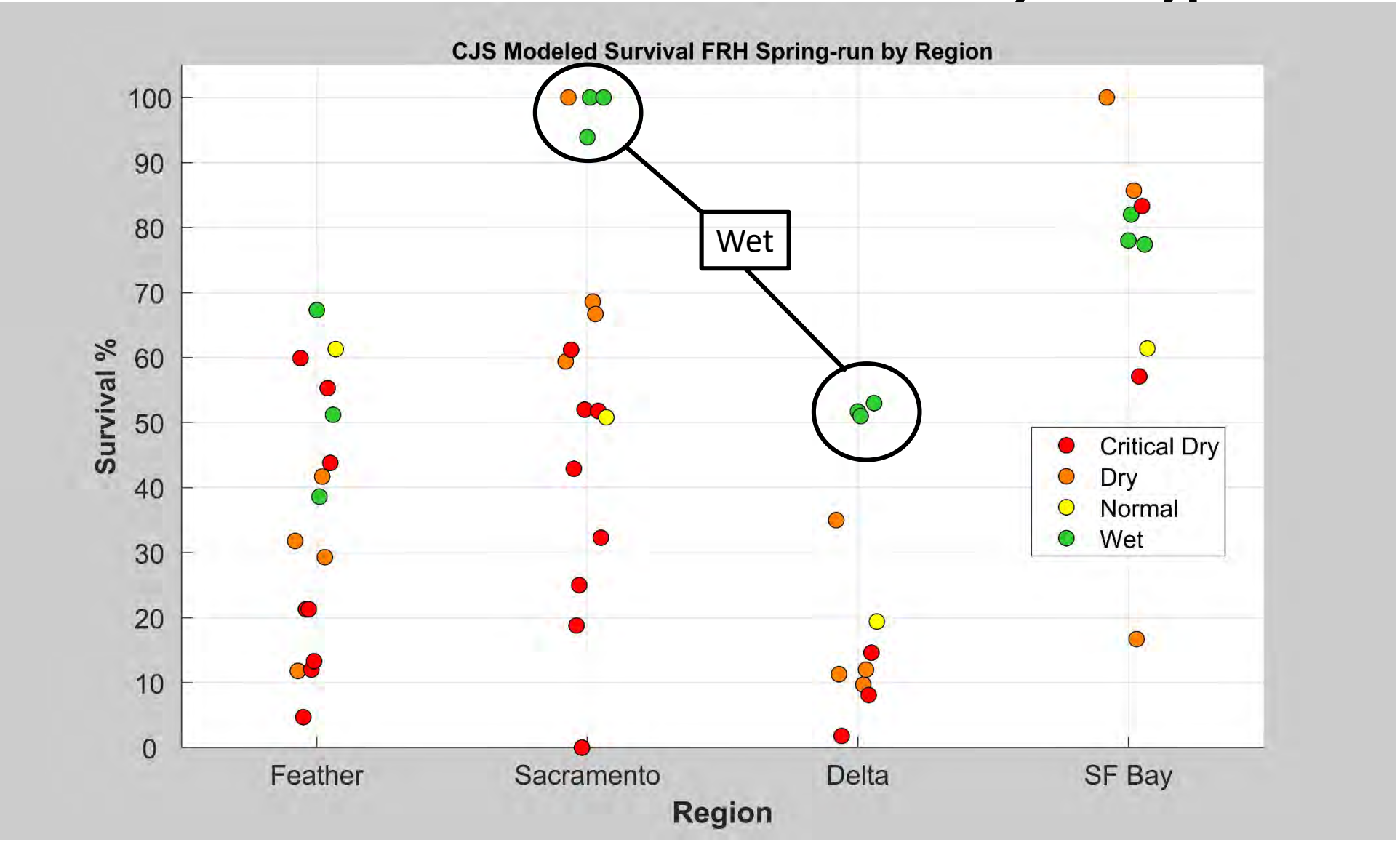
Preliminary data – do not cite

RESULTS: % SURVIVAL BY REGION – water year type



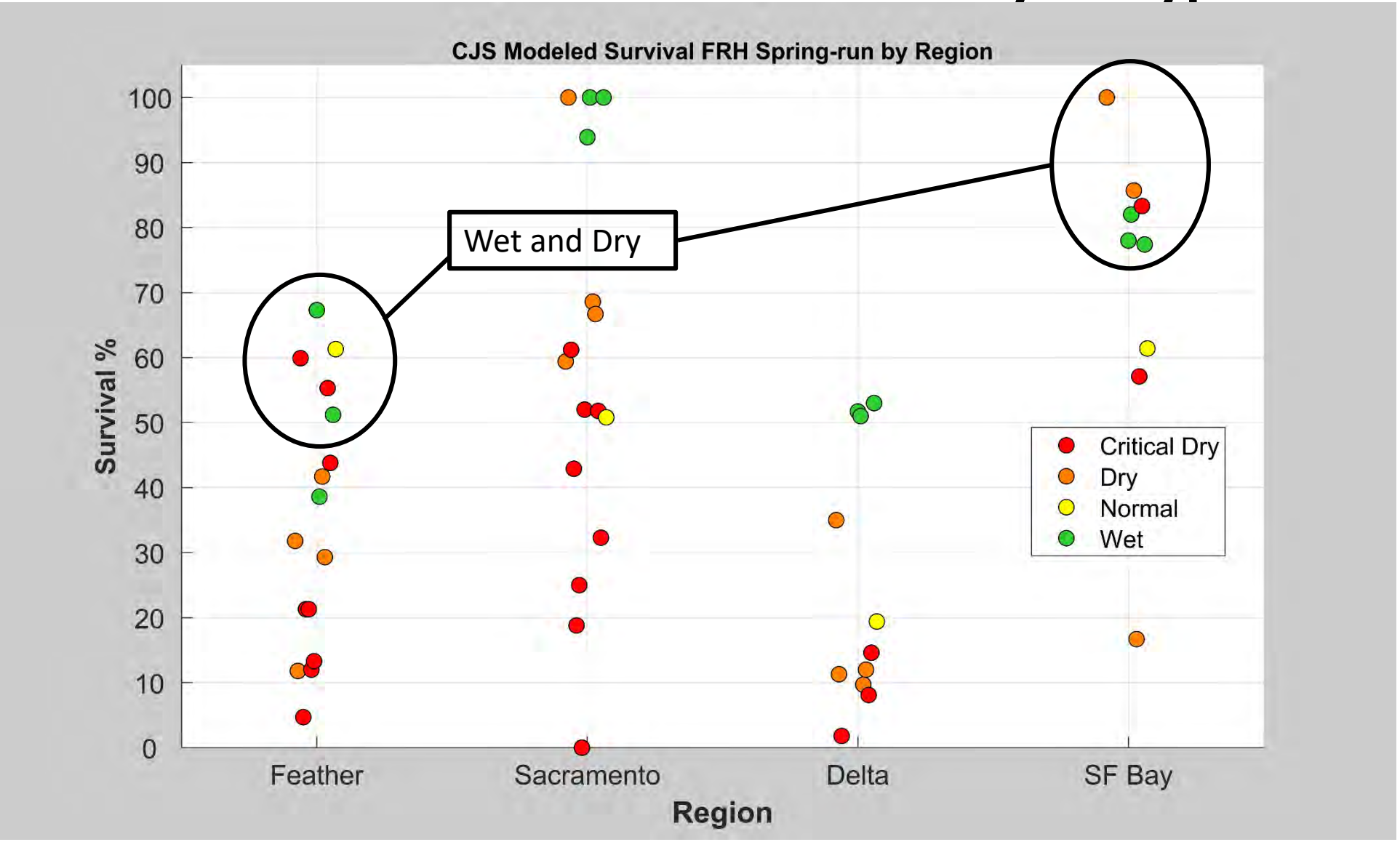
Preliminary data – do not cite

RESULTS: % SURVIVAL BY REGION – water year type



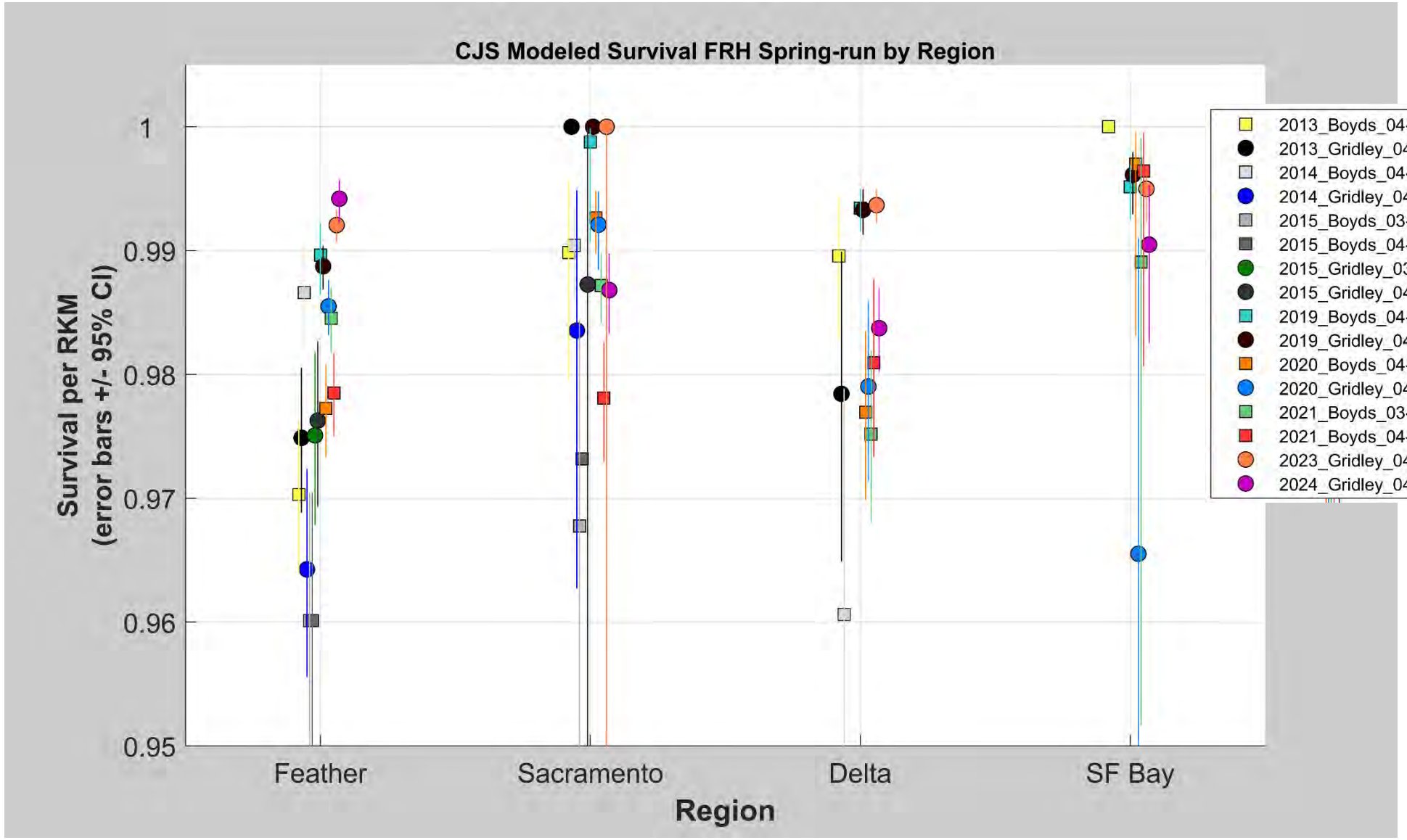
Preliminary data – do not cite

RESULTS: % SURVIVAL BY REGION – water year type



Preliminary data – do not cite

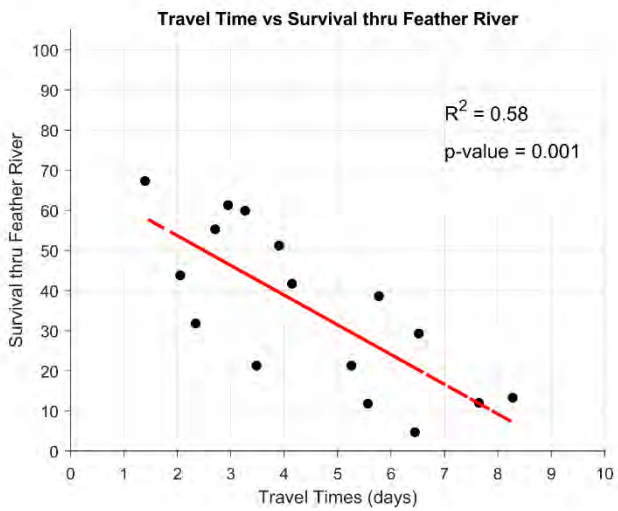
RESULTS: SURVIVAL PER RKM BY REGION



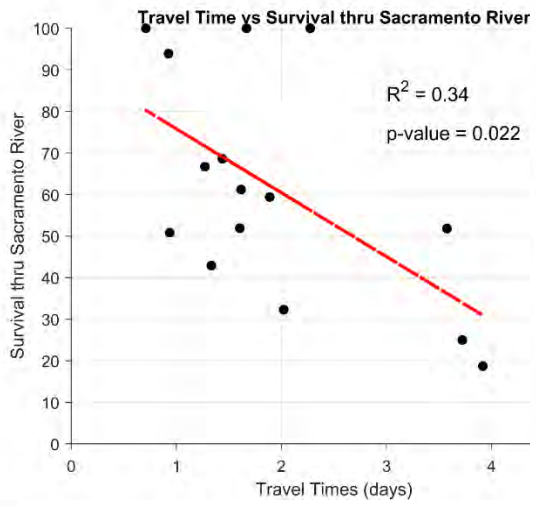
Preliminary data – do not cite

Survival and travel time:

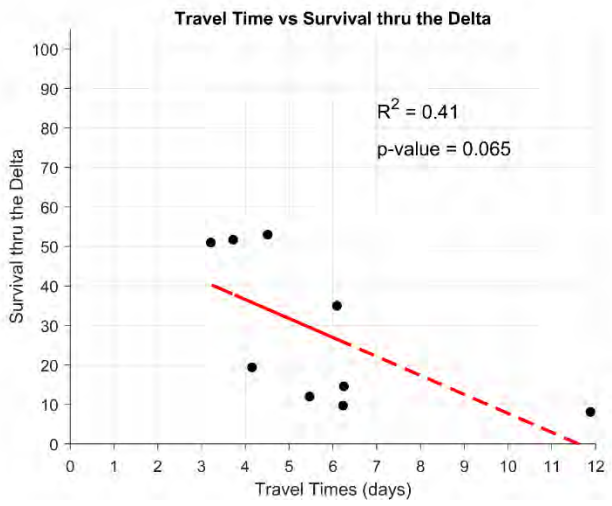
Feather R.



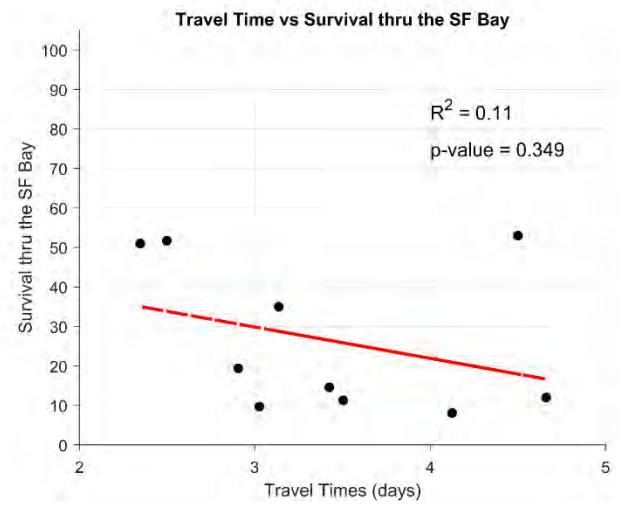
Sacramento R.



Delta



SF Bay



Shorter travel time -> higher survival

Preliminary data – do not cite

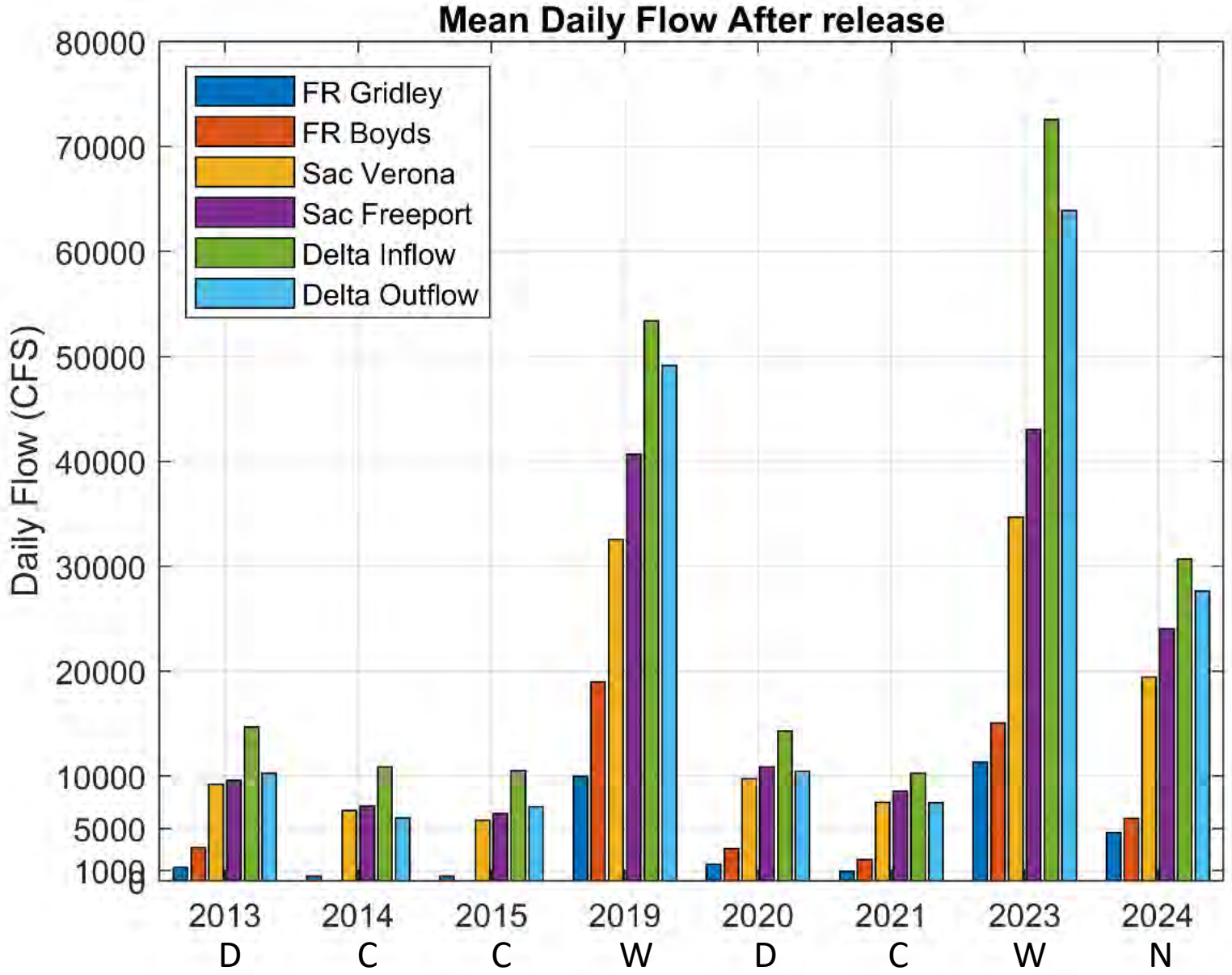
Survival and Covariates: Hypotheses

Many release groups over many years will have variation in factors that affect survival. This provides an opportunity to test assumptions.

FLOW – higher flow will increase survival
fish move faster downstream

TURBIDITY – higher turbidity will increase survival
visual predators are less effective

TEMPERATURE – higher temperature will decrease survival
metabolic strain on cold water species
predator fish need to eat more



Pulled covariate values relative to days after release date:

Feather – 0 to 6 days

Sacramento – 2 to 8 days

Delta – 8 to 14 days

SF Bay – 10 to 20 days

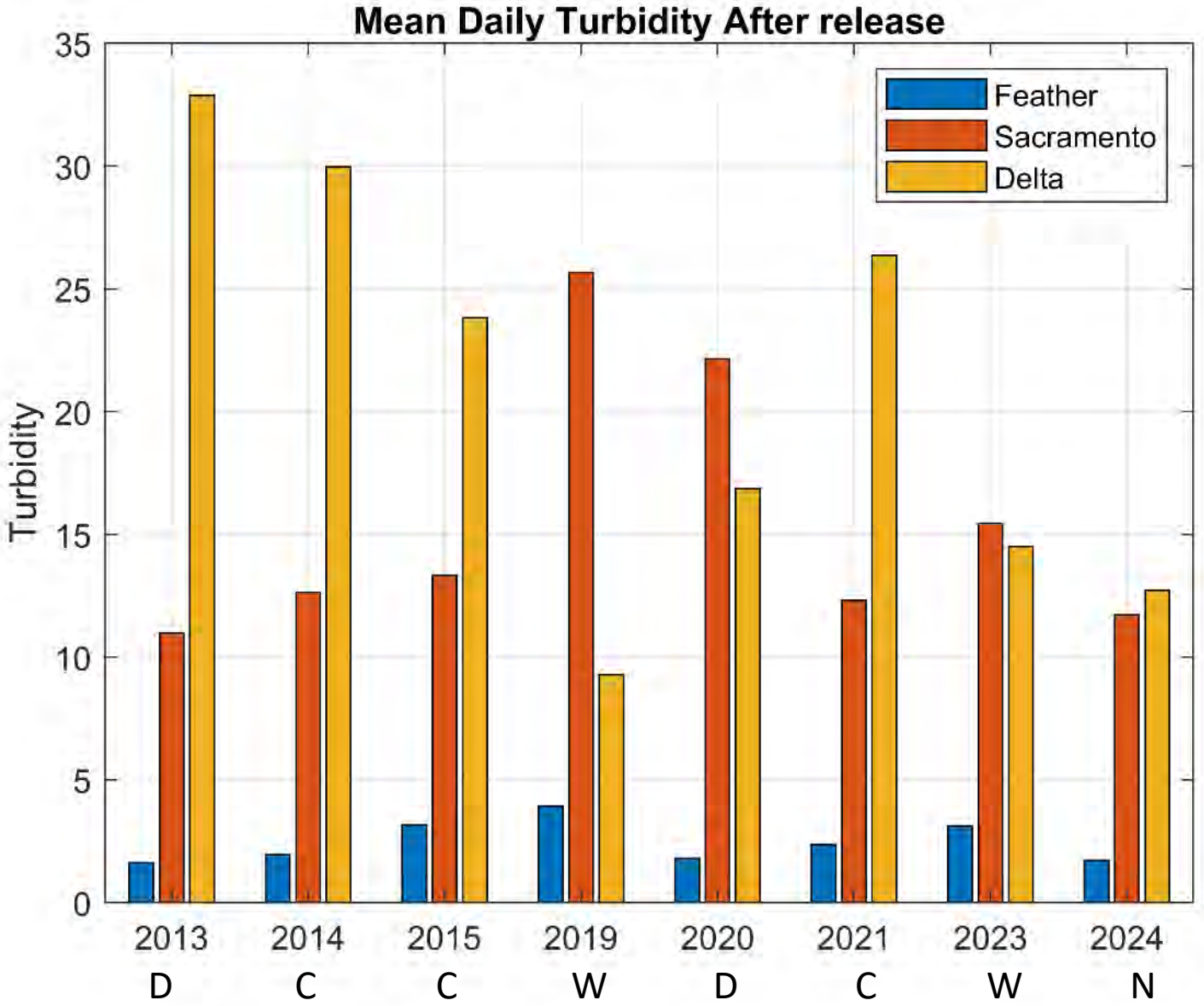
Gridley << Boyds

Low flow years:
Verona = Freeport

High flow years:
Verona < Freeport

2023 Delta flows much higher than 2019

Preliminary data – do not cite

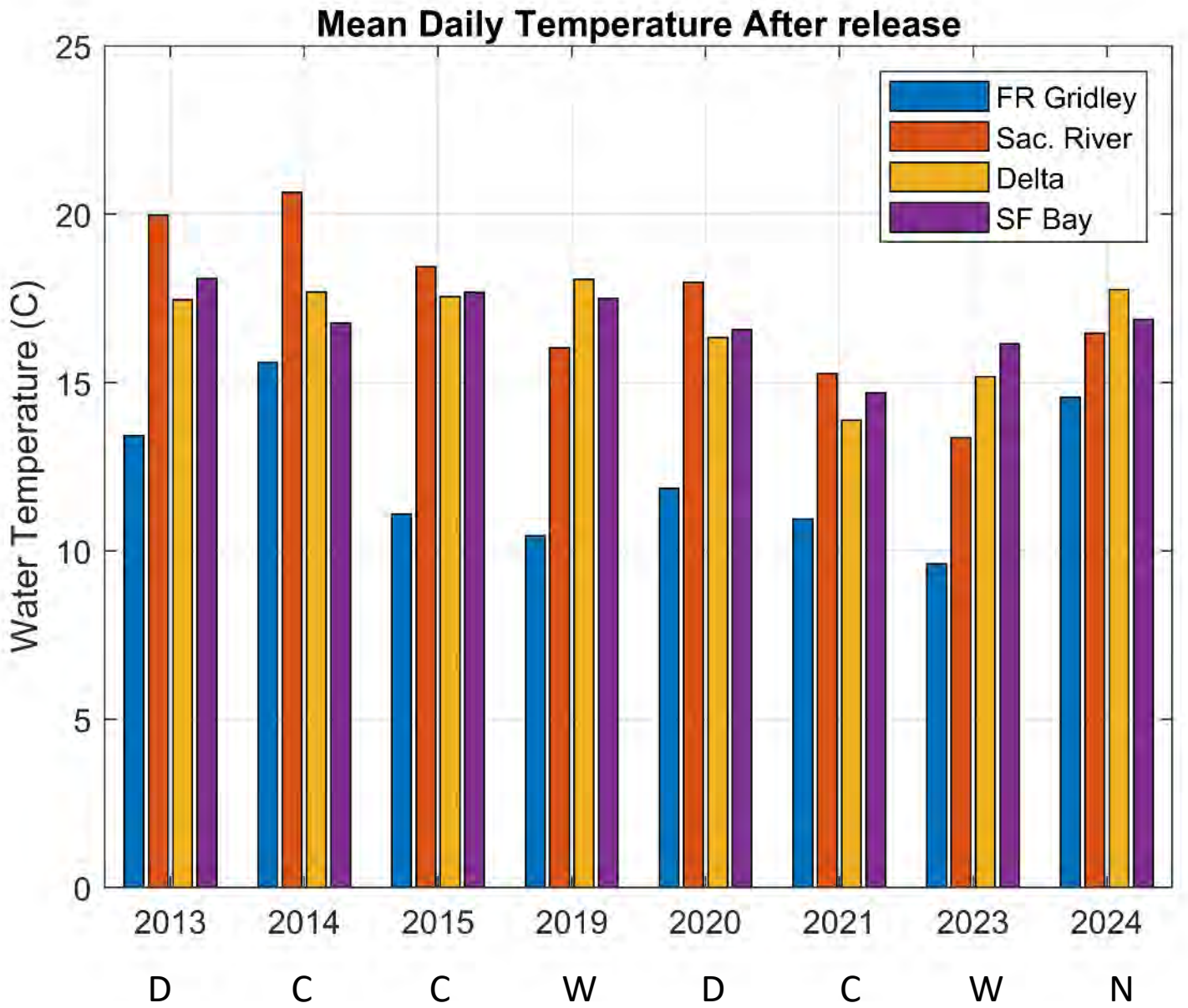


Feather << Sac R.

Feather and Sac R. turbidity high during wet years, and 2020.

Delta turbidity high during the dry years.

Preliminary data – do not cite

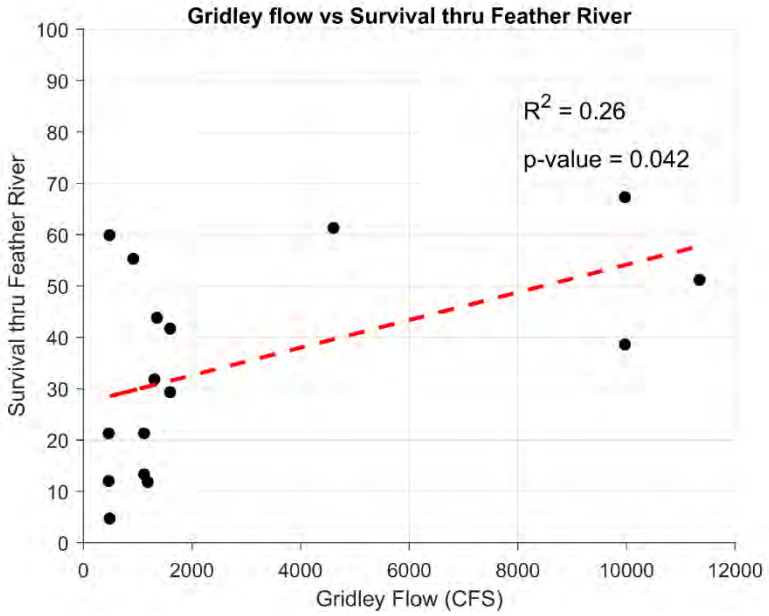


Temperature in Feather River colder than other regions

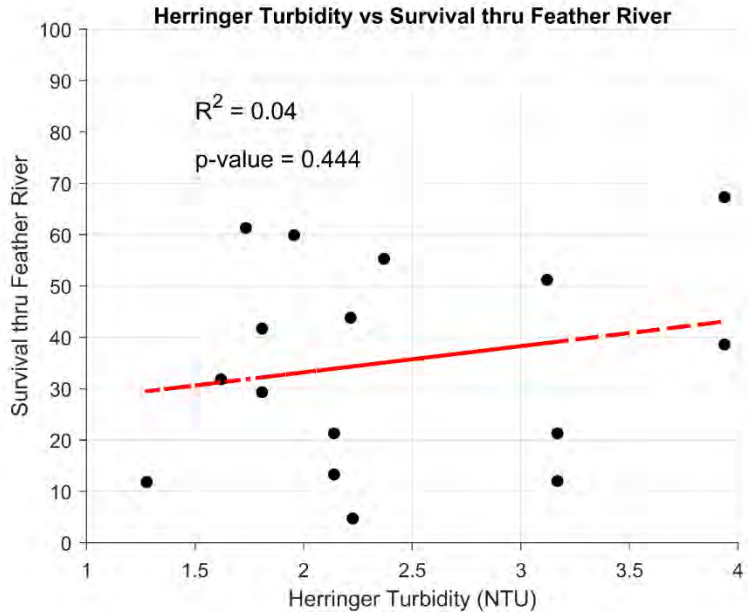
Sac R. warmest during dry years

Preliminary data – do not cite

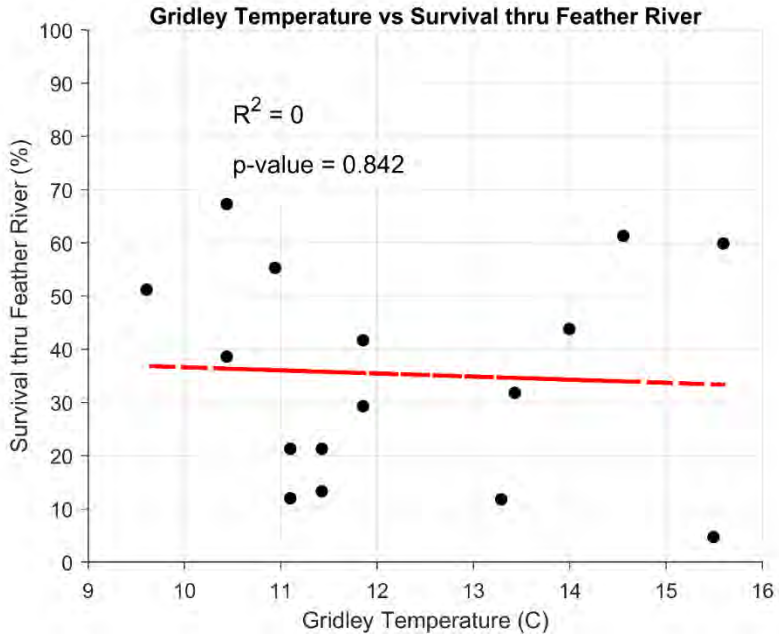
Survival and Covariates: Feather River



FLOW



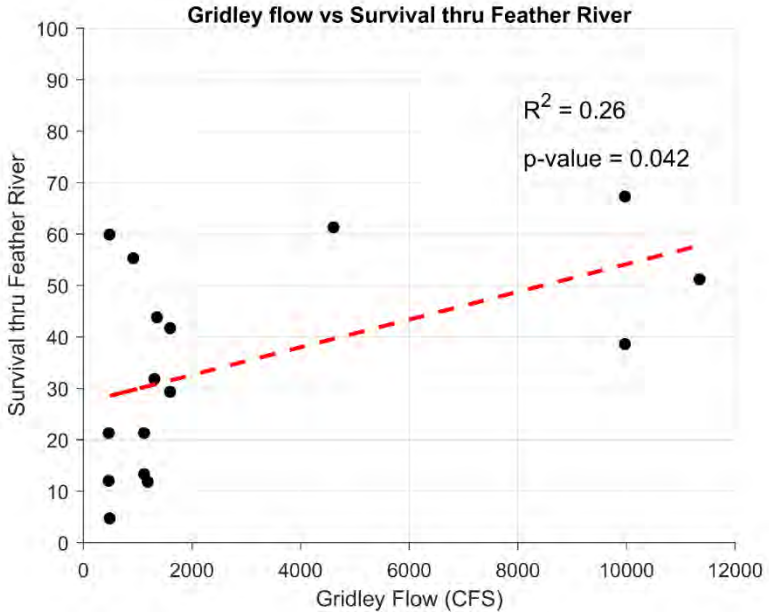
TURBIDITY

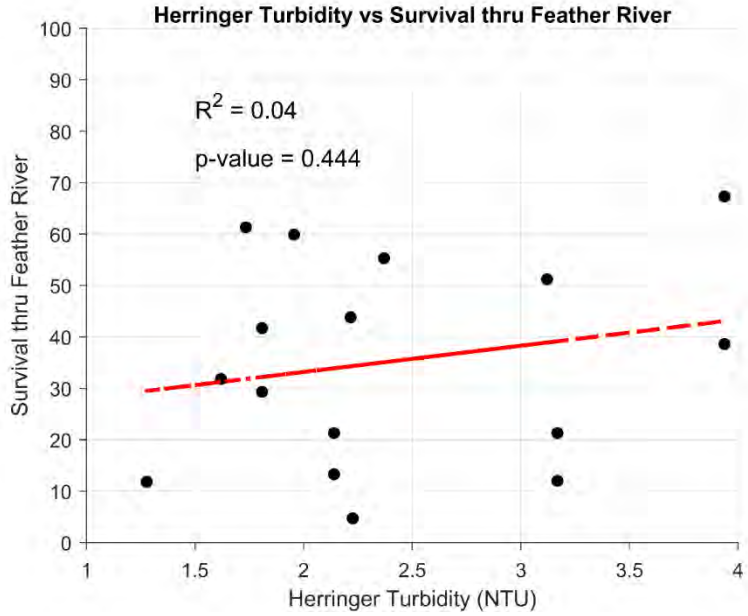


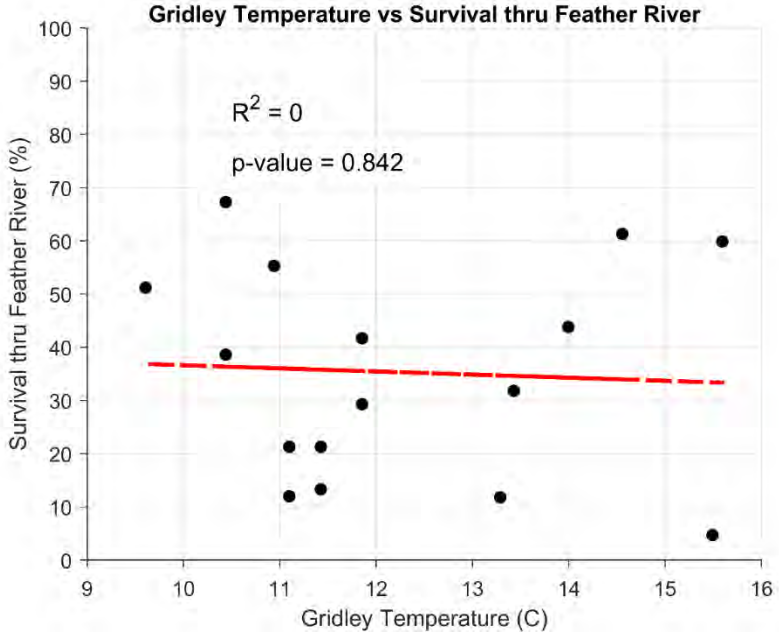
TEMPERATURE

Preliminary data – do not cite

Survival and Covariates: Feather River







FLOW

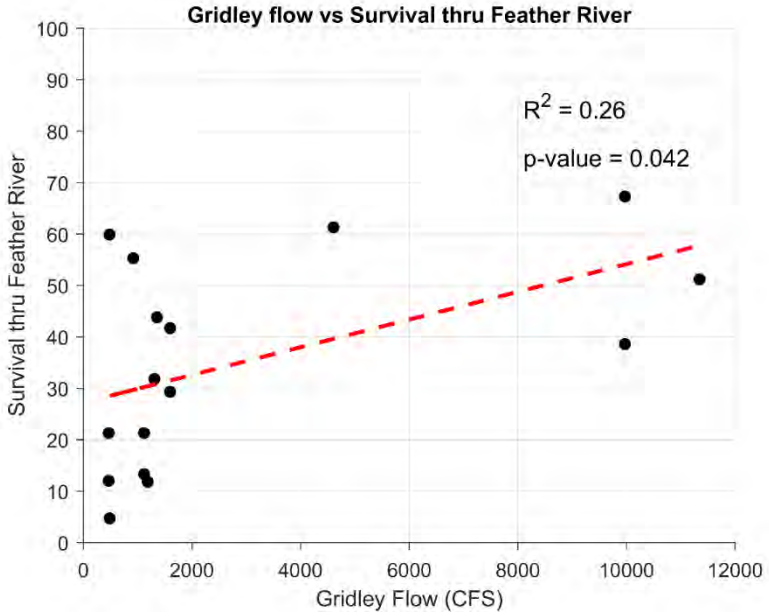
TURBIDITY

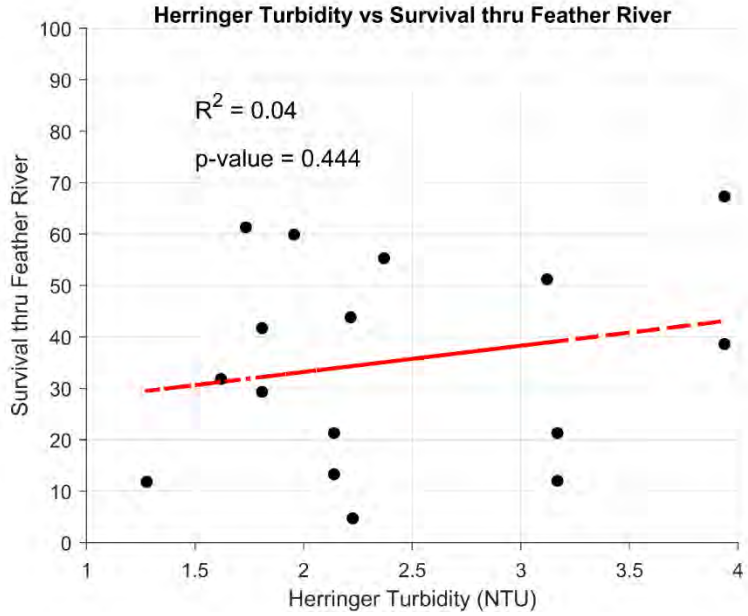
TEMPERATURE

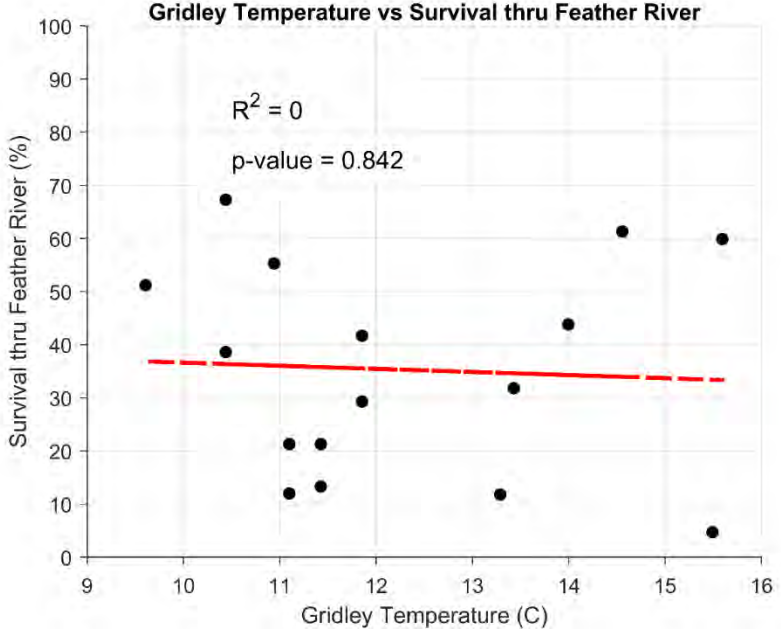


Preliminary data – do not cite

Survival and Covariates: Feather River







FLOW



TURBIDITY

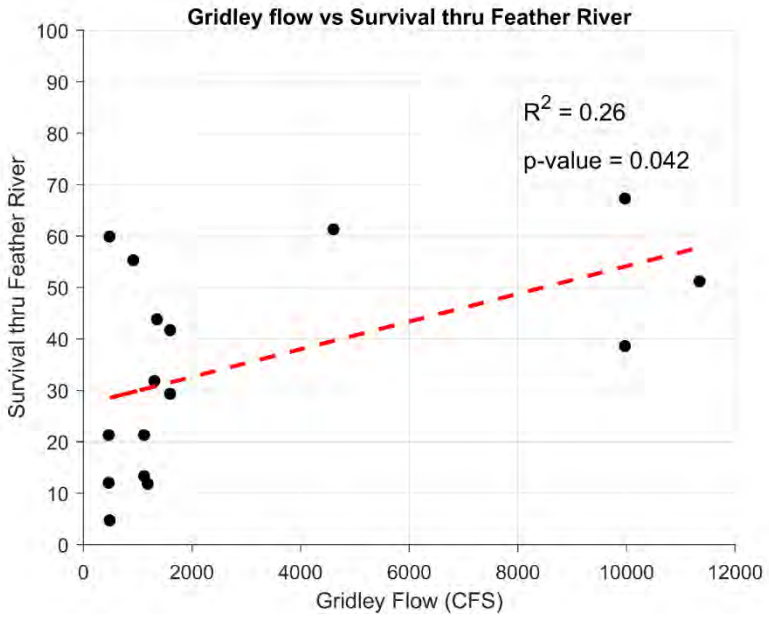


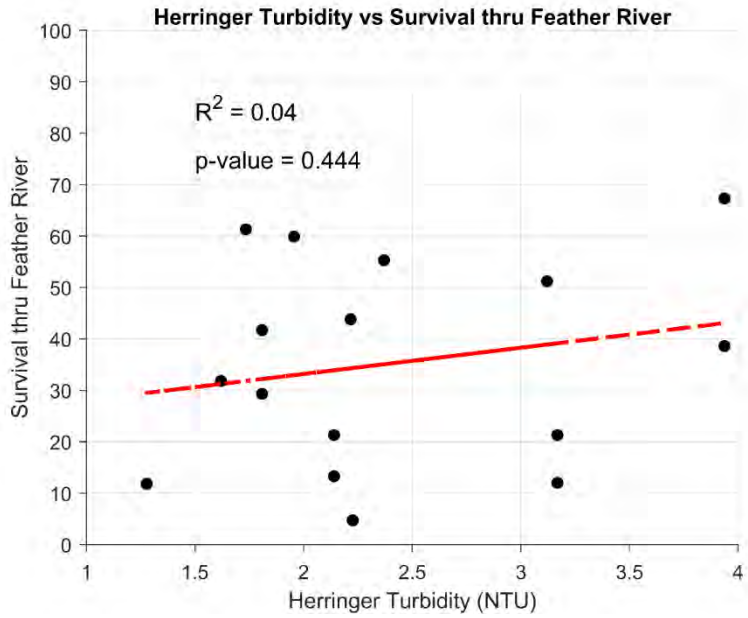
But… Values very low

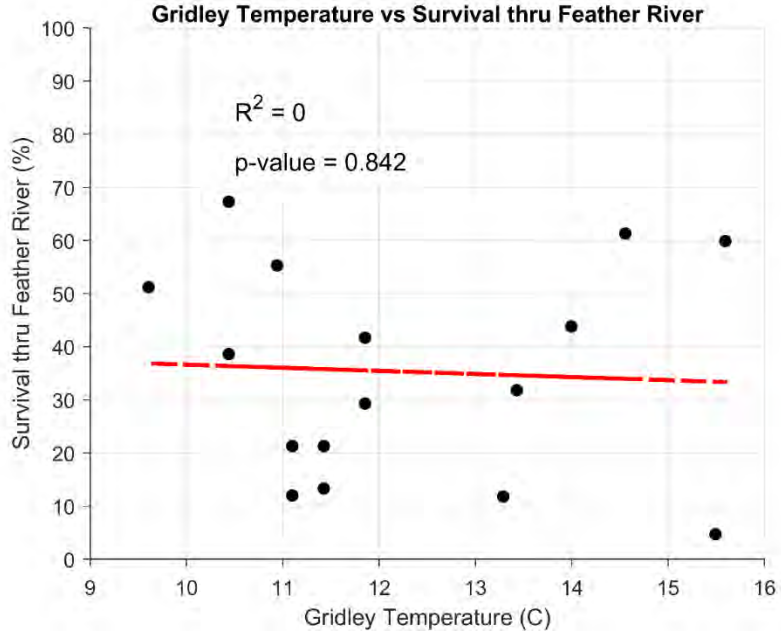
TEMPERATURE

Preliminary data – do not cite

Survival and Covariates: Feather River







FLOW

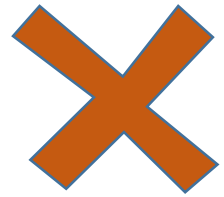


TURBIDITY



But… Values very low

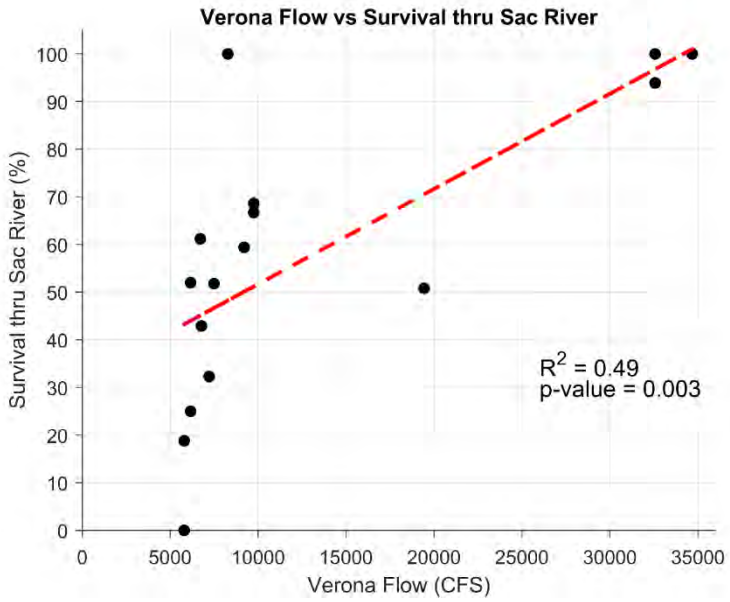
TEMPERATURE



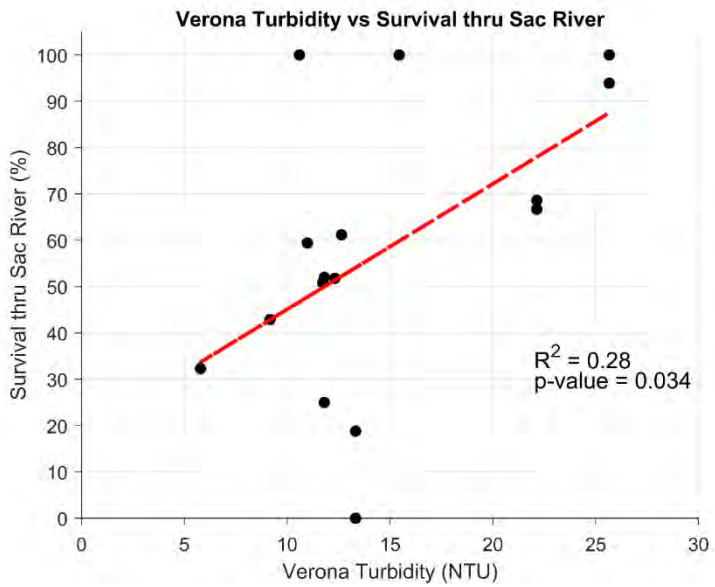
But… temps cool

Preliminary data – do not cite

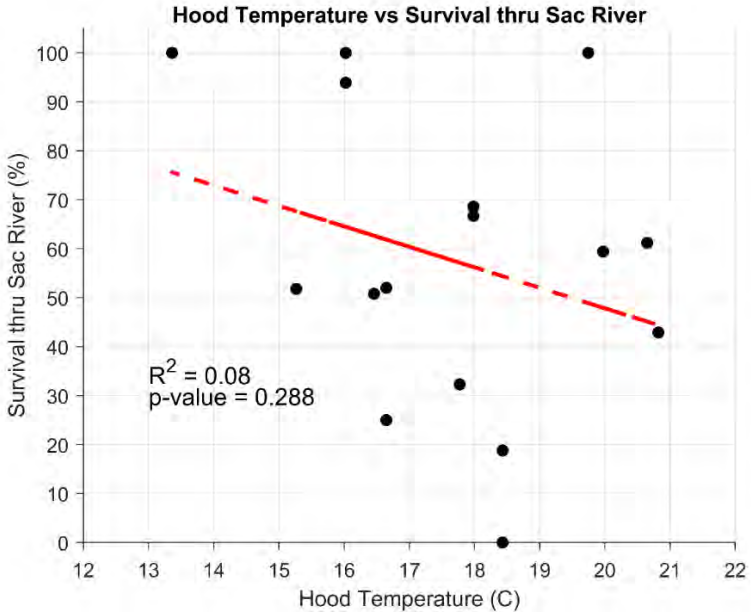
Survival and Covariates: Sacramento River



FLOW



TURBIDITY

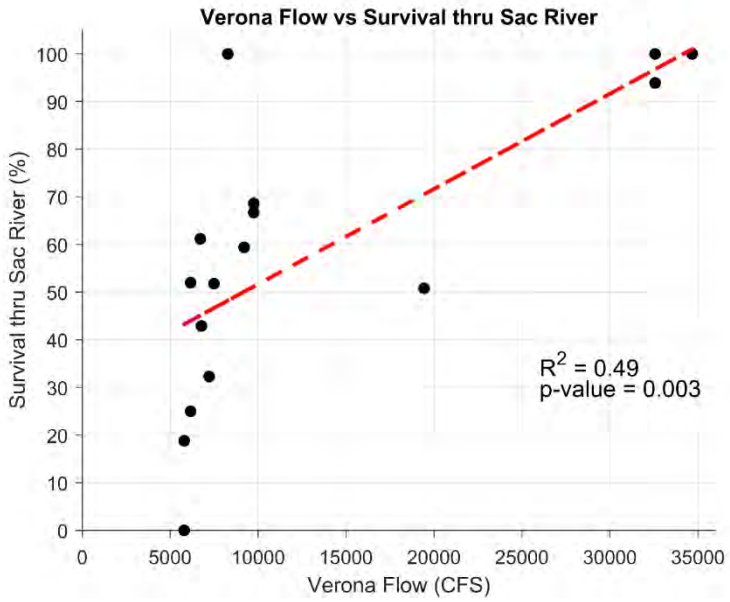


TEMPERATURE

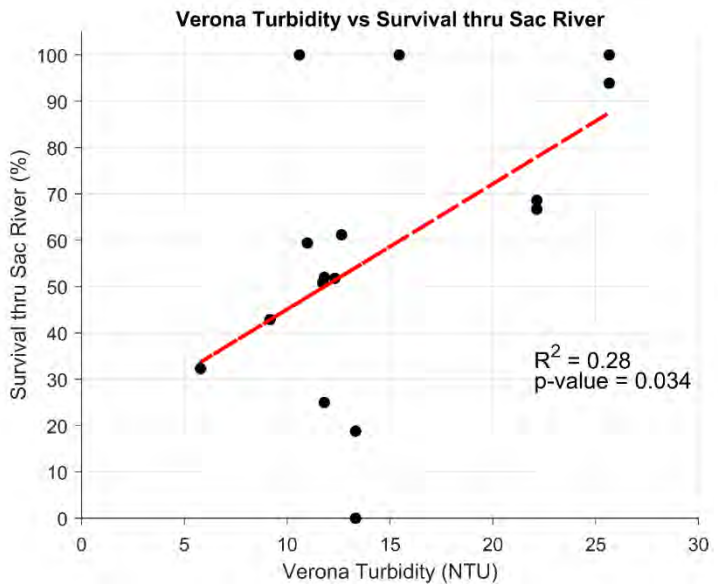


Preliminary data – do not cite

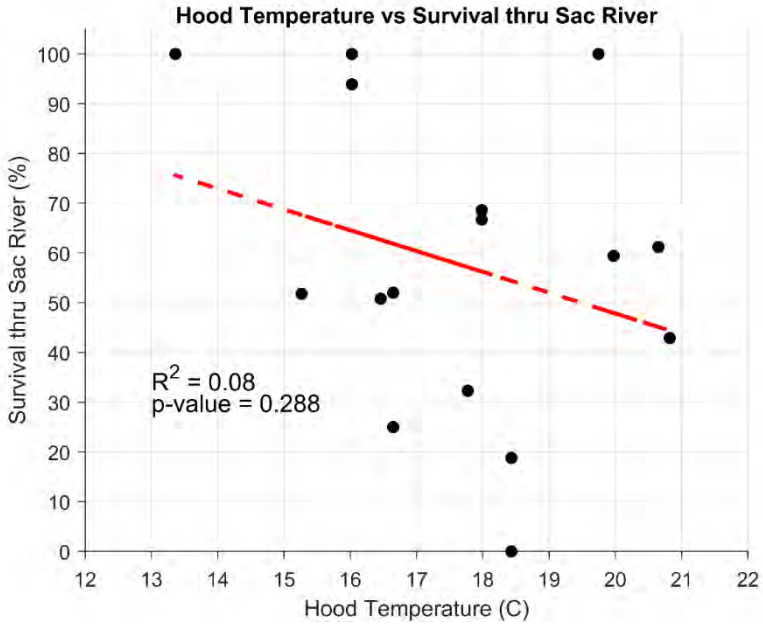
Survival and Covariates: Sacramento River



FLOW



TURBIDITY

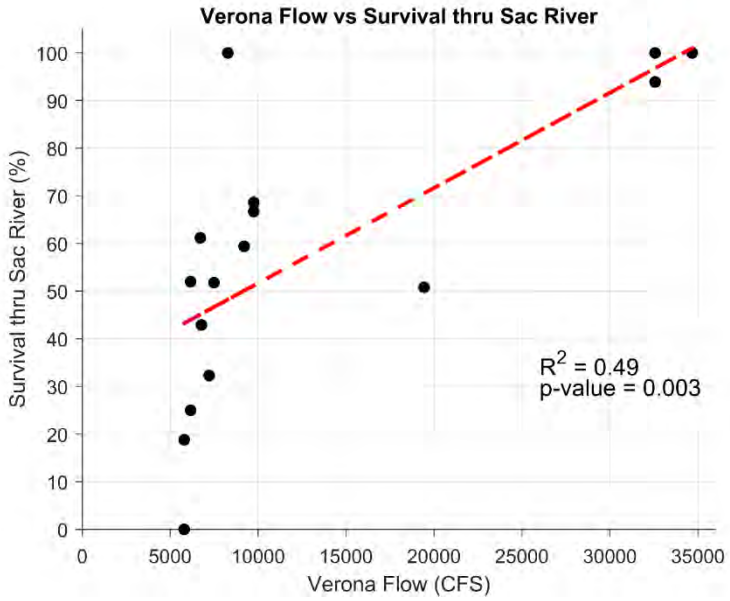


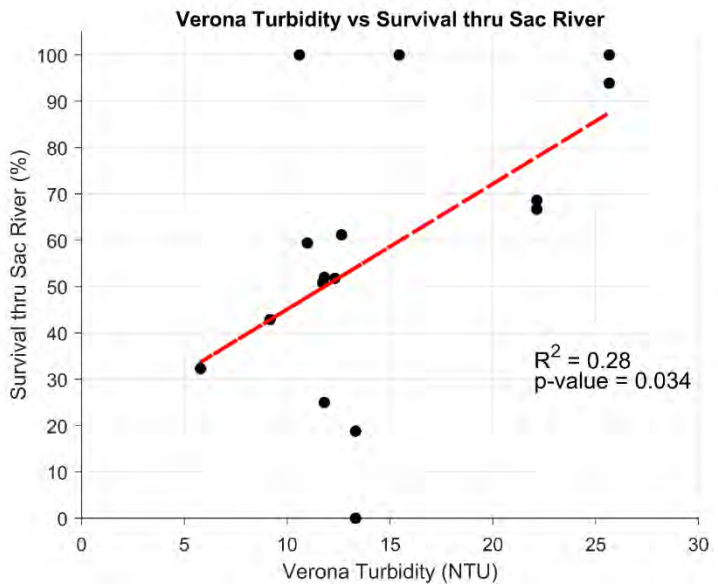
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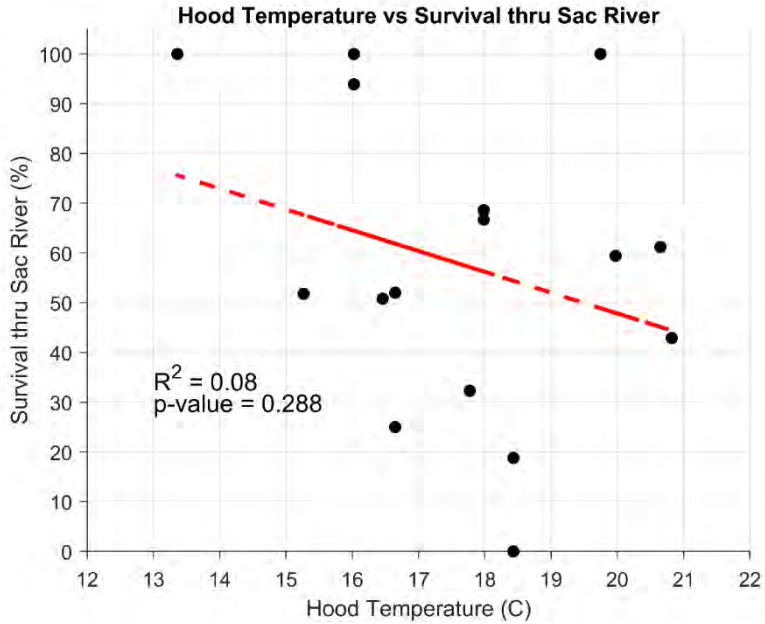
Much higher values

Preliminary data – do not cite

Survival and Covariates: Sacramento River







FLOW



TURBIDITY



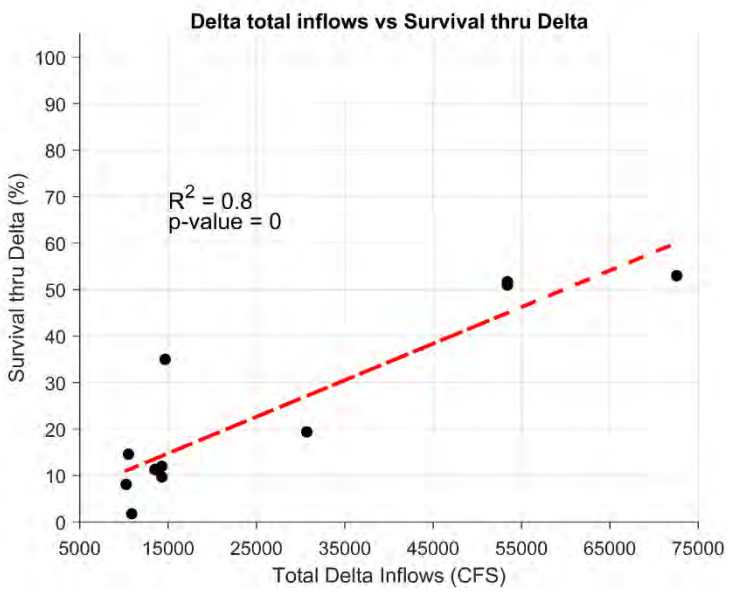
Much higher values

TEMPERATURE



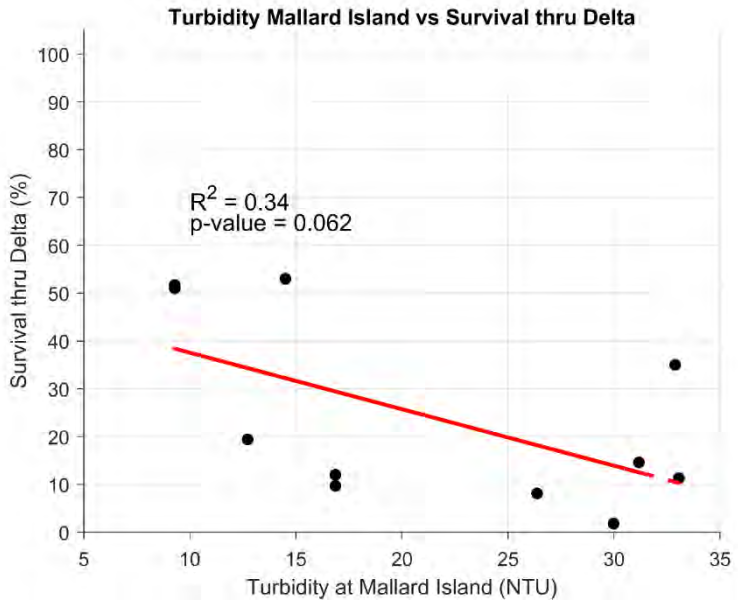
Preliminary data – do not cite

Survival and Covariates: Delta

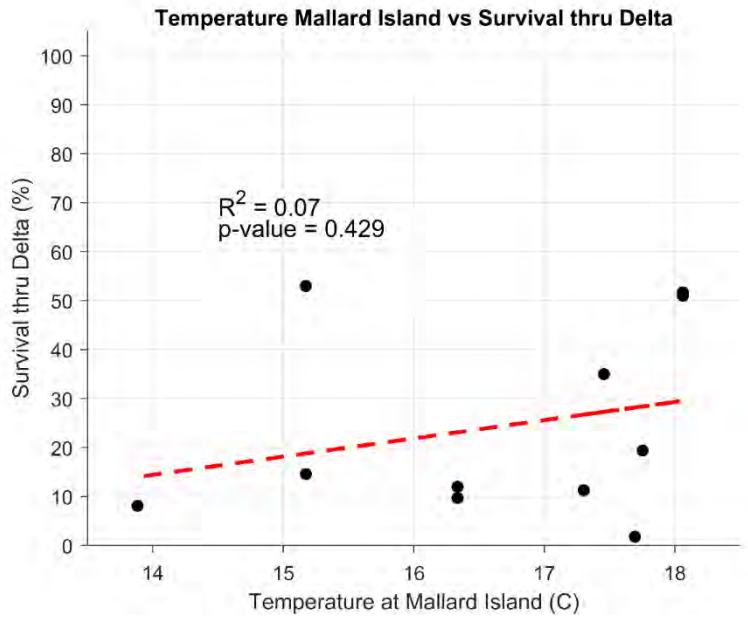


FLOW





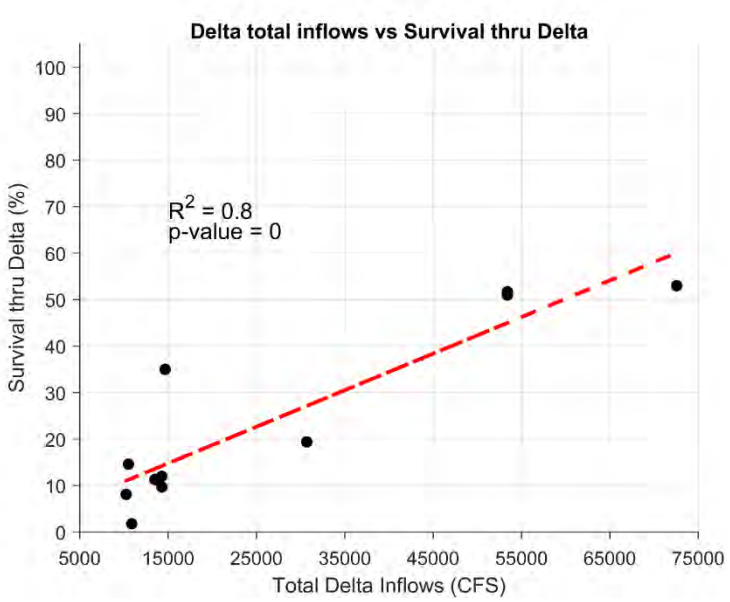
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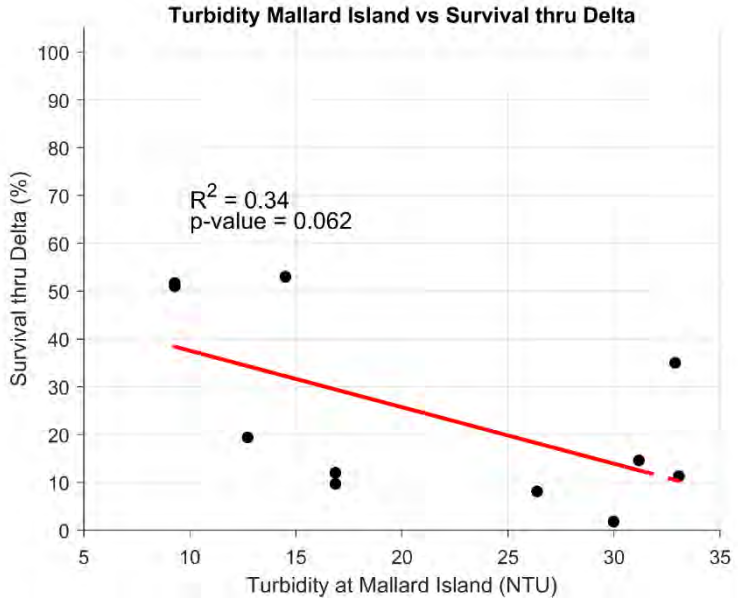


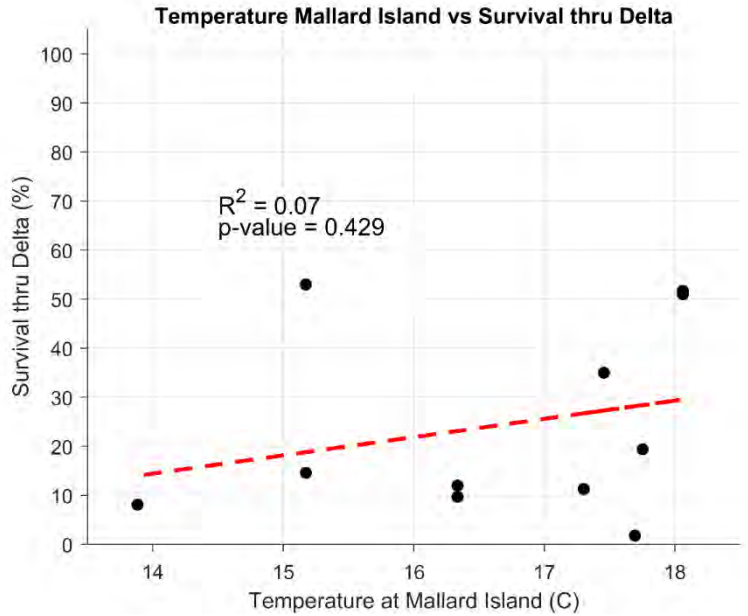
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Preliminary data – do not cite

Survival and Covariates: Delta







FLOW



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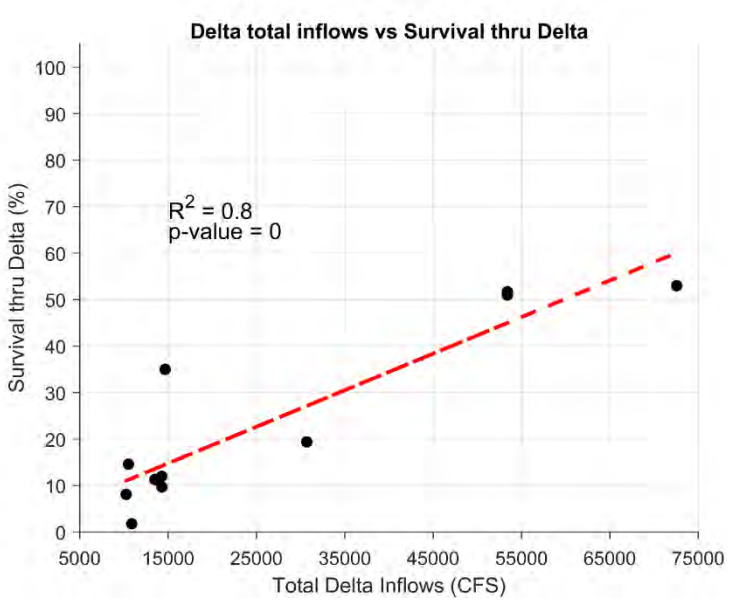


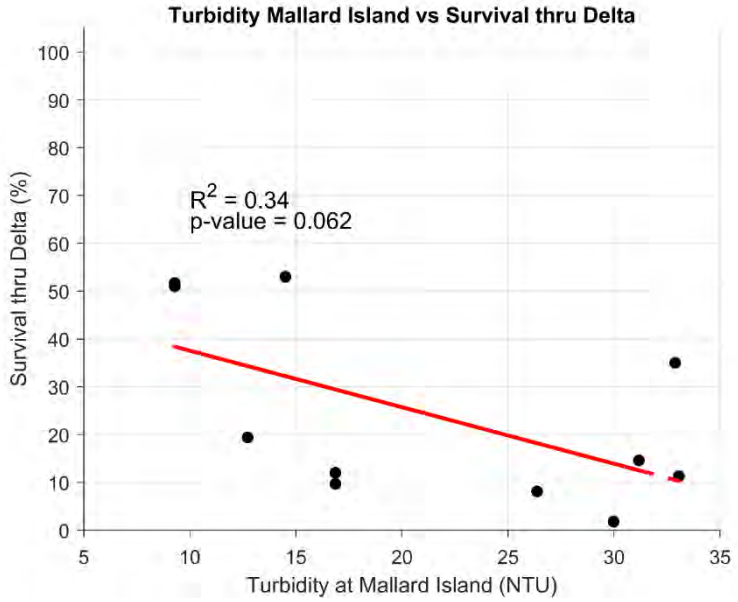
Turbidity = Survival

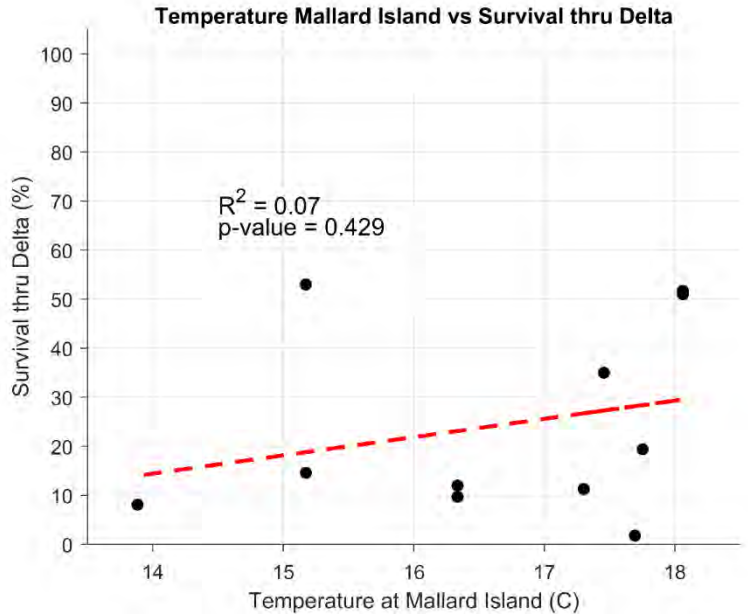
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Preliminary data – do not cite

Survival and Covariates: Delta







FLOW



TURBIDITY



↑ Turbidity = ↓ Survival

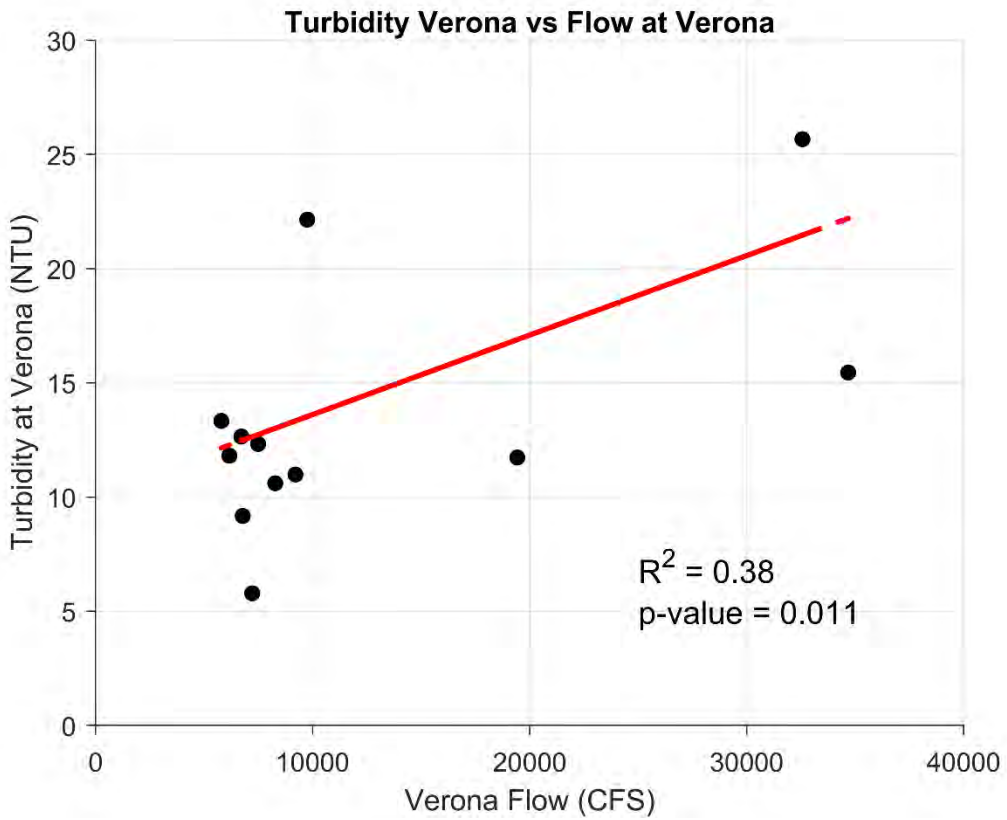
TEMPERATURE



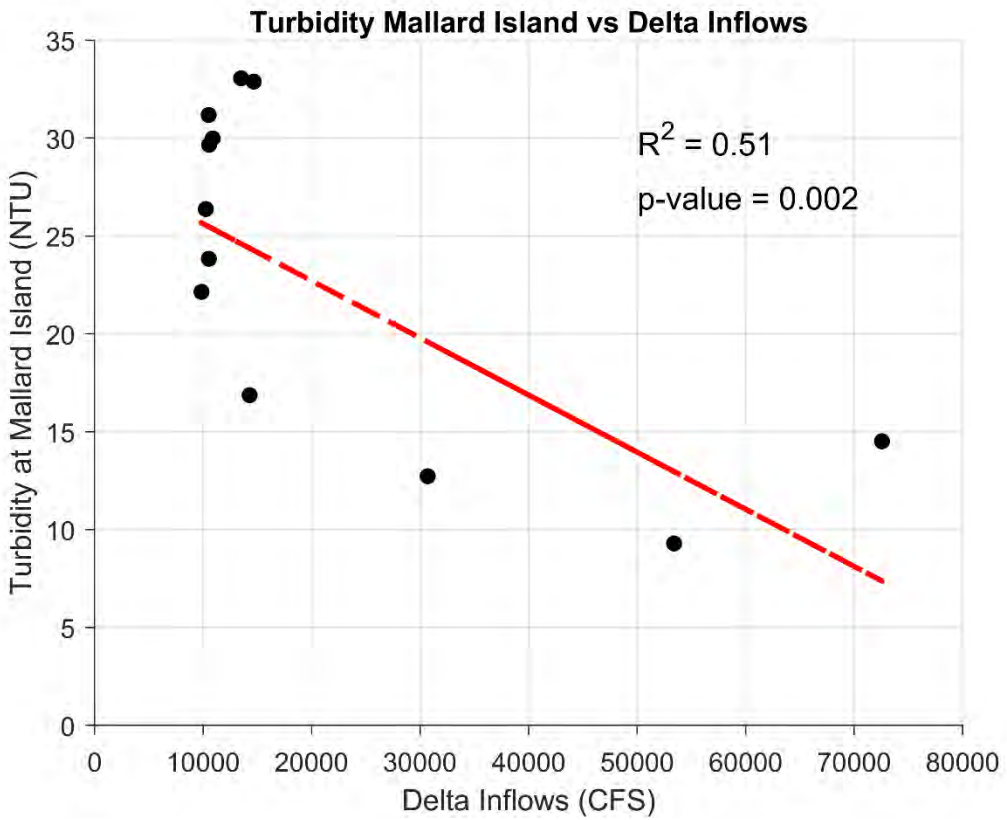
Preliminary data – do not cite

Turbidity vs Flow

Sac. River

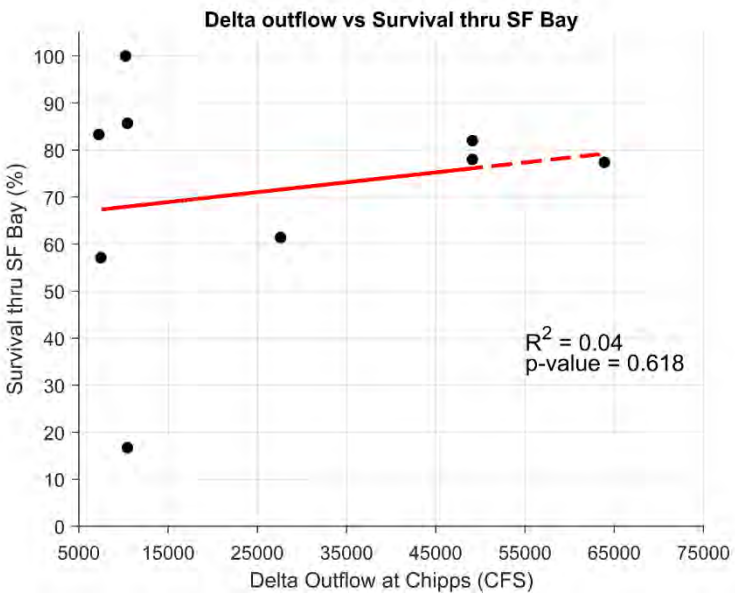


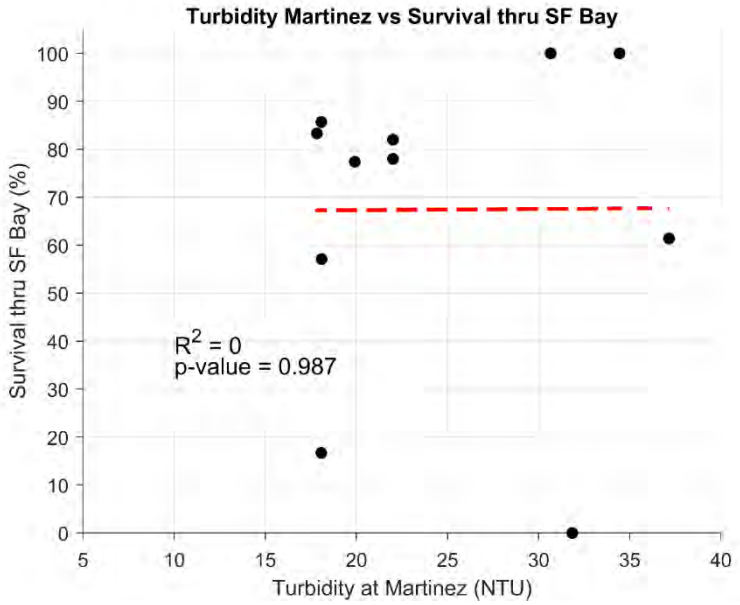
Delta

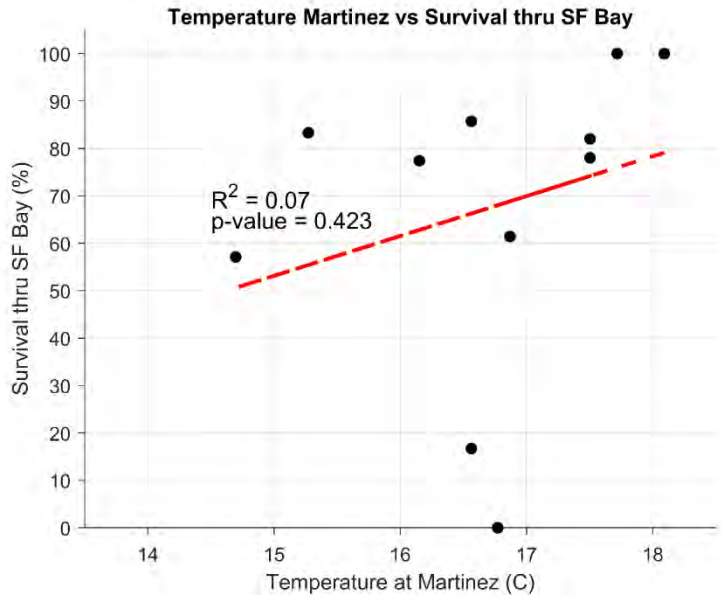


Preliminary data – do not cite

Survival and Covariates: SF Bay







FLOW

TURBIDITY

TEMPERATURE

Preliminary data – do not cite

Conclusions

- Outmigration success was:
  - very low during low flow conditions (0-5%)
  - much higher during high flow conditions (~20%).
- Travel Time for the four regions –
  - About 3/6 days Feather R.
  - About 2 days Lower Sacramento R.
  - About 6 days thru Delta
  - About 3 days thru SF Bay

  } 12.7 days total outmigration to Golden Gate
- Fish Speed for the four regions:
  - Mean of 20 rkm/day in Feather, Delta and SF Bay
  - Fish moved faster in Lower Sac R – mean of 38 rkm/day.
- Flow was the most important covariate for survival
  - Significant positive relationship for Feather River, Sacramento River, and Delta
  - But not for SF Bay
- Turbidity important for Sac R (+)
  - Sac turbidity was positively correlated with Sac flows – here turbidity and flows may be a factor in survival
  - Delta turbidity was negatively correlated with Delta in flows – here flows are the main factor in survival
- Temperature not correlated with survival
  - Fish migrate before major increase in temperature


Funding:
California Dept. Water Resources
US Bureau of Reclamation
California Dept. Fish and Wildlife
Anadromous Fish Restoration Program
US Fish and Wildlife
Ecosystem Restoration Program
ECOSYSTEM
RESTORATION
PROGRAM
California Department of Fish & Wildlife
National Oceanic & Atmospheric Administration
US Fish & Wildlife Service
CALIFORNIA
FISH & WILDLIFE
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
AFRP
Anadromous Fish Restoration Program

Developing an Improved Understanding of Pathogen Impacts for Feather River Spring-Run Chinook Salmon

Miles Daniels

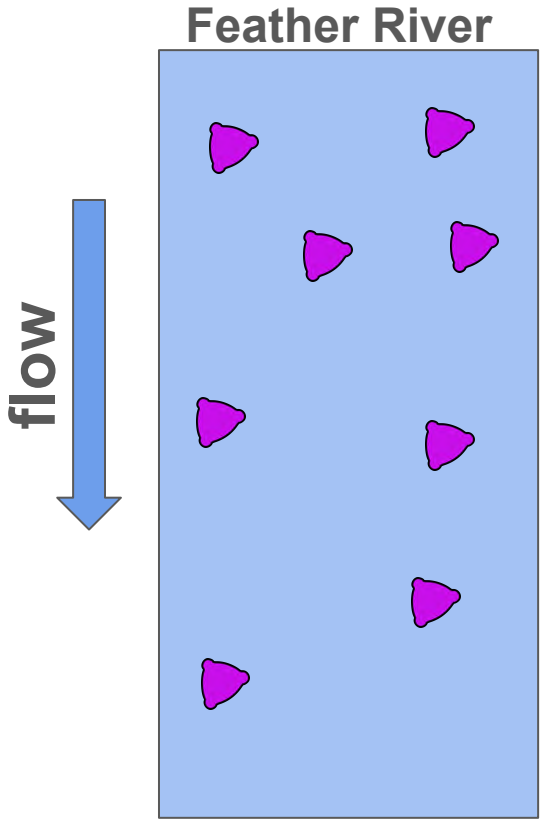
Salmon Restoration Federation
May 2, 2025

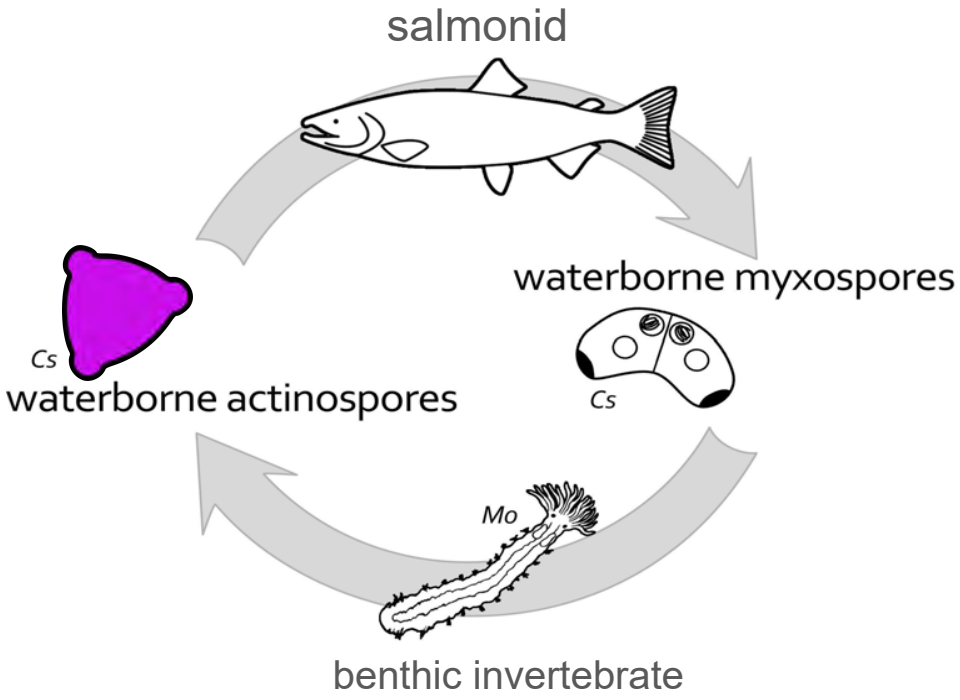
UC SANTA CRUZ | Fisheries Collaborative Program

Funding:
CDFW: Q1996036
MWDSC: 193912
CA DWR: 4600014526

Why care about pathogens?

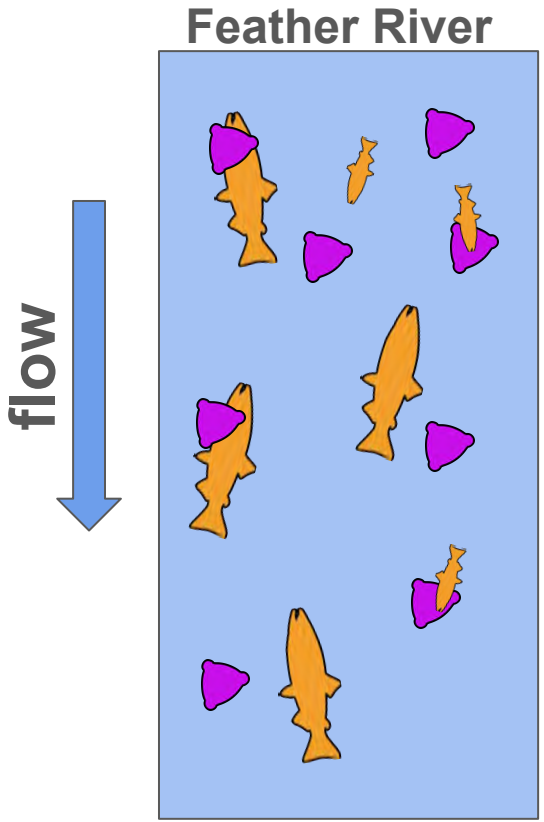
Ceratonova shasta (*C. shasta*)

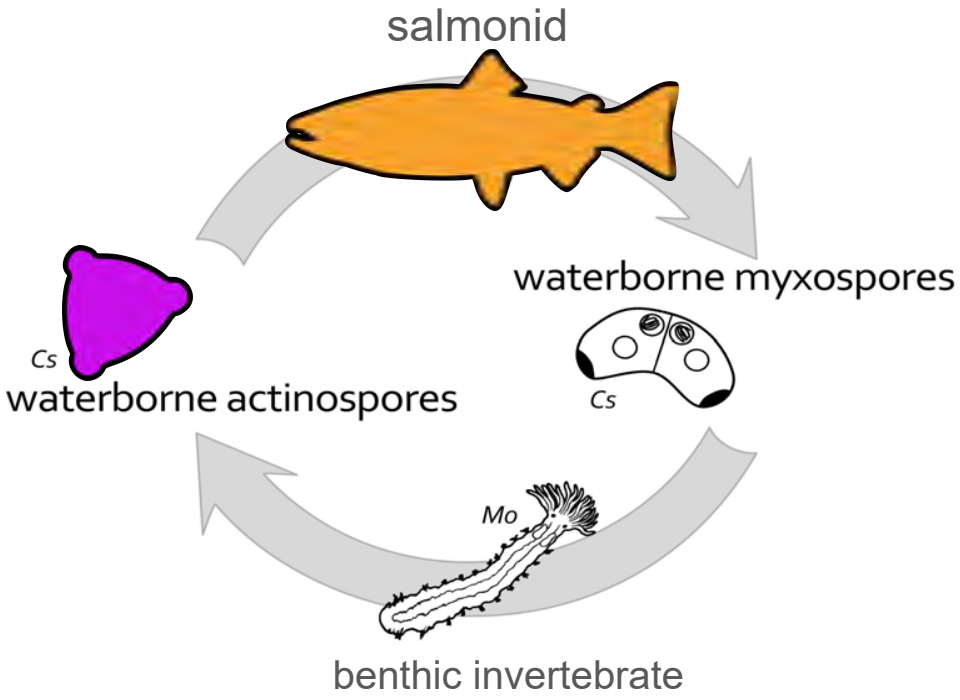




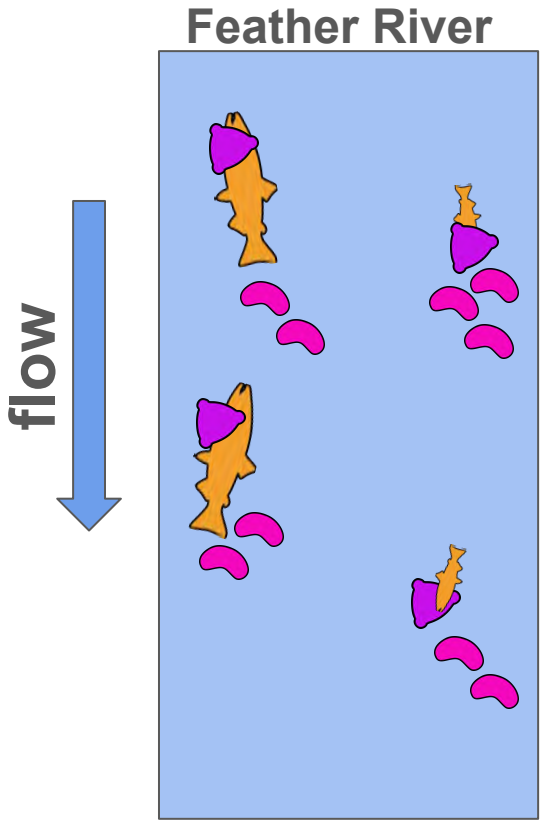
*Life cycle adapted from Daniels *et al*. 2021 Prop 1 proposal. Illustrator: S. Atkinson.

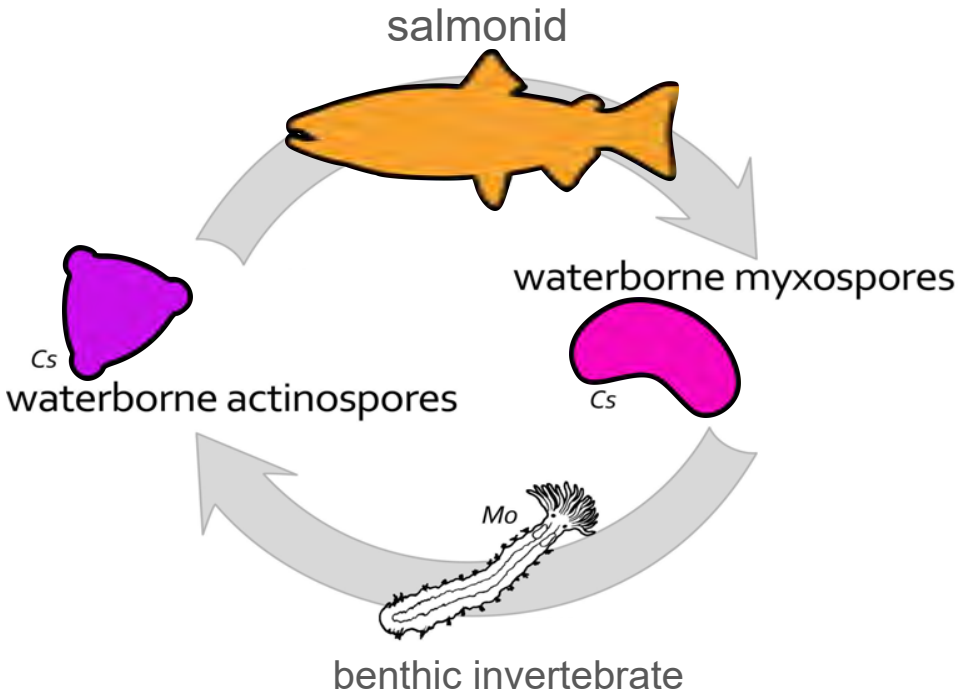
Ceratonova shasta (*C. shasta*)



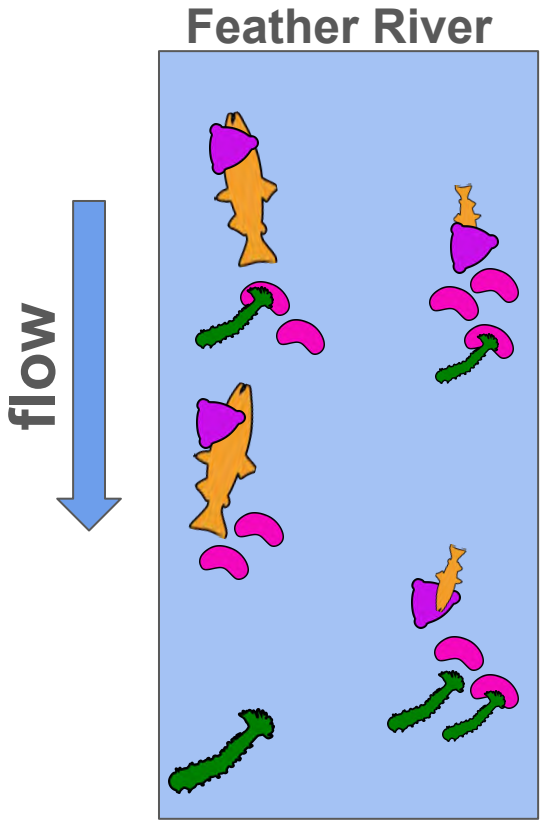


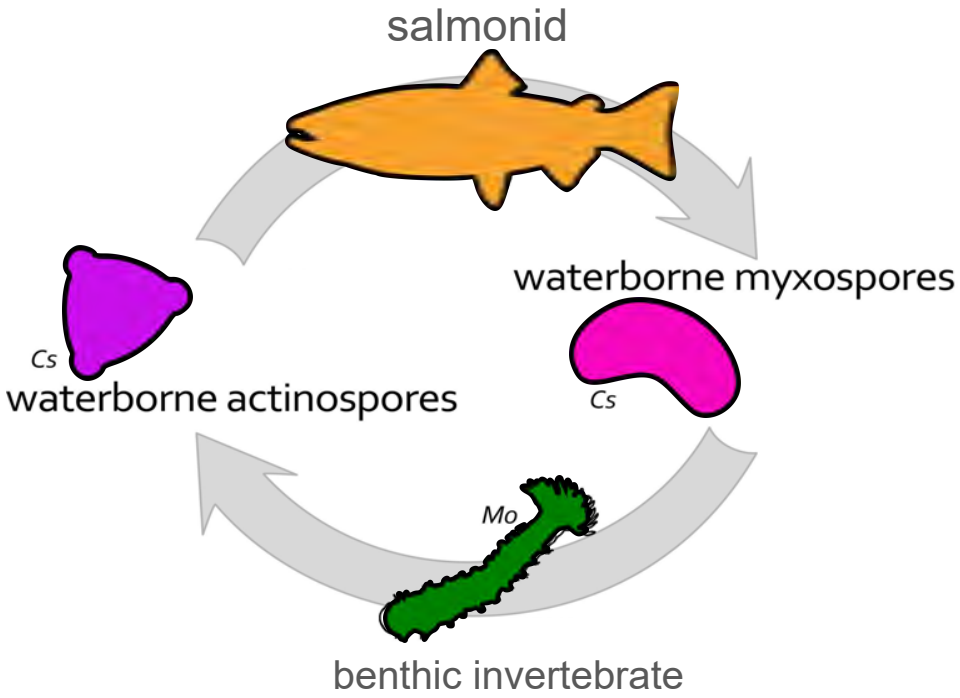
Ceratonova shasta (*C. shasta*)





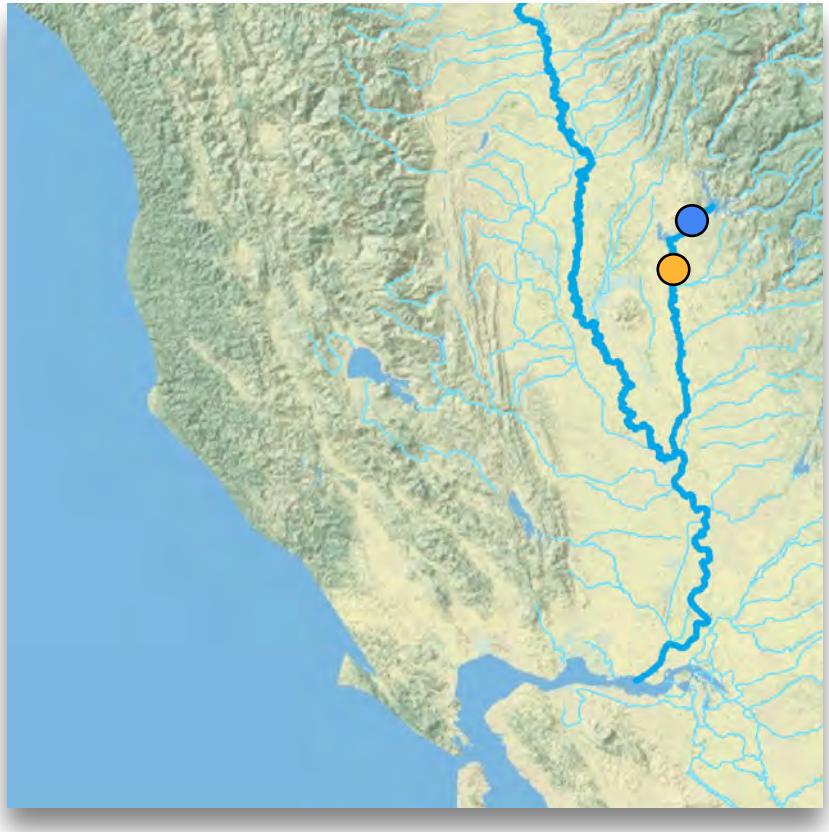
Ceratonova shasta (*C. shasta*)





Is there evidence
C. shasta impacts on the
Feather River?

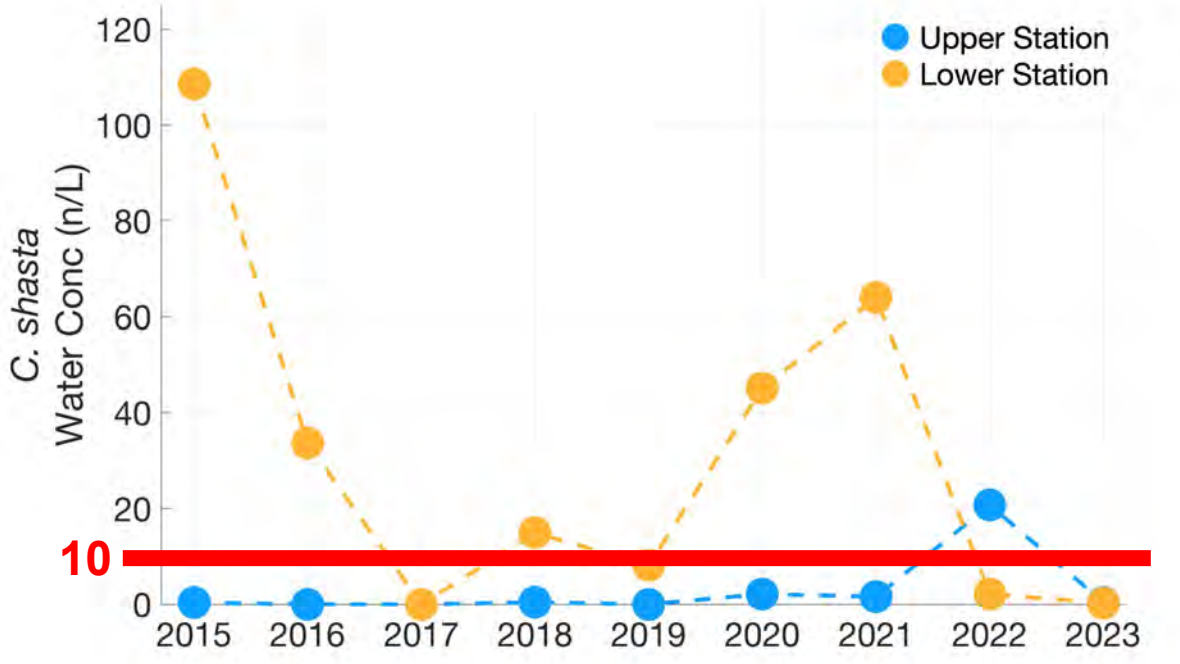
Two long term monitoring stations



Upper station

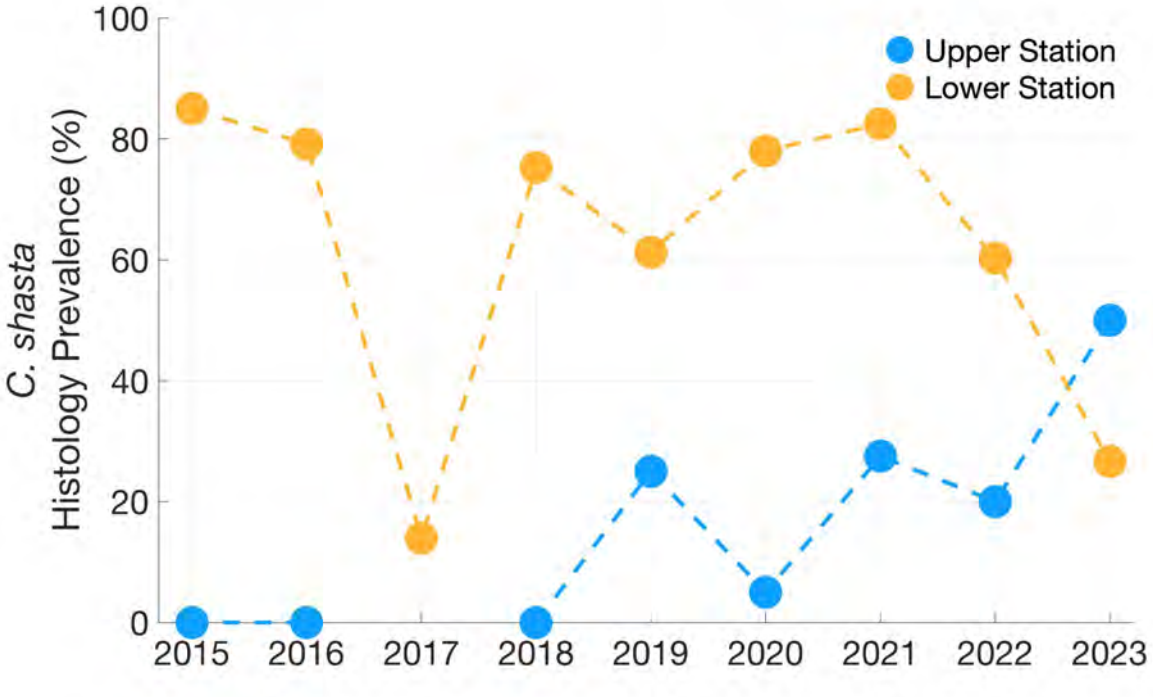
Lower station

What is in the water?



**Markers are averages of a given year*

What is in the fish?



**Markers are averages of a given year*

How are we developing an improved understanding to predict these dynamics?

The Team















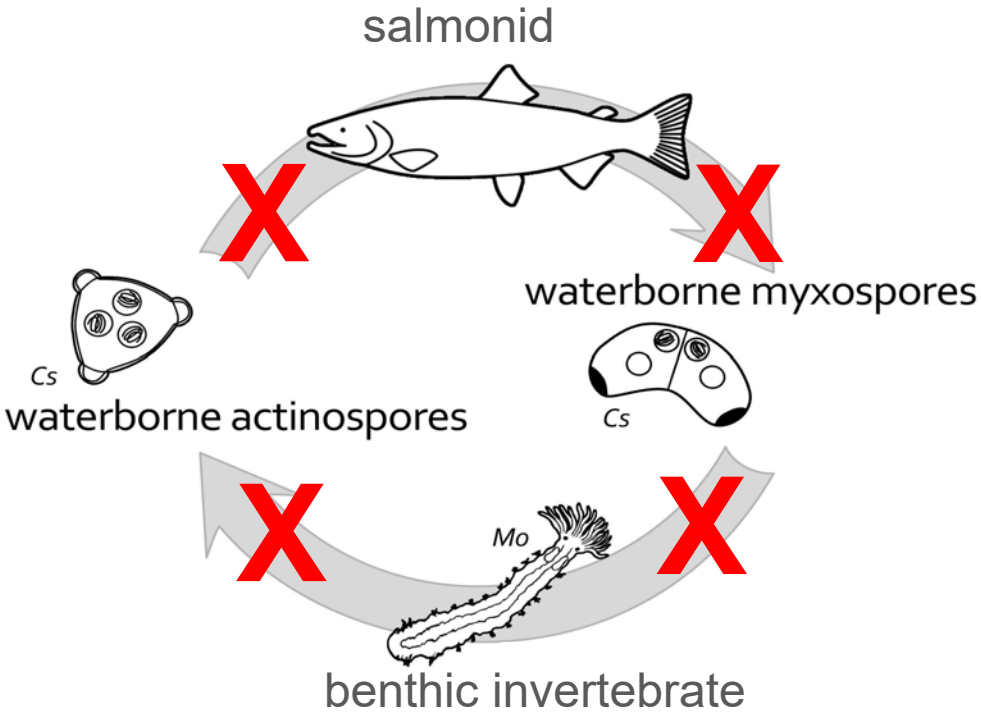




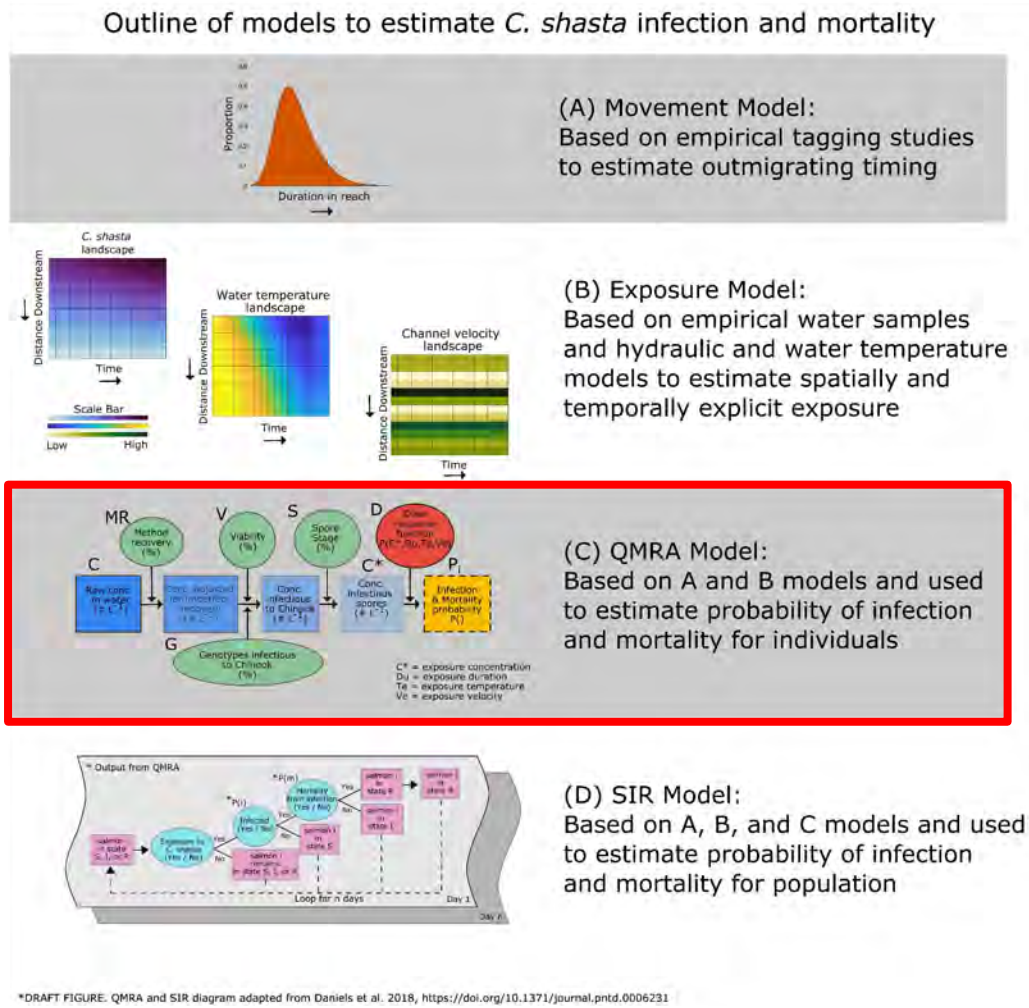
UCDAVIS
UNIVERSITY OF CALIFORNIA

Oregon State
University

Our goal is to find ways to disrupt transmission



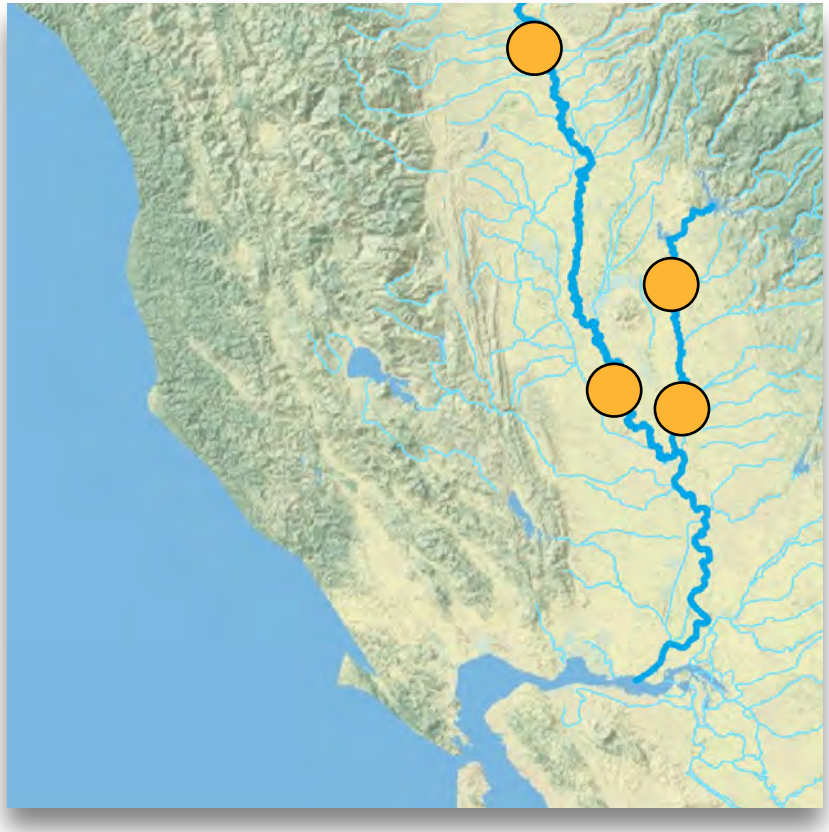
Big picture



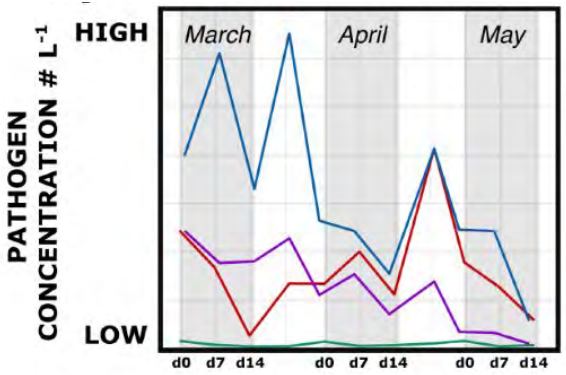
*DRAFT FIGURE. QMRA and SIR diagram adapted from Daniels et al. 2018, https://doi.org/10.1371/journal.pntd.0006231

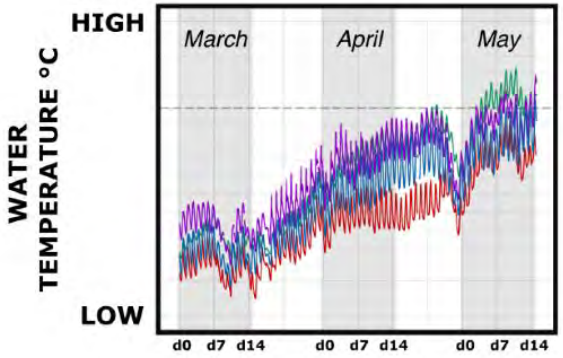
Sentinel study to develop **infection** dose-response model

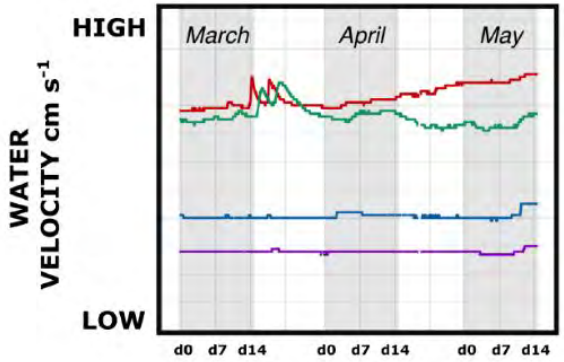
Study sites



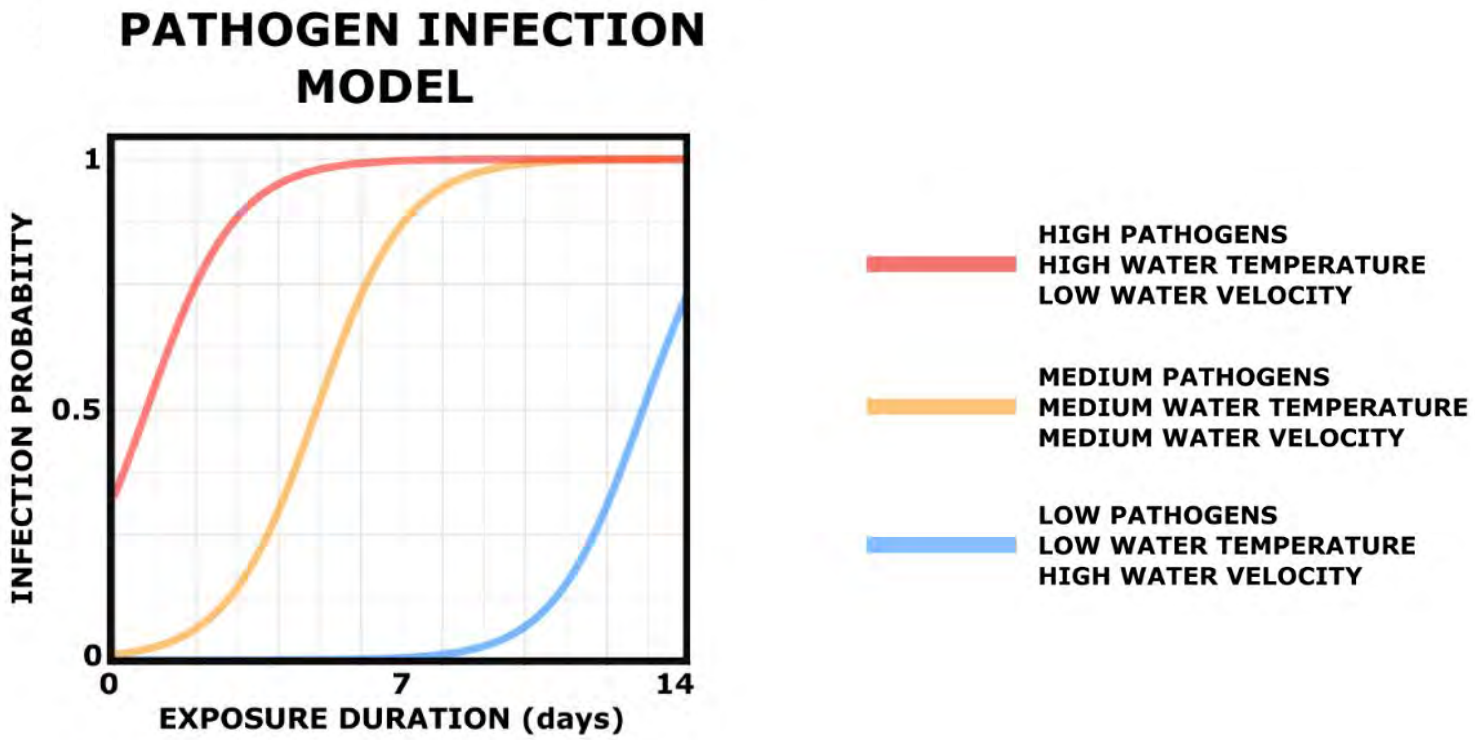
Environmental covariates monitored



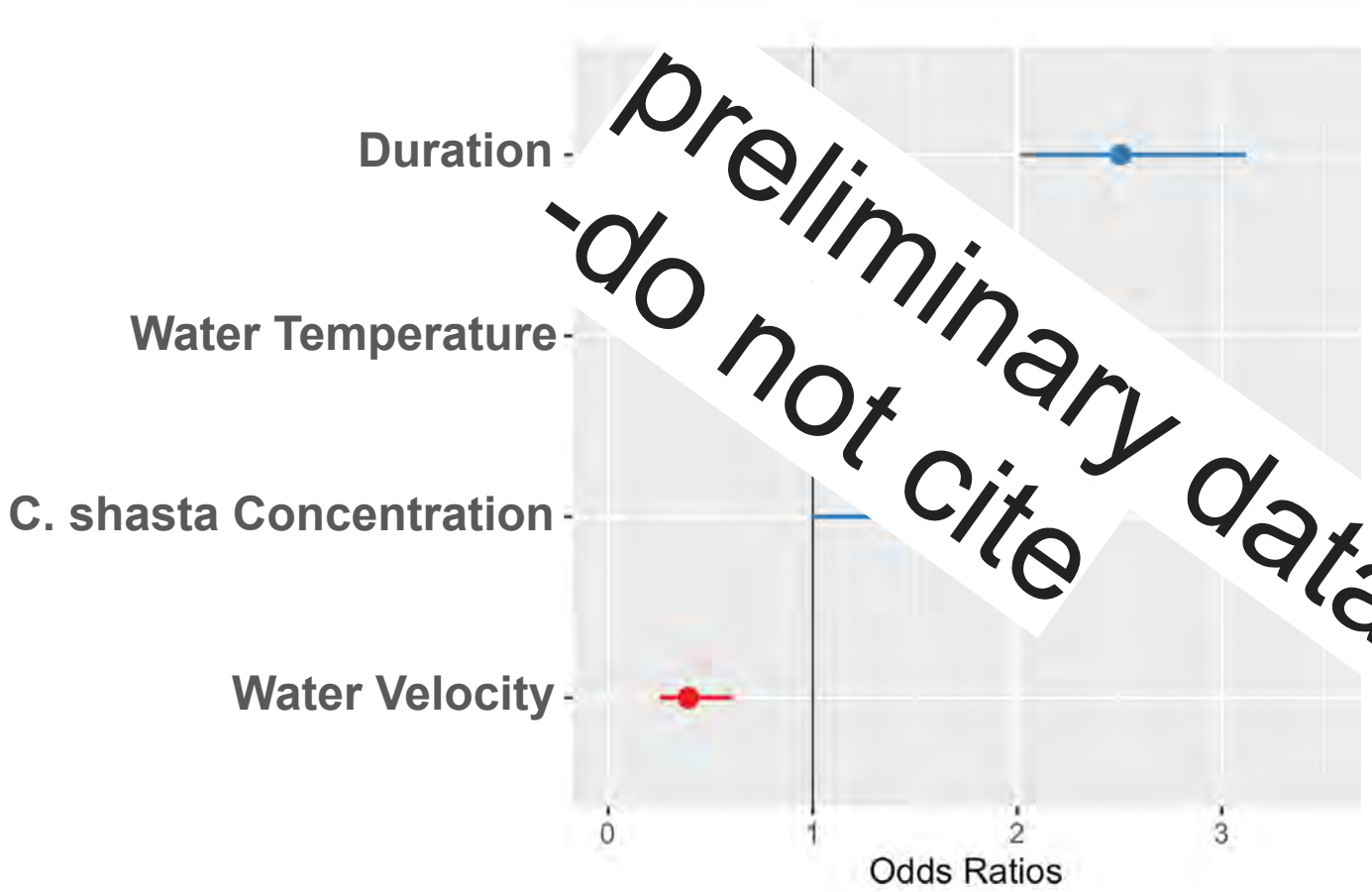




Example dose-response model



Results

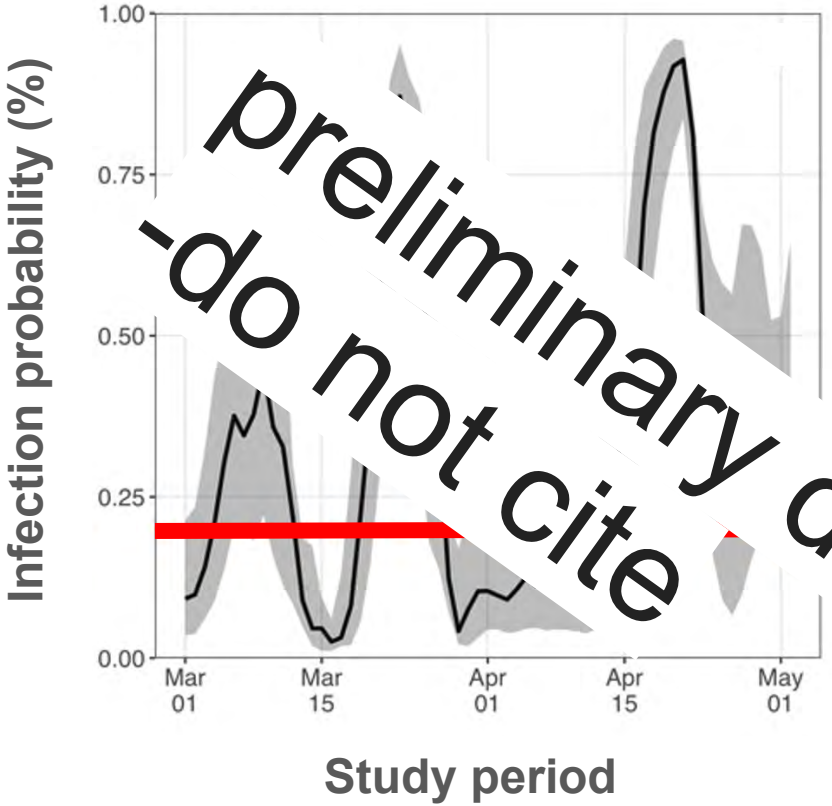


preliminary data
-do not cite

*in review for publication

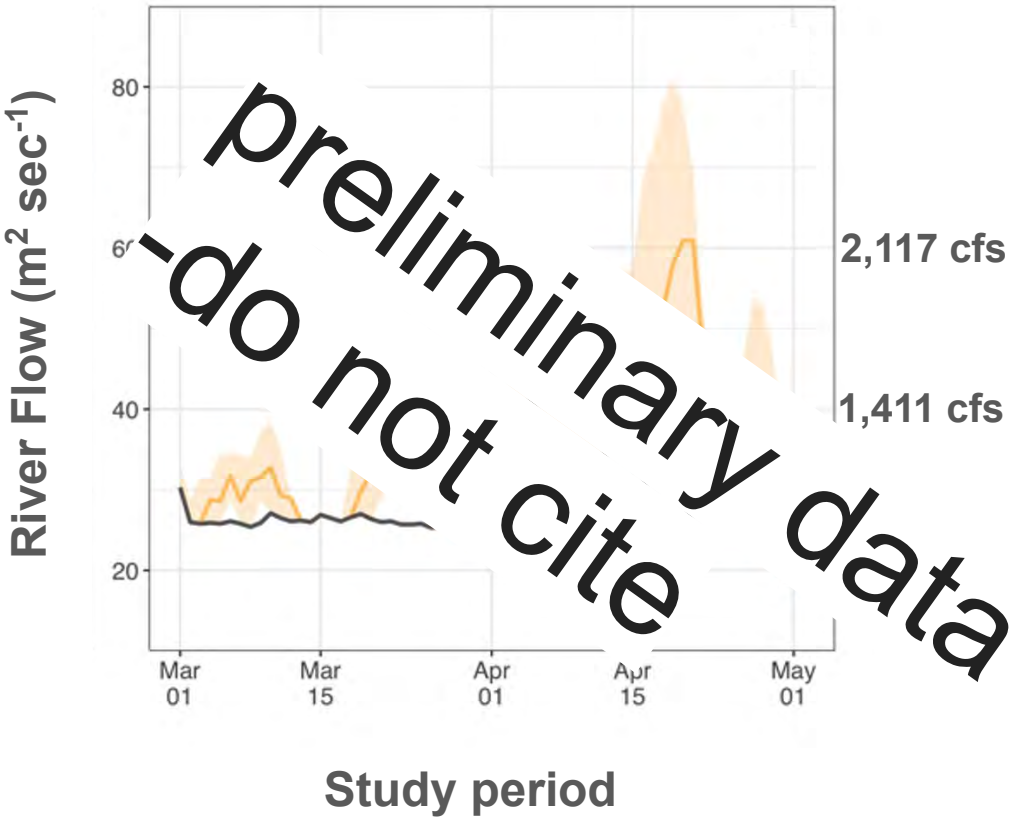
How can we use these tools to help better understand disease dynamics?

Application of model (dilution is the solution)



*in review for publication

Application of model (dilution is the solution)

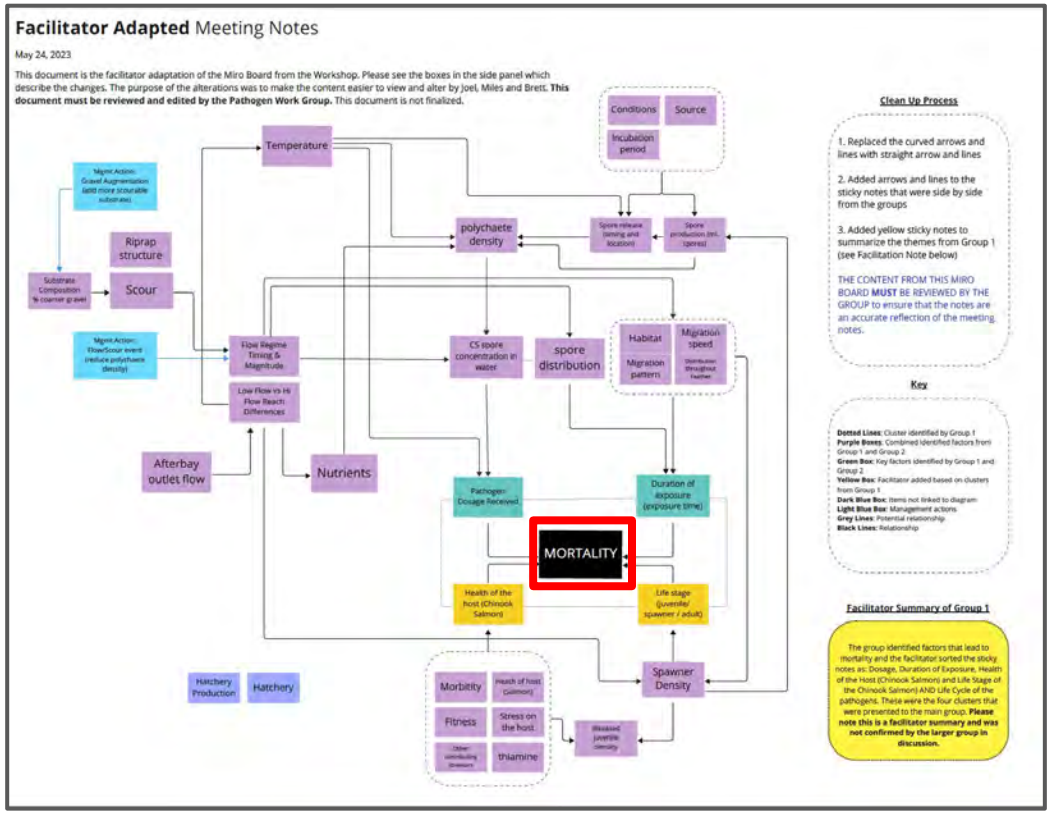


*in review for publication

Things not explained

- Movement model
- Environmental models of water temperature and river hydrology and hydraulics
- Additional components of QMRA, such as adjusting for spores infectious to salmon by genotype and or life stage
- Lots of other work occurring to understand full pathogen life cycle
  - additional sentinel studies
  - finer resolved water sampling
  - benthic invertebrate research
  - combining field and laboratory data
  - and more…

Conclusions and future work



*in alphabetical order

Feather River Pathogen Team
Julie Alexander (OSU)
Anna Allison (CDFW)
Sabrina Bell (DWR)
Scott Foott (USFWS)
Dani Hartwigsen (CSUC)
Brett Harvey (DWR)
Alana Imrie (PSMFC)
Jason Kindopp (DWR)
Ryon Kurth (DWR)
Joel Llamas (CDFW)
Gabriel Loera (CDFW)
Colin Purdy (CDFW)
Nick Som (USGS)
Ron Stone (USFWS)

Dose-Response Model
Benjamin Atencio (UCSC)
Stephen Atkinson (OSU)
Richard Connon (UCD)
Scott Foott (USFWS)
Sascha Hallett (OSU)
Camilo Sanchez (UCD)
Amelie Segarra (UCD)

Thanks for listening!

Miles Daniels
miles.daniels@ucsc.edu

Funding:
CDFW: Q1996036
MWDSC: 193912
CA DWR: 4600014526

Spring-Run Chinook Salmon Reintroduction Pilot Study in the North Fork Feather River Upstream of Oroville Dam



California Department Of Water Resources
Division of Multi-Benefit Initiatives/Division of Integrated Science and Engineering

Project Initiation

- Central Valley has limited habitat for spring-run
- Need for diverse, climate resilient alternatives to support spring-run Chinook salmon
- Assessed many areas in the Feather River Watershed
- North Fork Feather Above Lake Almanor has the most potential

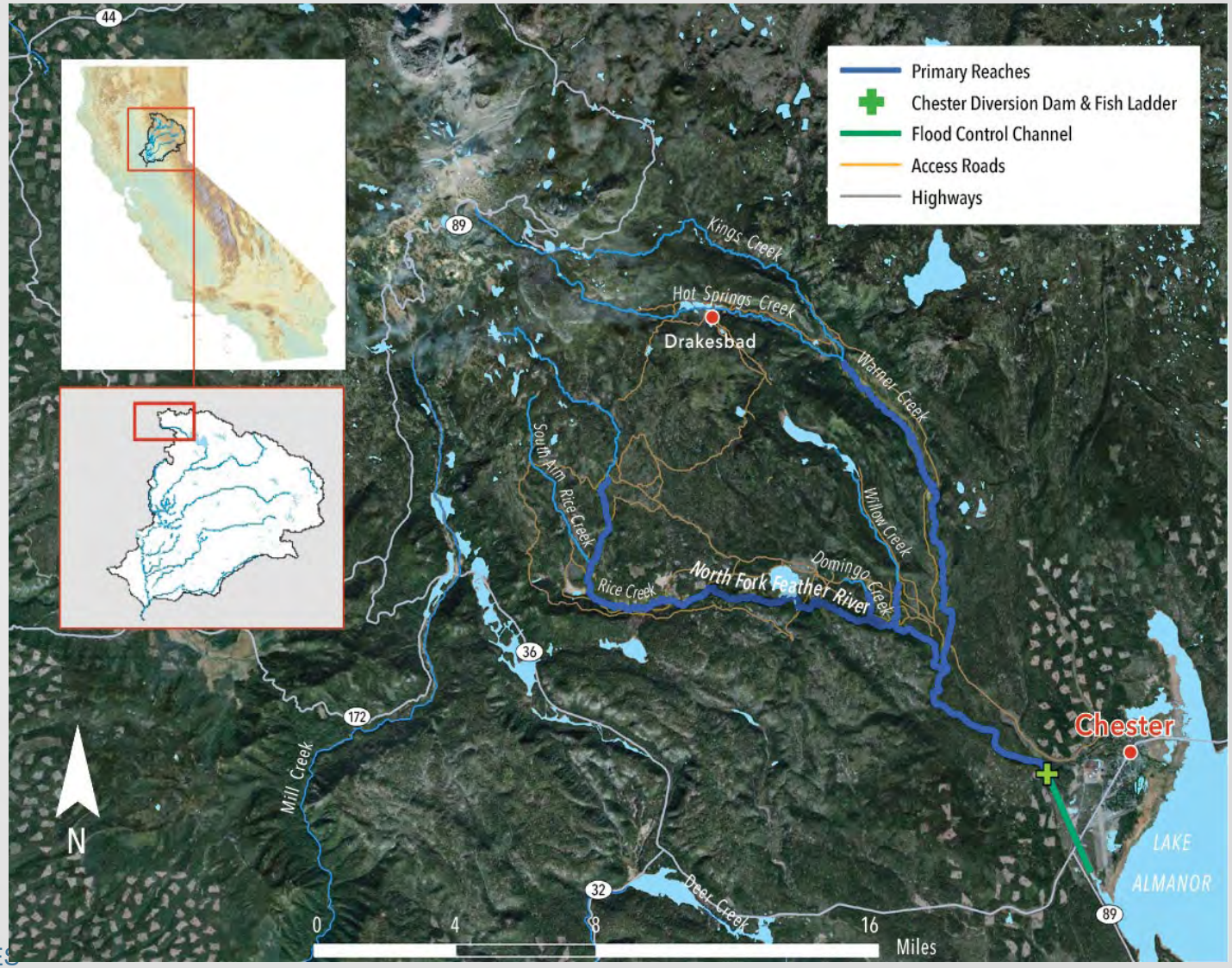
Objective

Evaluate potential for spring-run Chinook salmon reintroduction to the North Fork Feather River above Lake Almanor



Study Tasks

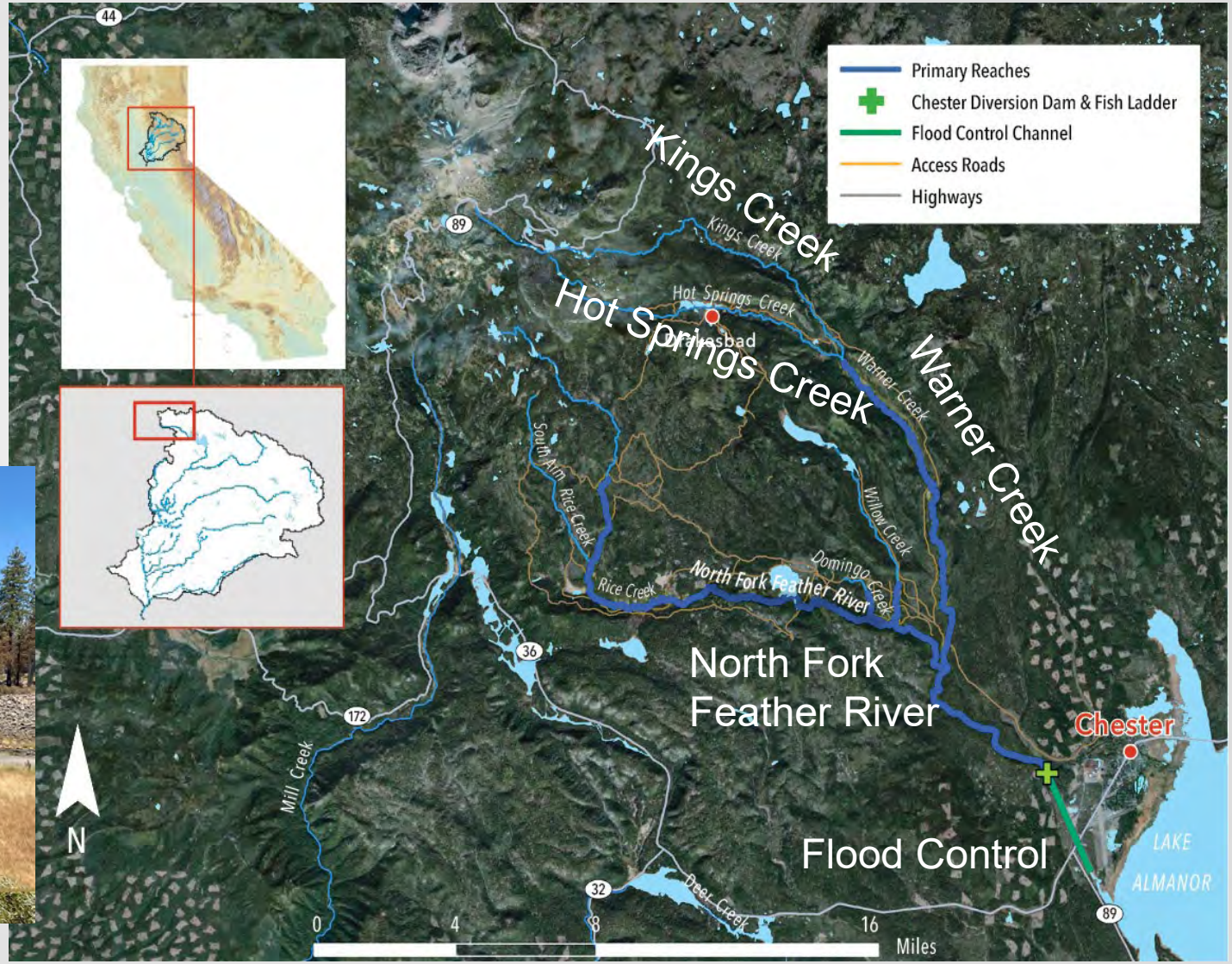
- Habitat assessment
- In-river egg incubation
- Juvenile trapping
- Emigration behavior



Access and Existing Infrastructure







Permitting, Agreements & Outreach

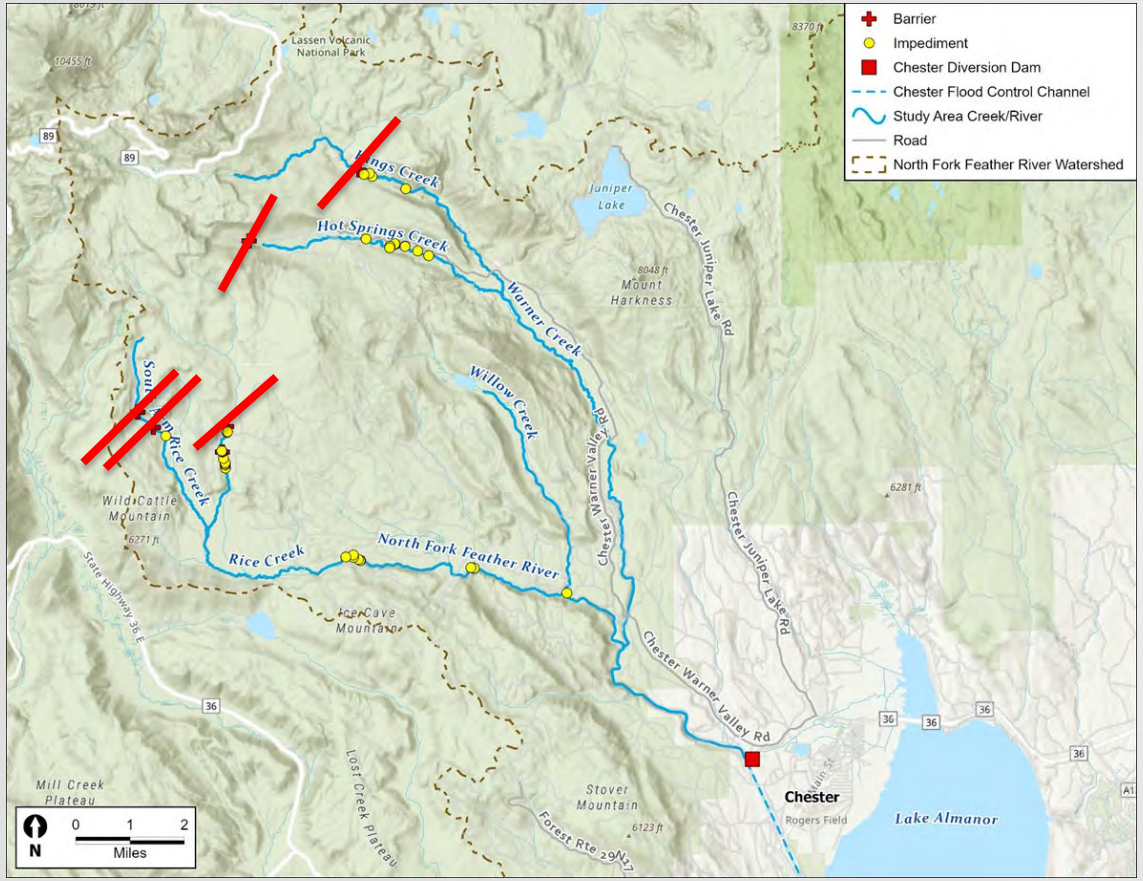
- CDFW & NMFS Scientific Collecting Permit (triploid)
- CDFW Fish Request
- Access permits and agreements for public and private lands
- CVFPB & USACE Minor Alterations – in progress
- County agreements
- Community meetings
- Maidu Summit Consortium
- Monthly Newsletter
- Interactions with public

Project Site Conditions



- Harsh winters, hot summers
- Large fluctuations in flow
- Constant adjustments to project

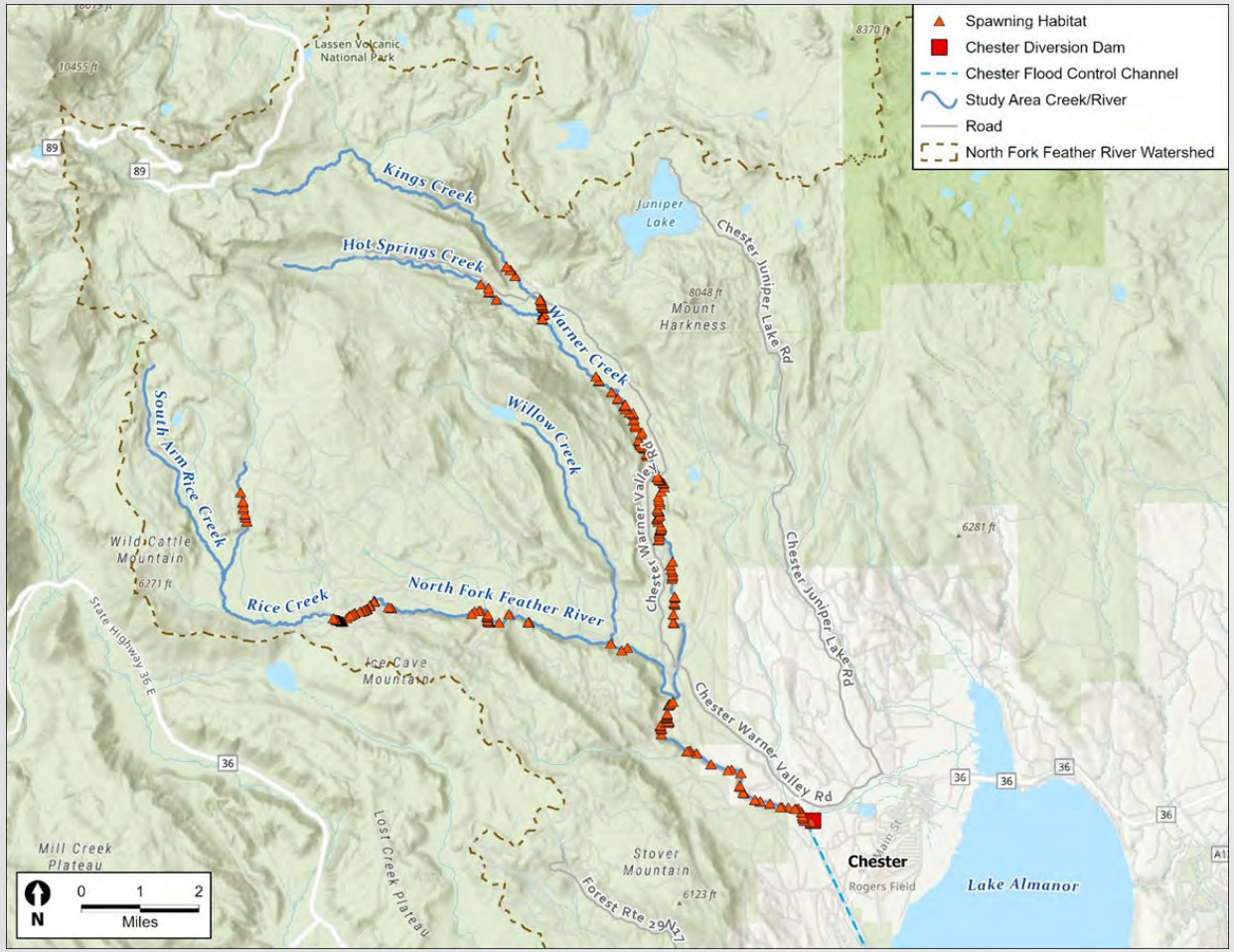
Habitat: Barrier Assessment



- > 43 miles of channel habitat
- Recorded impediments
- Informed spawning gravel surveys



Habitat: Spawning Gravel



- > 60% of channels below barriers assessed
- 230 sites with suitable gravel for spawning
- Gravel reaches widen as you move downstream

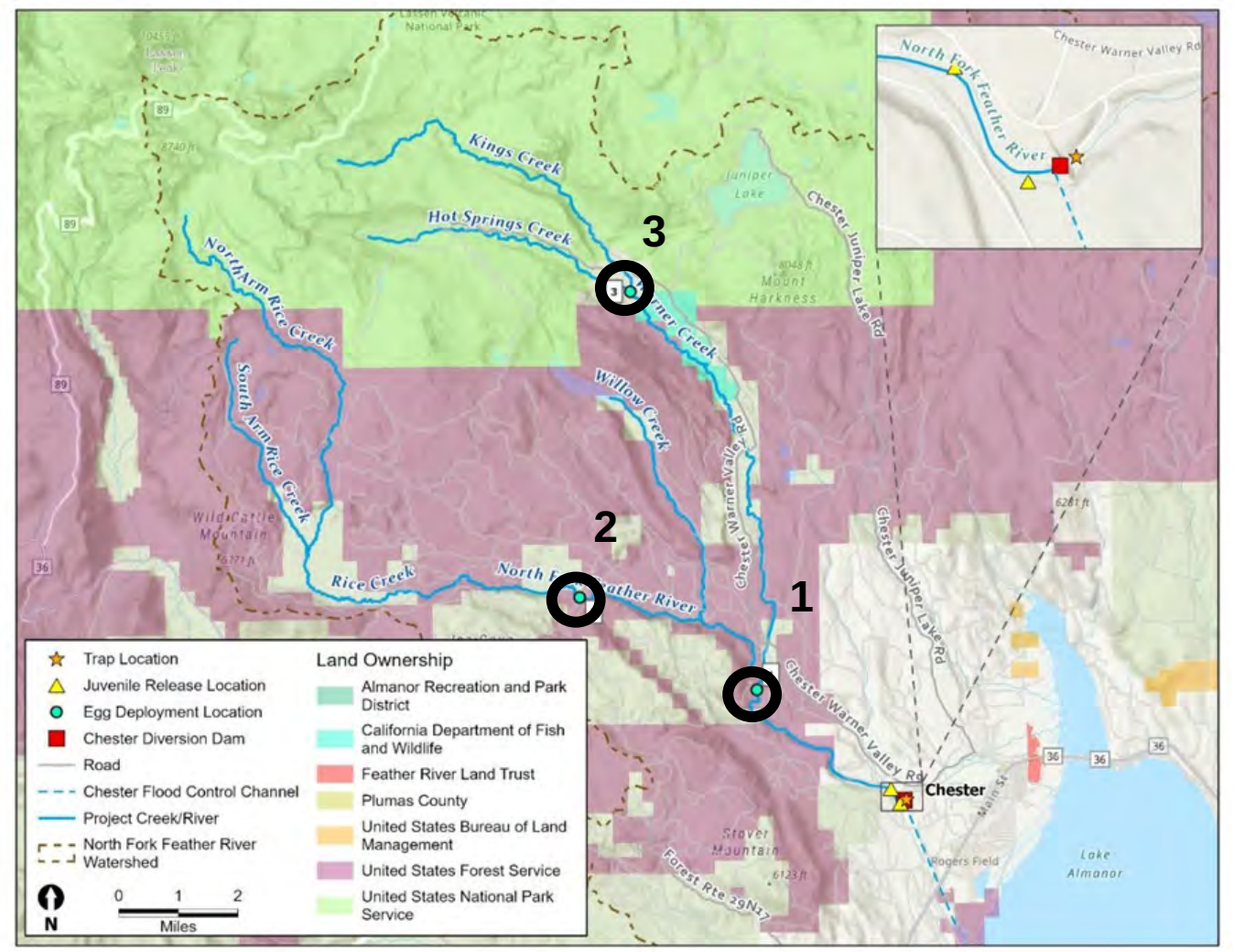
Habitat: Holding Pools



- 182 holding pools
- Majority on Warner Creek
- Longest pools on Hot Springs Creek



Egg Incubation



1. Confluence of North Fork Feather and Warner
2. River Loop Campground
3. Confluence Hot Springs and Kings

Egg Collection and Rearing

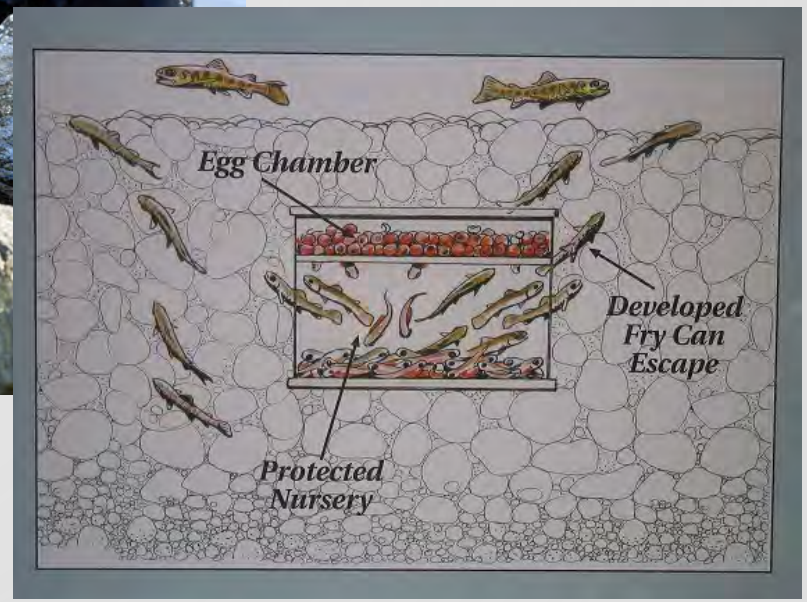
- ~200,000 eggs collected at FRFH
- Triploid → infertile
- 5 PBT groups
- Reared at CDFW's Silverado Fisheries Base
- ~30,000 juveniles released for trap efficiency trials



In-river Incubation: Hatch Boxes

- ~ 65k eggs over 3 locations
- Whitlock-Vibert egg box
- ~250 chinook eggs fit in top compartment
- Alevin can fit through the mesh to bottom compartment
- “Hotels” of 4 boxes anchored





In-river Incubation: Hydraulic Egg Injection





- ~ 60k eggs in one location
- Water pumps out sediment and gravel
- Eggs to passively fall into from funnel into pocket
- 2 pockets: upper and lower
- ~ 800 eggs per pocket

Juvenile Capture

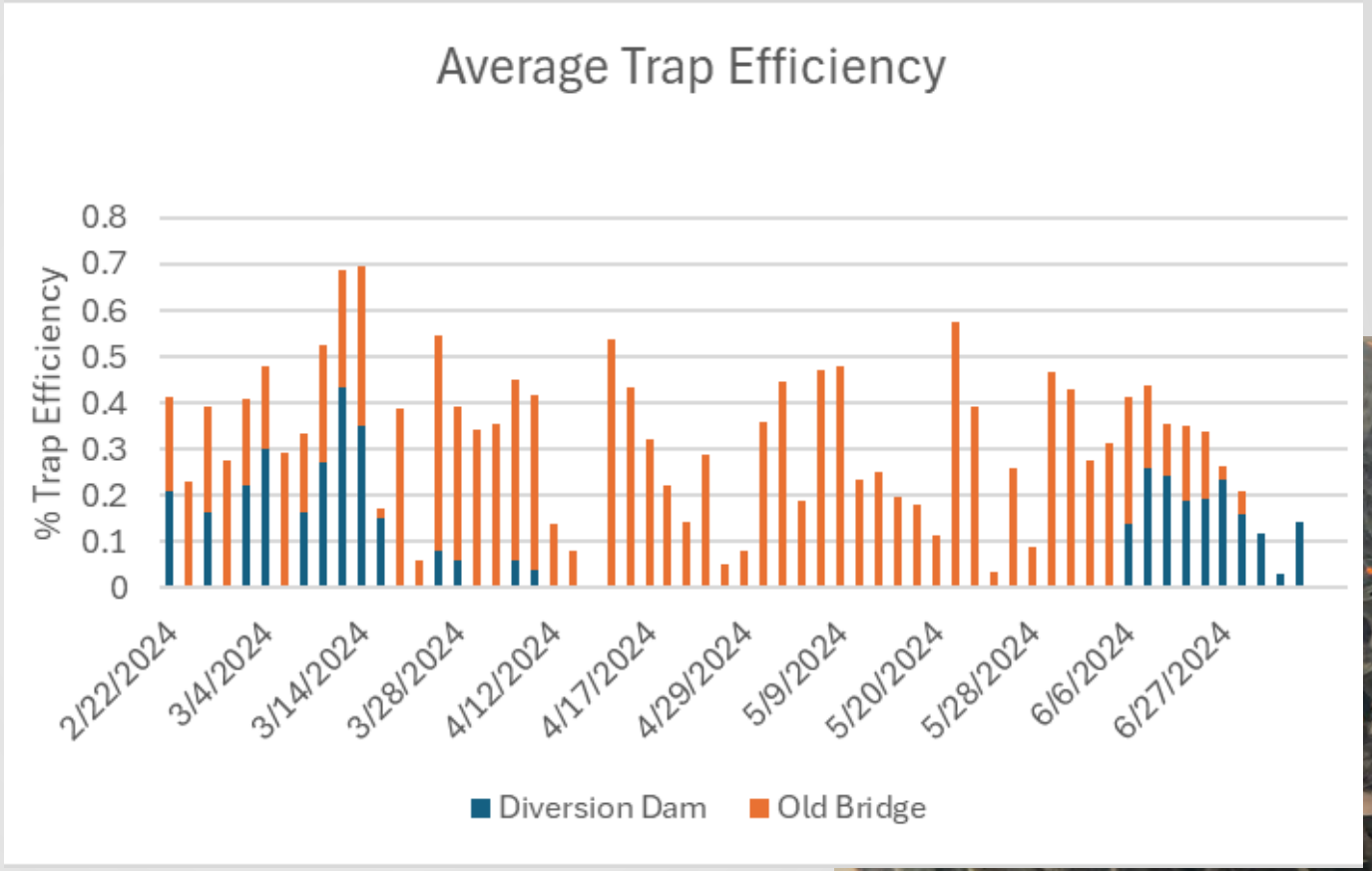
- Understand migration routing
- Various traps, locations, and configurations used
- Support different flows and conditions
- Emigration timing of all life-histories
- Estimate trap capture efficiency of all life-stages available

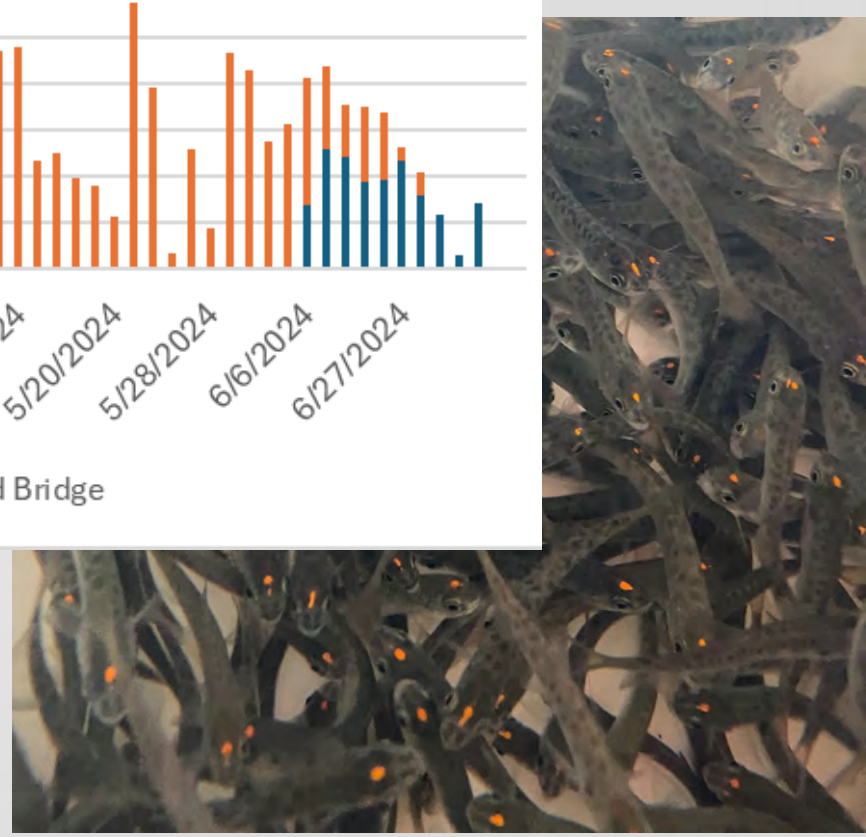




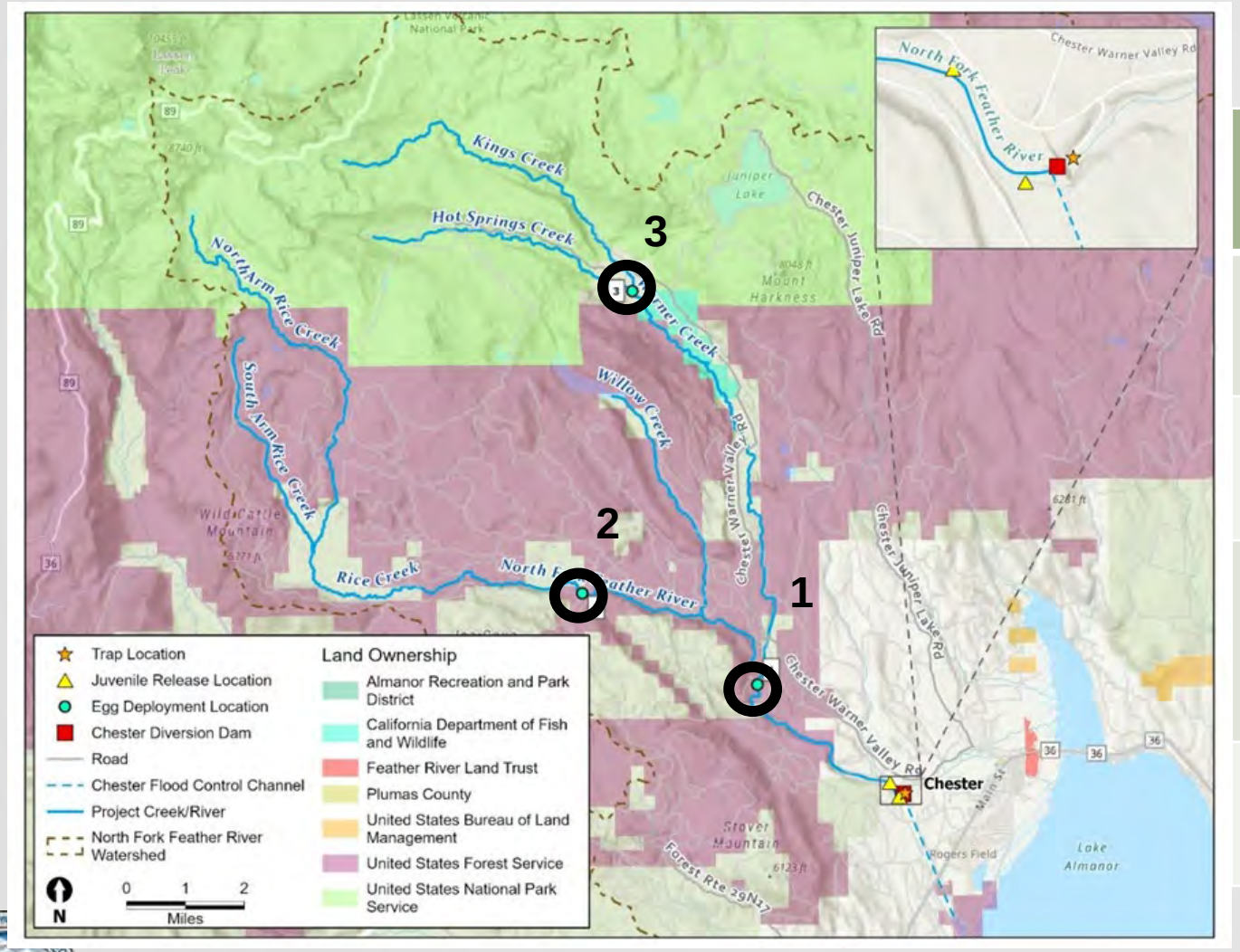
Trap Efficiency Releases

- Juveniles reared at Silverado and in river used
- VIE and Bismark tagging
- Flow changes in mid March
- Diversion Dam traps stopped fishing in Spring





Parent Based Tagging Results



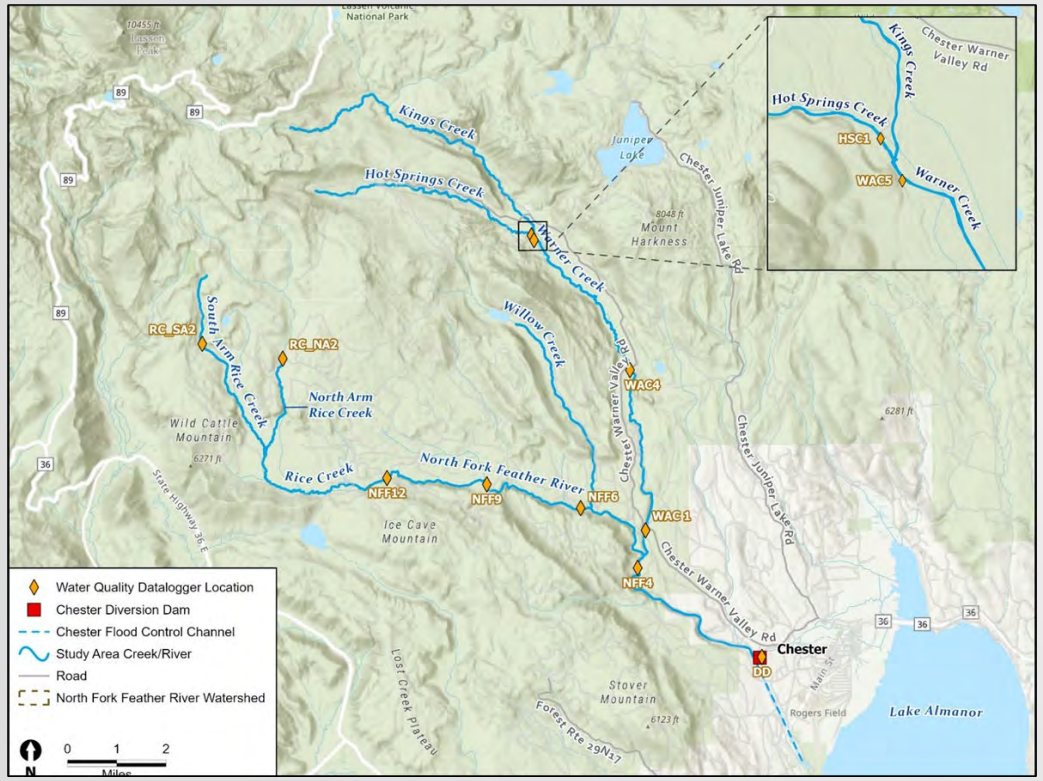
Location	Quantity	Method	Number Recovered
1 - NF below Warner	62,916	Injection	1106
1 - NF below Warner	16,463	Hatch box	0
2 - NF River Loop Camp	16,968	Hatch box	8
3 – Hot Spring and Kings	14,992	Hatch box	24

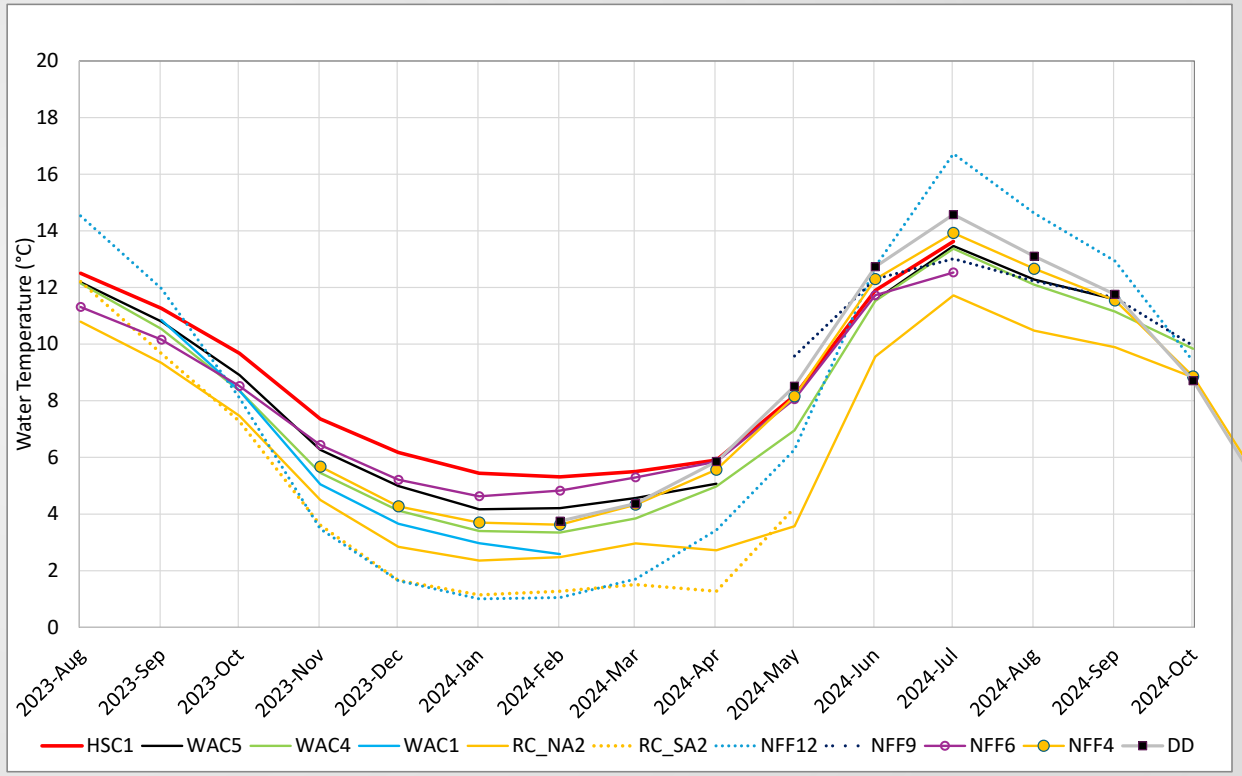
Emigration Behavior



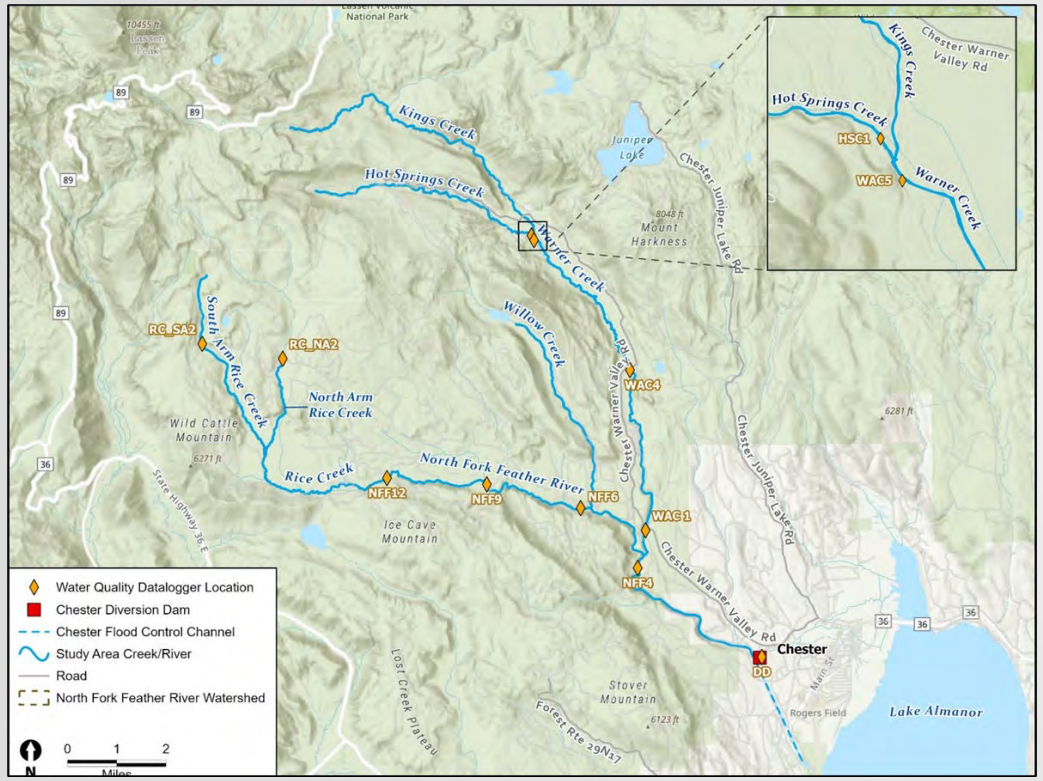
- Snorkel surveys
- 12 yearlings from November – March
- Stream type rearing possible

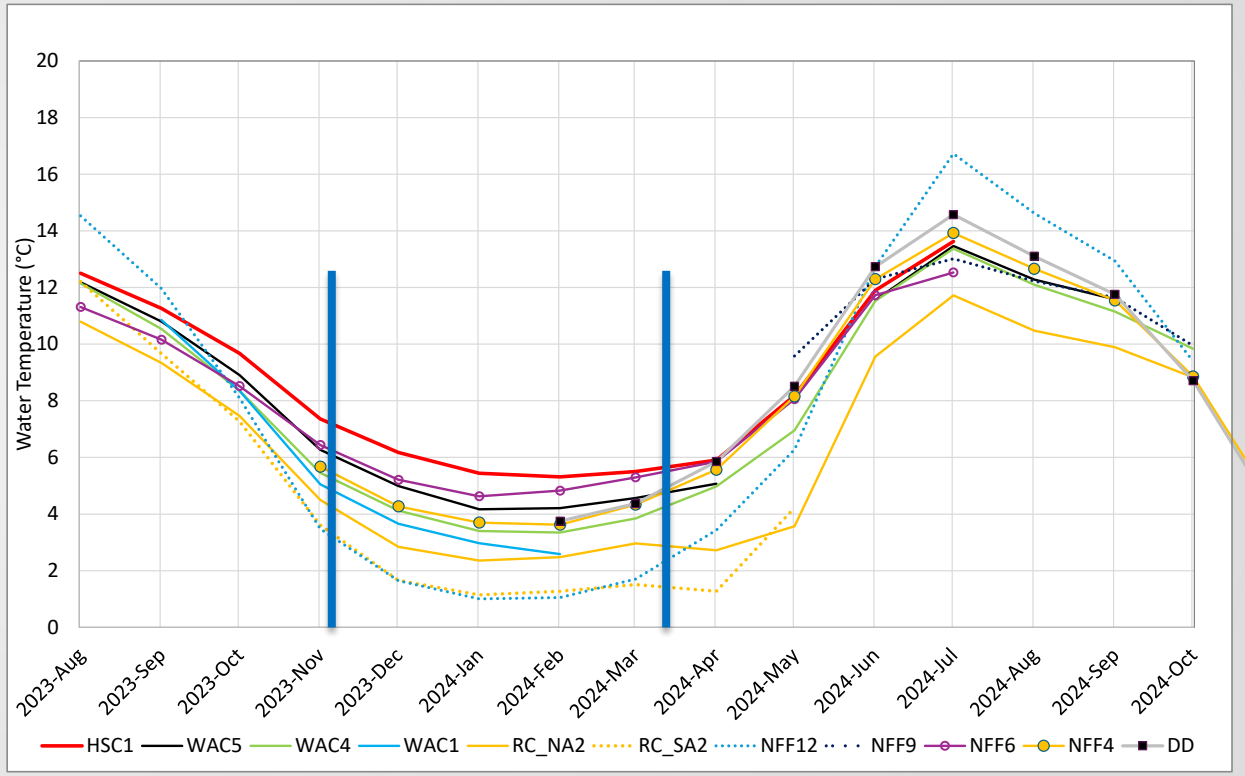
Water Temps


Kings Creek
Hot Springs Creek
Juniper Lake
Chester Juniper Lake Rd
Mount Harkness
Willow Creek
Chester Warner Valley Rd
RC_SA2
RC_NA2
South Arm Rice Creek
North Arm Rice Creek
Wild Cattle Mountain
Rice Creek
North Fork Feather River
NFF12
NFF9
NFF6
WAC4
WAC 1
NFF4
DD
Chester
Ice Cave Mountain
Stover Mountain
Lake Almanor
Rogers Field
Lost Creek Plateau
Forest Rte 29N17
HSC1
WAC5
Warner Creek
Water Quality Datalogger Location
Chester Diversion Dam
Chester Flood Control Channel
Study Area Creek/River
Road
North Fork Feather River Watershed
0 1 2
Miles


Water Temperature (°C)
0
2
4
6
8
10
12
14
16
18
20
2023-Aug
2023-Sep
2023-Oct
2023-Nov
2023-Dec
2024-Jan
2024-Feb
2024-Mar
2024-Apr
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NFF9
NFF6
NFF4
DD

Next Steps

- Emergent fry traps
- Adult transport study
- Keep up trapping efforts
- Custom traps
- Utilize infrastructure
- Predators
- Pathogens



Acknowledgements

- DWR DISE Feather River Program
- DWR Multibenefit Initiative
- Pacific States Marine Fisheries Commission
- ICF
- CDFW
- USFS
- Plumas County
- Maidu Summit Consortium
- CVFPB
- NMFS

Thank you



