Eight decades of hatchery salmon releases in the California Central Valley: Factors influencing straying and resilience

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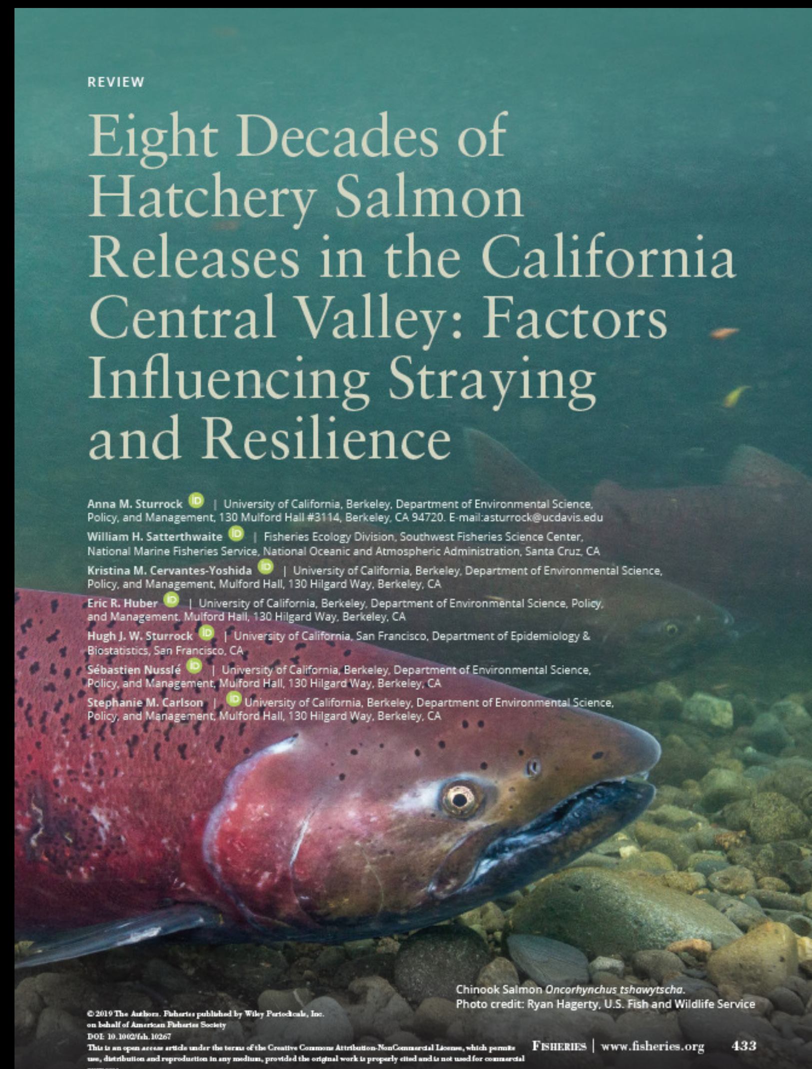
REVIEW

Eight Decades of Hatchery Salmon Releases in the California Central Valley: Factors Influencing Straying and Resilience

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Chinook Salmon *Oncorhynchus tshawytscha*.
Photo credit: Ryan Hagerty, U.S. Fish and Wildlife Service

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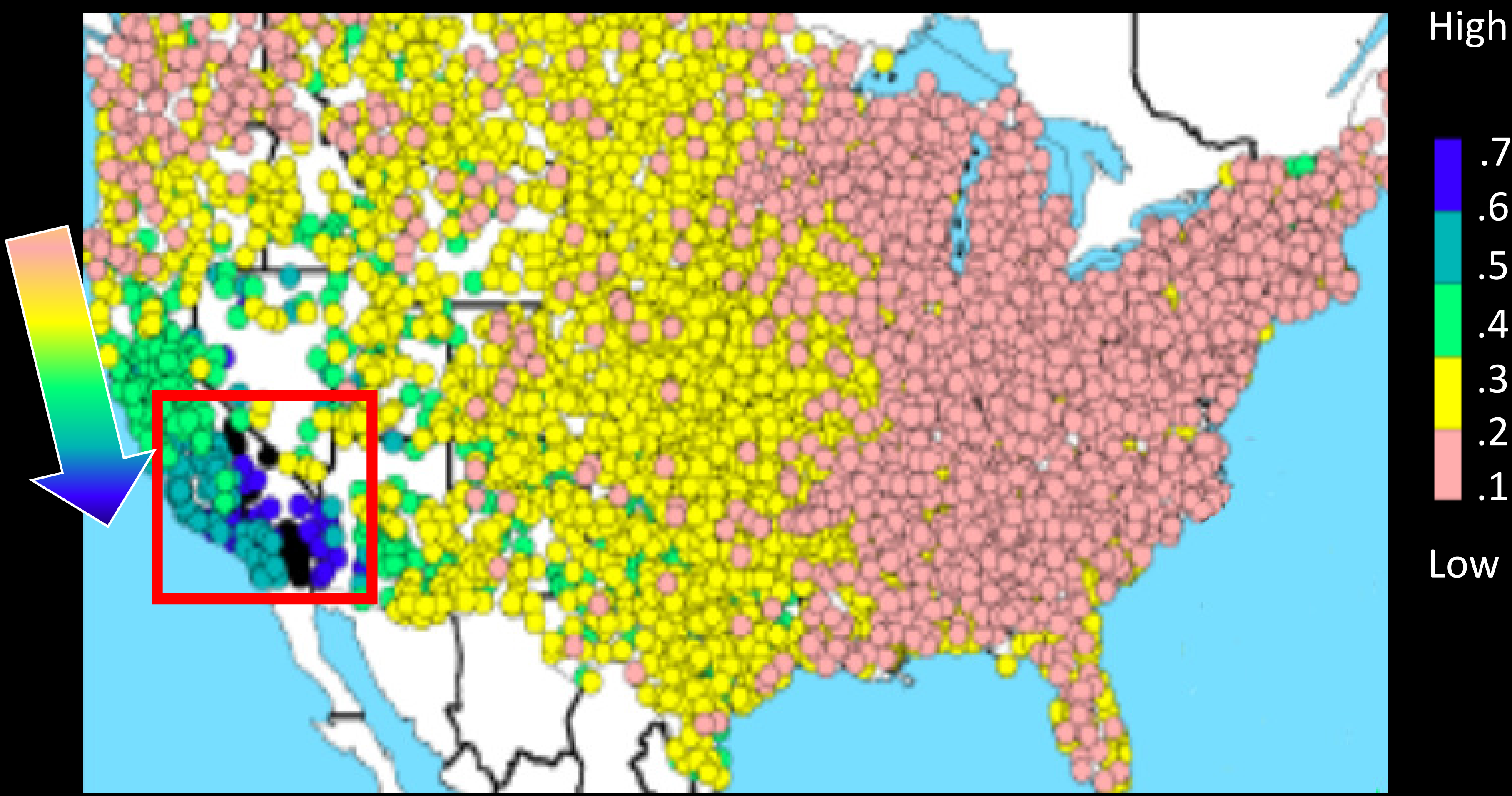
SALMON LIFE HISTORY DIVERSITY

Coefficients of variation in total precipitation (1951-2008)



Dettinger et al. 2011

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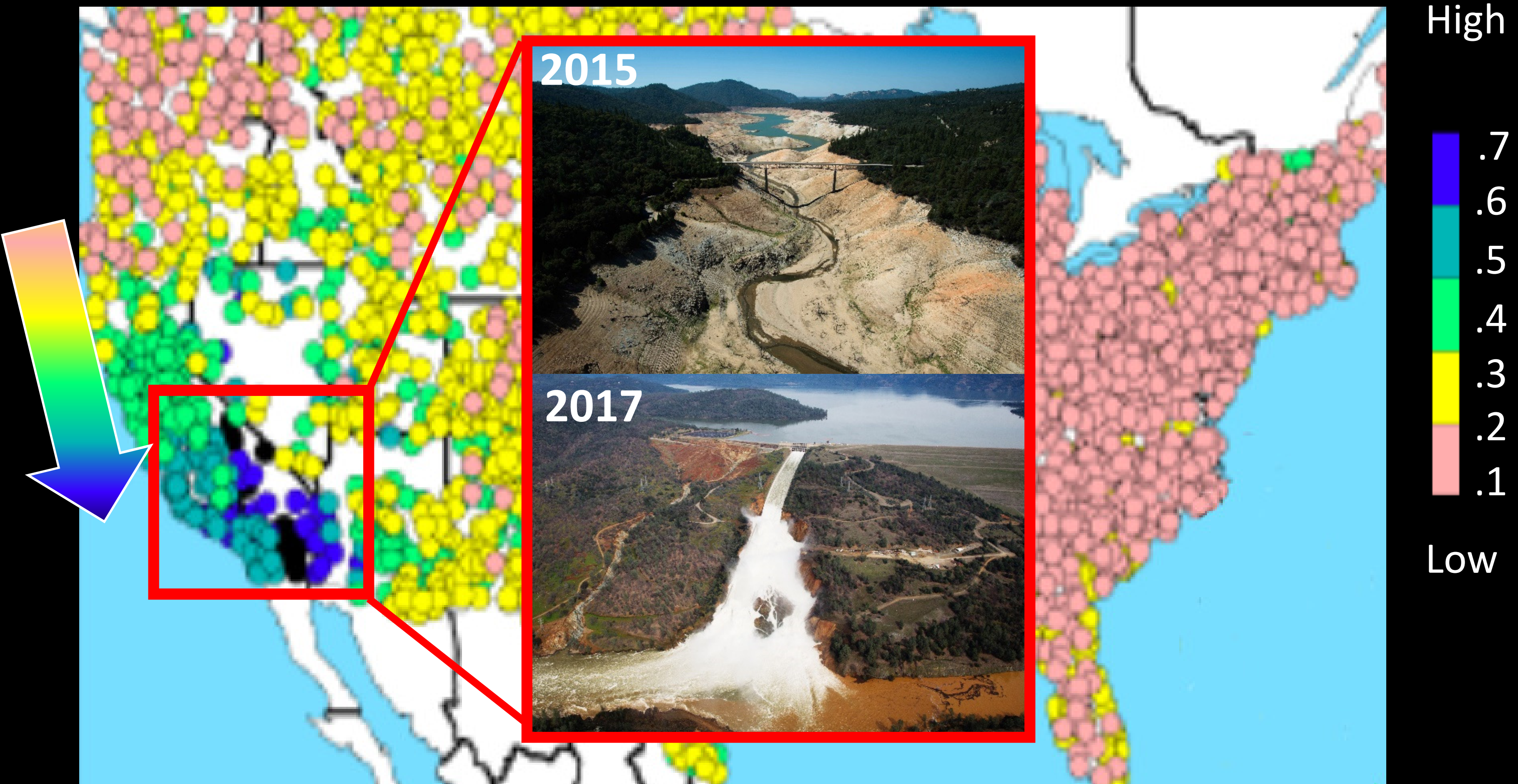

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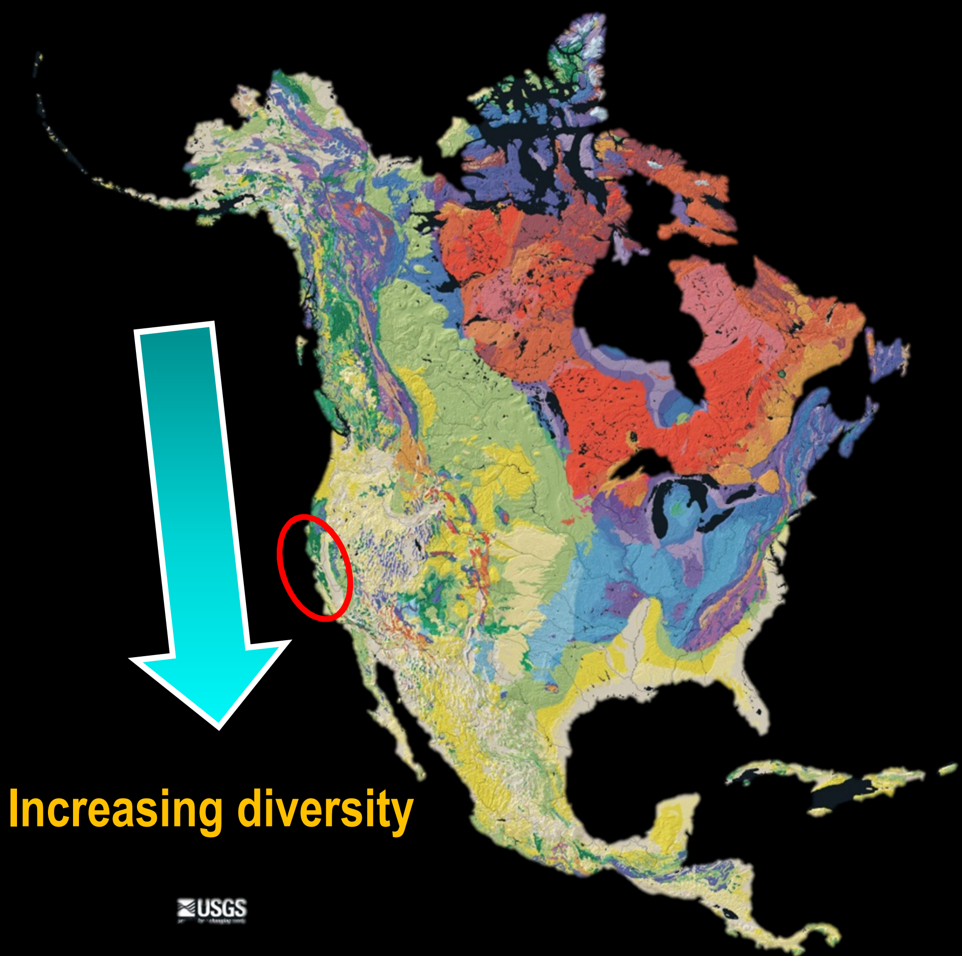
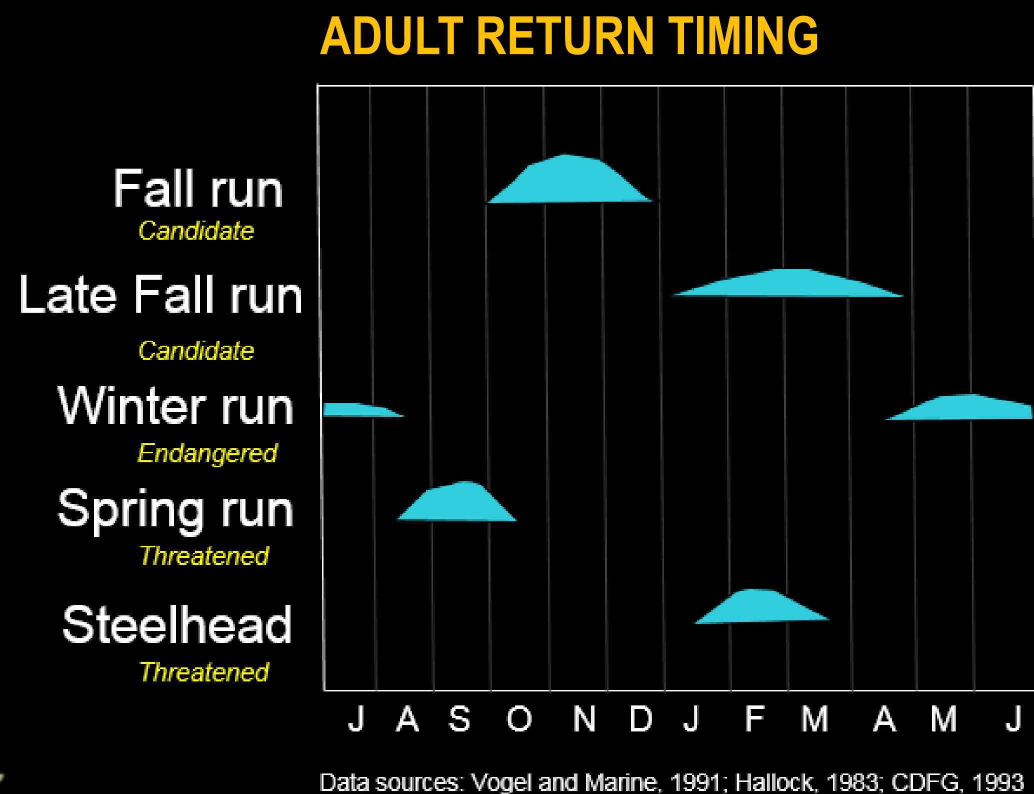
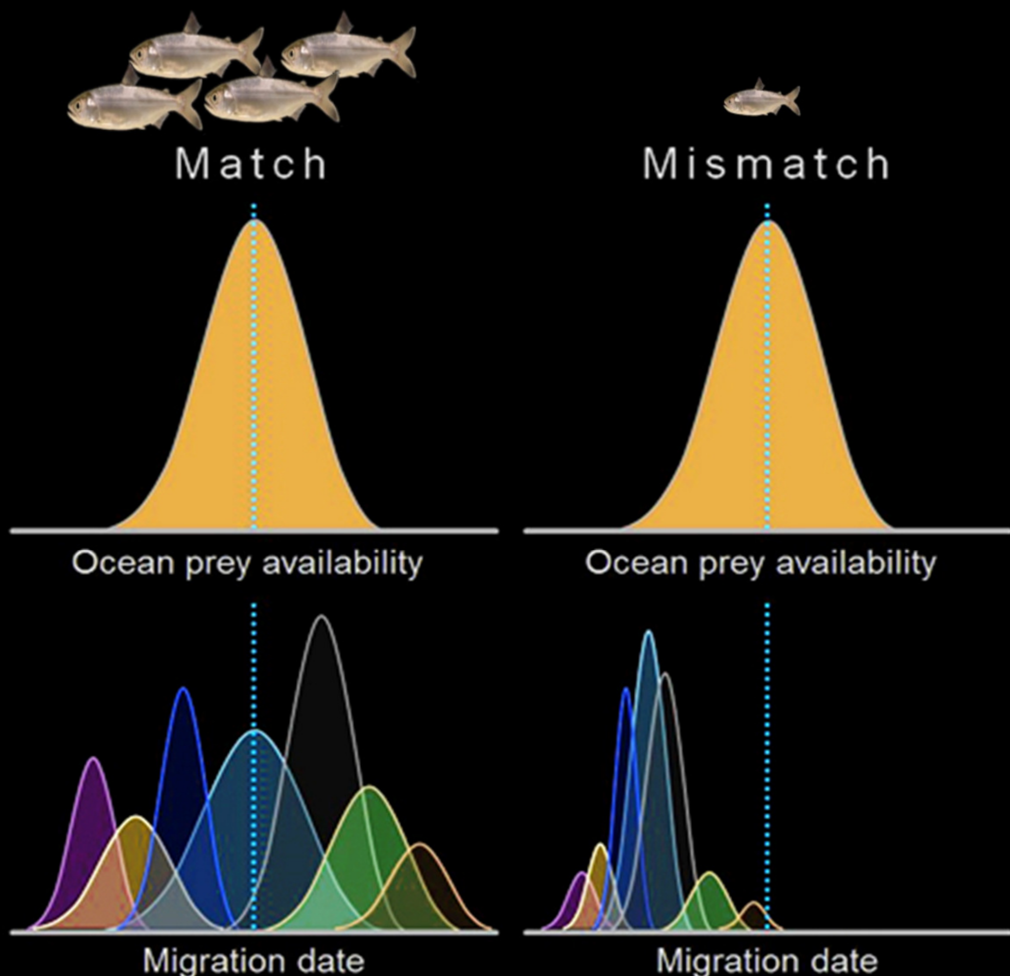




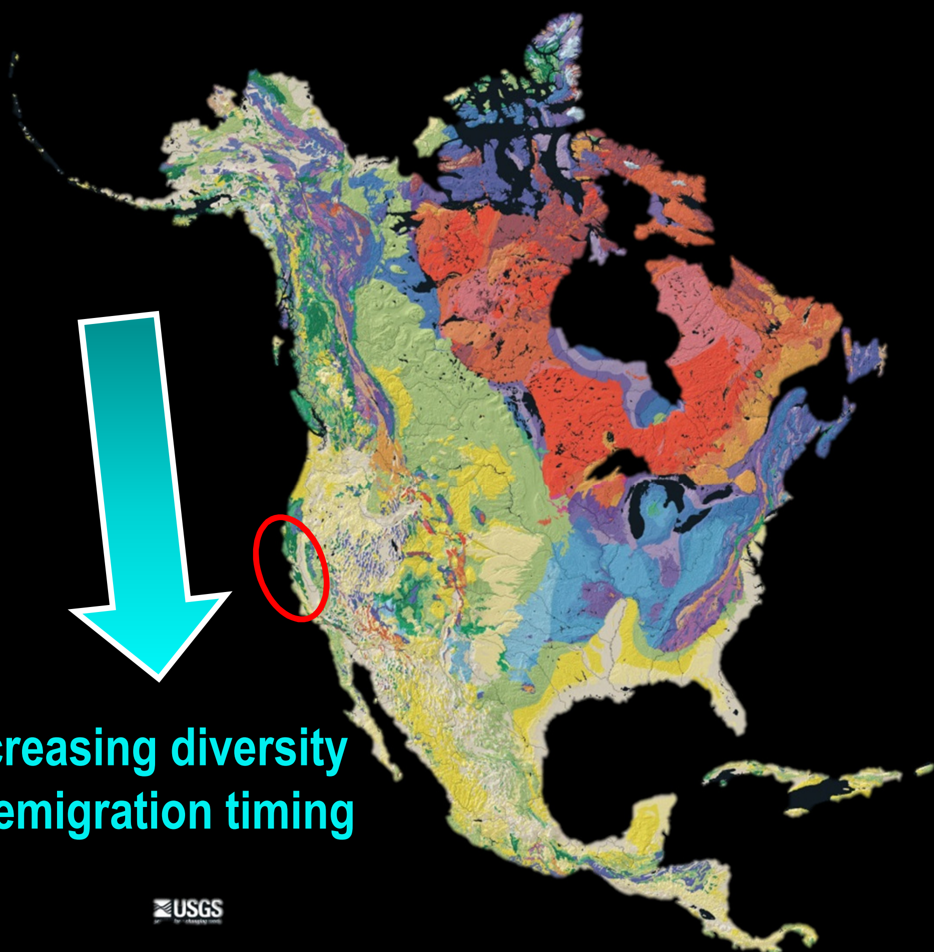
Upwelling is particularly variable off the CA coast and likely to become even less predictable with climate change.

A narrower range of ocean arrival dates increases risk of match-mismatch events → volatile recruitment.



Courtesy of S. Carlson

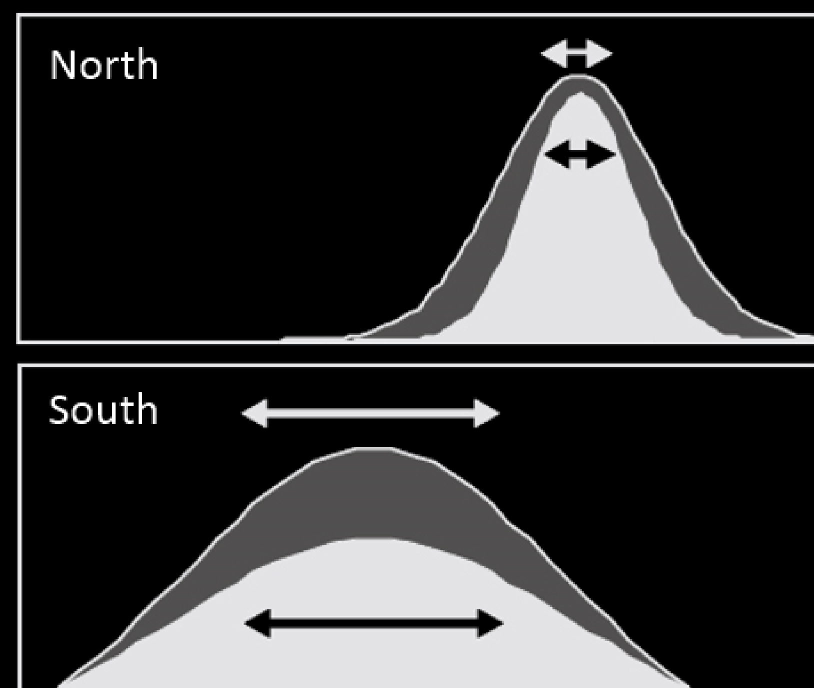
SALMON LIFE HISTORY DIVERSITY



Increasing diversity in emigration timing

USGS

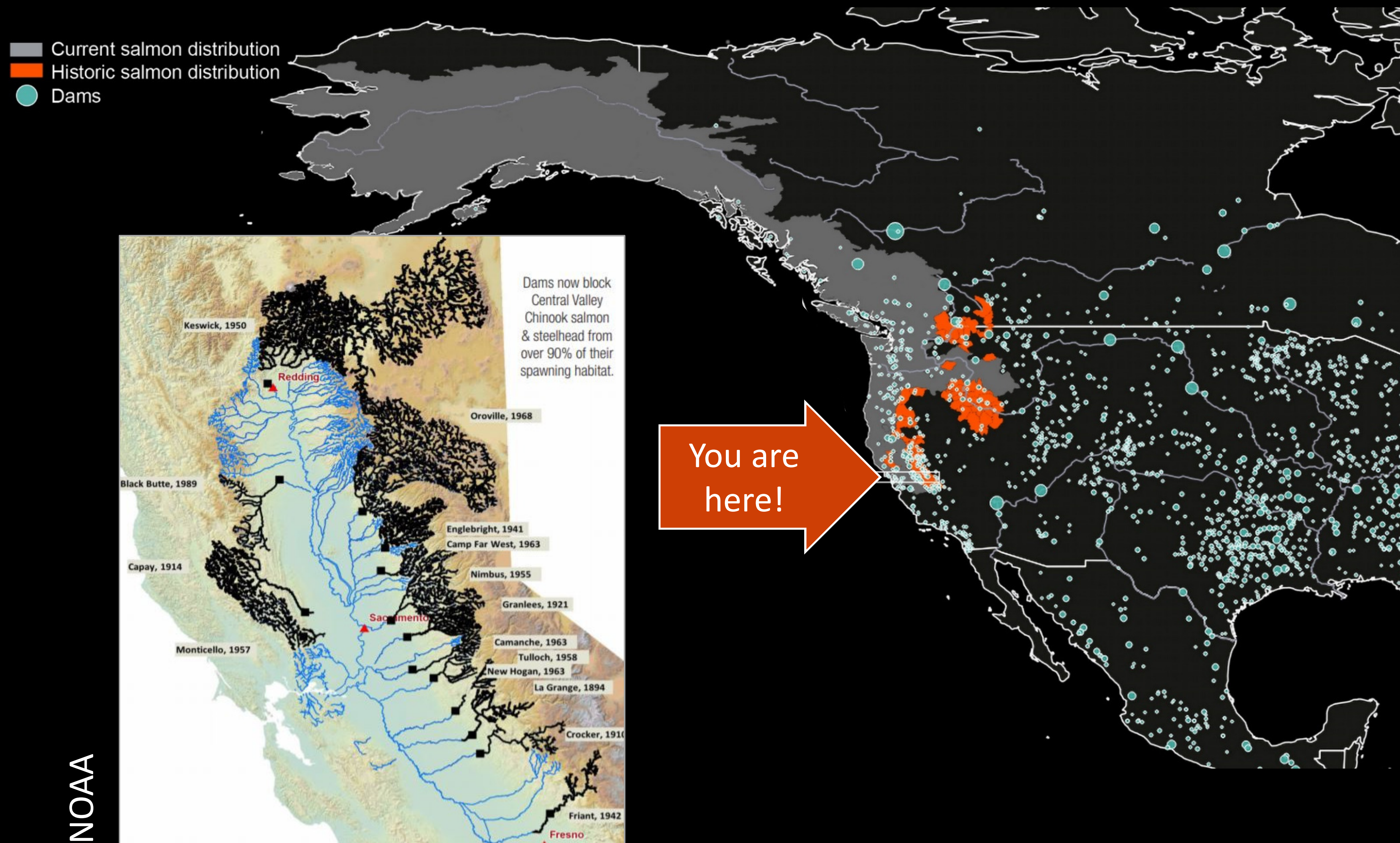
JUVENILE EMIGRATION TIMING



Coho salmon

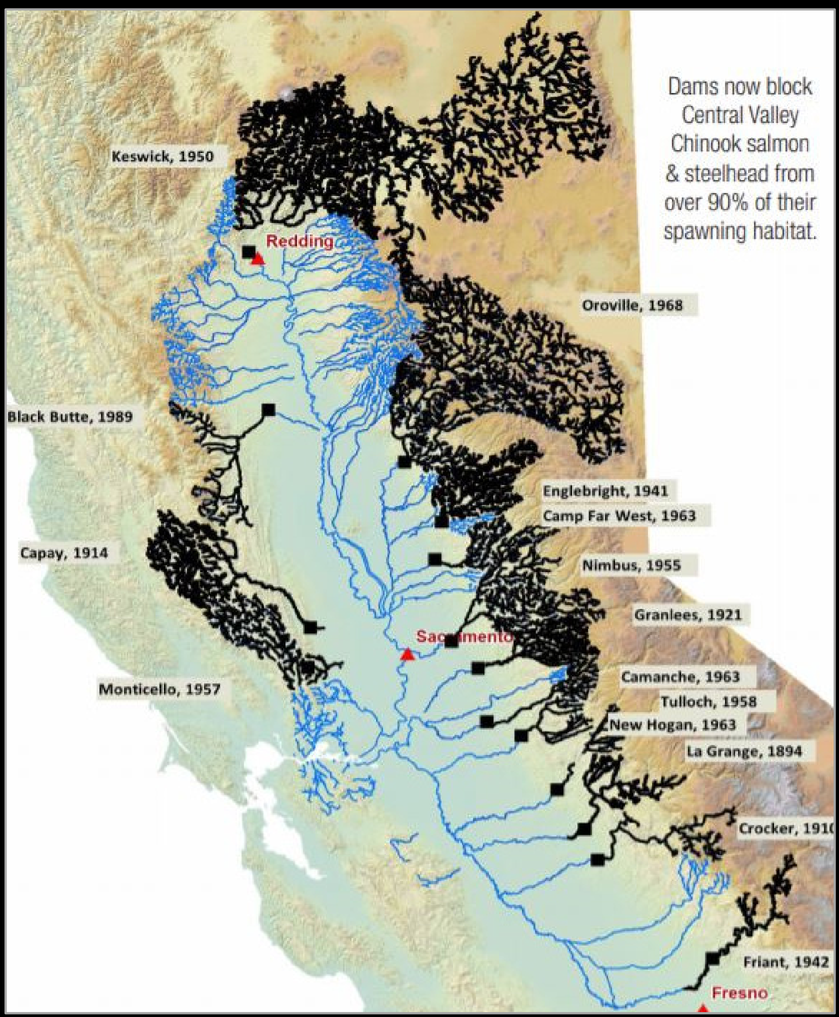
Spence, B. C. and J. D. Hall (2010). CJFAS 67(8): 1316-1334

SALMON IN CALIFORNIA



NOAA

Can we replace 'lost production' AND support natural populations using hatcheries?



Typically ~95% of salmon return to their natal stream resulting in local adaptation & higher numbers of offspring.

High levels of hatchery straying can hinder local adaptation, introduce maladapted genes, and reduce broodstock size.

Photos courtesy of T. Quinn

www.fws.gov/coleman/happenings.html

Study justification

- Limited synthesis of system-wide trends in Central Valley hatchery releases.

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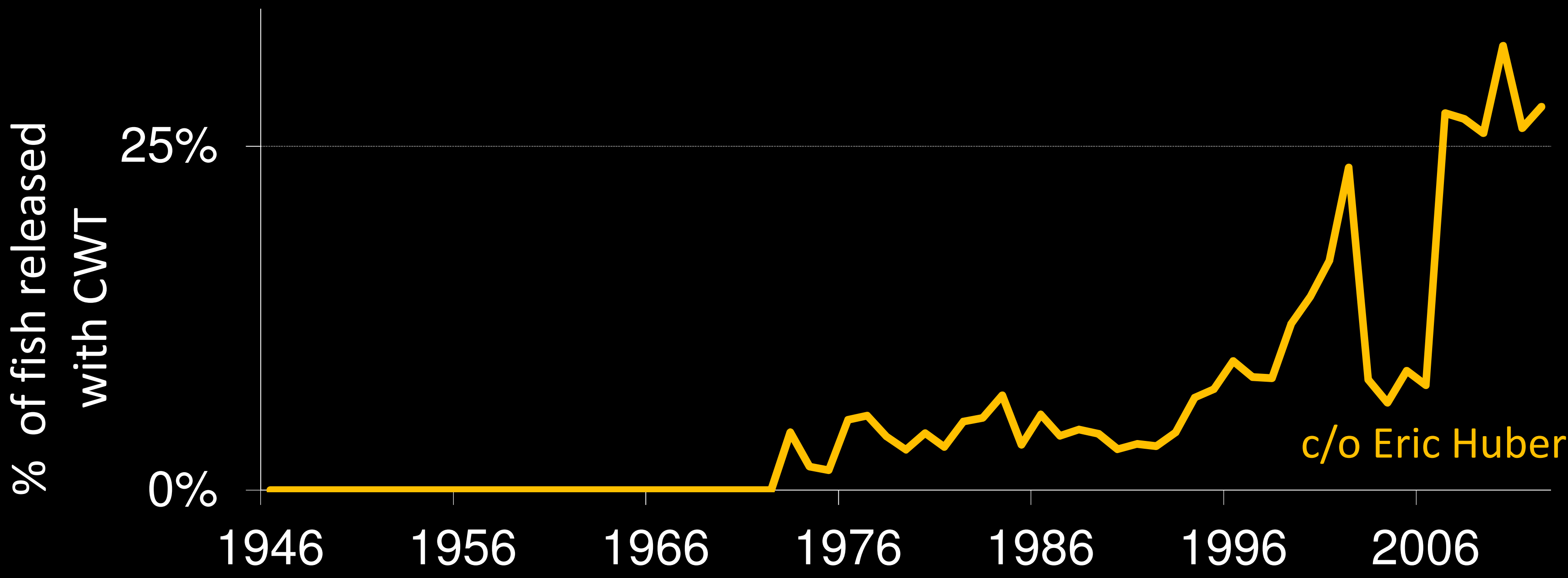

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Study objectives

(1) Georeference all fall run Central Valley hatchery releases since 1941.
(2) Document spatiotemporal historical trends.
(3) Quantify population responses (e.g. straying) to differing management actions and environmental conditions.

History

Eric Huber transcribed information from >200 reports (Huber & Carlson, SFEWS 2015)

This study:

- Georeferenced all releases.
- Measured transport & outmigration distances in ArcGIS.
- Estimated transit times & ocean arrival days.
- Visualized data using R Shiny [baydeltalive.com/fish/hatchery-releases].

Ranse Reynolds - retired Nimbus Hatchery manager - at his home in Woodland (8/5/15).

Straying model

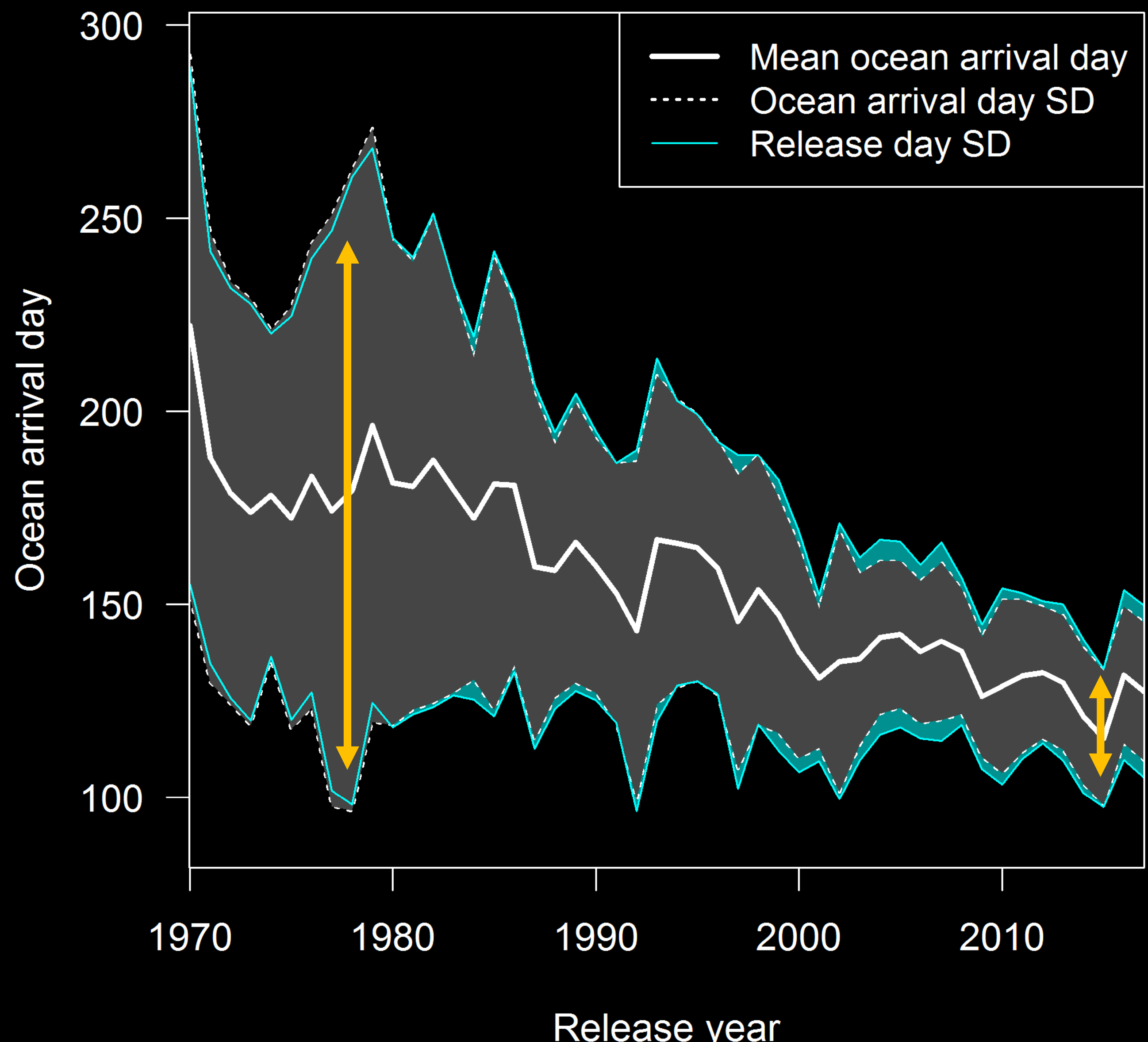
- Estimated straying rates for BY2006-12 releases (2008-15 returns):

$$1-\left[\frac{\text{N* recovered in source hatchery or natal stream}}{\text{N* recovered anywhere in freshwater}}\right] * \text{sampling fraction}$$

- Modeled rate using beta regression (**betareg** pkg). Best model selected using multi-model inference and AICc.

- Predictors included hatchery*transport distance, release month, fish size, fish stage, run size, return age, run year, return flow, release flow, flow discrepancy (return-release flow), return temperature, DCC (N days open), mean PDO of return year, PDO discrepancy (return-release PDO).

Spatiotemporal trends in hatchery releases



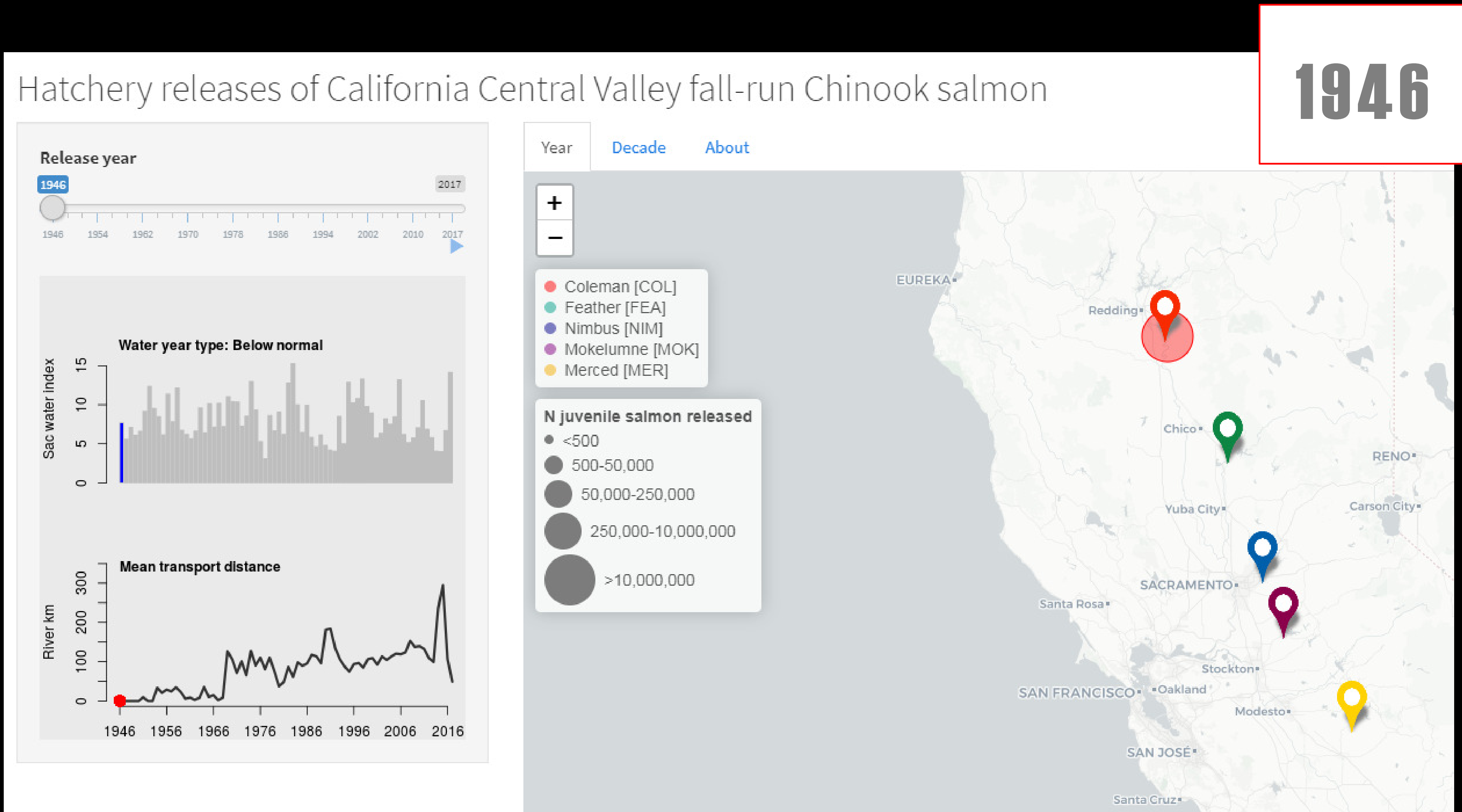
Hatchery salmon entering the ocean over a narrower spread of dates

→ match-mismatch with ocean upwelling events

→ swings in recruitment

Background | Methods | History | Model | Summary

Spatiotemporal trends in hatchery releases



https://baydeltalive.com/fish/hatchery-releases

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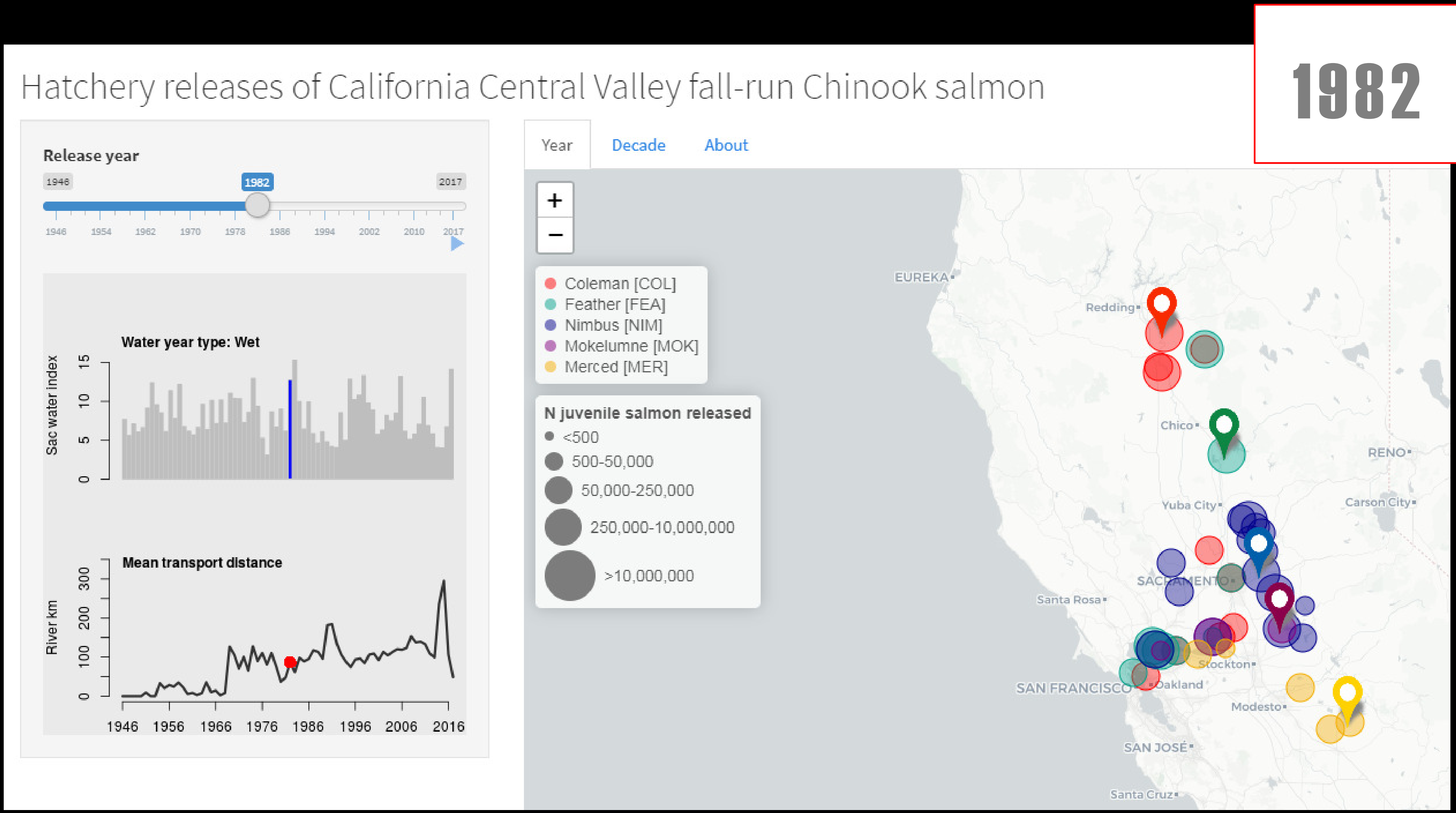

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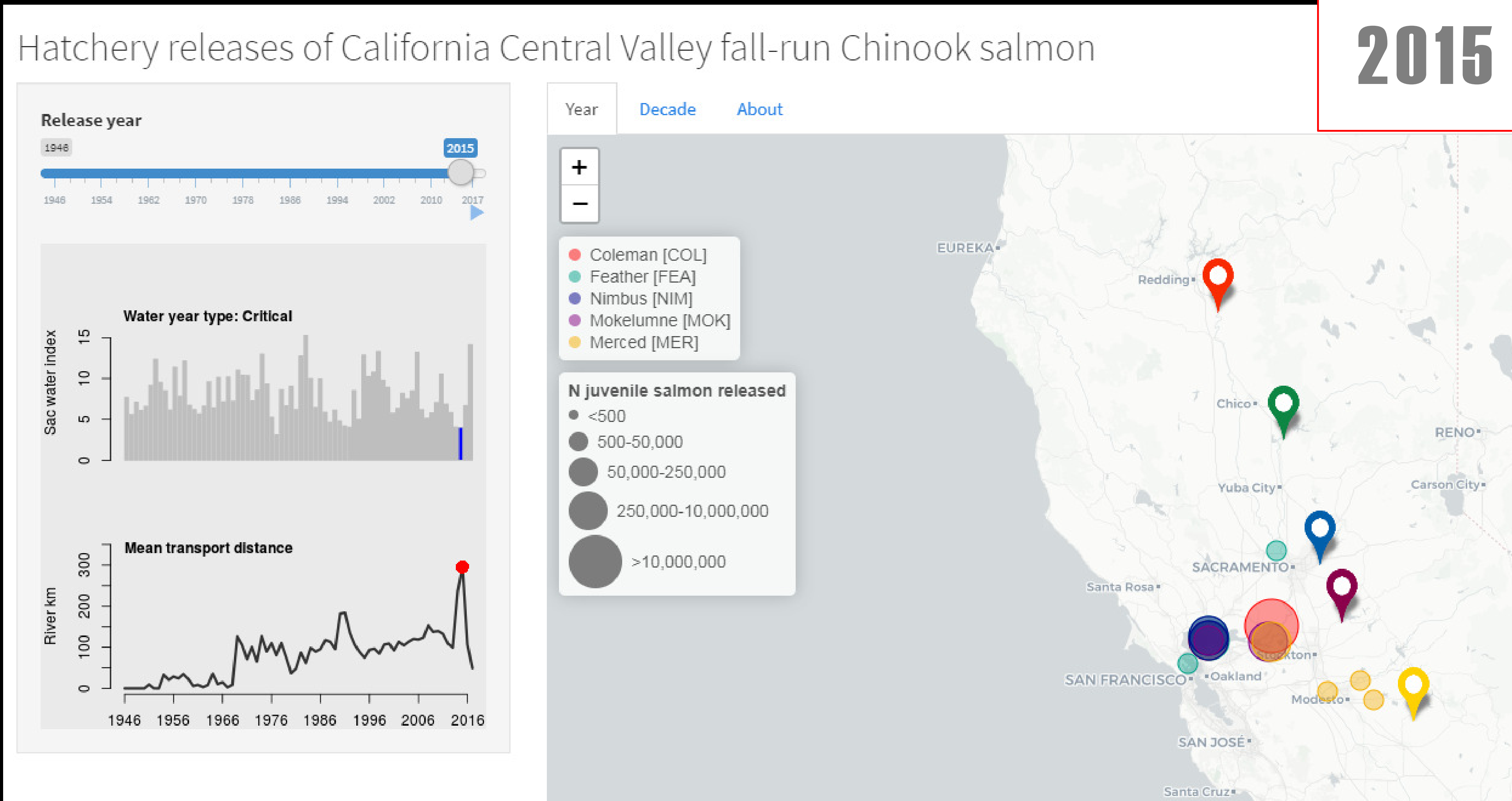
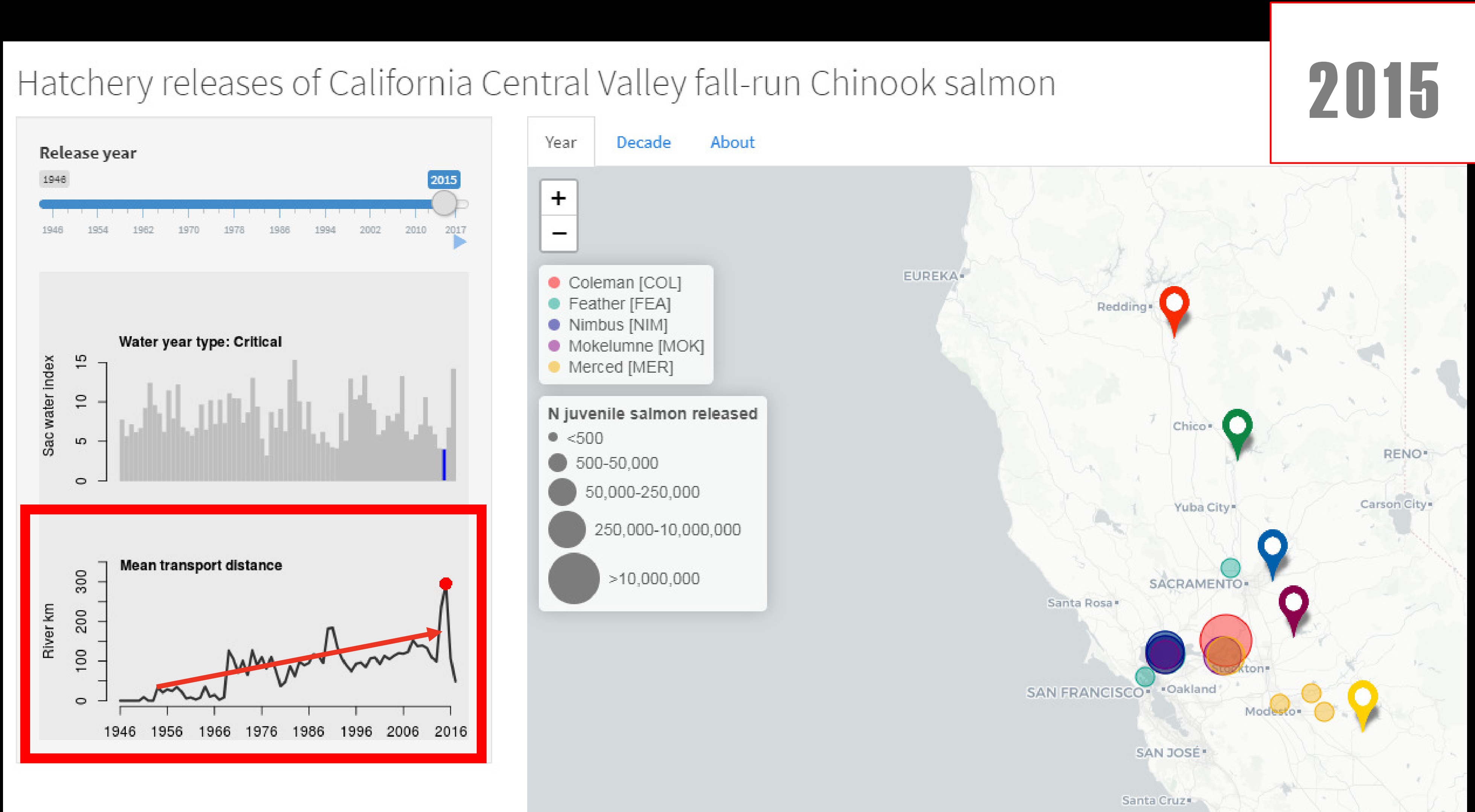


2015

https://baydeltalive.com/fish/hatchery-releases

>99% FISH RELEASED IN DELTA OR BAY

Spatiotemporal trends in hatchery releases



https://baydeltalive.com/fish/hatchery-releases

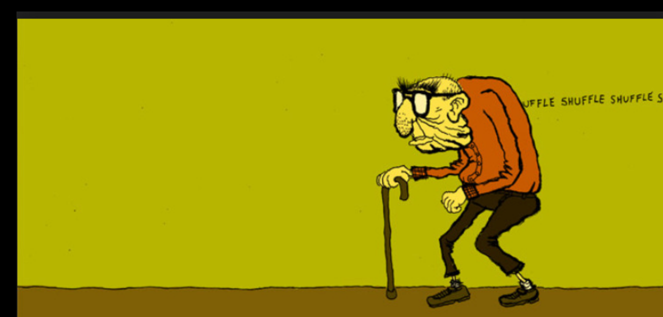
>99% FISH RELEASED IN DELTA OR BAY

Which factors drive straying behavior?

Model explained ~50% of the variance in fall run hatchery fish straying rate.

Straying rates were higher when

- The fish were trucked further downstream.
- Return flows were lower.
- They returned older.



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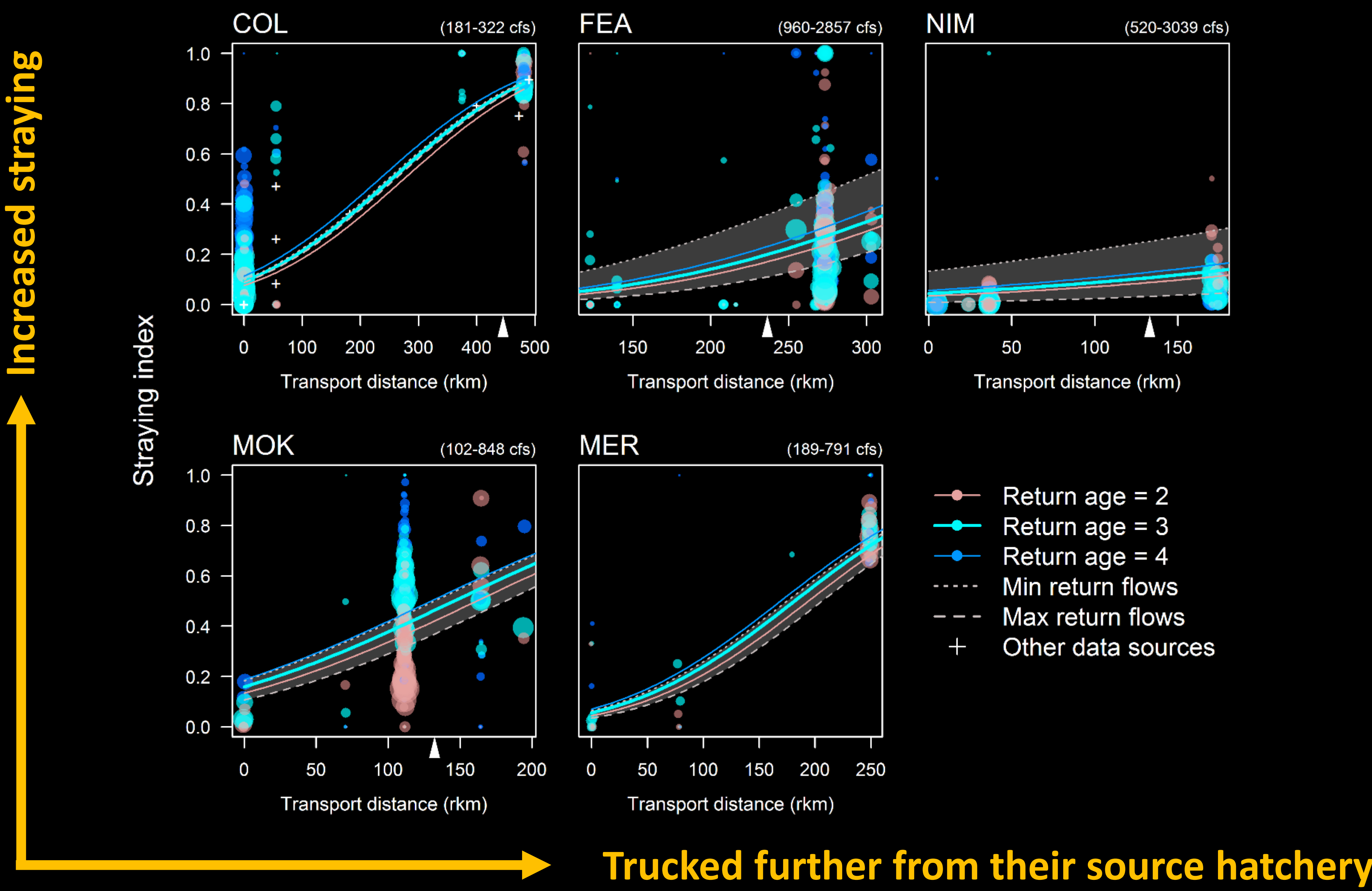

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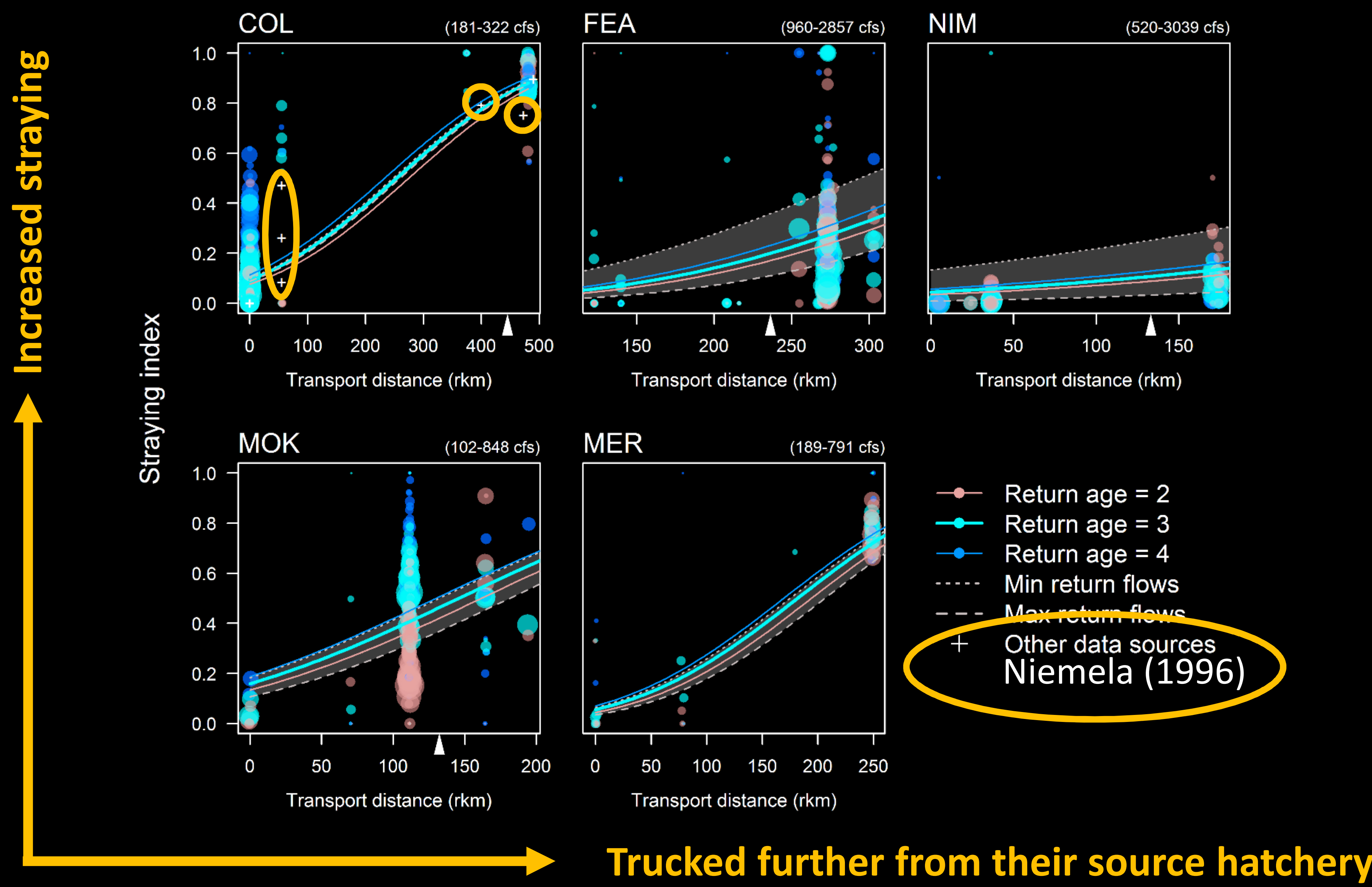

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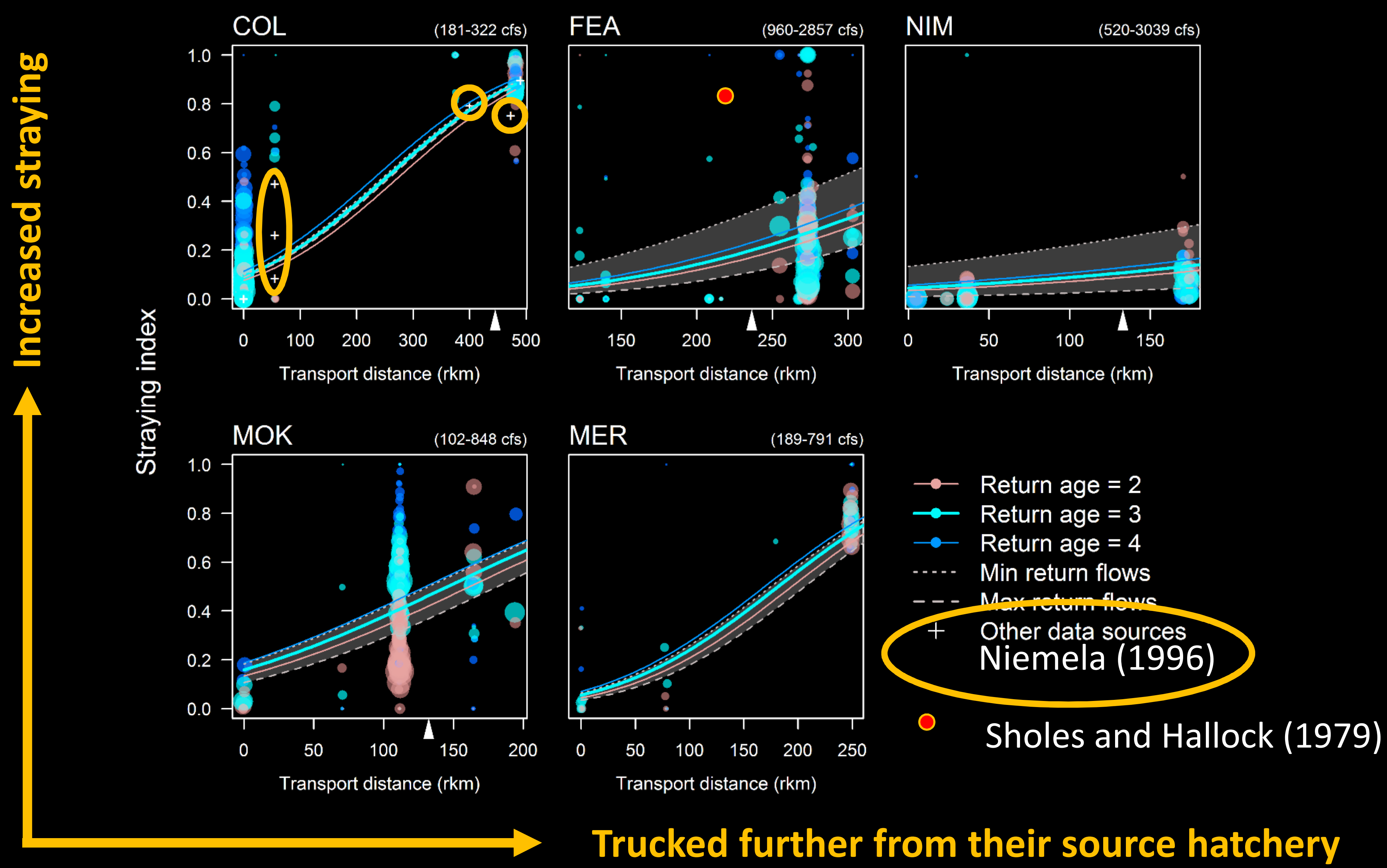

Some data gaps

1. Need more carefully-designed experiments to estimate survival vs. straying rates as a function of transport distance, release age/timing, river flows, and release types (e.g. trucking vs. on-site vs. barged) and more replication (recovery data for 2008-2017 returns and CFM reports for 2010-2015 so far - https://wildlife.ca.gov/Fishing/Ocean/Regulations/Salmon)

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2. Need to better understand how hatchery practices alter maturation timing (jacking rates)

3. Need to better quantify ecological, genetic, demographic and fitness effects resulting from hatchery strays and hatchery-wild interactions
   - *How quickly would local adaptation re-evolve if straying rates were reduced?*
   - *How resilient are local adaptations to periodic increases in stray rates of varying frequency and/or magnitude?*

TAKE HOME MESSAGES

1. Today's hatchery portfolio less diverse than ever before -
    - *Fish size (almost all large smolts)*
    - *Abundance (approx. ~30 million every year)*
    - *Timing (almost all entering ocean in Apr-May)*
    - *Location (more clustered in Delta & Bay, particularly during droughts)*

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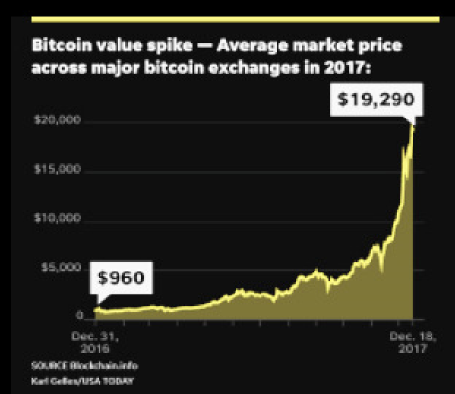
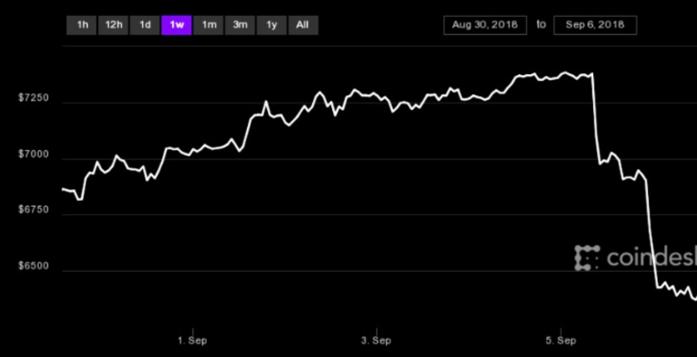
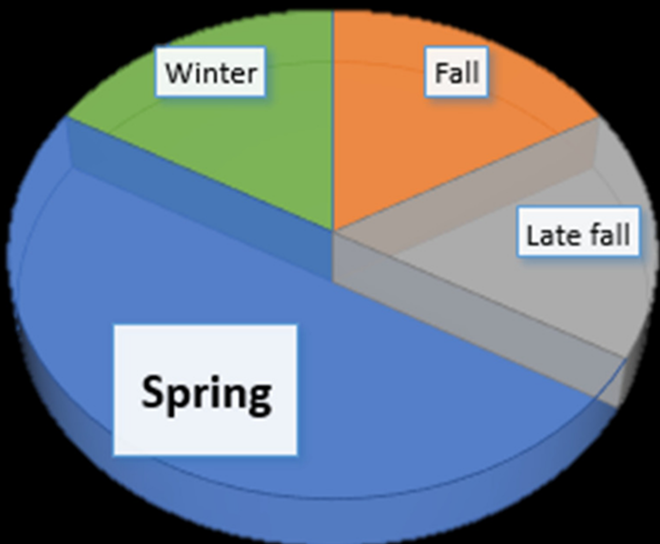
2. Trucking further → increased straying, increased genetic & demographic homogenization, loss of broodstock, increased survival advantage/numeric imbalance.

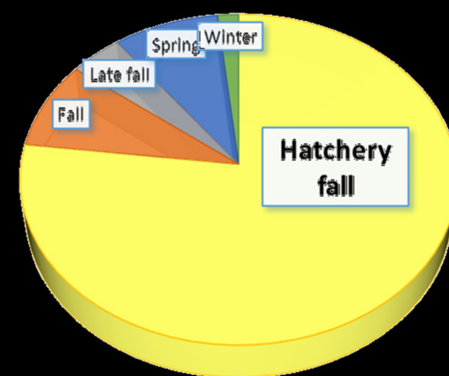




Bitcoin's value plummeted twice in 24 hours.
Coindesk

TAKE HOME MESSAGES





All (most) of our eggs are now in one over-leveraged basket… Can we increase abundance and resilience at the same time?

Acknowledgements

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Citations and database

Huber and Carlson (2015). "Temporal Trends in Hatchery Releases of Fall-Run Chinook Salmon in California's Central Valley." San Francisco Estuary and Watershed Science **13**(2).

Sturrock et al. (2019) “Eight Decades of Hatchery Salmon Releases in the California Central Valley: Factors Influencing Straying and Resilience”. Fisheries, 44(9), 433-444. doi:10.1002/fsh.10267

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Any questions or comments – please do not hesitate to get in touch:
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