Foodscapes in Action- Afternoon Session

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

Session Coordinators: Gabriel Rossi, Ph. D., Research Scientist, *UC Berkeley* and *California Trout Coastal River Ecologist*

Recent work in watersheds from Alaska to California has emphasized the central role of food in salmon resilience and recovery. A foodscape perspective expands our view of watershed management to consider the sources, phenology, and pathways of key food resources. It also focuses our attention on the conditions that allow salmon (and other mobile consumers) to track and exploit feeding opportunities across the riverscape. Like every aspect of salmon habitat, the foodscape has been (and continues to be) altered, simplified, and often severed. But unlike work on fish passage, water quality, or instream flow, we are only now beginning to realize the challenges and opportunities for recovering and maintaining healthy, functional foodscapes.

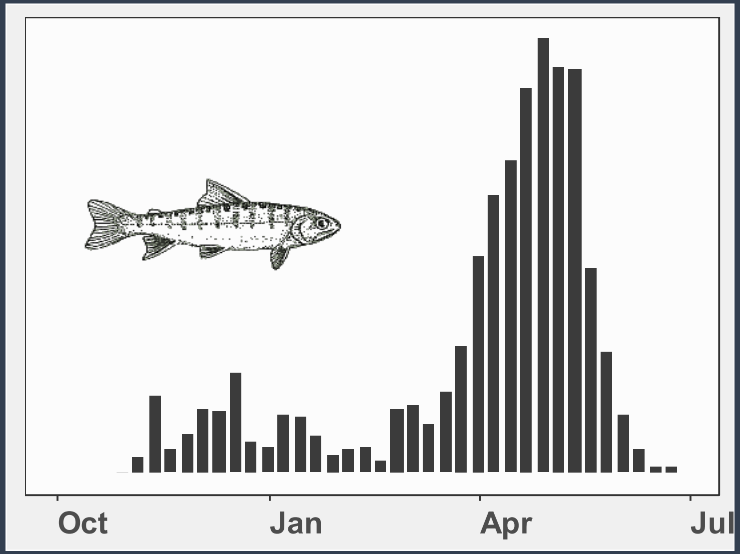
Join us as we examine “foodscapes in action” – specific projects and places where foodscape thinking is being applied to salmon conservation and recovery. This session will bring together stewards, managers, and researchers, who are developing methods to study, monitor, and restore foodscapes. We will consider foodscapes in relatively intact watersheds, which shed light on the key trophic pathways and spatiotemporal patterns of foraging and growth potential that support salmon populations. We will also consider foodscapes in heavily impacted systems, which provide a novel lens to consider how alternative restoration actions promote diverse and connected foraging and growth opportunities for fish. In both contexts, foodscape thinking reveals opportunities to find new and productive tools that can help move the needle on salmon population abundance, diversity, and resilience – opening new possibilities for watershed stewardship and bringing optimism in a time of ecological crisis.

Presentations

[Video Available here]

Food for Fish: Challenges and Opportunities for Quantifying Foodscapes in River Networks, Aimee Fullerton, Ph.D., *NOAA Fisheries*

Foodscape perspectives in the Russian River watershed



Mariska Obedzinski, Ted Grantham, Gregg Horton, and Stephanie Carlson

Berkeley UNIVERSITY OF CALIFORNIA

Sonoma Water

Sea Grant CALIFORNIA

US Army Corps of Engineers® San Francisco District

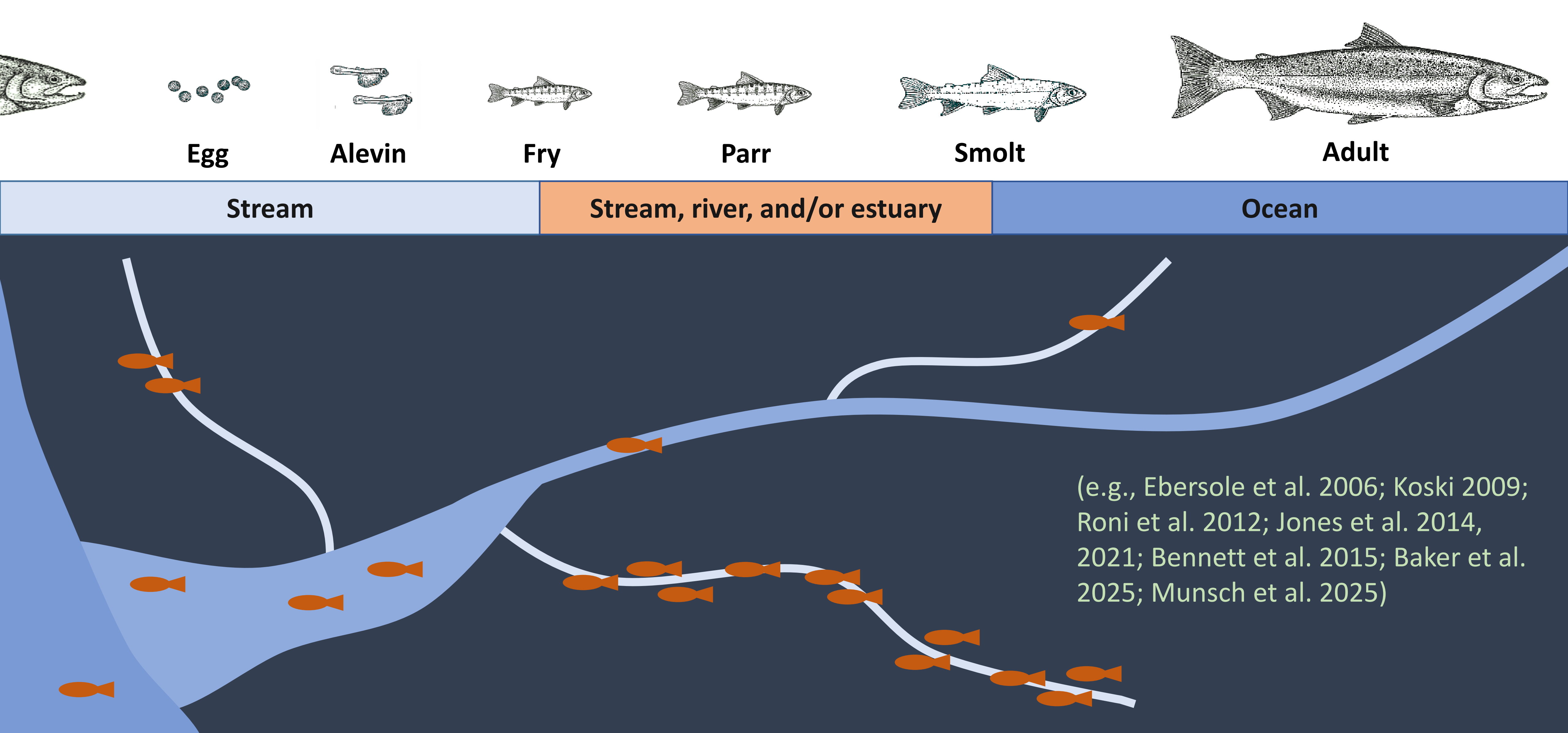
Salmonid Restoration Federation, May 2, 2025

Outline

1. Investigating early emigration of juvenile coho salmon in the Russian River

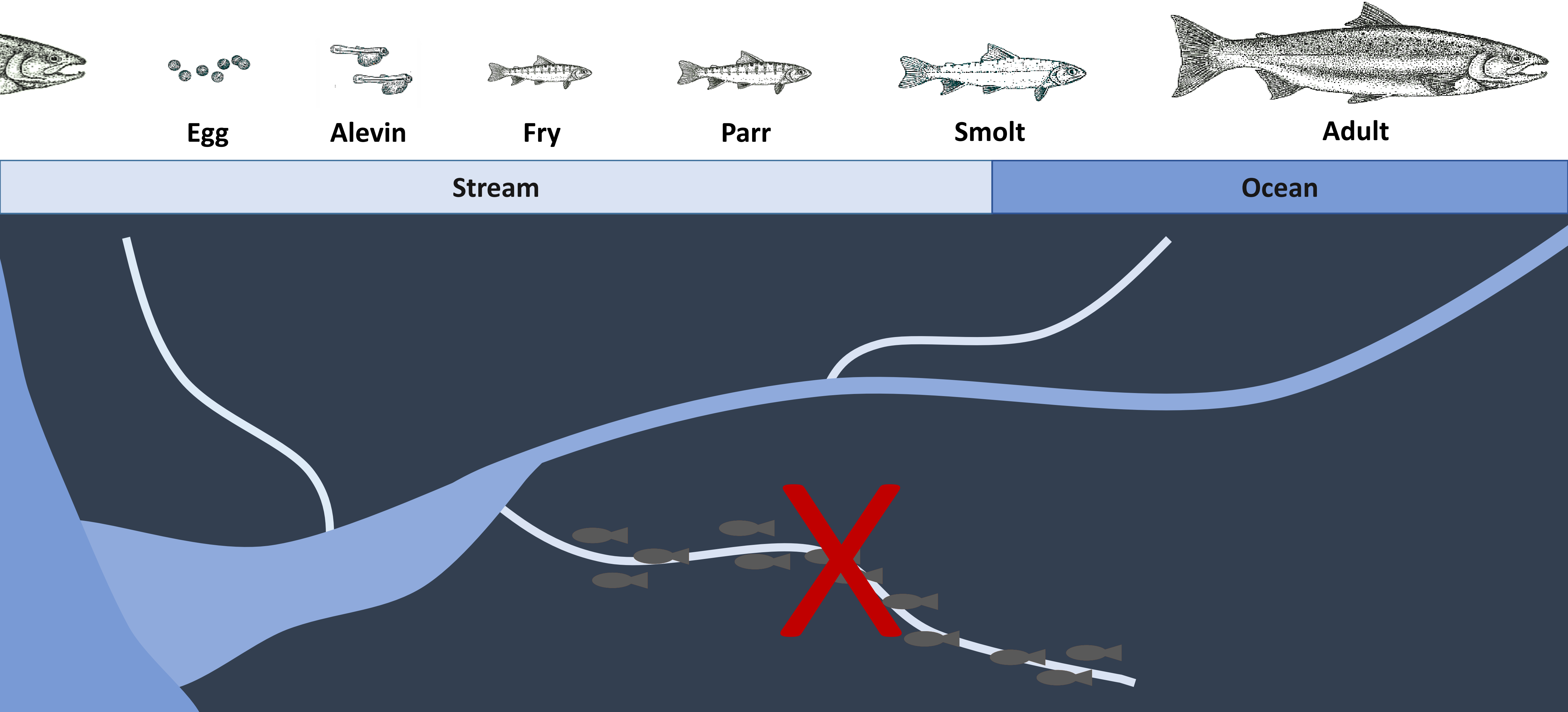
2. Foodscape perspectives on salmonid recovery in the Russian River

Coho life cycle and juvenile life history diversity

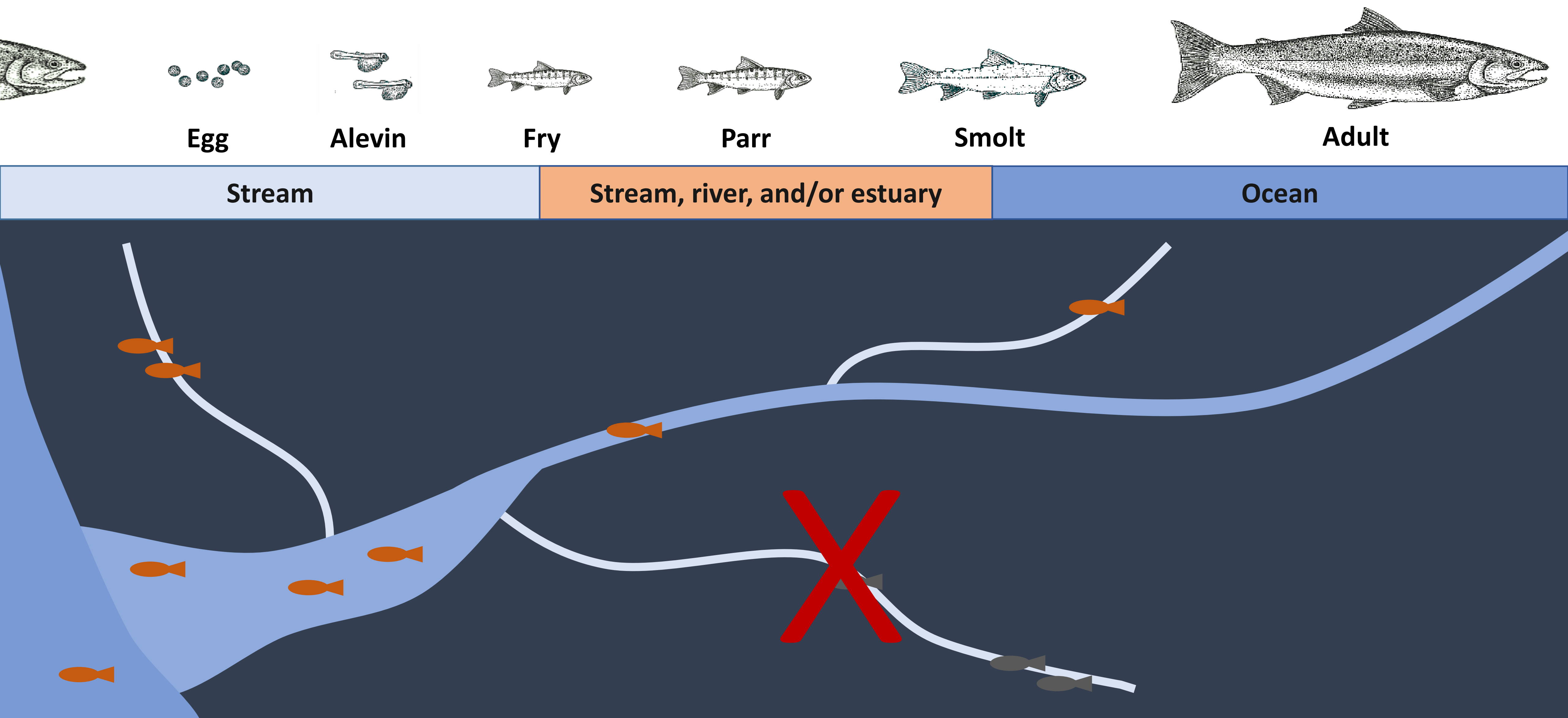


(e.g., Ebersole et al. 2006; Koski 2009; Roni et al. 2012; Jones et al. 2014, 2021; Bennett et al. 2015; Baker et al. 2025; Munsch et al. 2025)

Importance of juvenile life history diversity

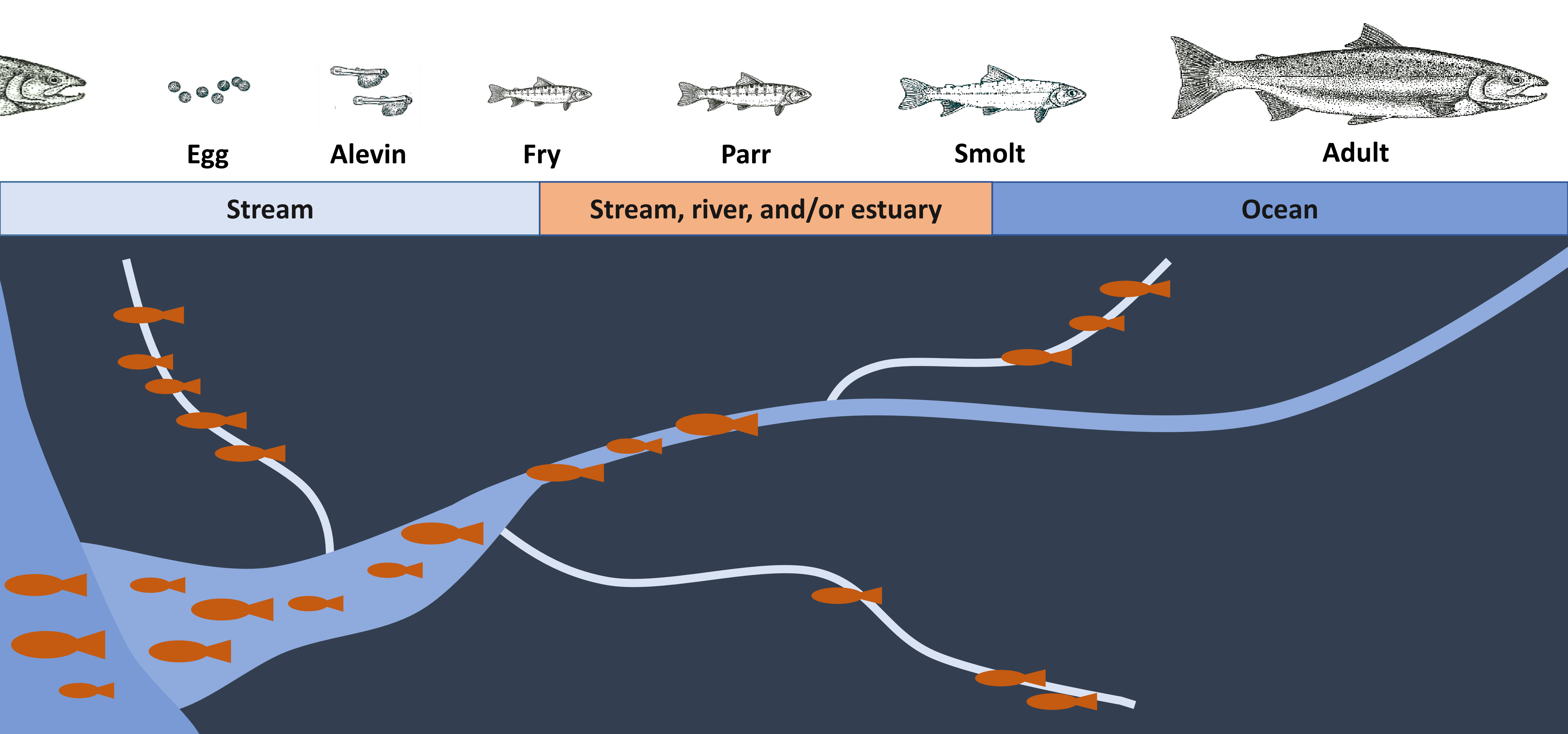


Bet hedging



Egg
Alevin
Fry
Parr
Smolt
Adult
Stream
Stream, river, and/or estuary
Ocean

Increasing productivity: more and/or bigger fish



Questions

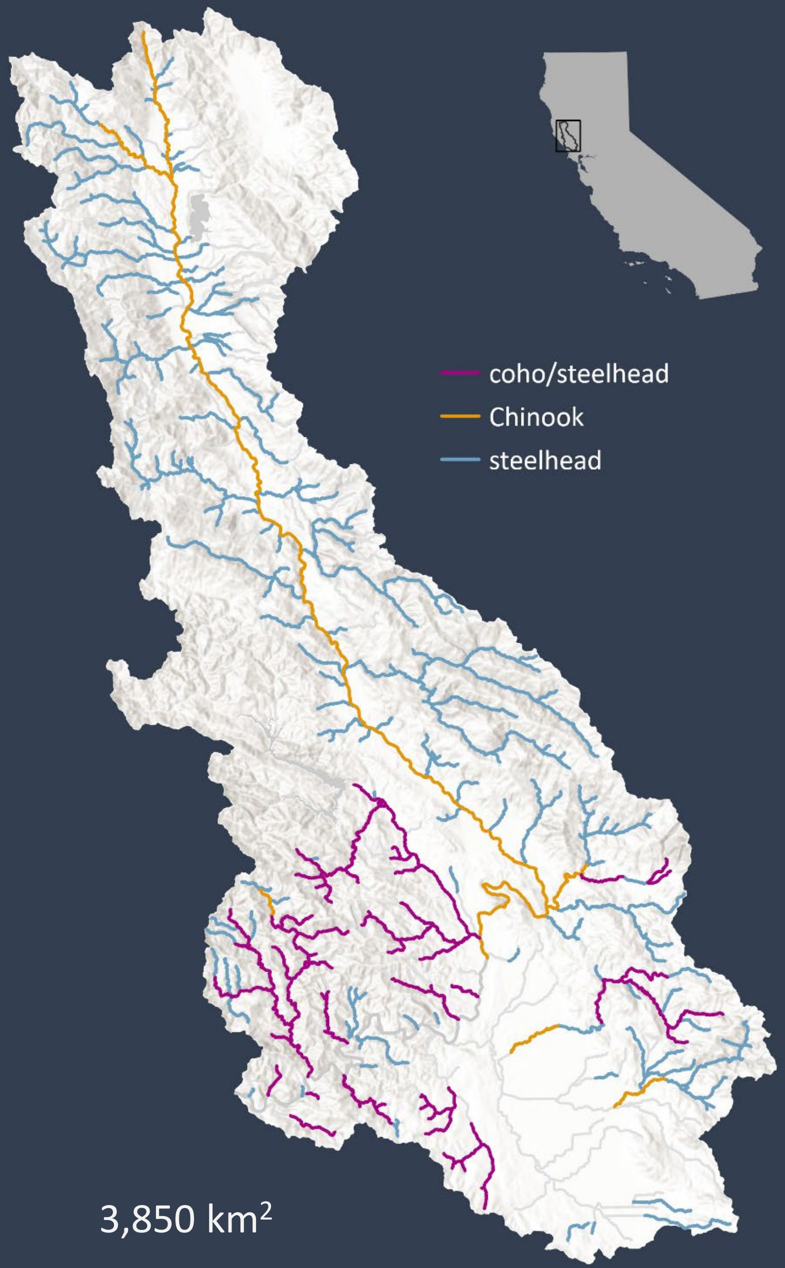
1. Does early emigration occur near the southern extent of the coho range?

2. What factors explain juvenile emigration timing?

3. Do juveniles that emigrate early contribute to adult returns?

Russian River Watershed

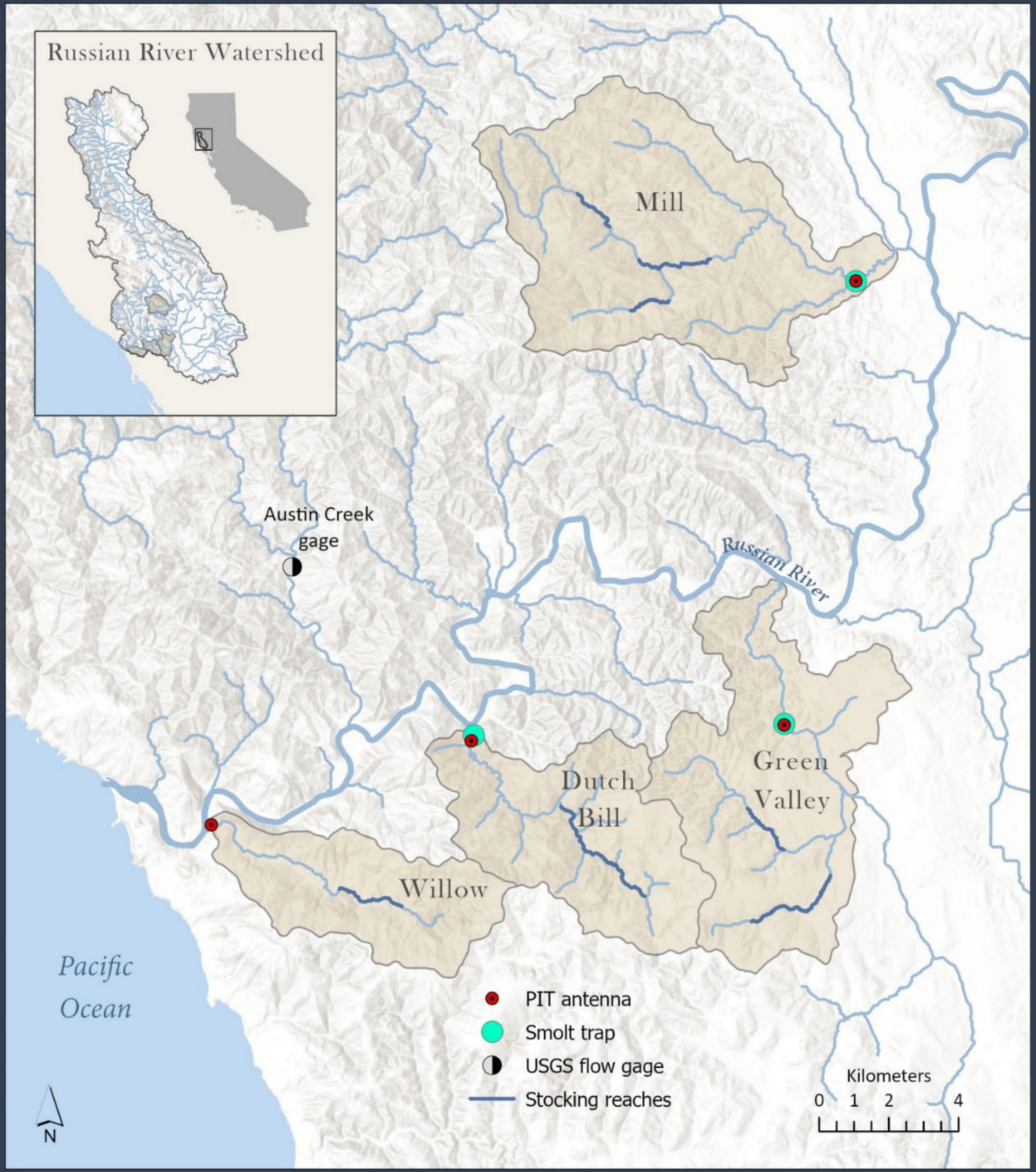
- Listed populations of steelhead, coho, and Chinook
- Small remnant wild population of coho with annual releases of juveniles from a conservation hatchery
- Rainfall-dominated hydrograph with common intermittency



Study streams

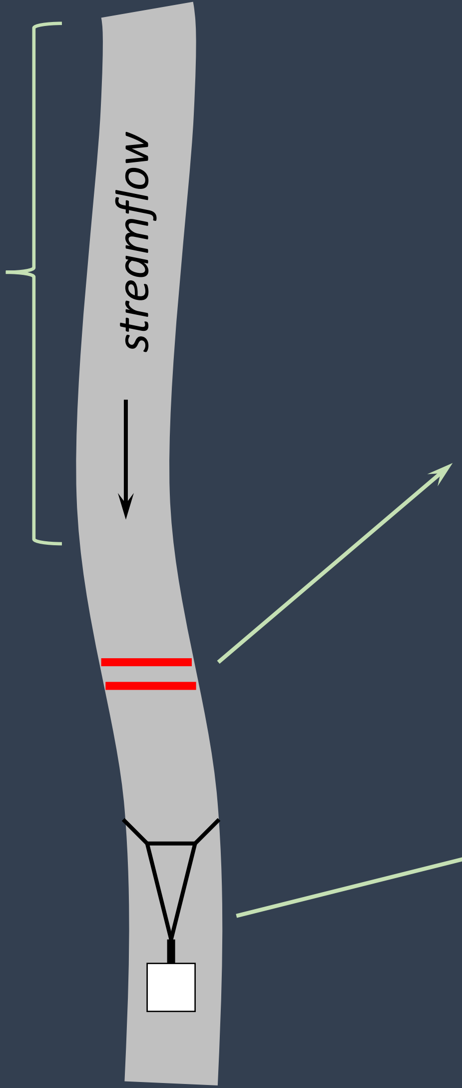
- Hatchery releases of juvenile coho in fall
- 4 streams & 11 years
- Genetically similar family groups
- 15% of juveniles PIT-tagged

Fall: Nov (8-9 mo old)



Monitoring stations: PIT antenna array and smolt trap

Marked fish
released



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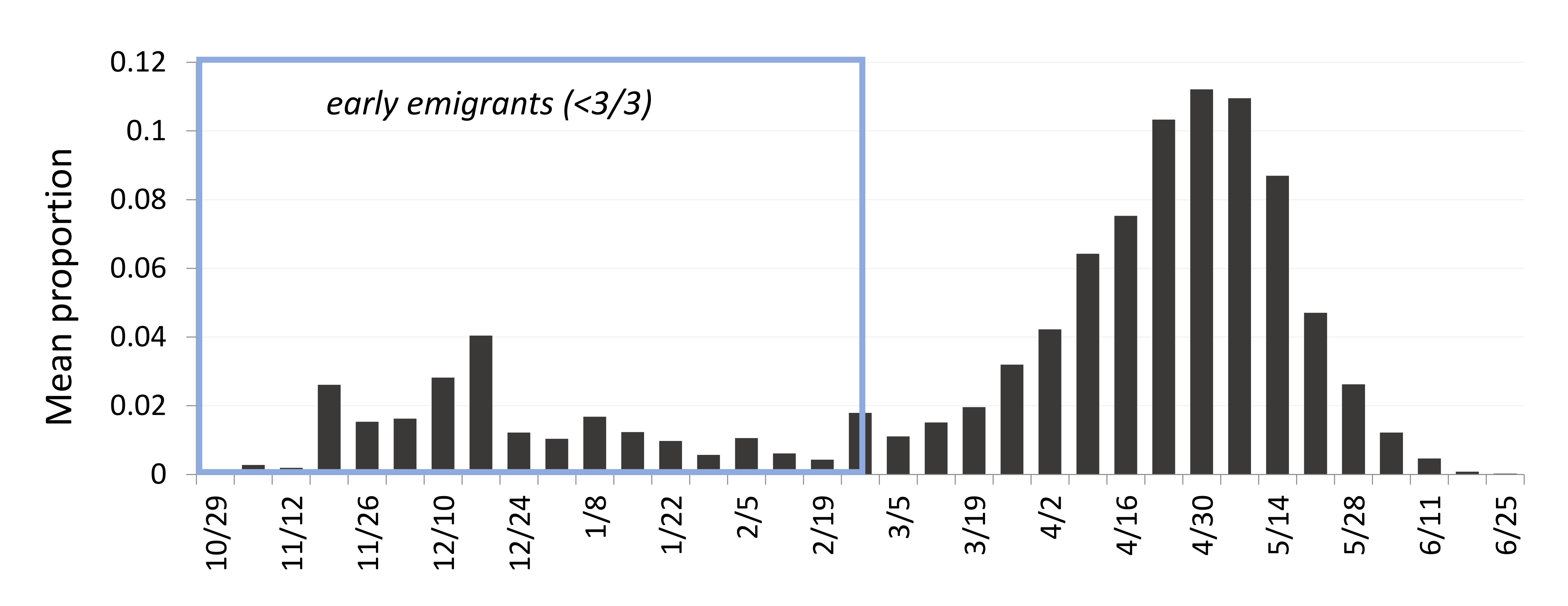
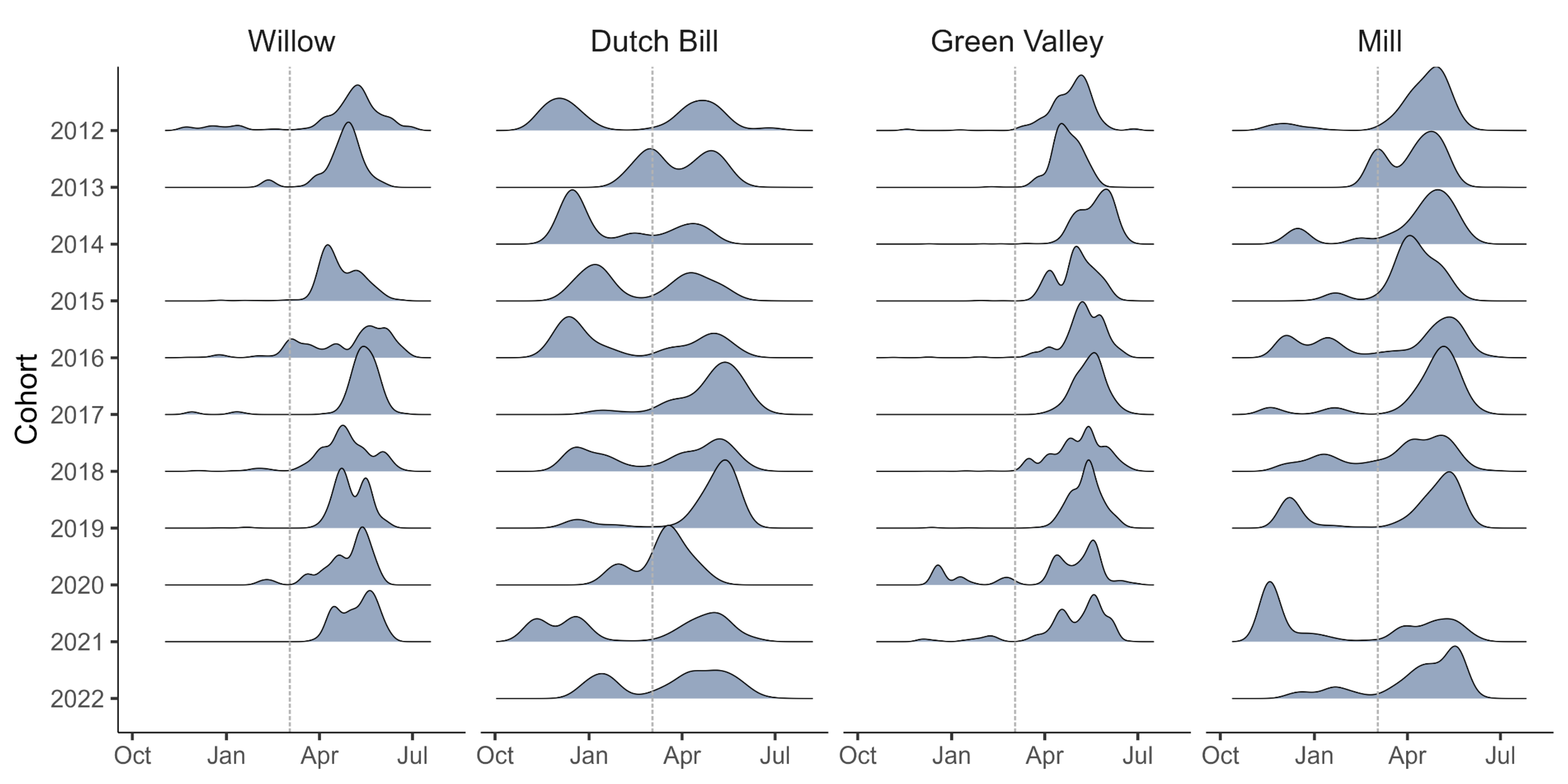
Juvenile coho emigration timing



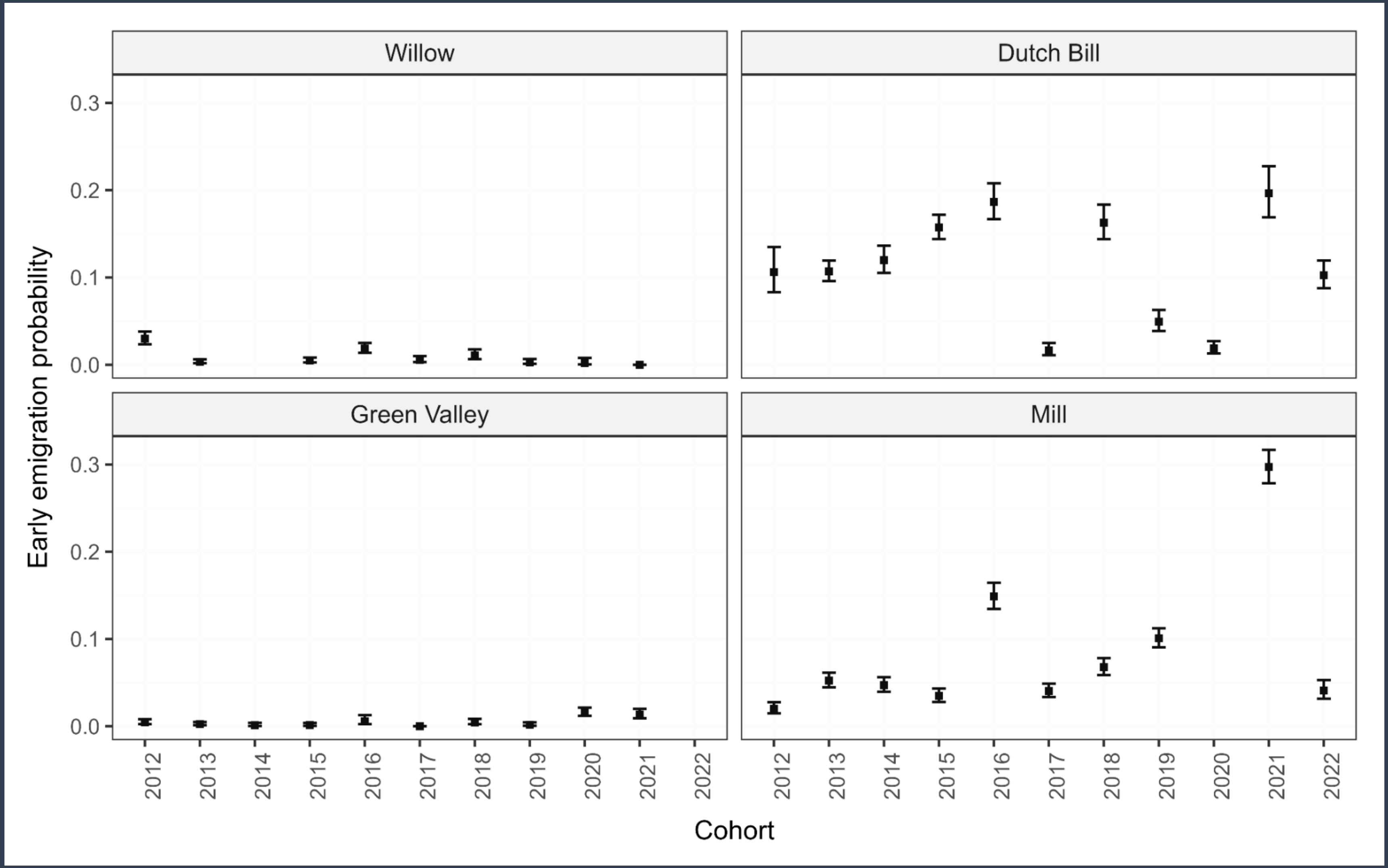
Fall/winter parr

Spring smolt

Emigration timing across streams and years



Estimated probability of emigrating early (< 3/3) using a multistate emigration model



89,728 individual encounter histories

```
1000000000 1;
1001001001 1;
1001001000 1;
1220000000 1;
1000000000 1;
1000000000 1;
1000000000 1;
1001001001 1;
1220000000 1;
1000000000 1;
1000000000 1;
1001001000 1;
1000000000 1;
```

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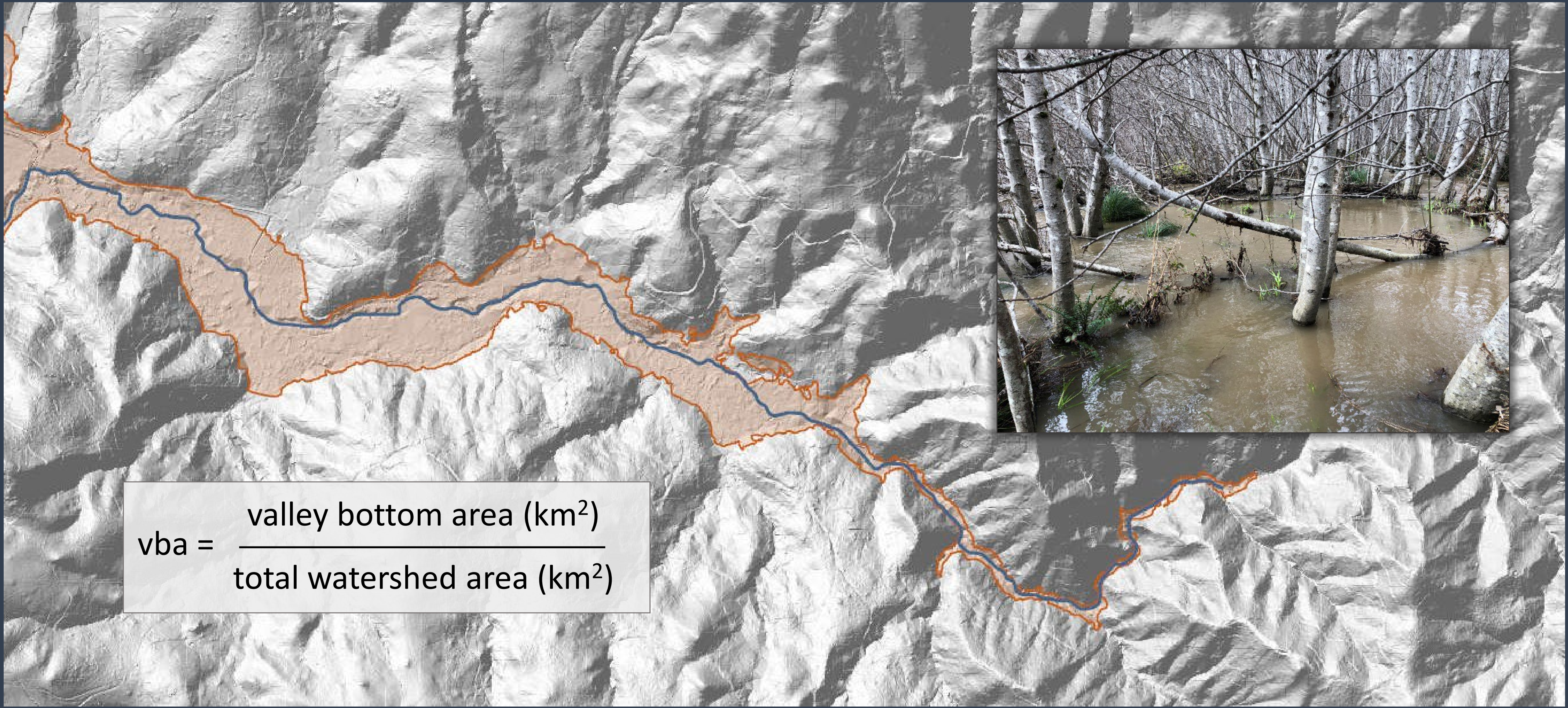
Potential factors influencing probability of early emigration

- Geomorphic: amount of floodplain habitat
- Hydroclimatic: flow and temperature
- Biotic: density and individual size

* Constructed models with different covariates to evaluate relative influence of these factors on early emigration probability

Geomorphic factor: Valley bottom area (vba)



$$vba = \frac{\text{valley bottom area (km}^2\text{)}}{\text{total watershed area (km}^2\text{)}}$$

Valley bottom extraction tool (V-BET) (Gilbert et al. 2014)

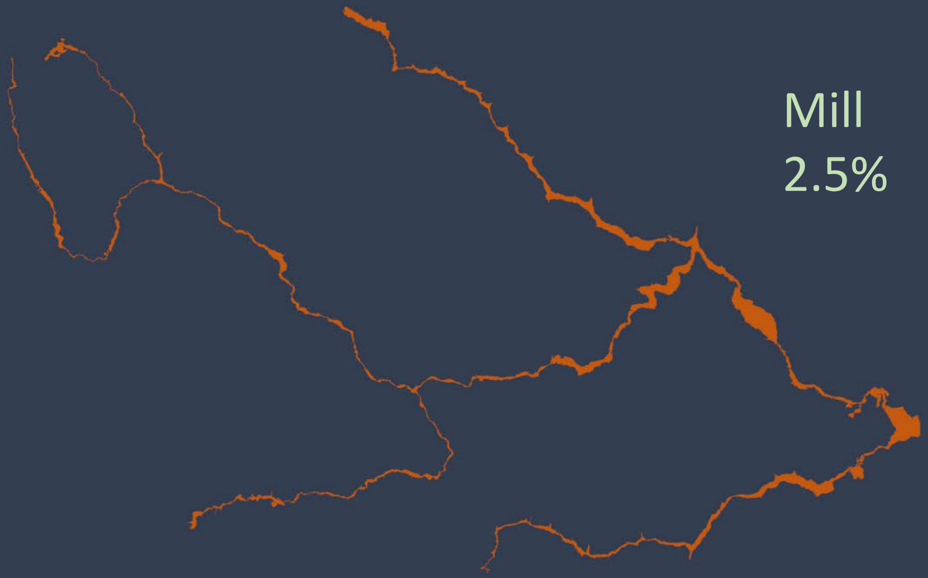
High vba

Low vba

Willow **7.9%**

Dutch Bill 2.7%

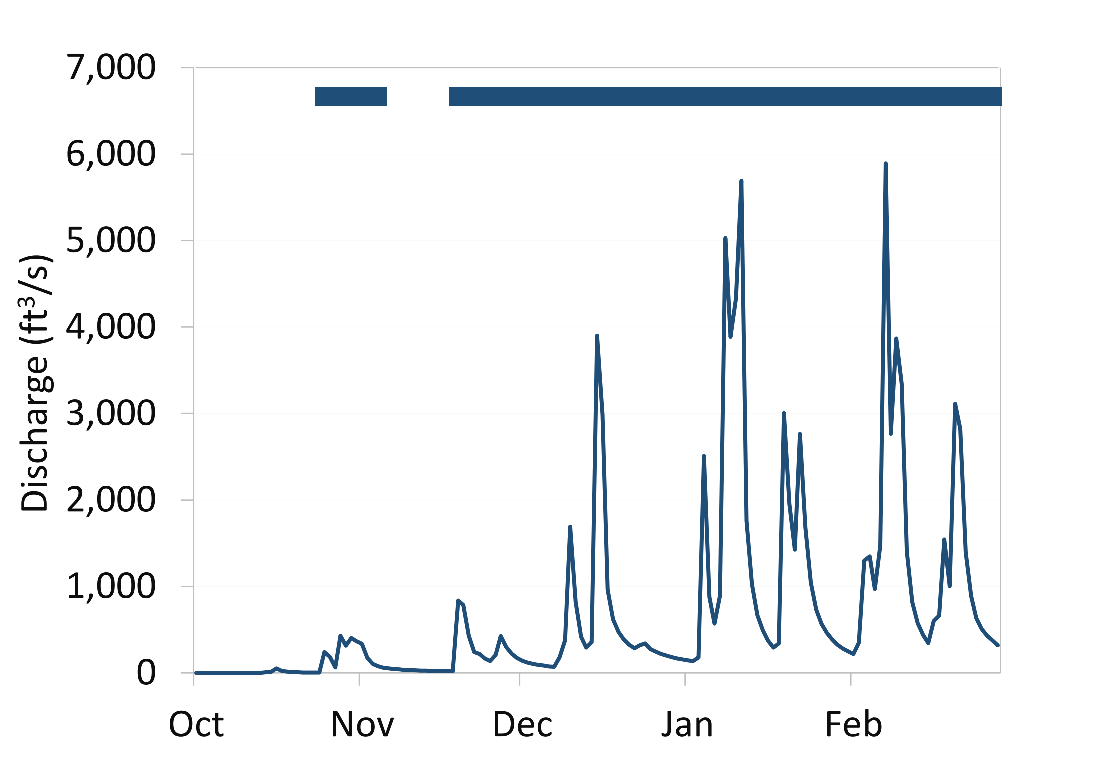
Green Valley **9.4%**



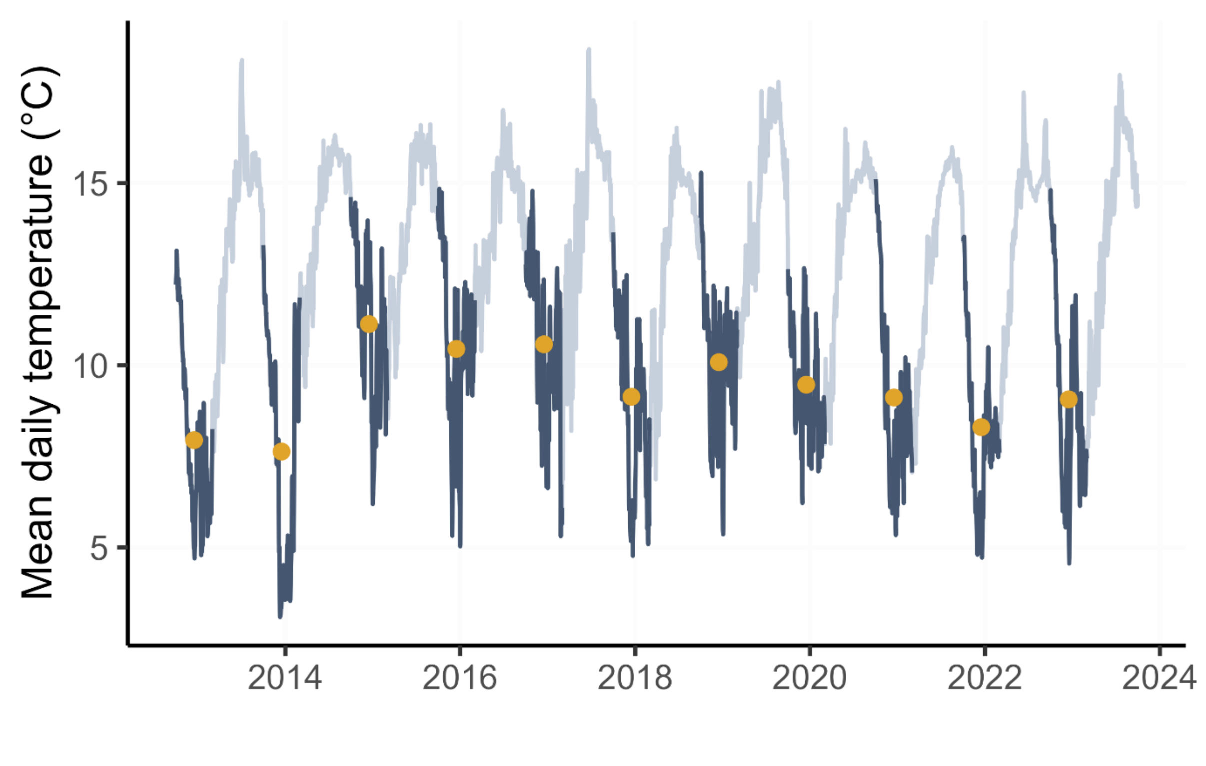
Mill 2.5%

Hydroclimatic factors: winter flow and temperature

Duration of high flow



Mean temperature



Biotic factors: density and size

Fall density of juvenile salmonids

Individual fork length (mm)

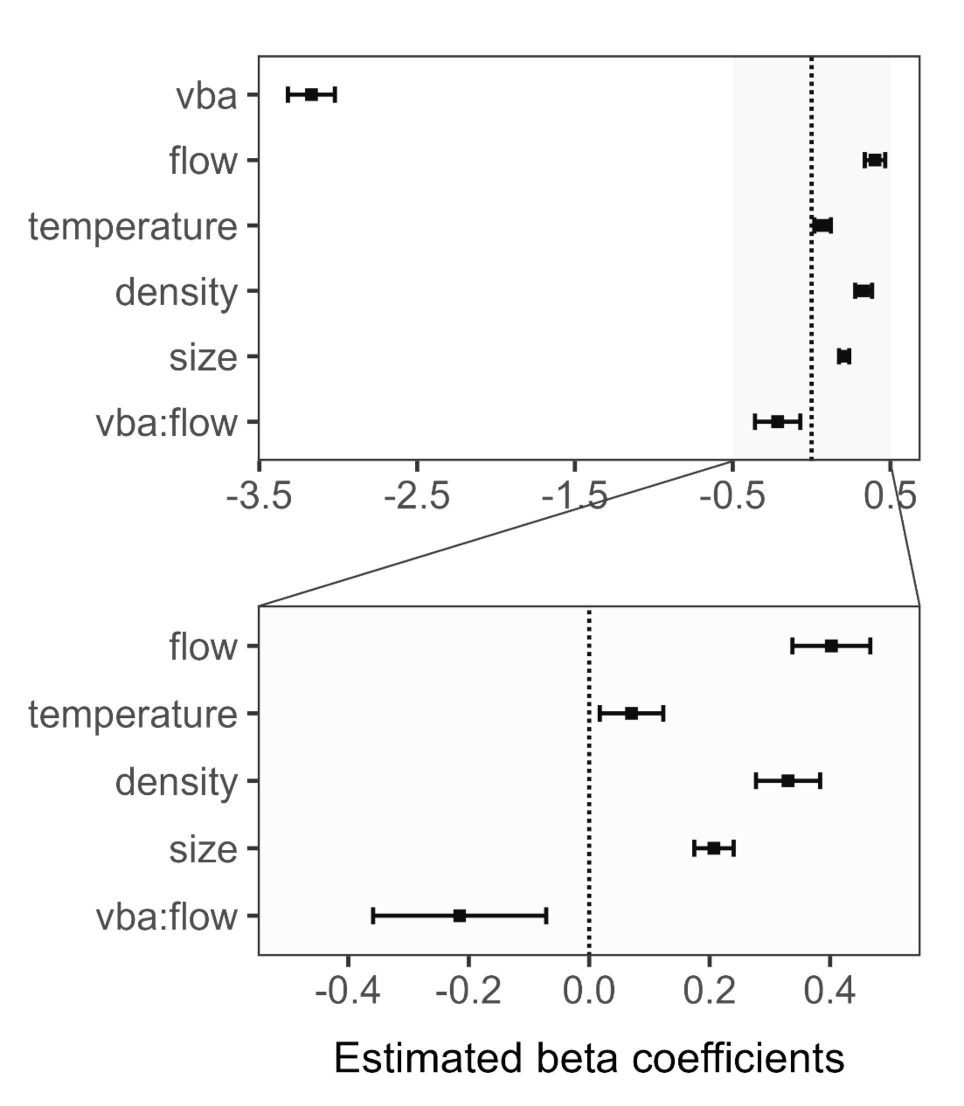
Vba: flow interaction

Expected flow to have a stronger effect on early emigration in streams with less floodplain habitat (lower vba)

Covariate model set

Model	ΔAICc	AICc weight	Likelihood
vba + flow + density + temperature + size + vba:flow	**0.0**	**0.9**	**1.0**
vba + flow + density + size + vba:flow	4.7	0.1	0.1
vba + flow + density + temperature + size	6.5	0.0	0.0
vba + flow + density + size	16.1	0.0	0.0
vba + flow + density + vba:flow	152.8	0.0	0.0
vba + flow + density	163.4	0.0	0.0
vba + flow + vba:flow	286.6	0.0	0.0
vba + flow	287.2	0.0	0.0
vba	628.2	0.0	0.0
flow	2286.3	0.0	0.0
density	2355.3	0.0	0.0
size	2685.3	0.0	0.0
temperature	2695.8	0.0	0.0
no covariates	2769.6	0.0	0.0

Covariate effects



Questions

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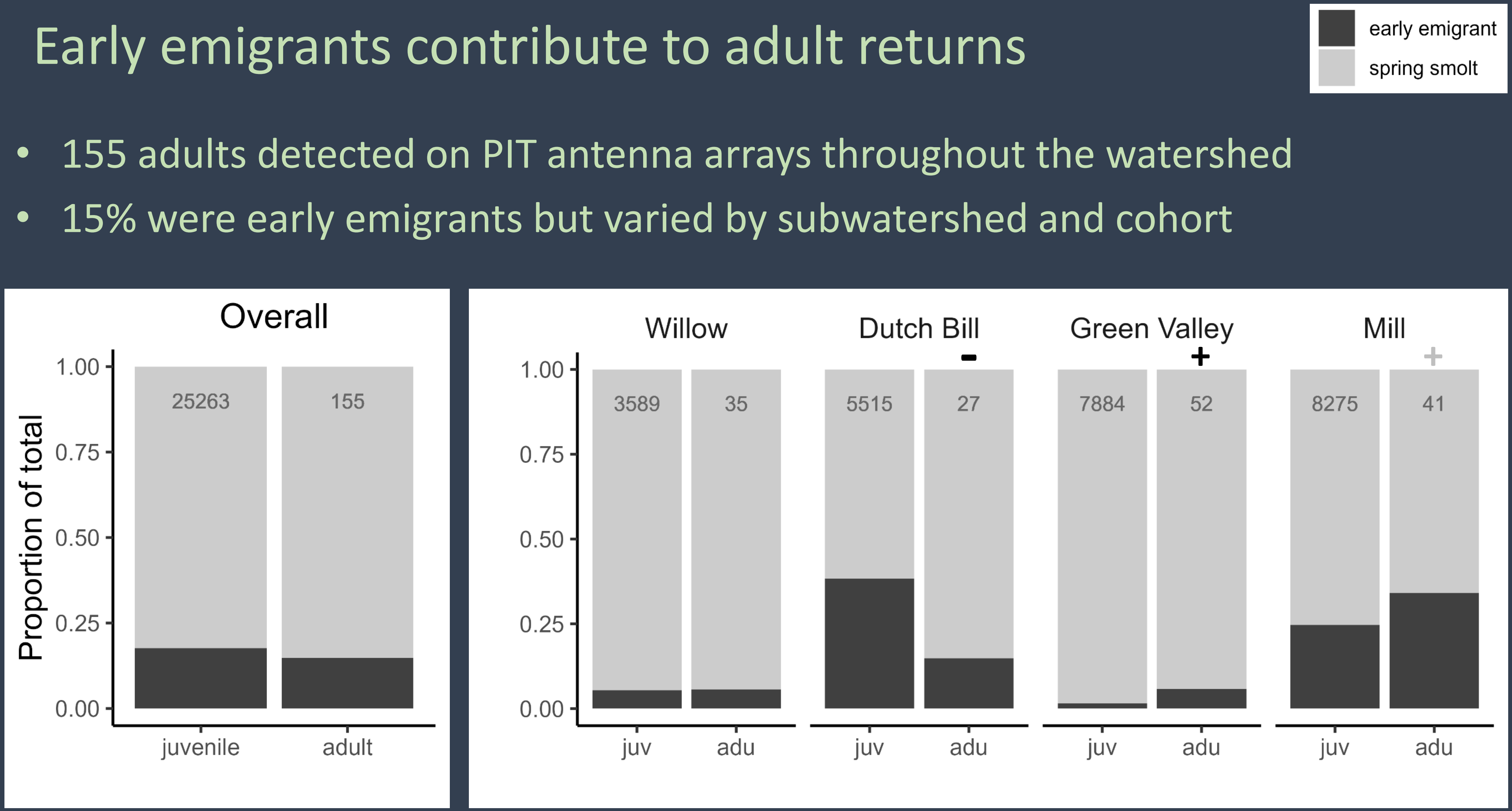
Early emigrants contribute to adult returns

- 155 adults detected on PIT antenna arrays throughout the watershed
- 15% were early emigrants but varied by subwatershed and cohort



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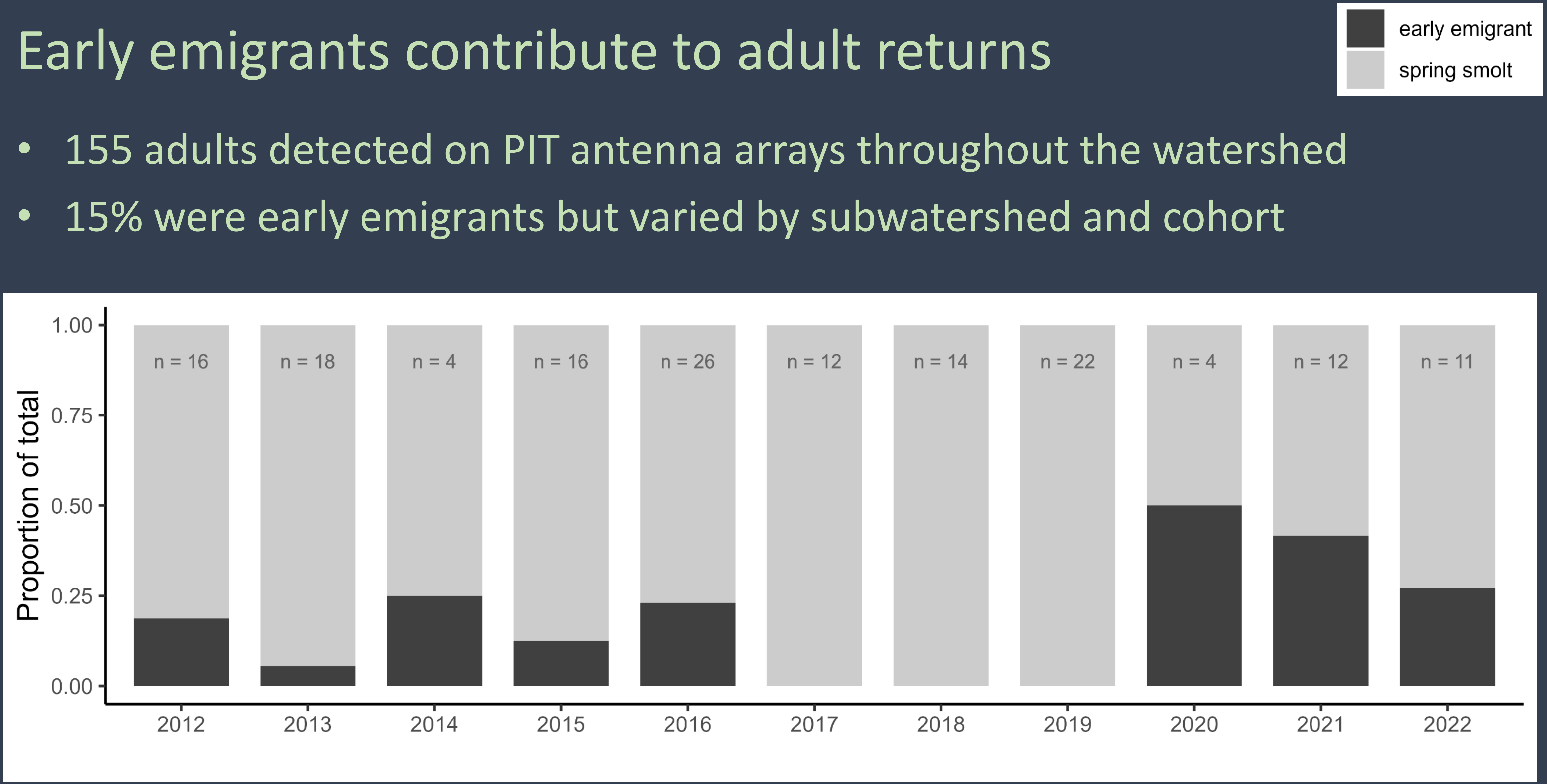
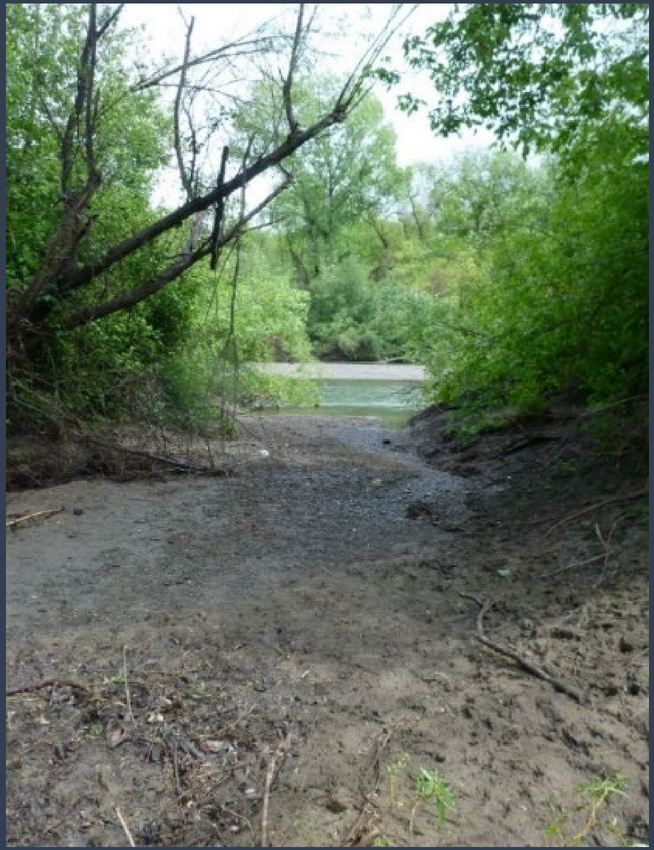
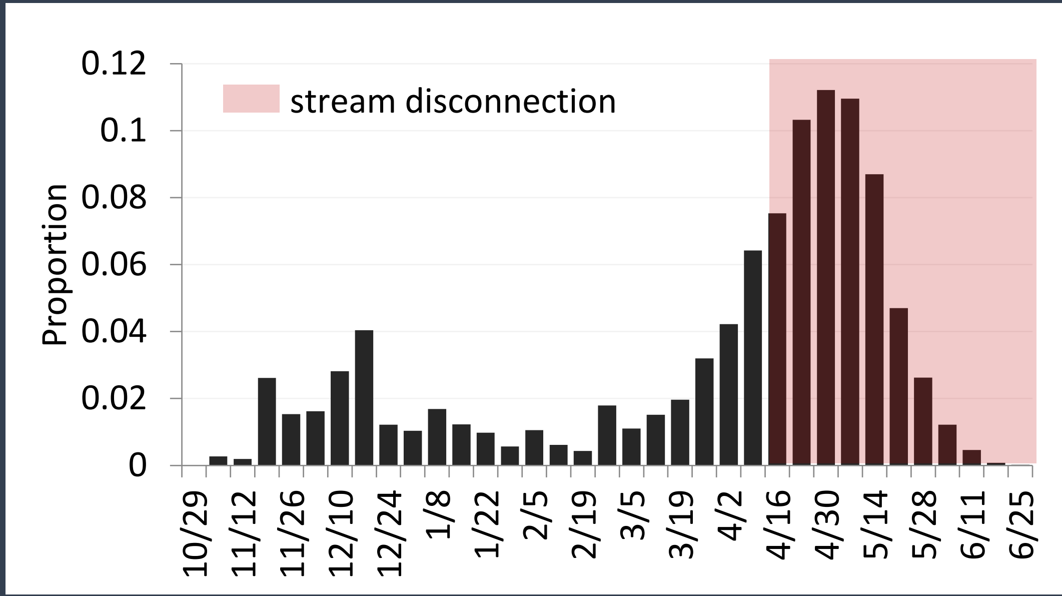


Early emigrants may a critical role in years with streamflow disconnection in early spring



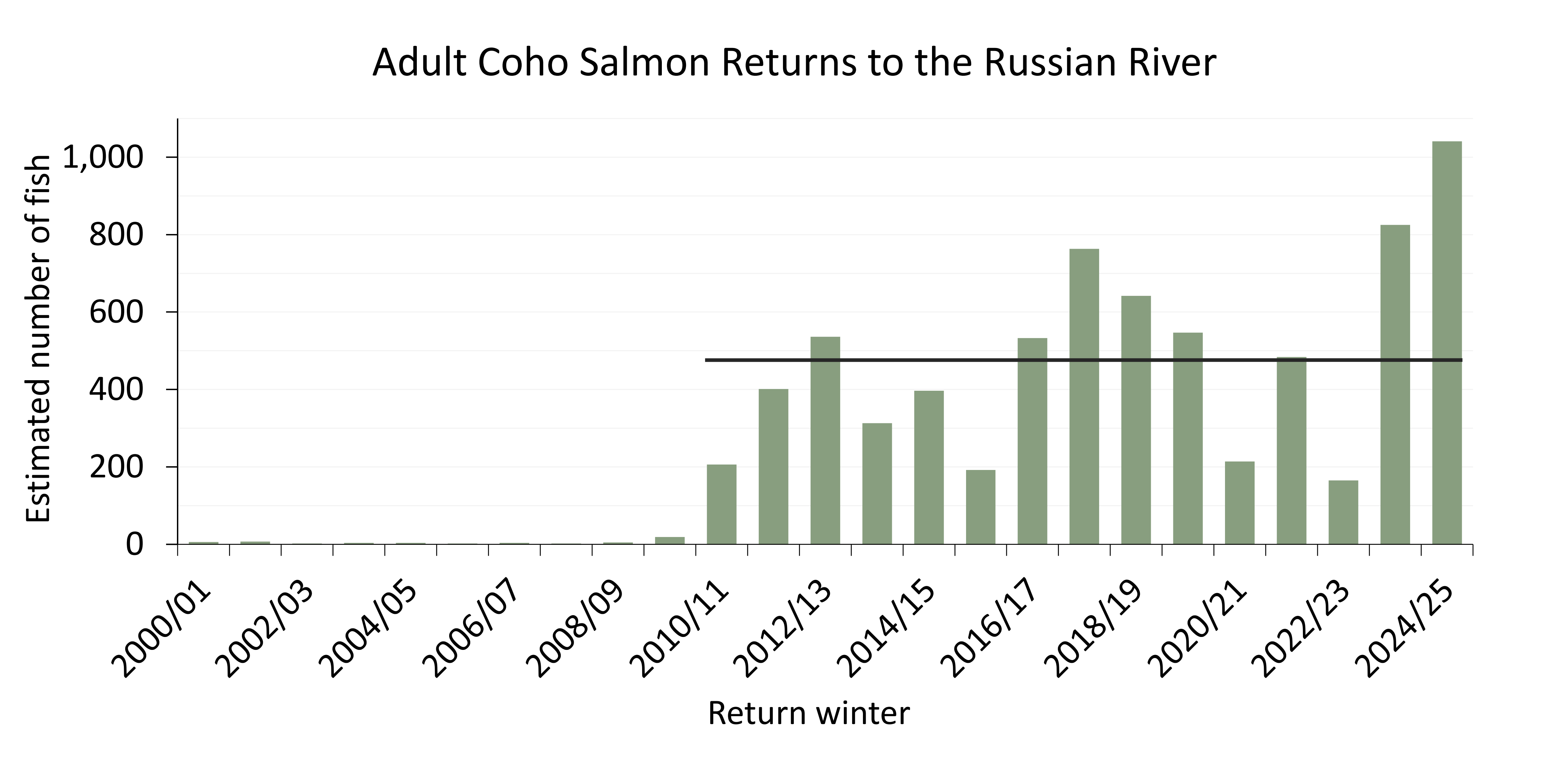


Outline

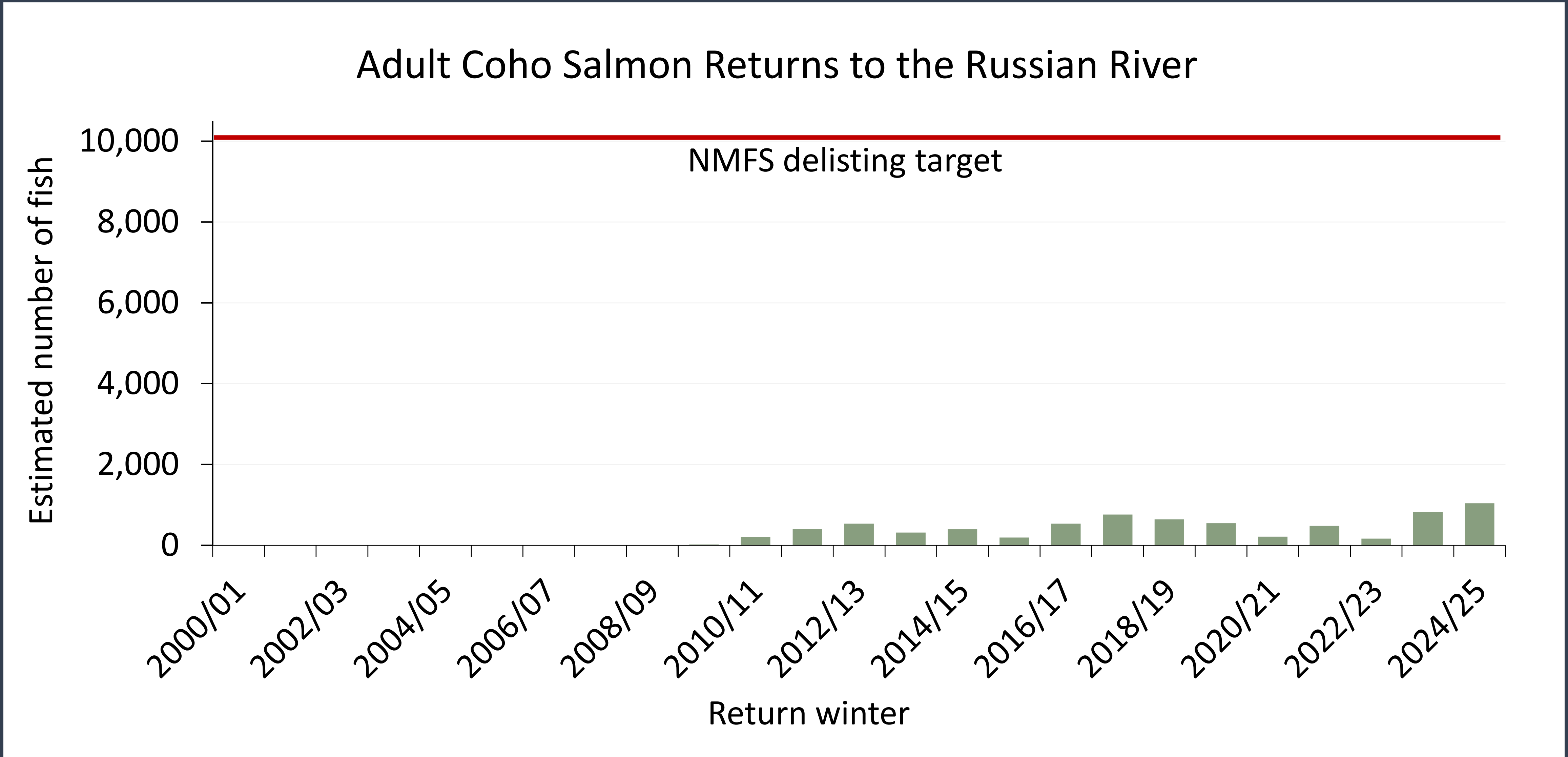
1. Investigating early emigration of juvenile coho salmon in the Russian River

2. Foodscape perspectives on salmonid recovery in the Russian River

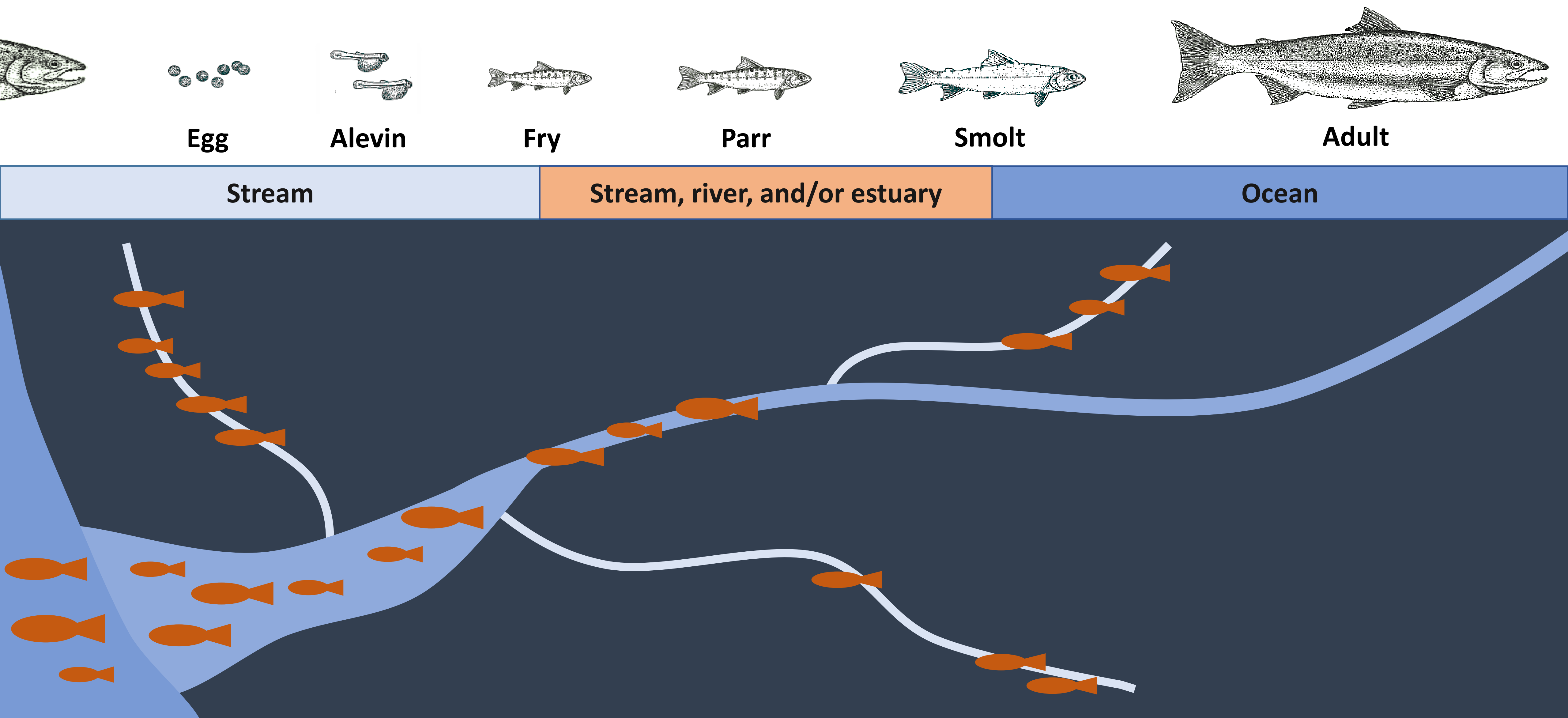
Russian River coho salmon: endangered status

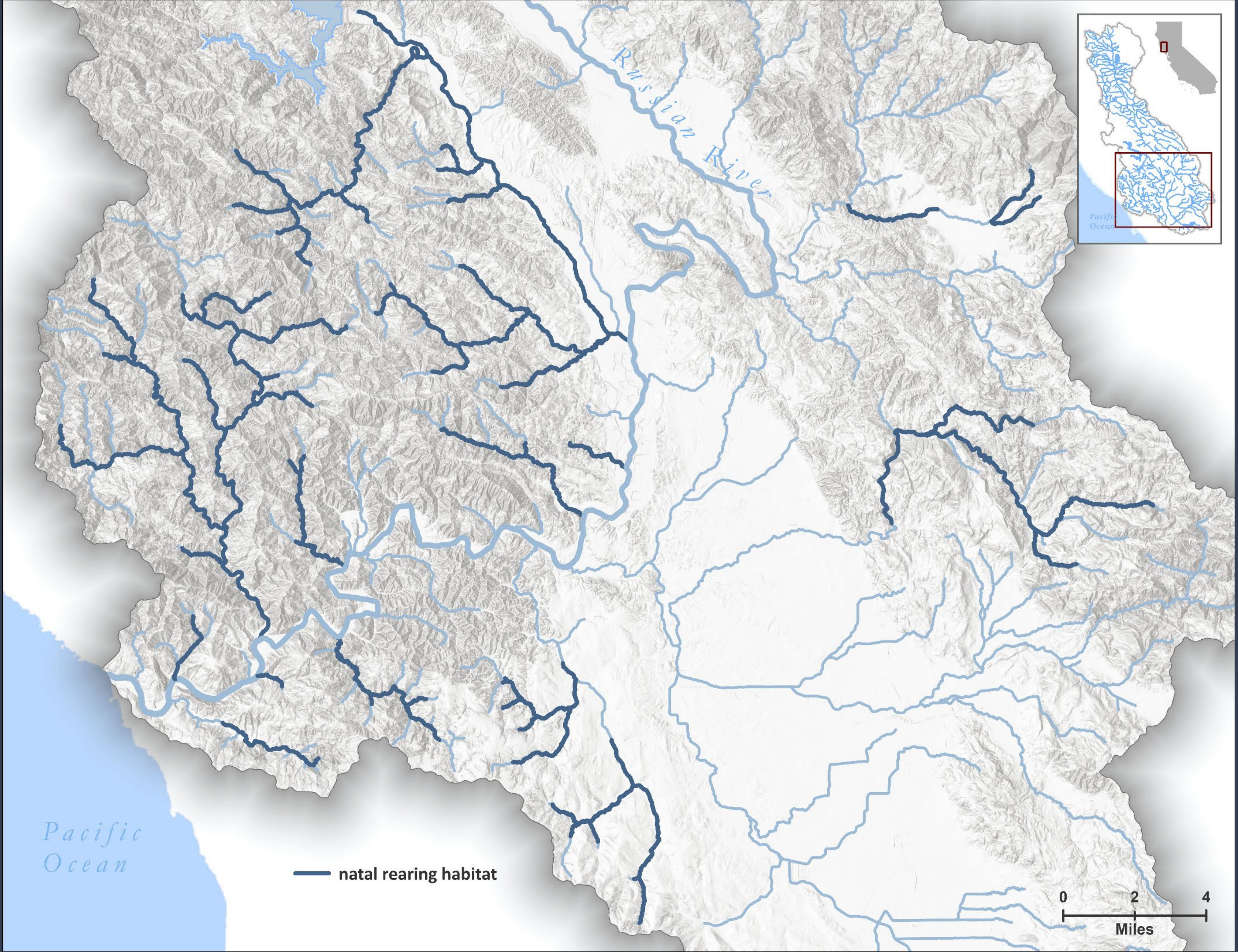


Still a long way to go…

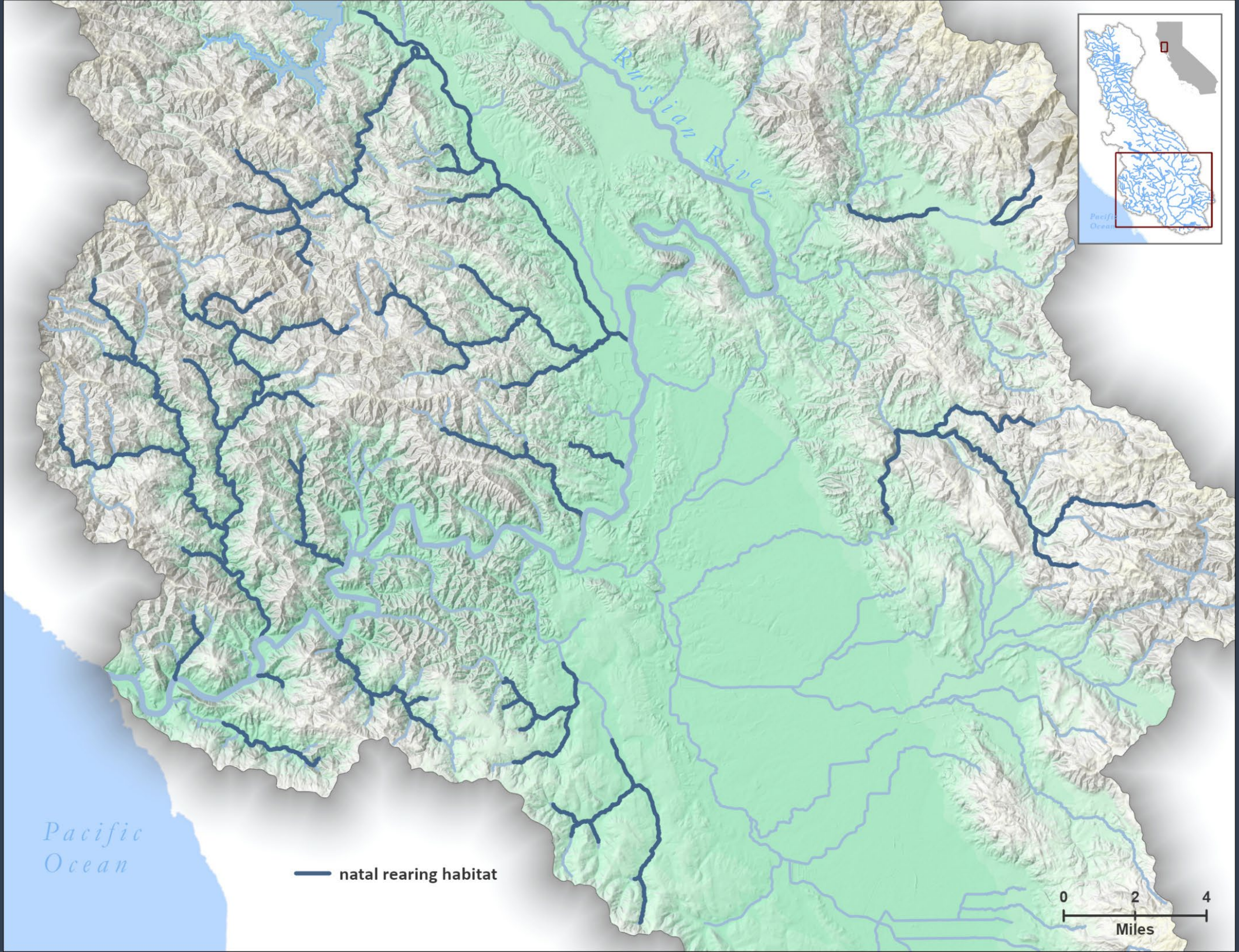


Increasing productivity: more and/or bigger fish



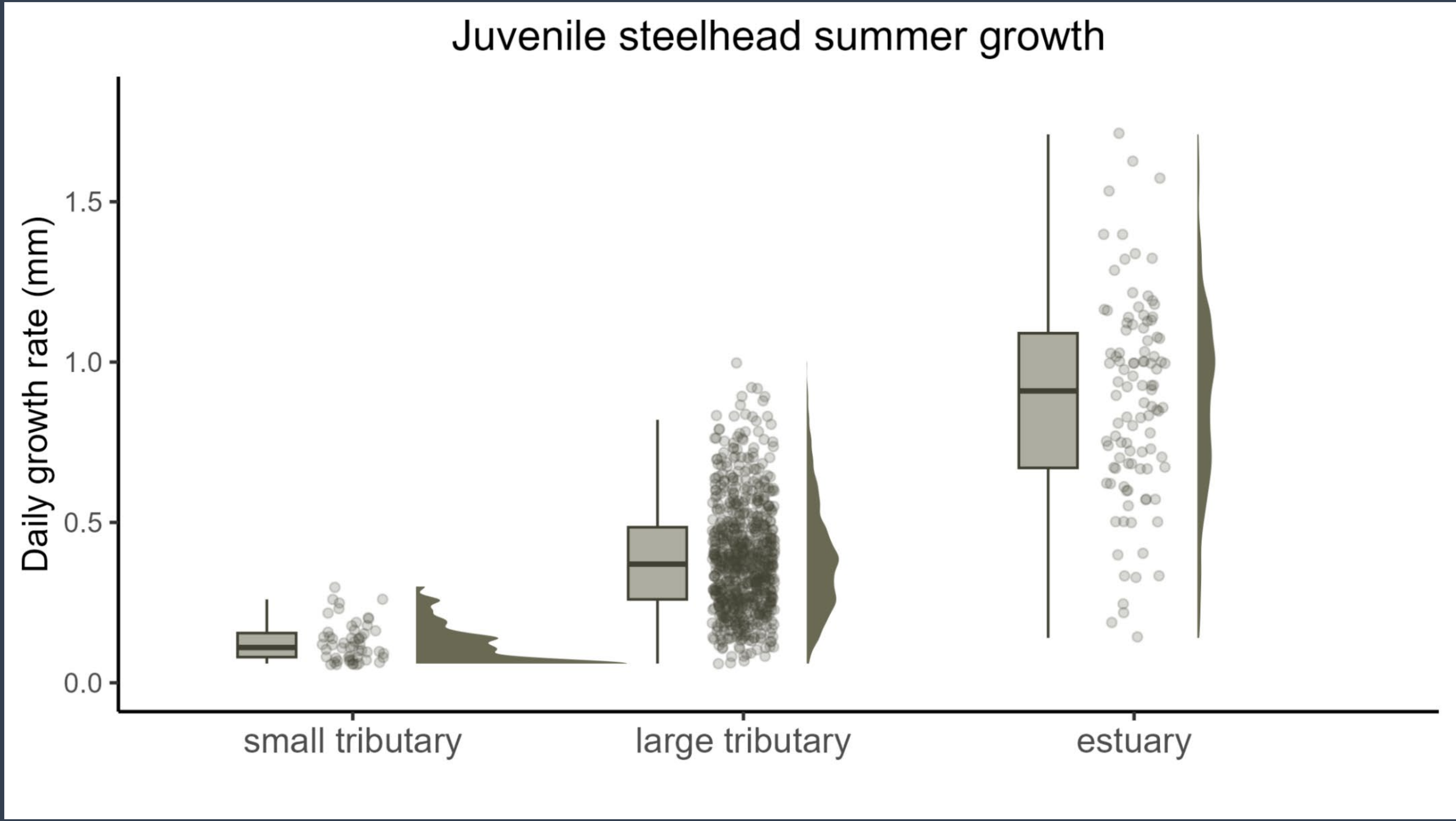


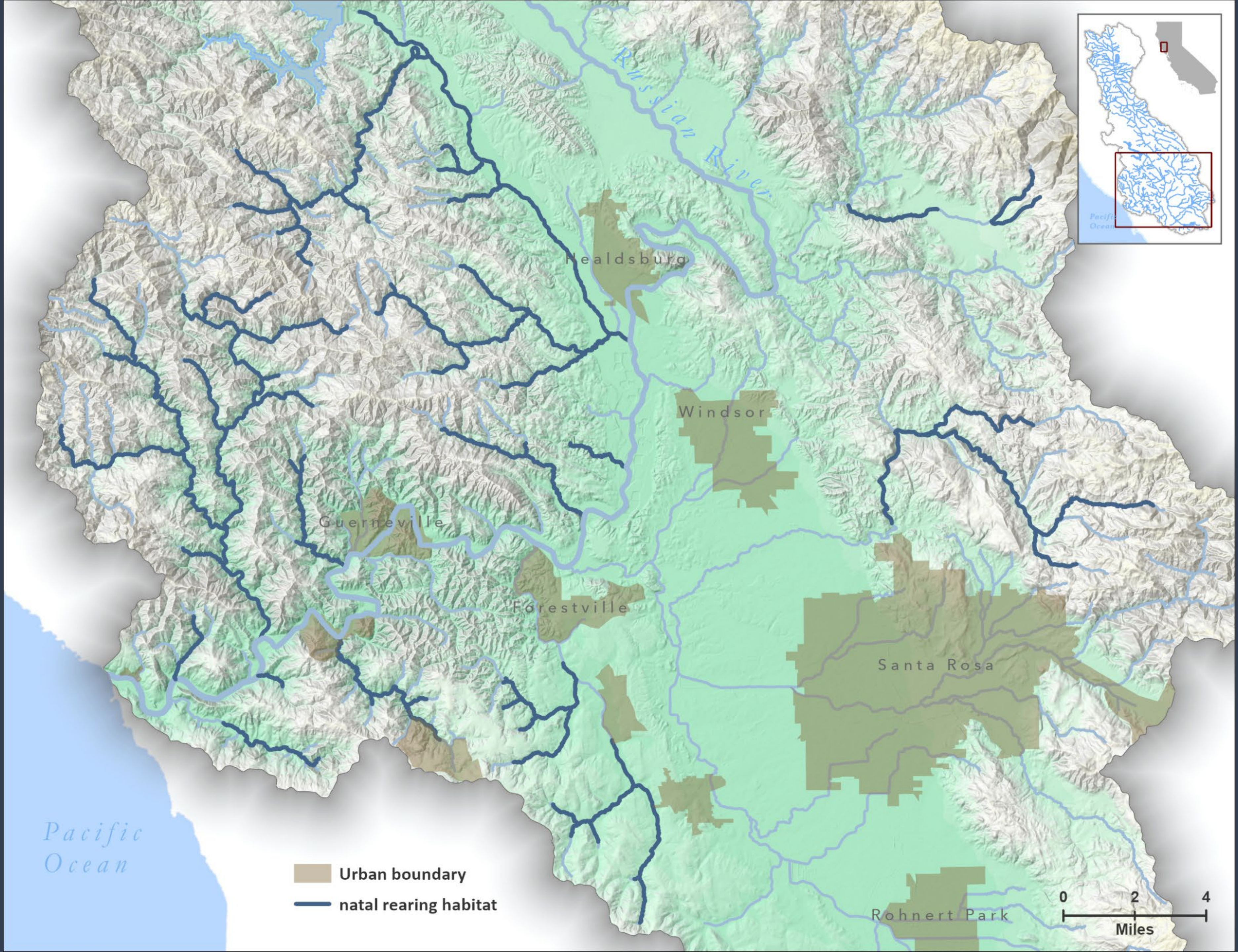
Russian River
Pacific Ocean
natal rearing habitat
0
2
4
Miles



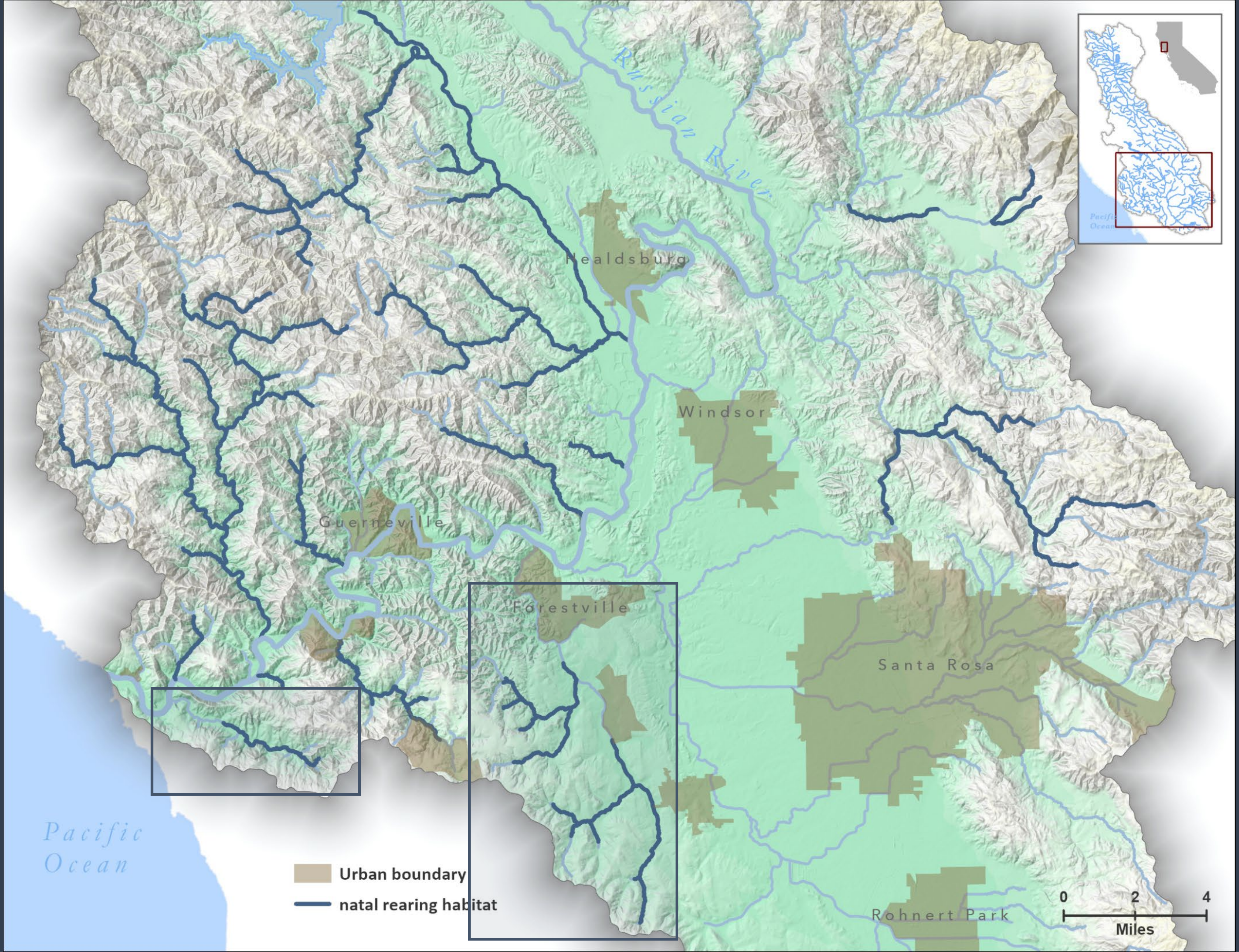
Russian River
Pacific Ocean
natal rearing habitat
0
2
4
Miles

Evidence of high growth opportunity in non-natal rearing habitat





Russian River
Healdsburg
Windsor
Guerneville
Forestville
Santa Rosa
Rohnert Park
Pacific Ocean
Urban boundary
natal rearing habitat
0
2
4
Miles



Russian River
Healdsburg
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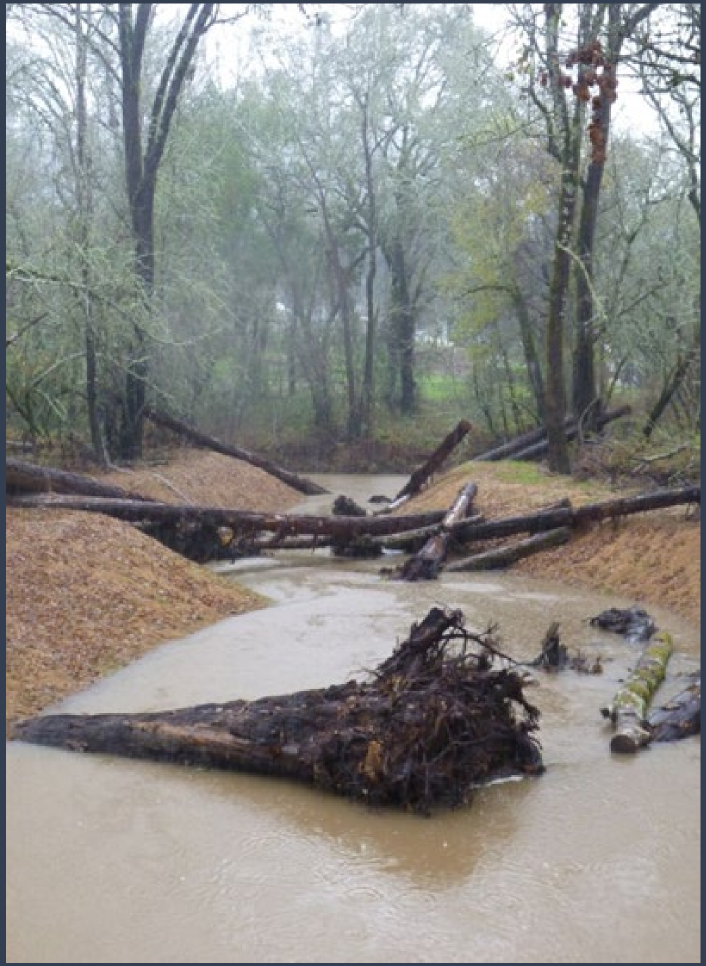
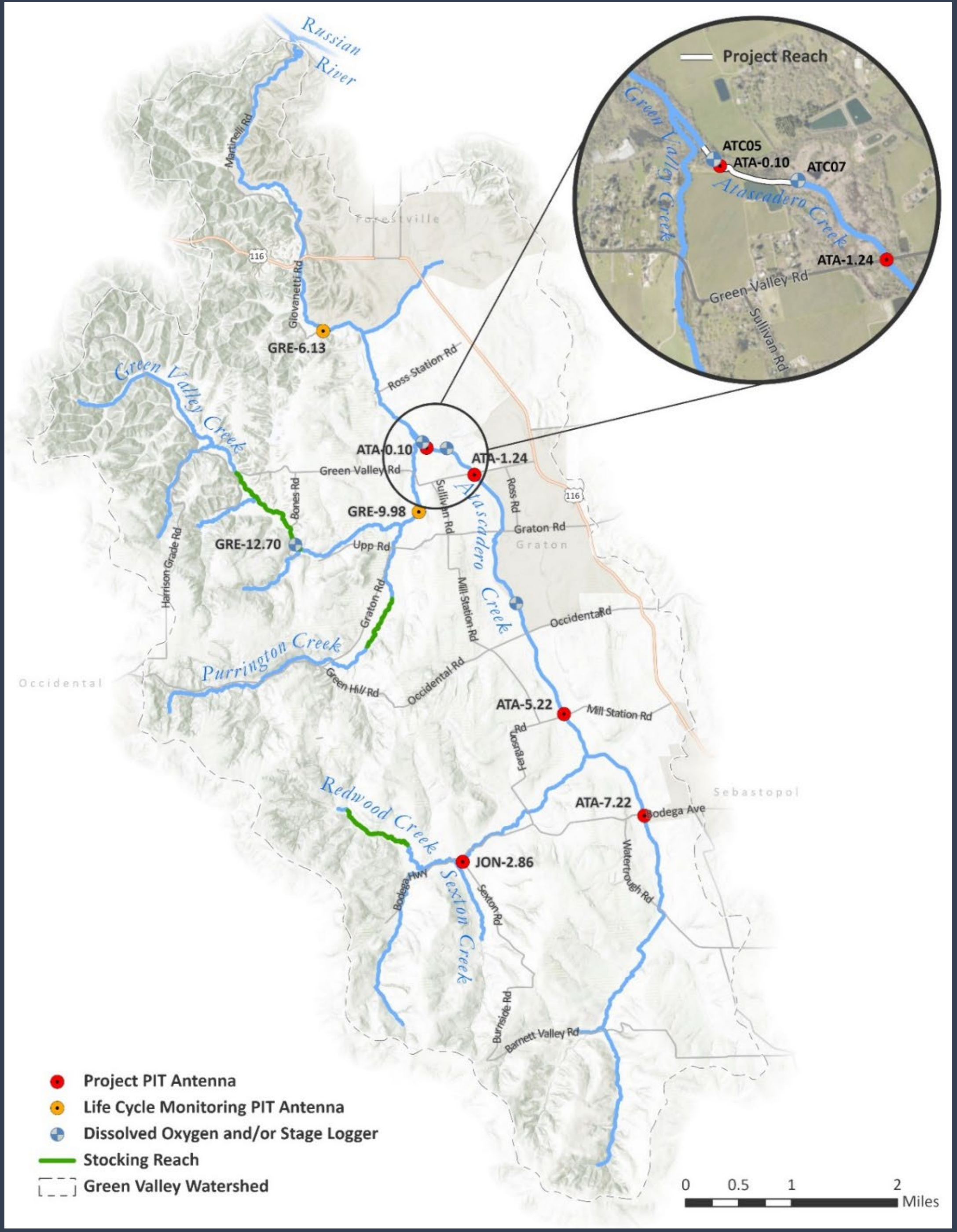
Forestville
Santa Rosa
Rohnert Park
Pacific Ocean
Urban boundary
natal rearing habitat
0 2 4
Miles

Increasing connectivity to floodplain habitat

GOLD RIDGE
RESOURCE CONSERVATION DISTRICT



Increasing quality of floodplain habitat




Willow Creek
Russian River Salmon and Steelhead Monitoring Program
Sea Grant
California
Russian River (Estuary)
RR-WIL-000.41
First Bridge
Second Bridge
Willow Creek
RR-WIL-003.70
Third Bridge
Pacific Ocean
PIT antenna
Smolt trap
Stage logger
0
0.25
0.5
1
Miles
Projection: NAD 1983 UTM Zone 10N
Source: Streams, Roads and Parcels (County of Sonoma); Hillshade and Imagery (Sonoma Veg Map/Esri)
Project: WillowCreek_Scout | Layout: SeaGrant_Landscape
Prepared By: California Sea Grant, Windsor, CA | Date: 8/22/2022

Acknowledgements

Nick Bauer, Andrew Bartshire, Will Boucher, George Pess, Albert Ruhi

Field and Hatchery Crews

Cooperating Landowners

UC Berkeley Freshwater Ecology Lab

Primary Funding Sources: *U.S. Army Corps of Engineers, CA Department of Fish and Wildlife, NMFS & NOAA Restoration Center, Sonoma County Water Agency*

US Army Corps of Engineers ®
San Francisco District

NOAA

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

Sonoma Water

WSP

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Questions?

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Sea Grant
CALIFORNIA

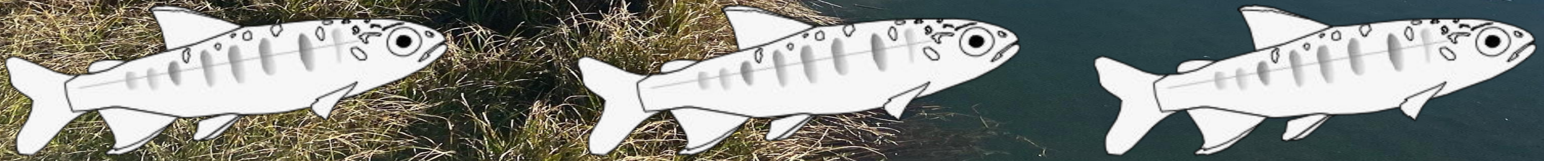
California Sea Grant: http://caseagrant.ucsd.edu/coho

UC Berkeley Freshwater Ecology: https://nature.berkeley.edu/freshwater

Causes and consequences of variation in juvenile salmon migration phenology

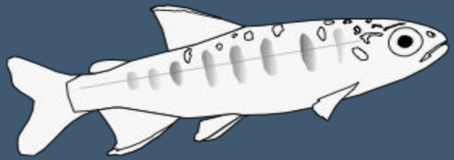
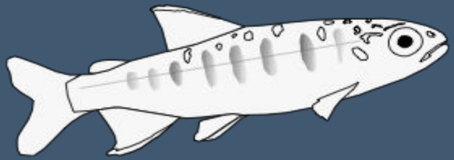
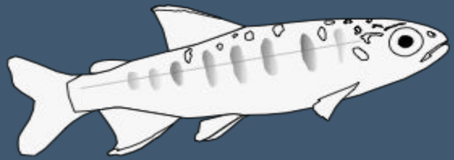
Hank Baker, PhD
University of California, Berkeley

Mariska Obedzinski, Ted Grantham, Stephanie Carlson



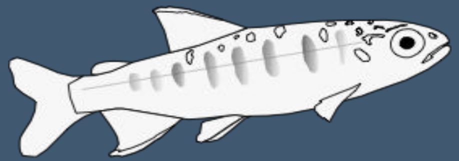
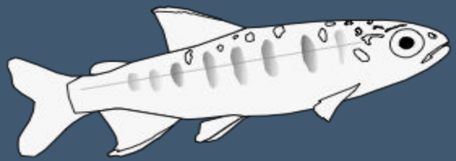
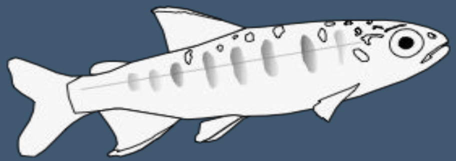
Key Takeaways:

1. Juvenile coho salmon are more diverse than is typically appreciated.

Key Takeaways:

1. Juvenile coho salmon are more diverse than is typically appreciated.
2. Even subtle diversity can have large effects on population dynamics.

Key Takeaways:

1. Juvenile coho salmon are more diverse than is typically appreciated.
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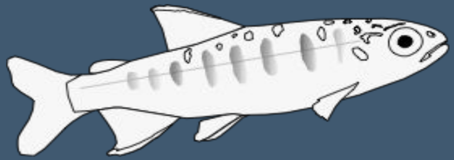
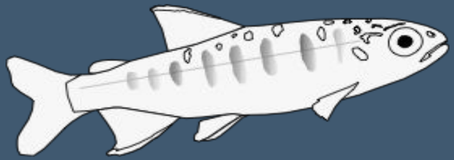
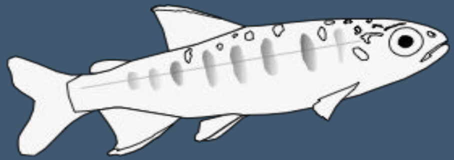
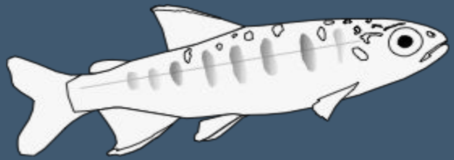
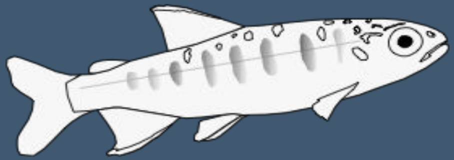
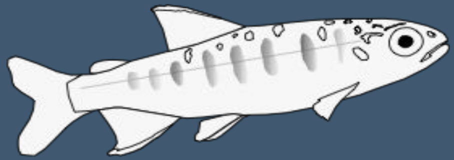
3. Managing for diversity will improve outcomes.

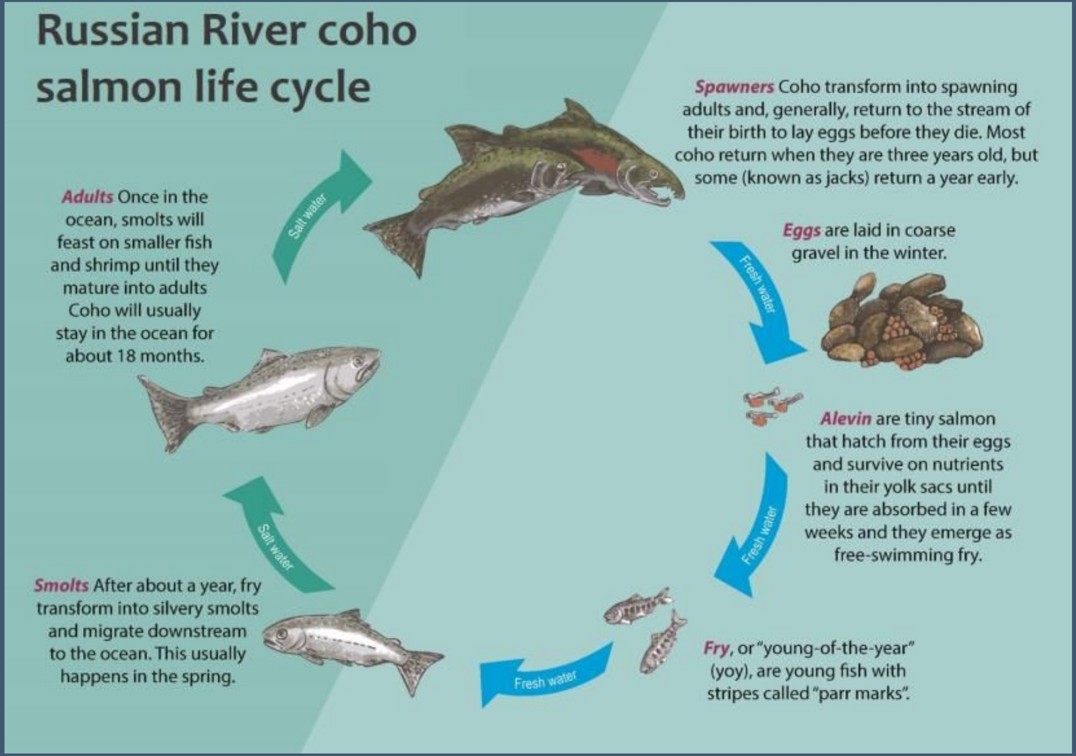




Key Takeaways:

1. Juvenile coho salmon are more diverse than is typically appreciated.
2. Even subtle diversity can have large effects on population dynamics.
3. Managing for diversity will improve outcomes.
4. Large datasets are required to understand ‘alternate’ phenotypes.

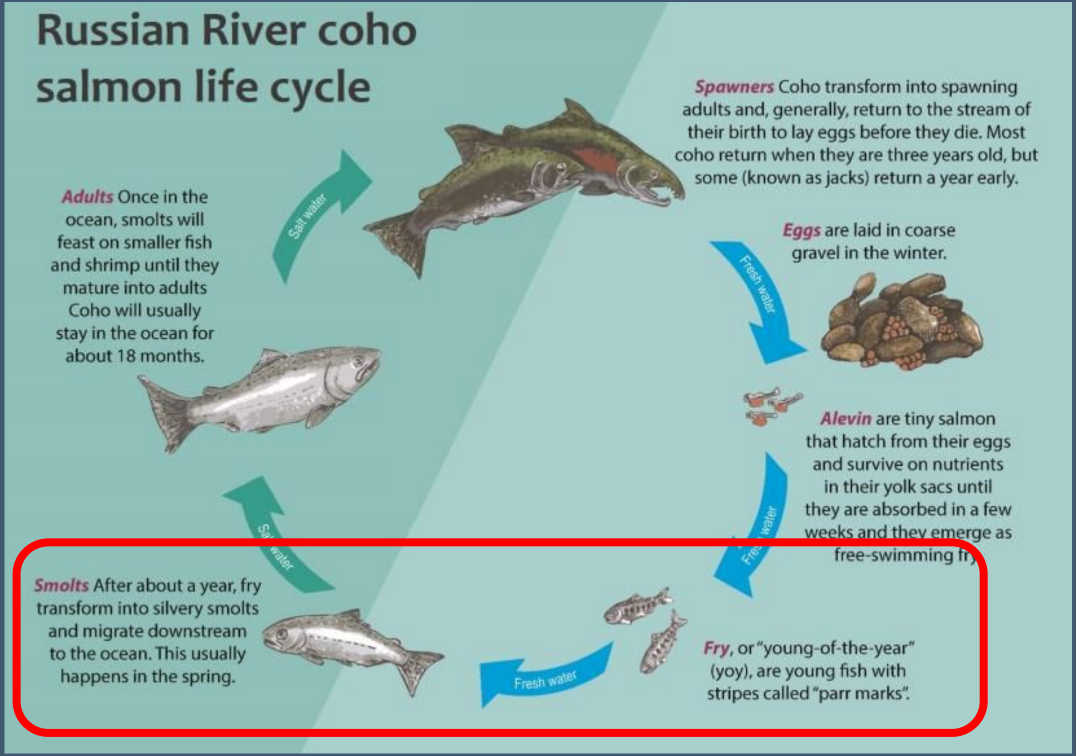




"Typical" coho salmon life history



California Sea Grant

"Typical" coho salmon life history



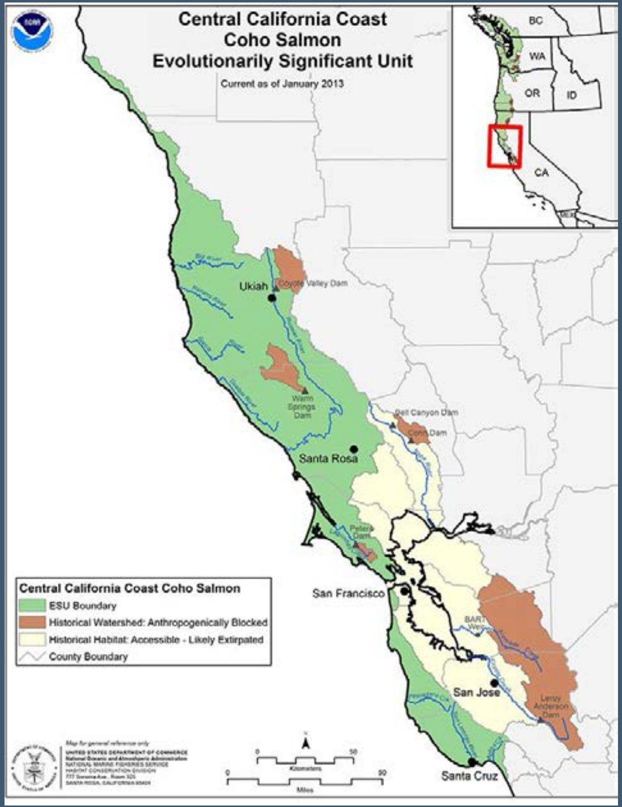
California Sea Grant

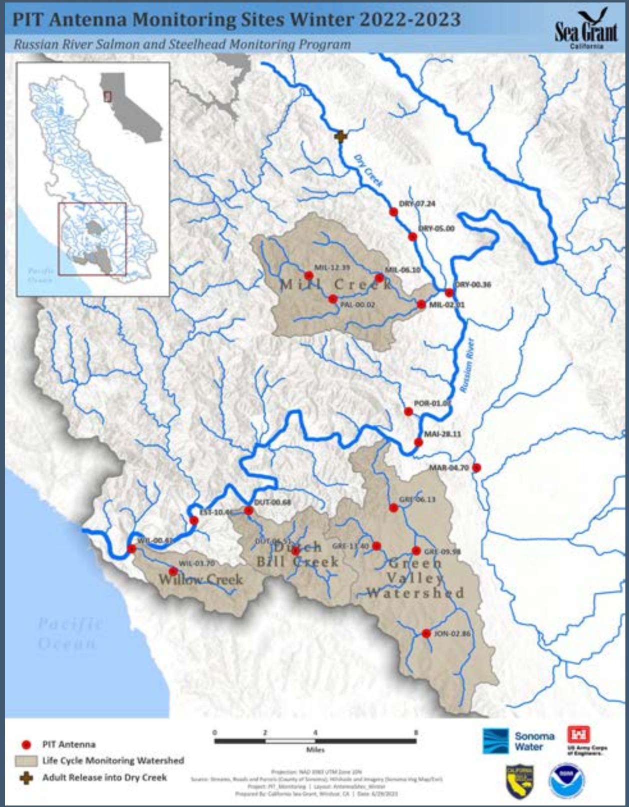
Outline

Part 1: Variation in movement within a single creek affects population dynamics

Part 2: Variation across the riverscape affects the frequency and phenology of non-natal rearing

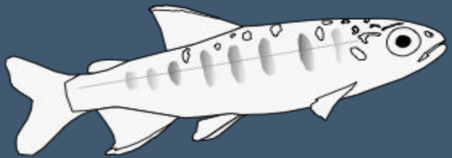
Endangered Central California Coast Coho Salmon

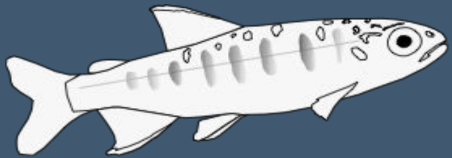


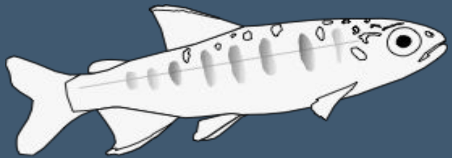


Intrapopulation variation in movement phenotypes is common

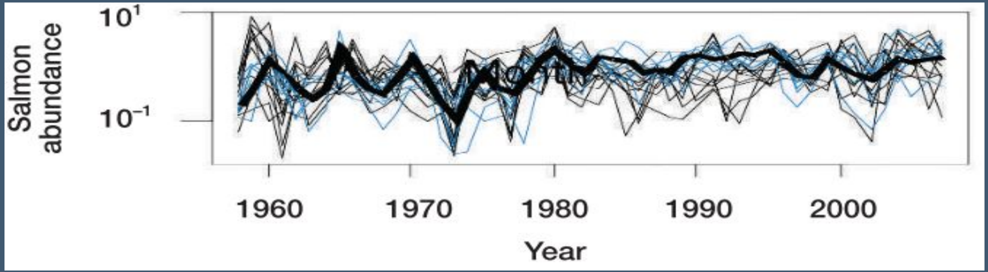
Diversity begets stability



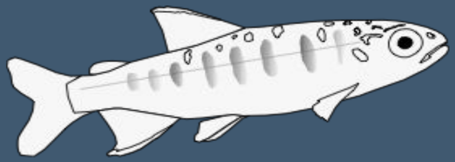
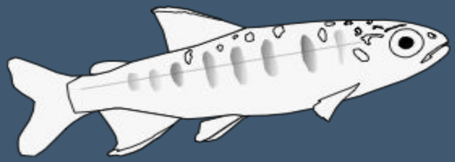
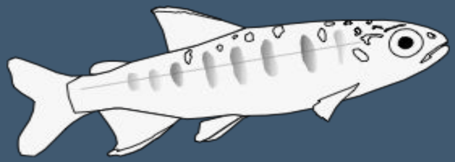




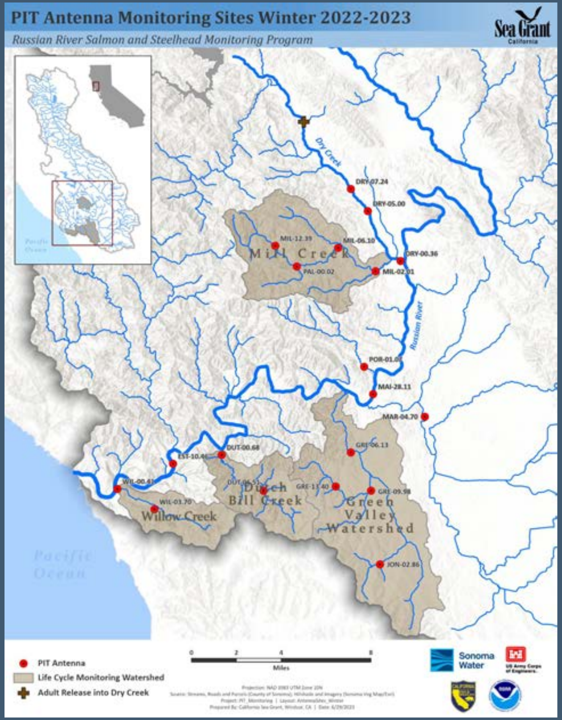
Diversity begets stability

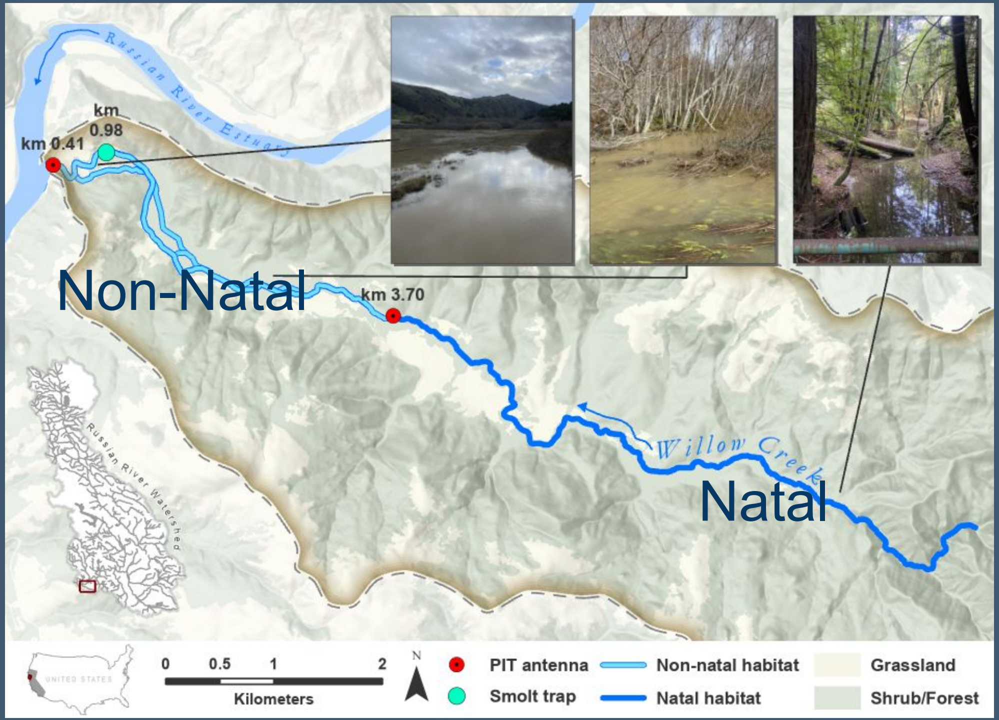


Schindler et al. 2010, *Nature*
Schindler et al. 2015, *Front Ecol Env*

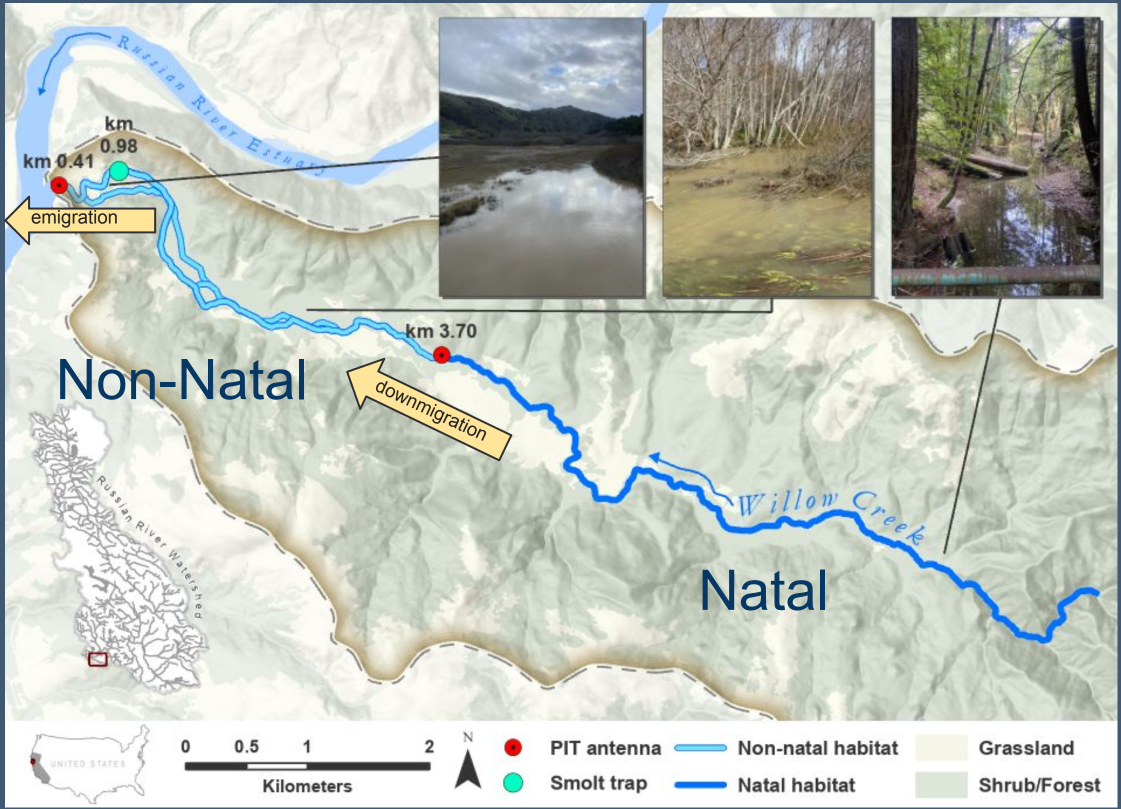




Part 1: Intrapopulation variation in rearing stabilizes population dynamics



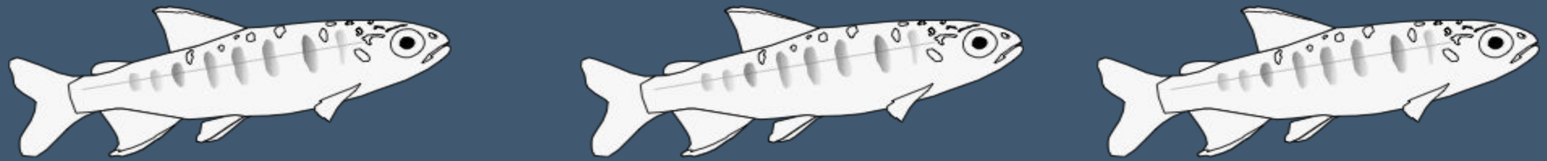


Characterizing movement phenotypes



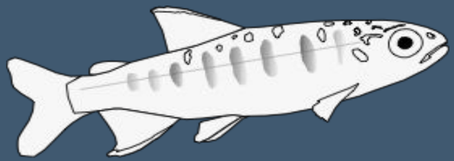
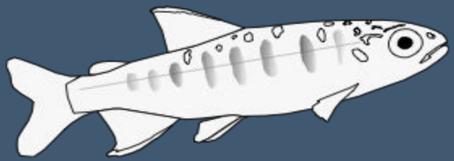
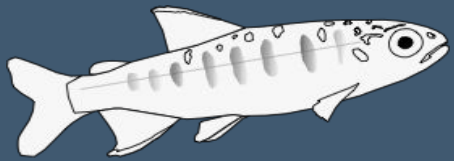
Research Questions:

1. Do juvenile coho salmon in Willow Creek exhibit variation in movement phenology and rearing strategies?



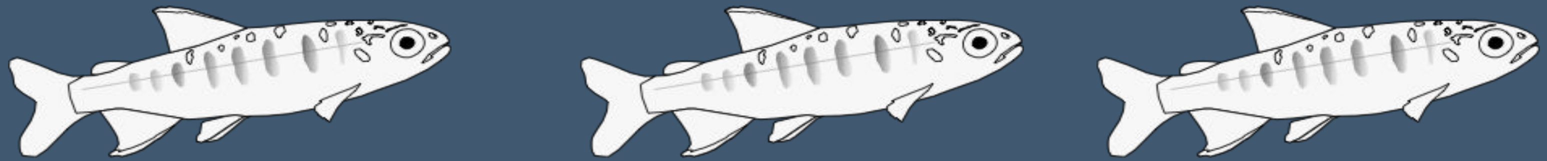
Research Questions:

1. Do juvenile coho salmon in Willow Creek exhibit variation in movement phenology and rearing strategies?
2. What are the consequences of variation for population dynamics?

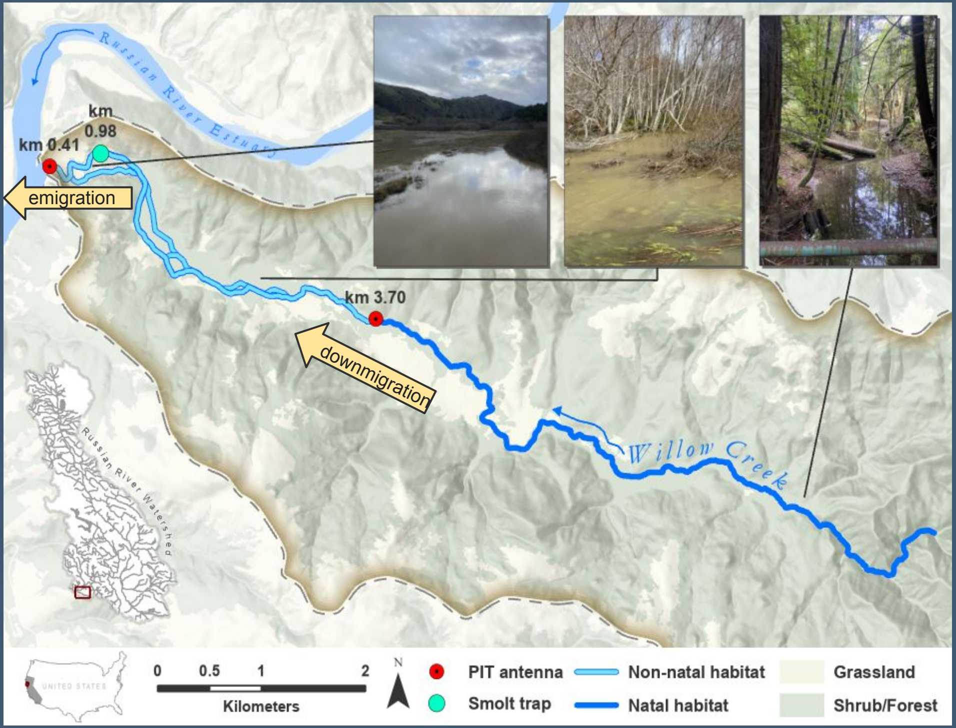




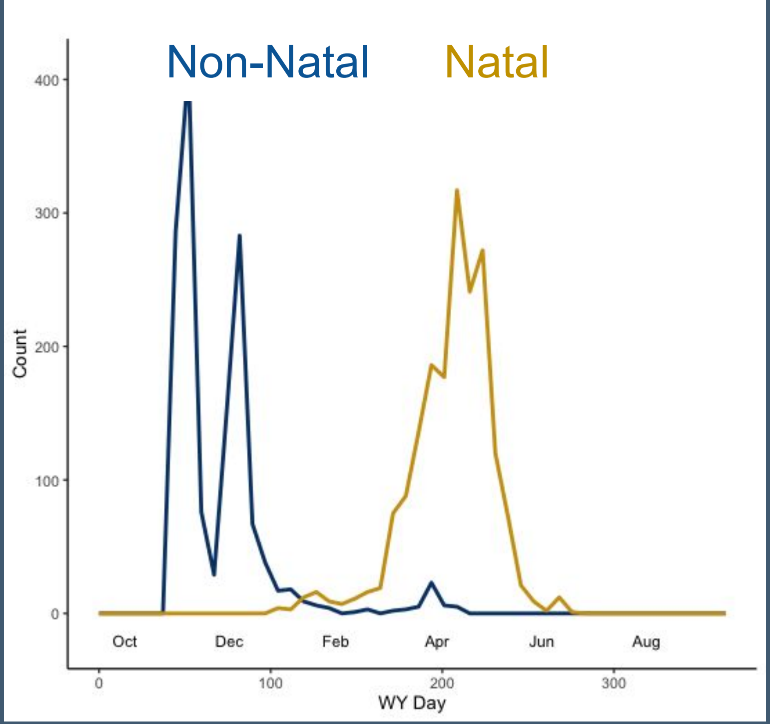
Research Questions:

1. Do juvenile coho salmon in Willow Creek exhibit variation in movement phenology and rearing strategies?
2. What are the consequences of variation for population dynamics?
3. Is variation in movement associated with
    a. Flow
    b. Intraspecific competition

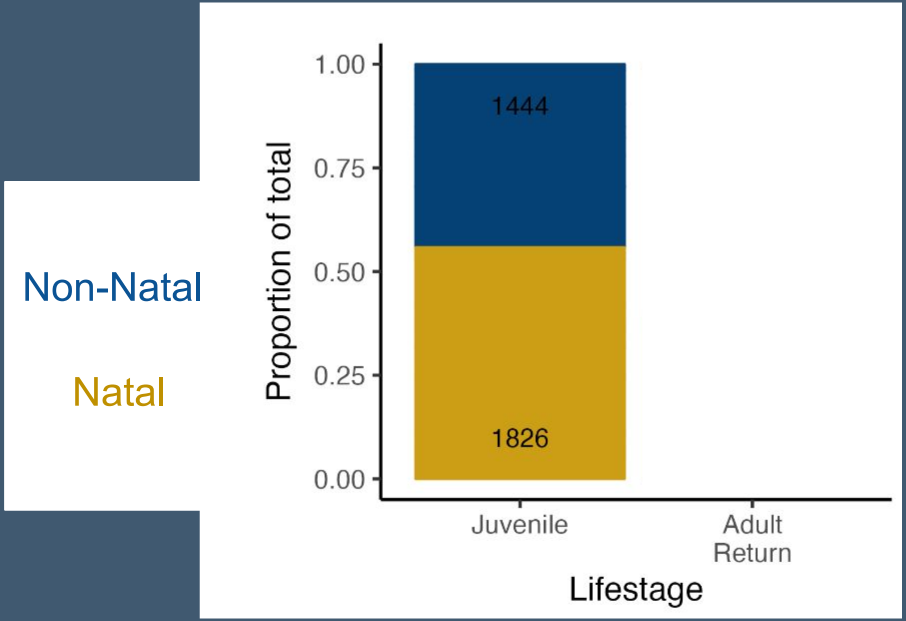


Coho salmon in Willow Creek exhibit two movement patterns





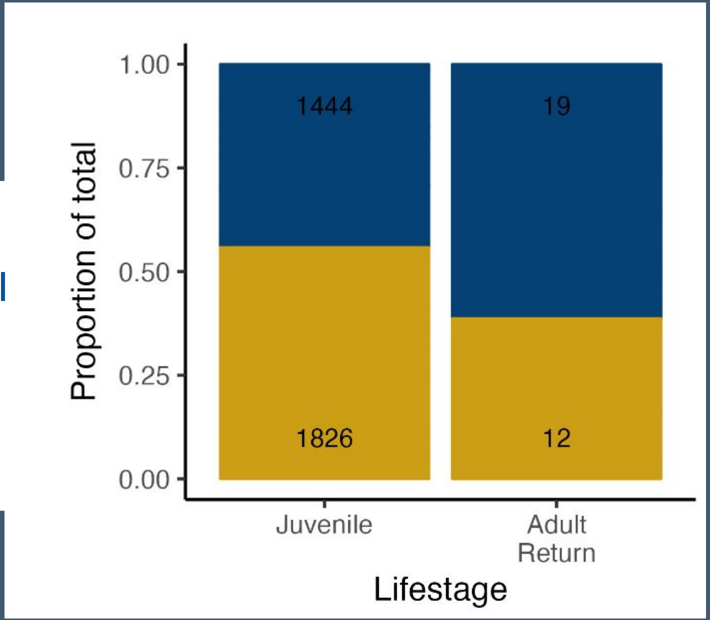
Non-natal rearing disproportionately contributes to adult returns



Non-natal rearing disproportionately contributes to adult returns

Non-Natal

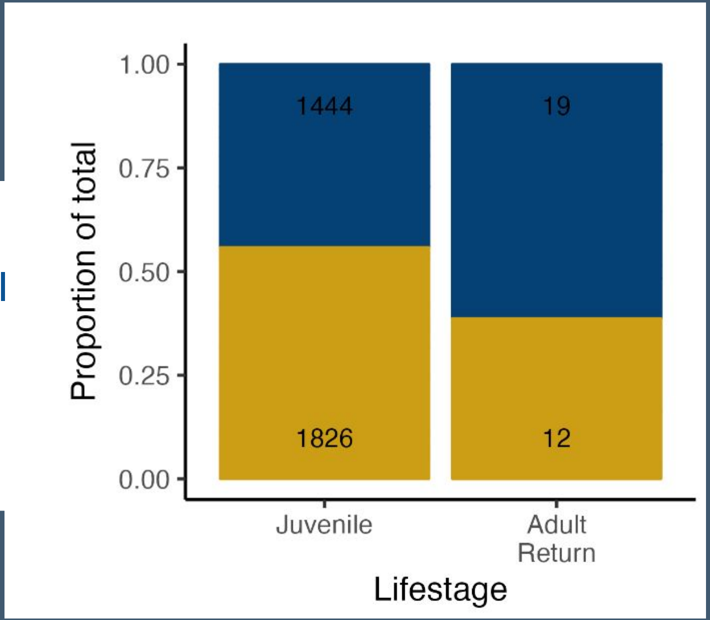
Natal

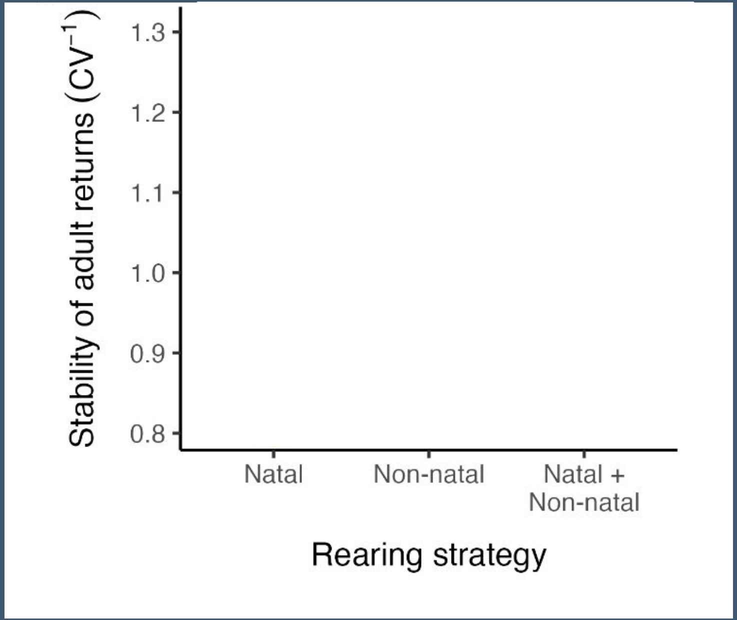


Non-natal rearing disproportionately contributes to adult returns and bolsters population stability

Non-Natal

Natal





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Non-Natal

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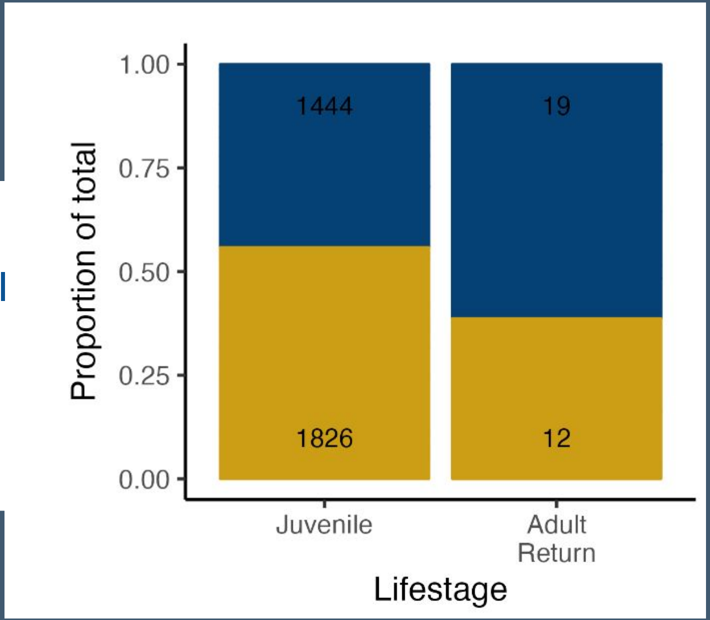
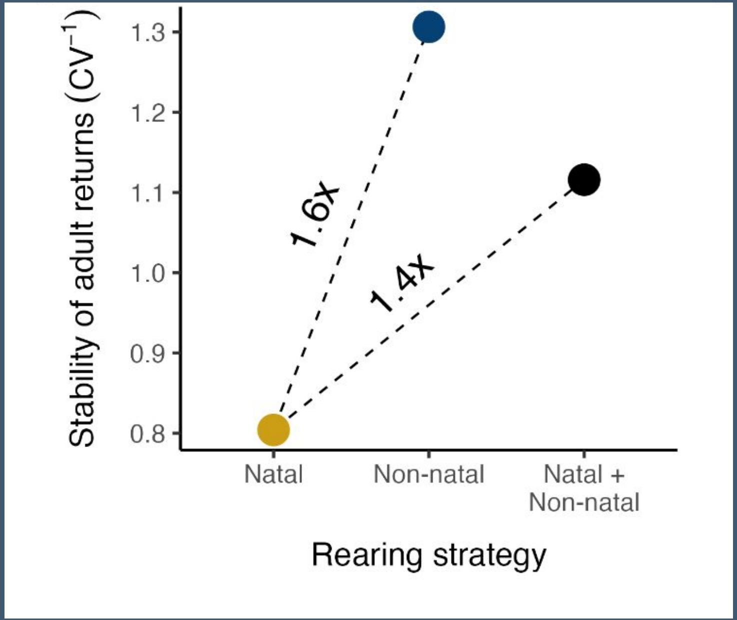
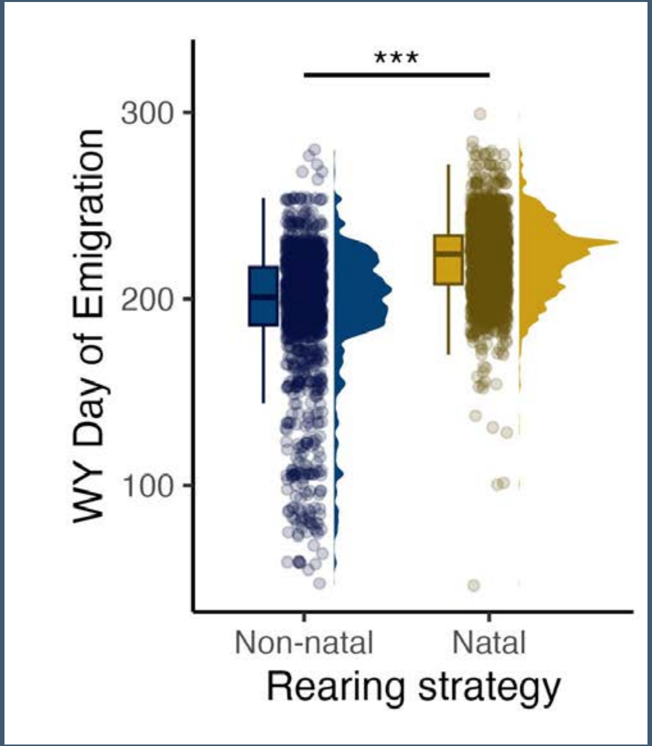
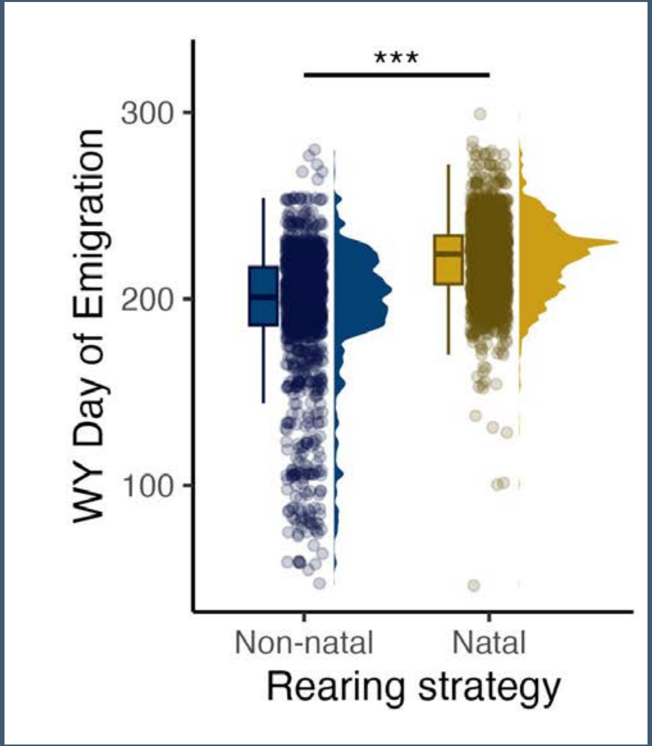


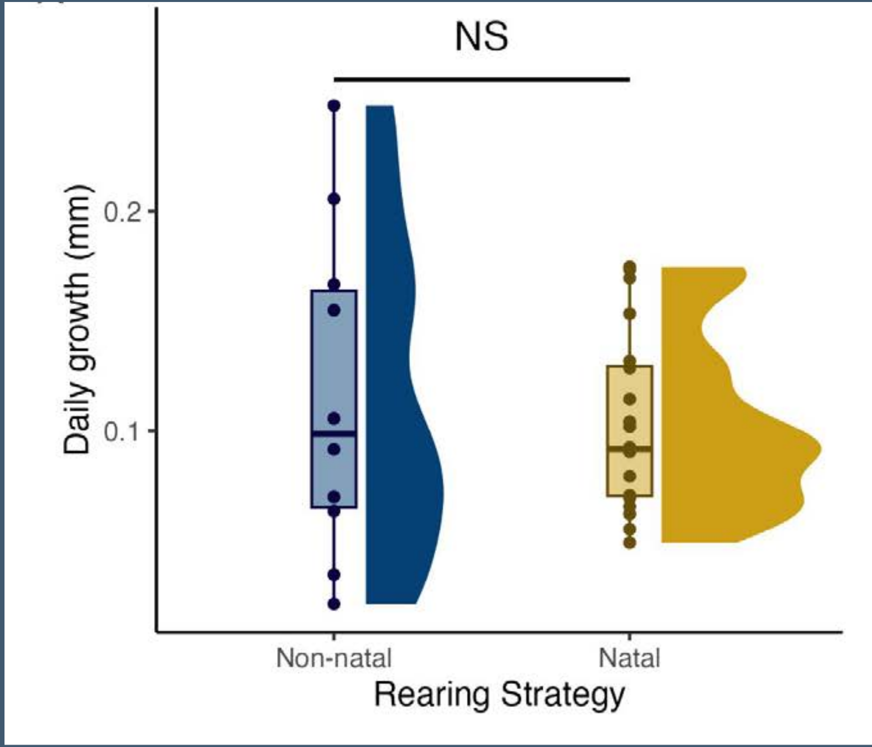


Adult returns may be mediated by differences in emigration timing



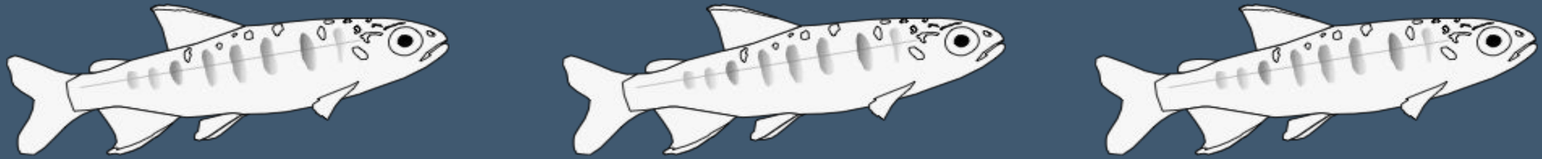
Adult returns may be mediated by differences in emigration timing and growth rate



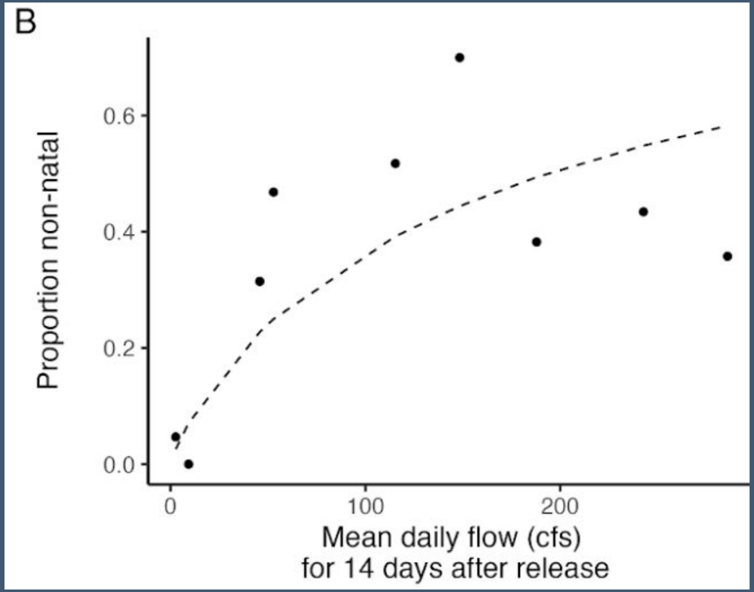


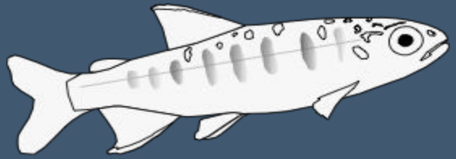
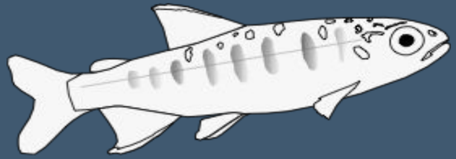
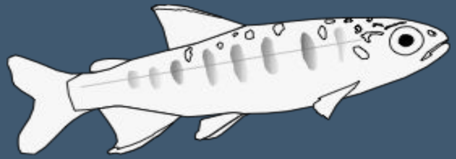
Predictors of variation in rearing strategy

- H1: Higher fish densities increase the proportion of non-natal rearing
- H2: Higher flow increases the proportion of non-natal rearing

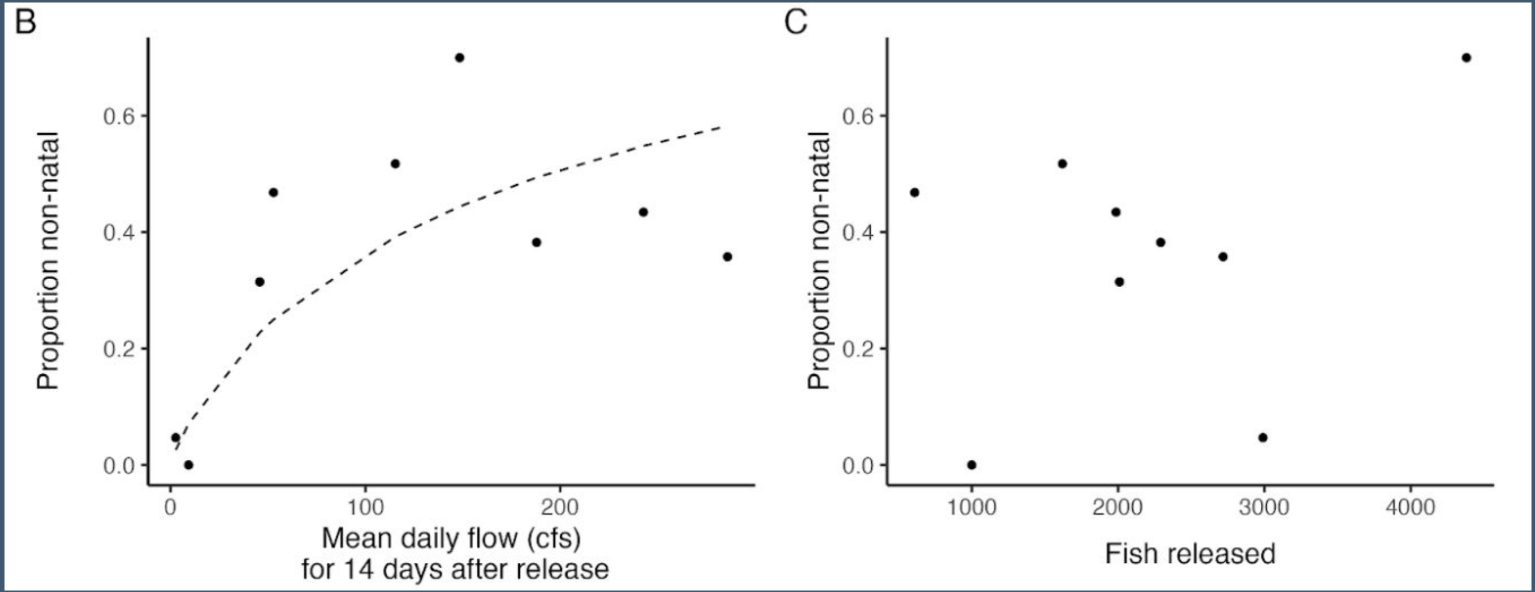


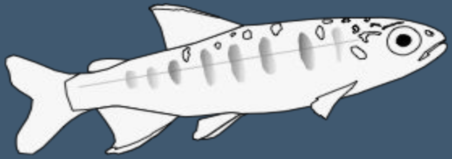
Non-natal rearing is reduced in low flow years

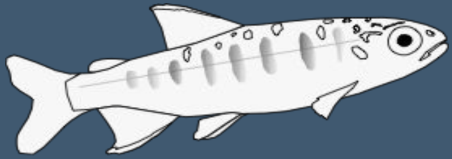


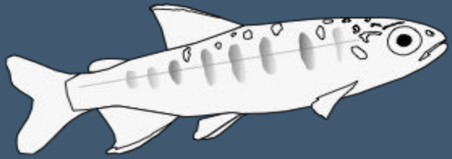




Non-natal rearing is reduced in low flow years, but is unrelated to intraspecific competition









Part 1 Conclusions:

- Juvenile coho exhibit bimodal variation in downmigration timing

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ECOLOGY LETTERS

LETTER | Open Access

Variation in Salmon Migration Phenology Bolsters Population Stability but Is Threatened by Drought

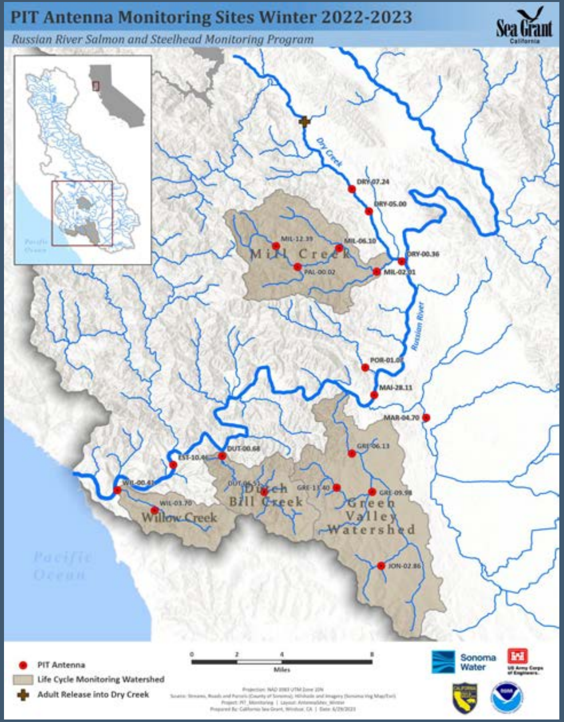
Henry K. Baker, Mariska Obedzinski, Theodore E. Grantham, Stephanie M. Carlson

First published: 23 February 2025 | https://doi.org/10.1111/ele.70081

Part 2: Non-natal rearing in other tributaries

Do recipient habitat characteristics affect the frequency, phenology, and location of non-natal rearing?

- Stream gradient
- Position within the river network



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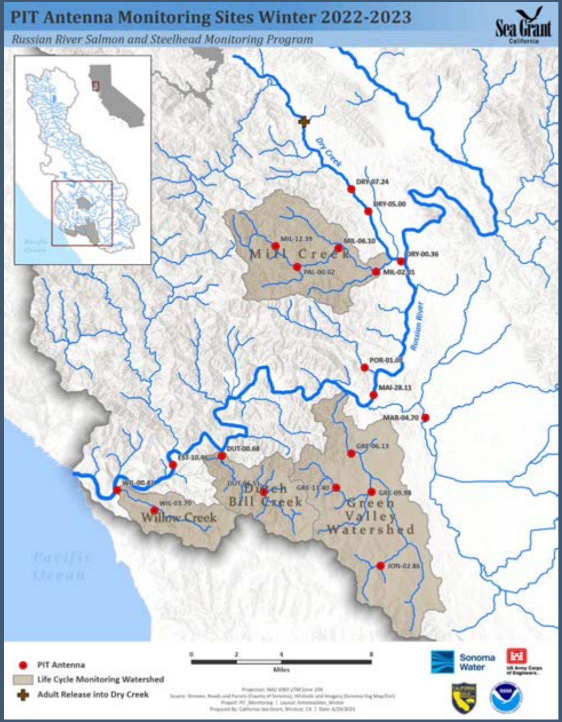
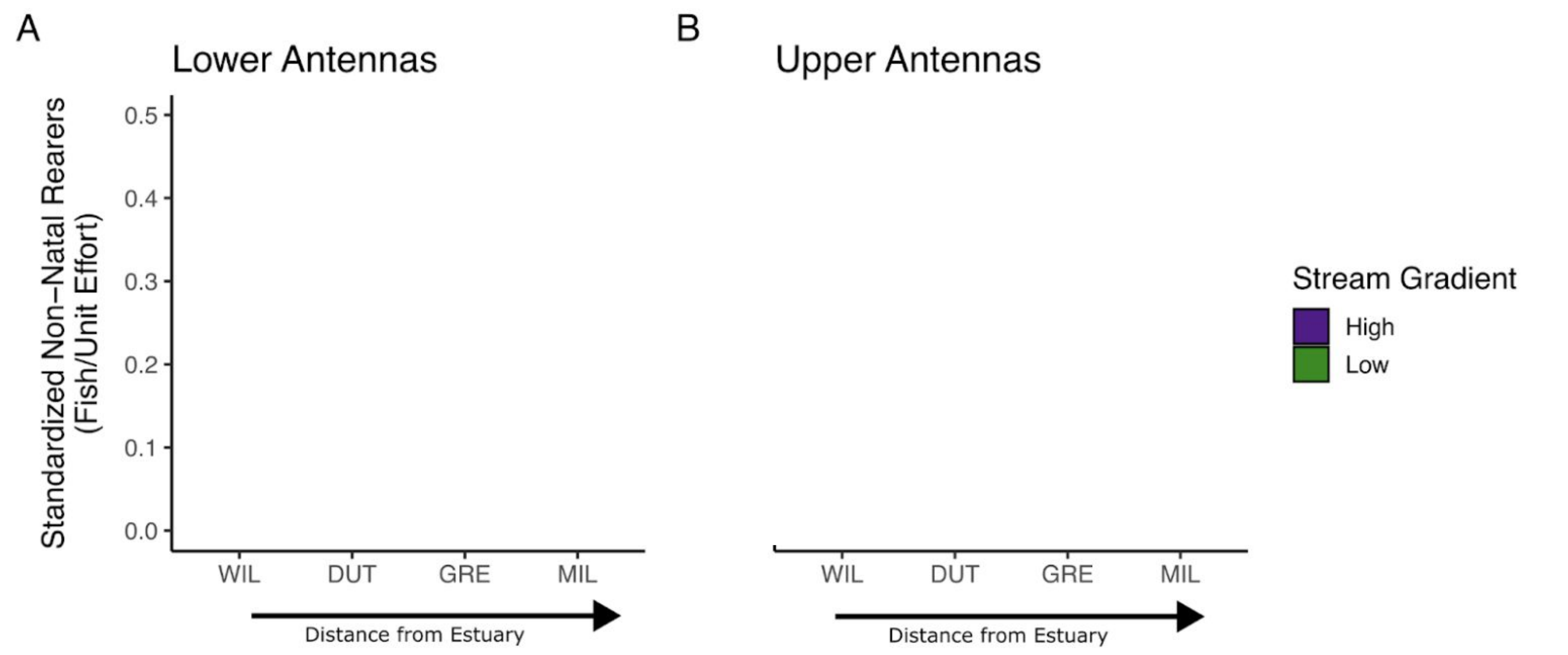
1,794,884 records of 374,969 individual fish

- Non-natal rearers: 31,639 observations of 2738 individual fish (0.73% of all fish)



Low network position yields more non-natal rearers; Stream gradient affects location of non-natal rearing



Low network position yields more non-natal rearers;
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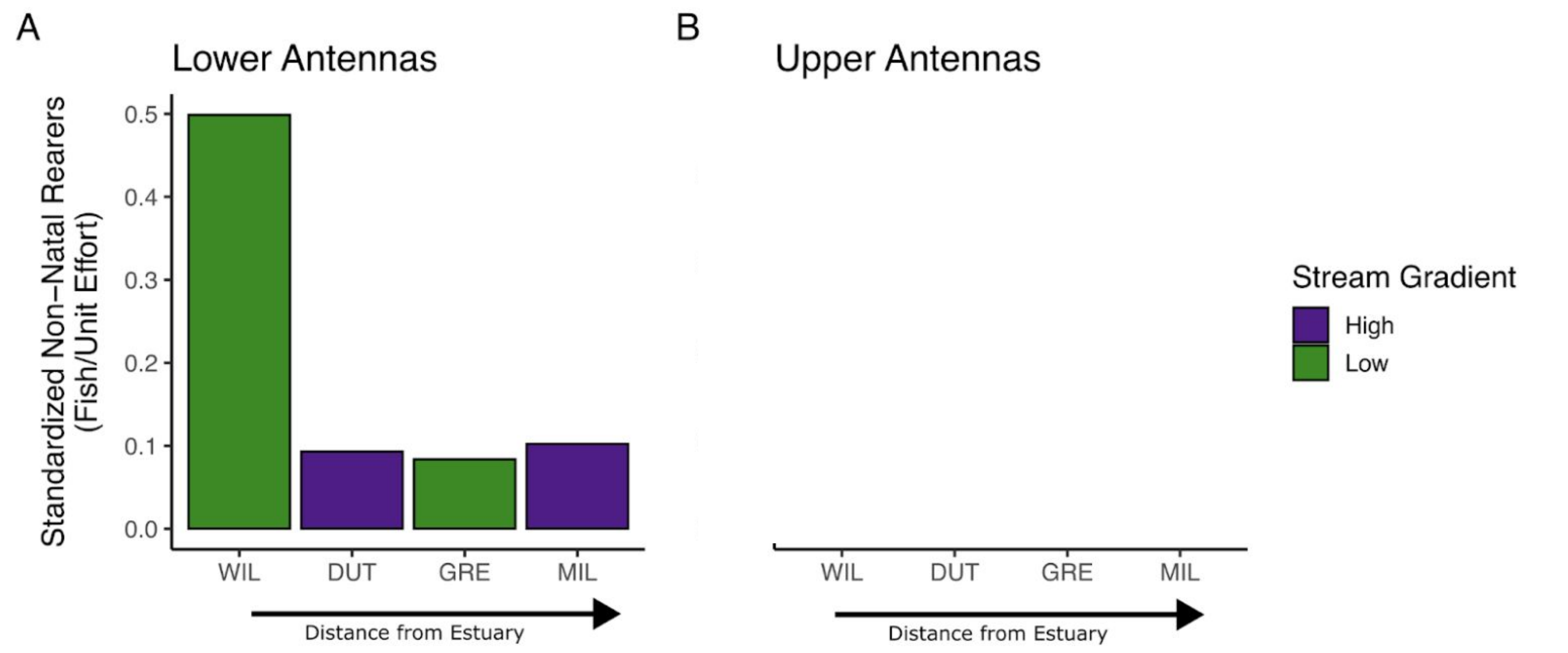
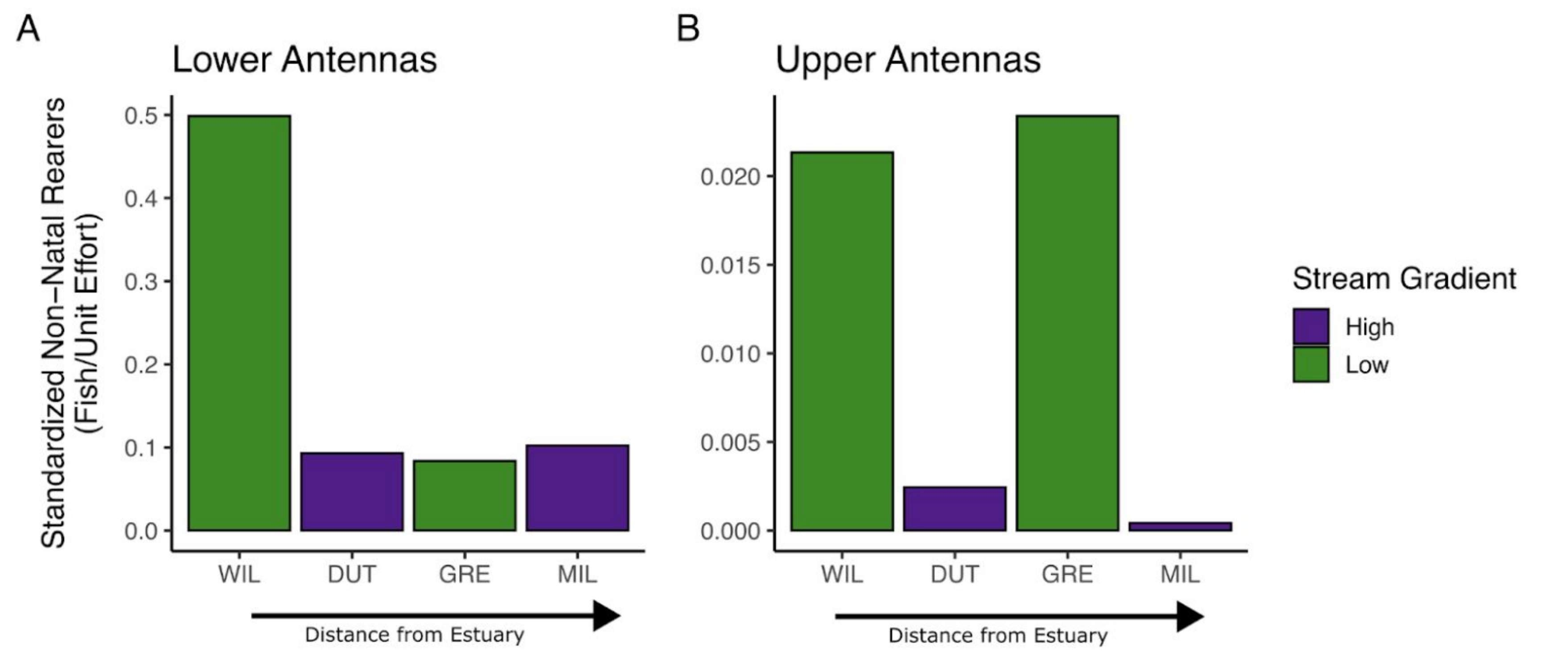
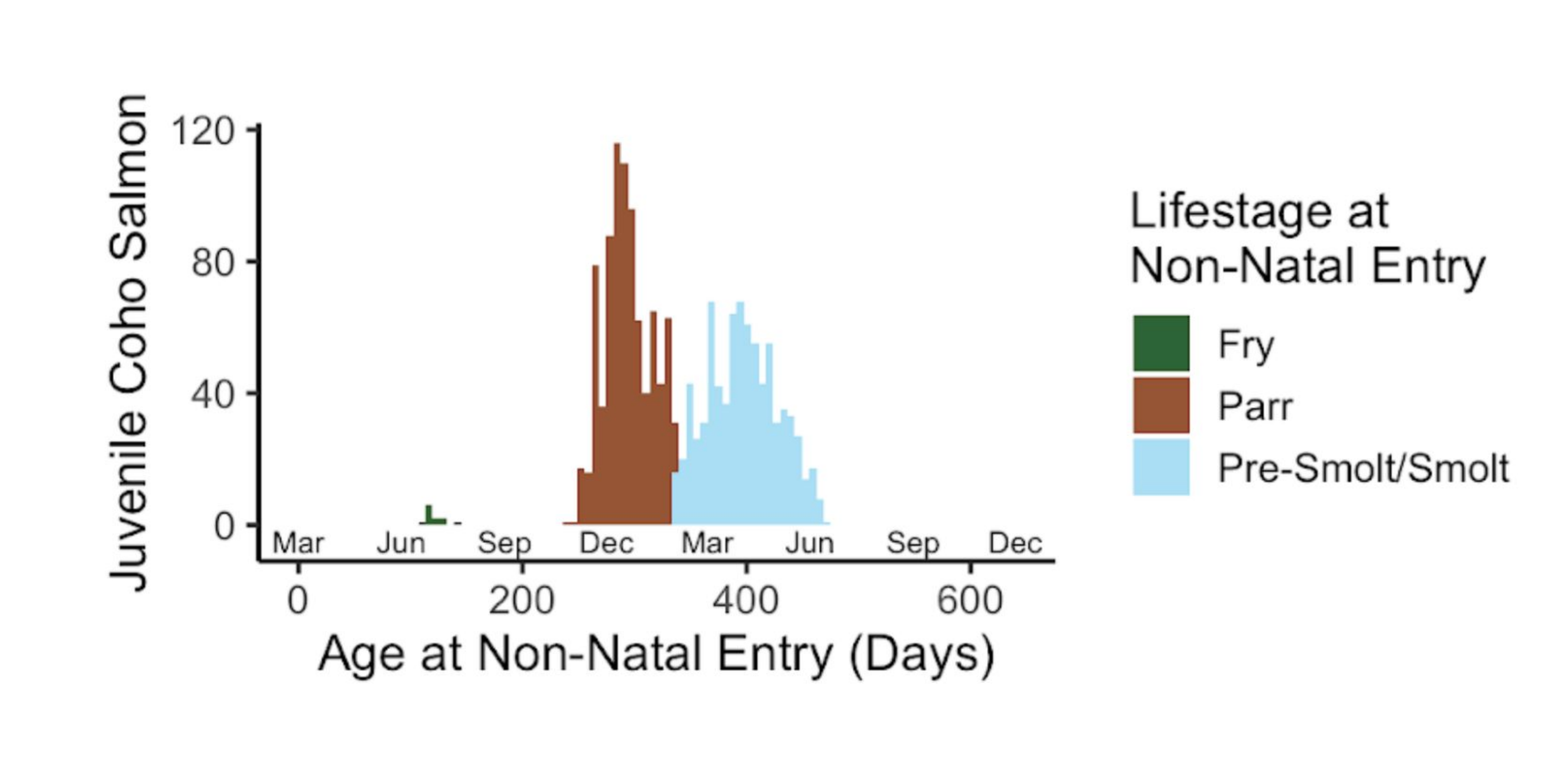


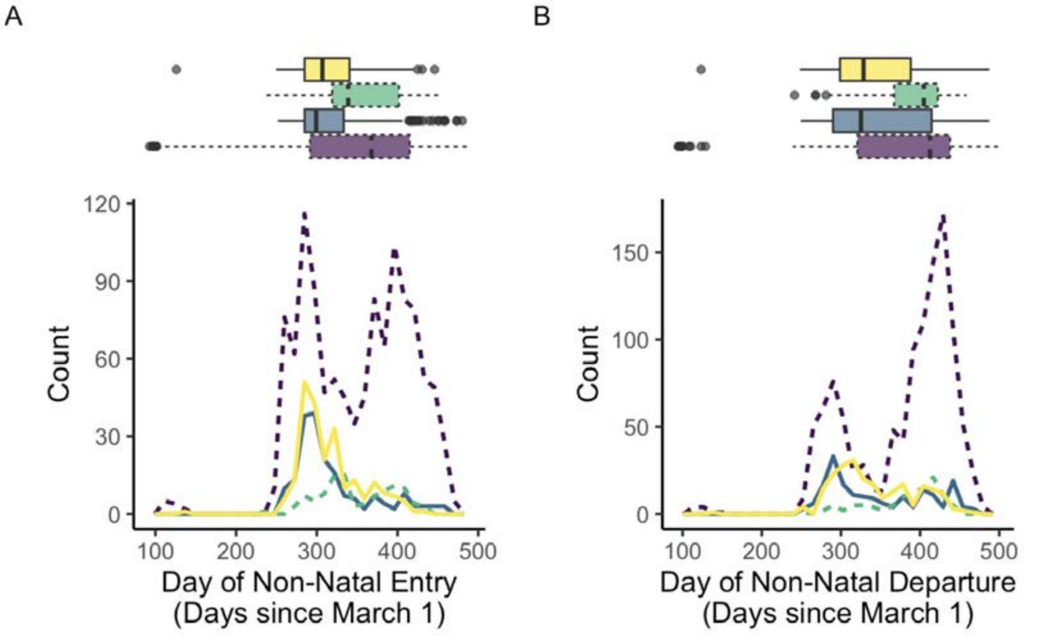
Low network position yields more non-natal rearers; Stream gradient affects location of non-natal rearing



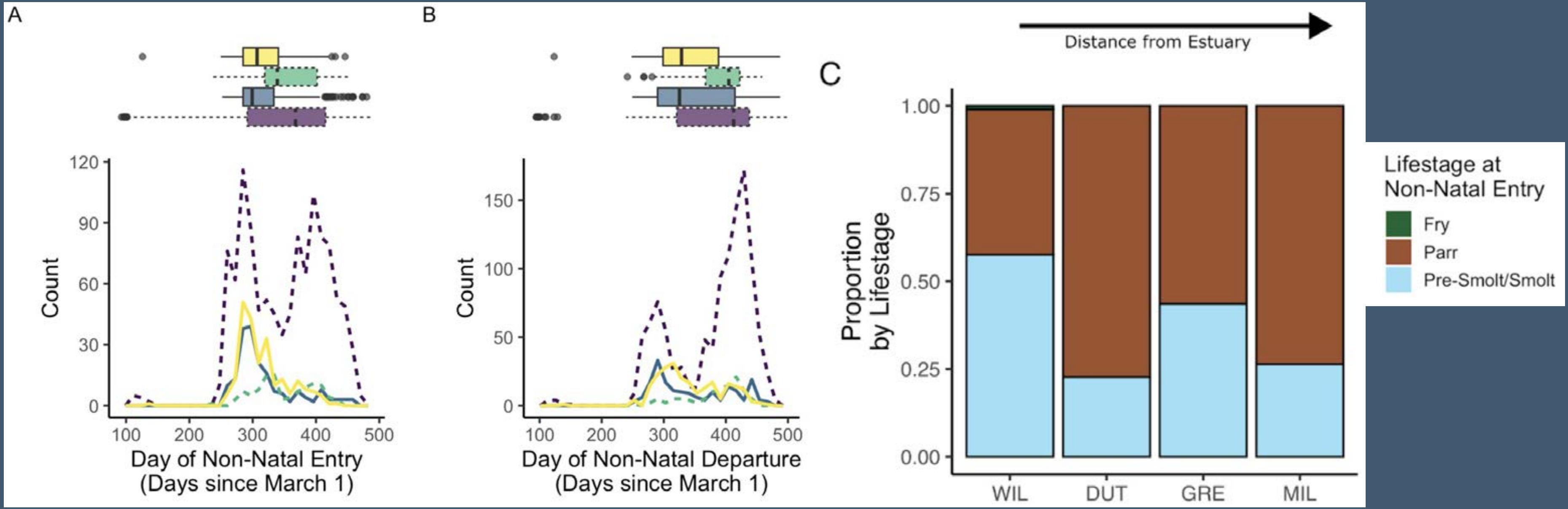
Phenology of non-natal entry



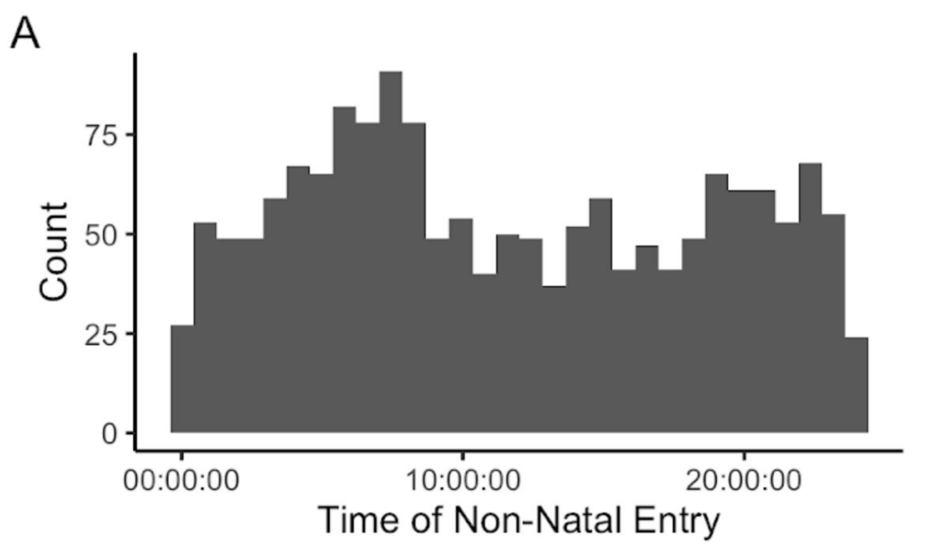
Stream gradient affects phenology of non-natal habitat use

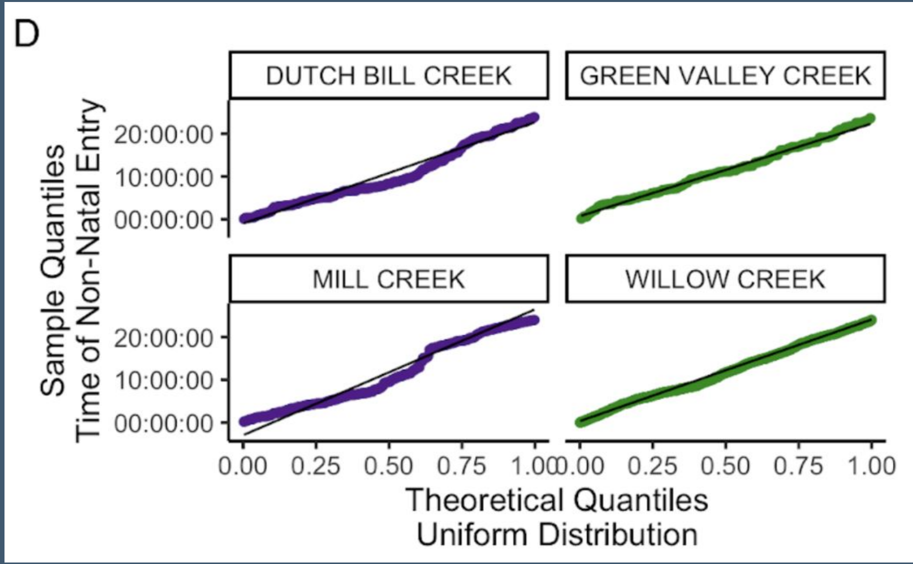


Stream gradient affects phenology of non-natal habitat use



Stream gradient affects time of day of non-natal habitat entry



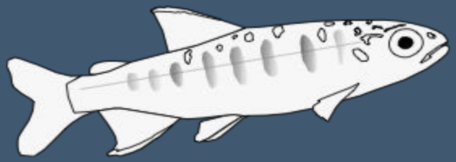
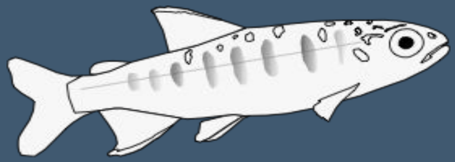
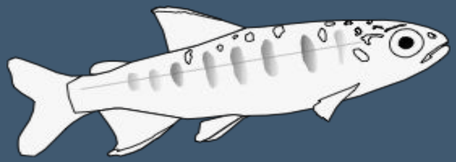


Part 2 Conclusions:

- Non-natal rearing is most common in stream nearest to the mouth
- Stream gradient affects timing of entry and location of rearing

Key Takeaways:

1. Juvenile coho salmon are more diverse than is typically appreciated.
2. Even subtle diversity can have large effects on population dynamics.
3. Managing for diversity will improve outcomes.
4. Large datasets are required to understand ‘alternate’ phenotypes.

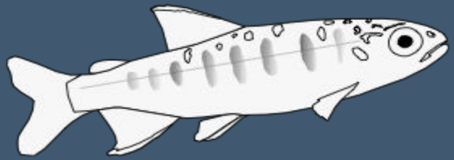




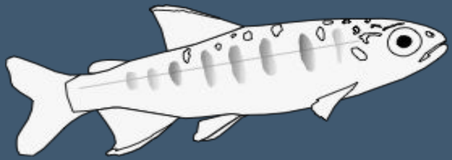
Acknowledgements

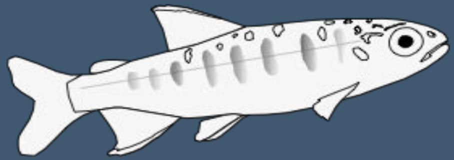
- Mariska Obedzinski (CSG, UC Berkeley)
- Ted Grantham (UC Berkeley)
- Stephanie Carlson (UC Berkeley)
- Will Boucher (Goldridge RCD)
- Gregg Horton (SW)
- Andrew Bartshire (CSG)
- Berkeley Freshwater Labs

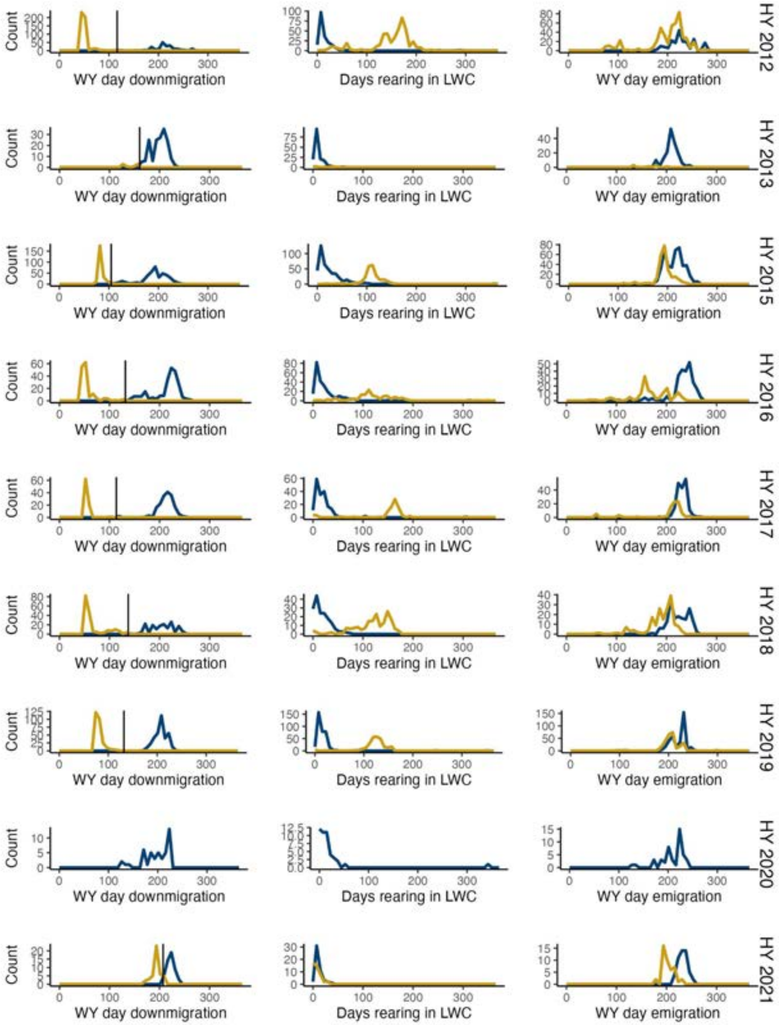
@hankbaker.bsky.social

hbaker@berkeley.edu









Count
WY day downmigration
Days rearing in LWC
WY day emigration
HY 2012
HY 2013
HY 2015
HY 2016
HY 2017
HY 2018
HY 2019
HY 2020
HY 2021

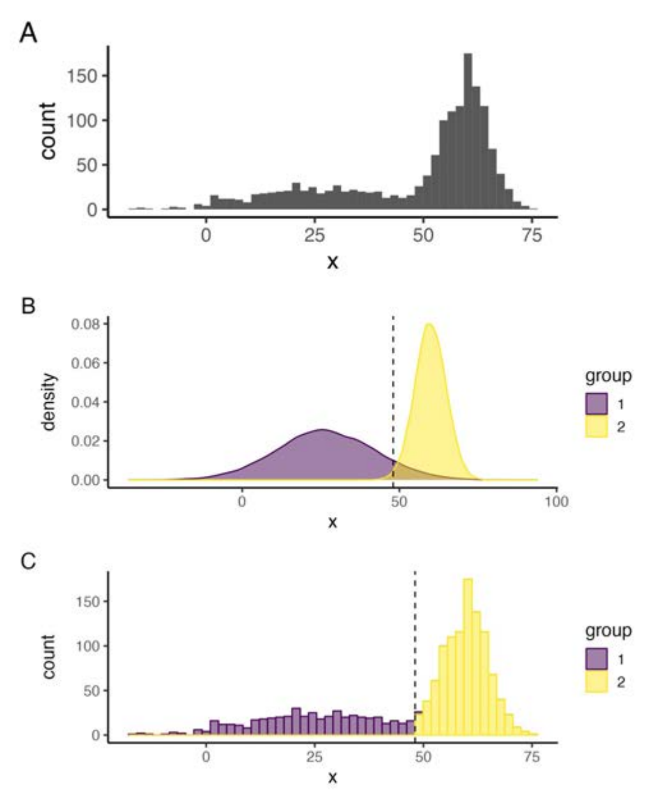
Classifying natal and non-natal rearing coho

Fit finite gaussian mixture model

Simulate data based on model

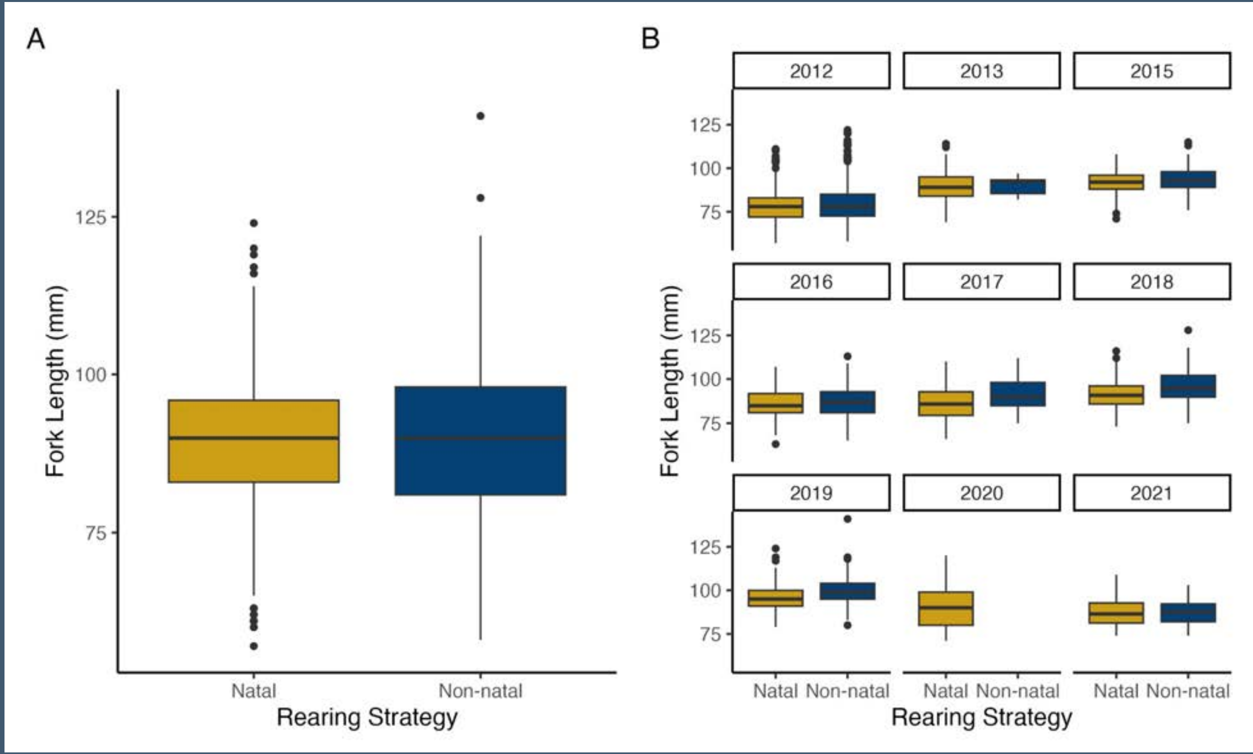
Find threshold that minimizes classification error

Apply threshold to empirical data

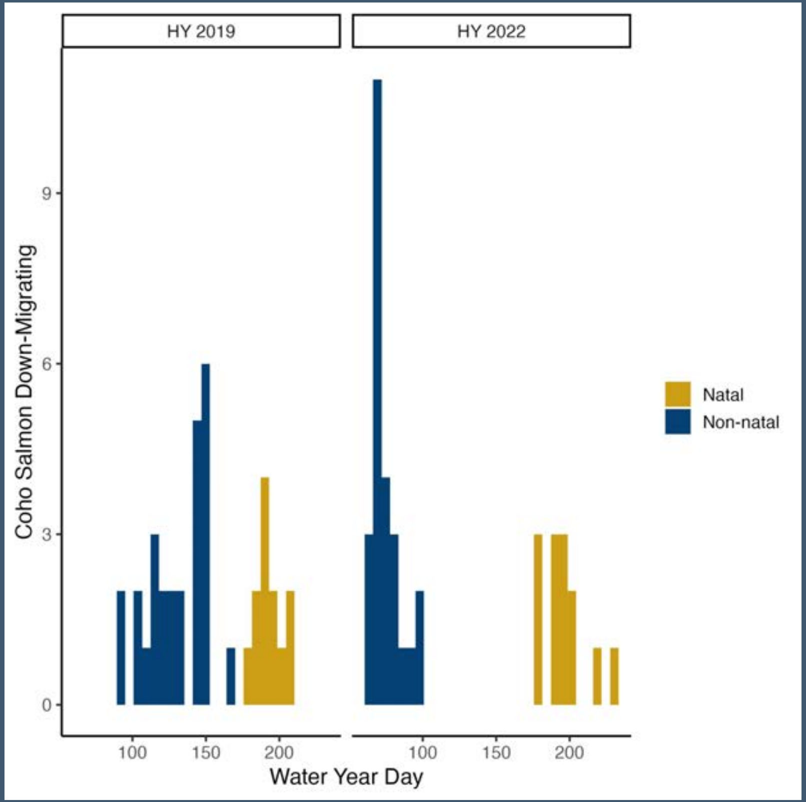


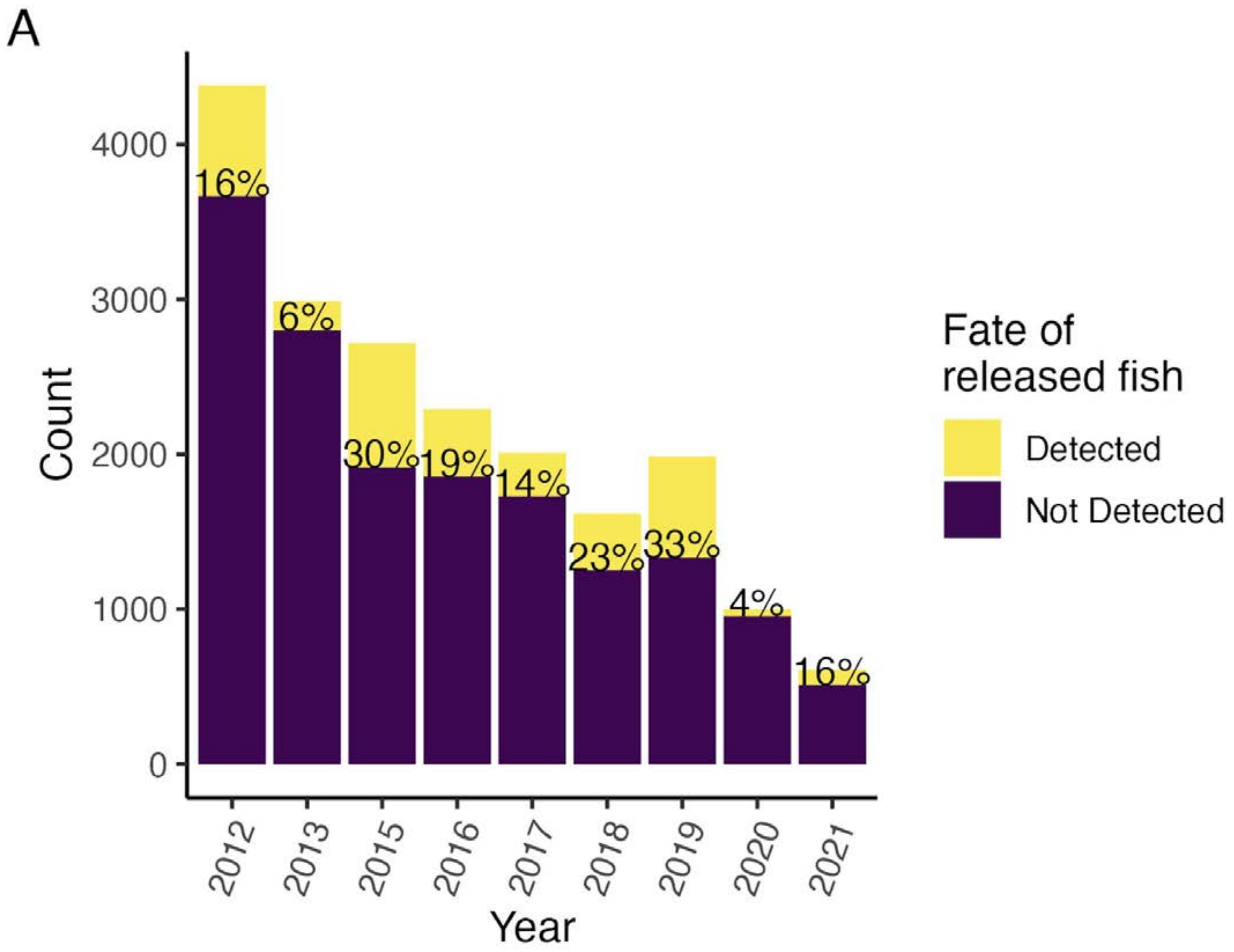
Sethi et al. (2017) *Fisheries Research*

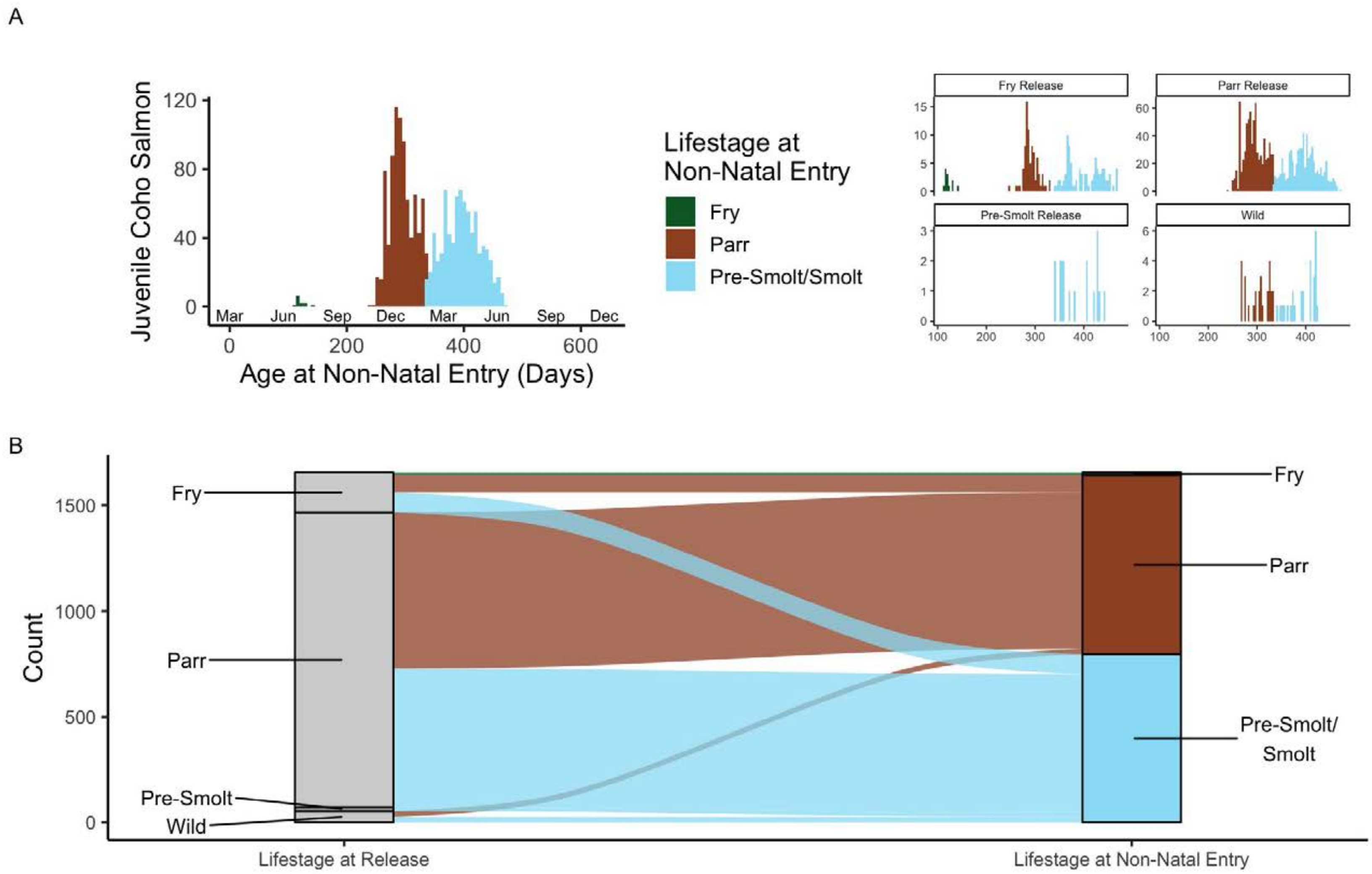
No differences in size at release



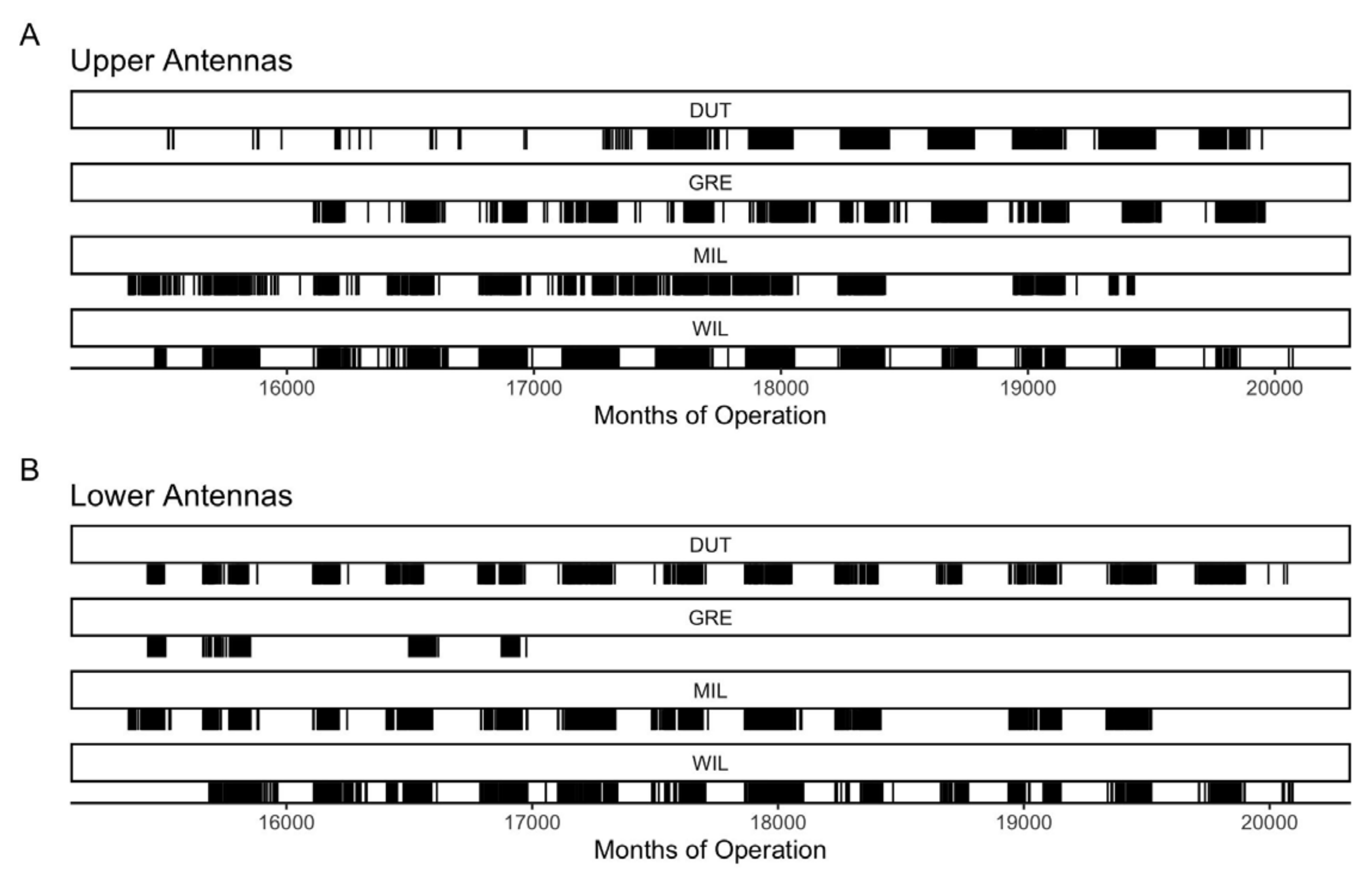
Wild fish also exhibit bimodal variation



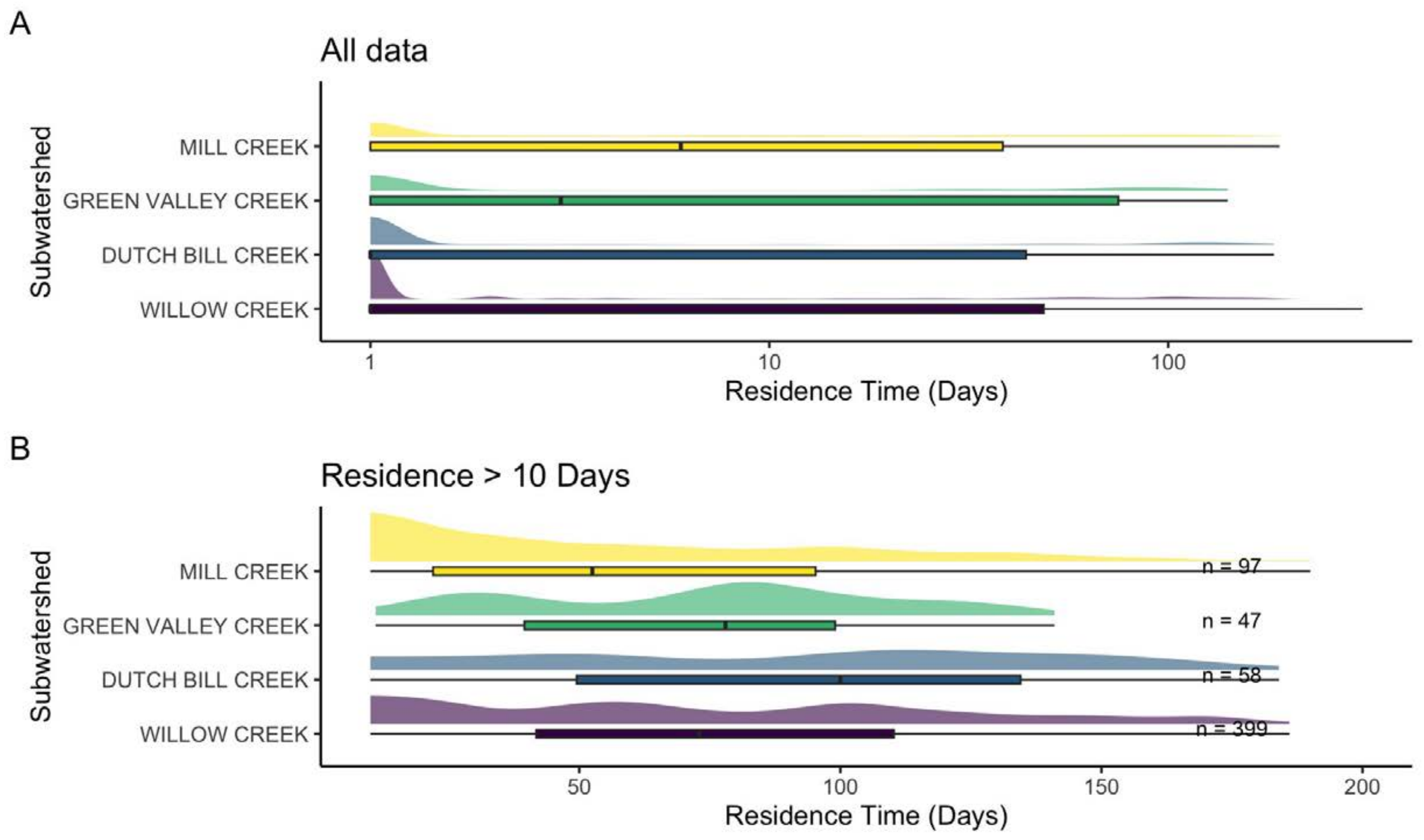

A
Count
4000
3000
2000
1000
0
16%
6%
30%
19%
14%
23%
33%
4%
16%
2012
2013
2015
2016
2017
2018
2019
2020
2021
Year
Fate of released fish
Detected
Not Detected

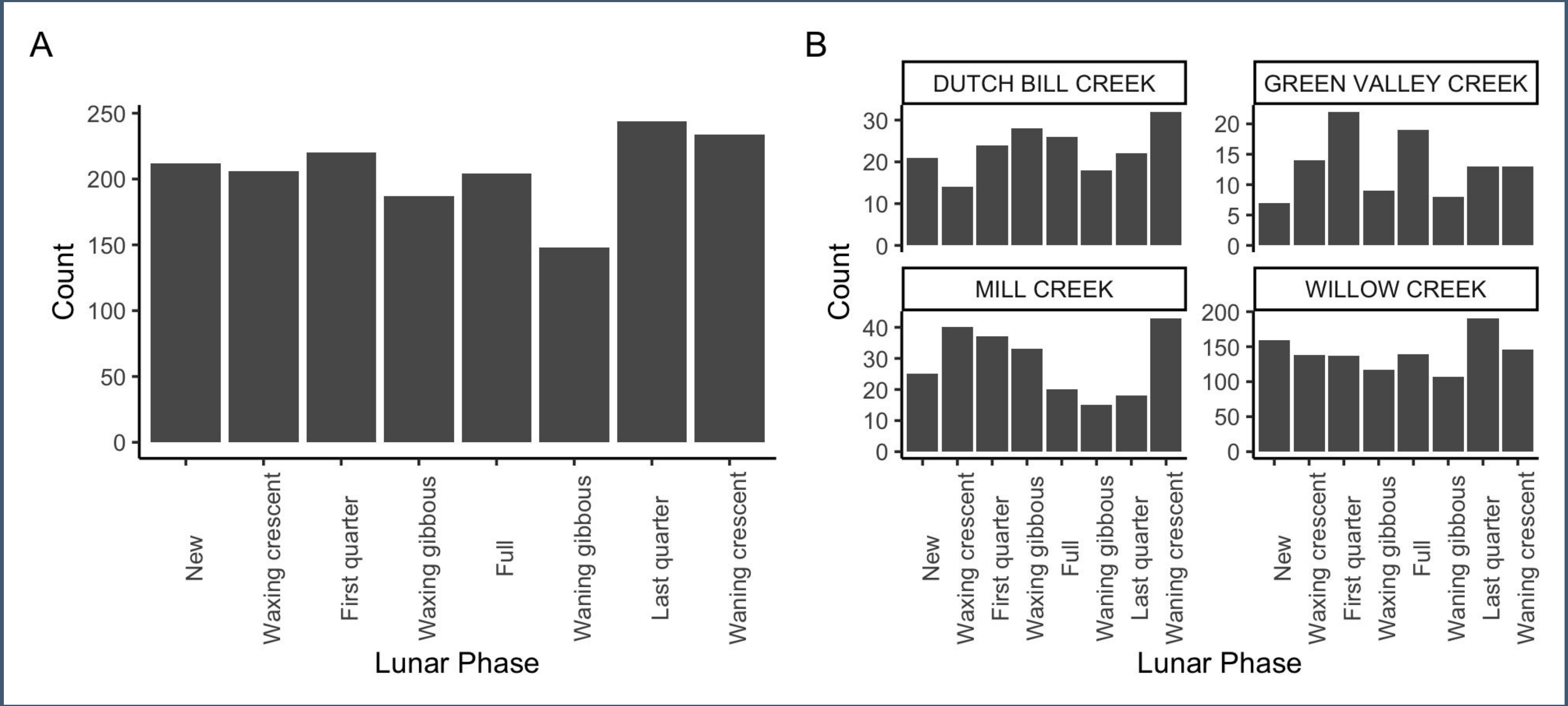


A
Juvenile Coho Salmon
120
80
40
0
Mar
Jun
Sep
Dec
Mar
Jun
Sep
Dec
0
200
400
600
Age at Non-Natal Entry (Days)
Lifestage at Non-Natal Entry
Fry
Parr
Pre-Smolt/Smolt
Fry Release
Parr Release
Pre-Smolt Release
Wild
B
Count
1500
1000
500
0
Fry
Parr
Pre-Smolt
Wild
Fry
Parr
Pre-Smolt/ Smolt
Lifestage at Release
Lifestage at Non-Natal Entry



A
Upper Antennas
DUT
GRE
MIL
WIL
16000
17000
18000
19000
20000
Months of Operation
B
Lower Antennas
DUT
GRE
MIL
WIL
16000
17000
18000
19000
20000
Months of Operation


A
All data
Subwatershed
MILL CREEK
GREEN VALLEY CREEK
DUTCH BILL CREEK
WILLOW CREEK
1
10
100
Residence Time (Days)
B
Residence > 10 Days
Subwatershed
MILL CREEK
GREEN VALLEY CREEK
DUTCH BILL CREEK
WILLOW CREEK
n = 97
n = 47
n = 58
n = 399
50
100
150
200
Residence Time (Days)


A
Count
250
200
150
100
50
0
New
Waxing crescent
First quarter
Waxing gibbous
Full
Waning gibbous
Last quarter
Waning crescent
Lunar Phase
B
DUTCH BILL CREEK
GREEN VALLEY CREEK
MILL CREEK
WILLOW CREEK
Count
Lunar Phase

River Rest Stops: The Effects of Floodplain Food Subsidies on Chinook Outmigration Transit Time

Adrian Loera

M.S Student Lusardi Lab UC Davis

Funded by CalTrout and The Bureau of Reclamation

Background

- Historic records show California's chinook salmon population decline as early as 1920's
- CA central valley salmon population has decreased to less than 75% of past numbers
- Fall/Late-Fall run salmon are listed as a species of concern; Spring run are threatened; and Winter run are endangered

- Channelization has created river disconnect from valuable floodplain habitats
- No longer have access to connecting floodplains
- NO ACCESS TO FLOOPLAIN = NO FOOD

Reconnecting Resources

- In 2017 California Trout launched the Fish Food Project
- High residence time of water in these floodplains creates dense zooplankton assemblages
- The project has shown the potential to bolster depleted food resources and help struggling fish populations

Water Export site

Rough and Ready Water Pump

Knights Landing, CA

Need for better understanding

- Current support for Fish Food Program is through caged fish data
- Need for an understanding of free-swimming behavior at these sites

Big picture

If fish are utilizing subsidy, it can better inform salmon management practices

Release salmon during times of high river productivity

Research Questions

Do floodplain food subsidies have an effect on salmon outmigration times?

Will outmigrating salmon spend longer times in subsidized portions of the river?

Methods

- Acoustic Telemetry Array
- Zooplankton Sampling
- Fish Growth Monitoring


Upstream Rec 1
Kirkville
Control Reach
Sub Zone Rec 1
Export Site
Subsidy Zone
Water Pump
Cranmore Rd
Sub Zone Rec 2
Subsidized Reach
Reclamation Rd
Robbins
Sub zone Rec 3

Acoustic Array

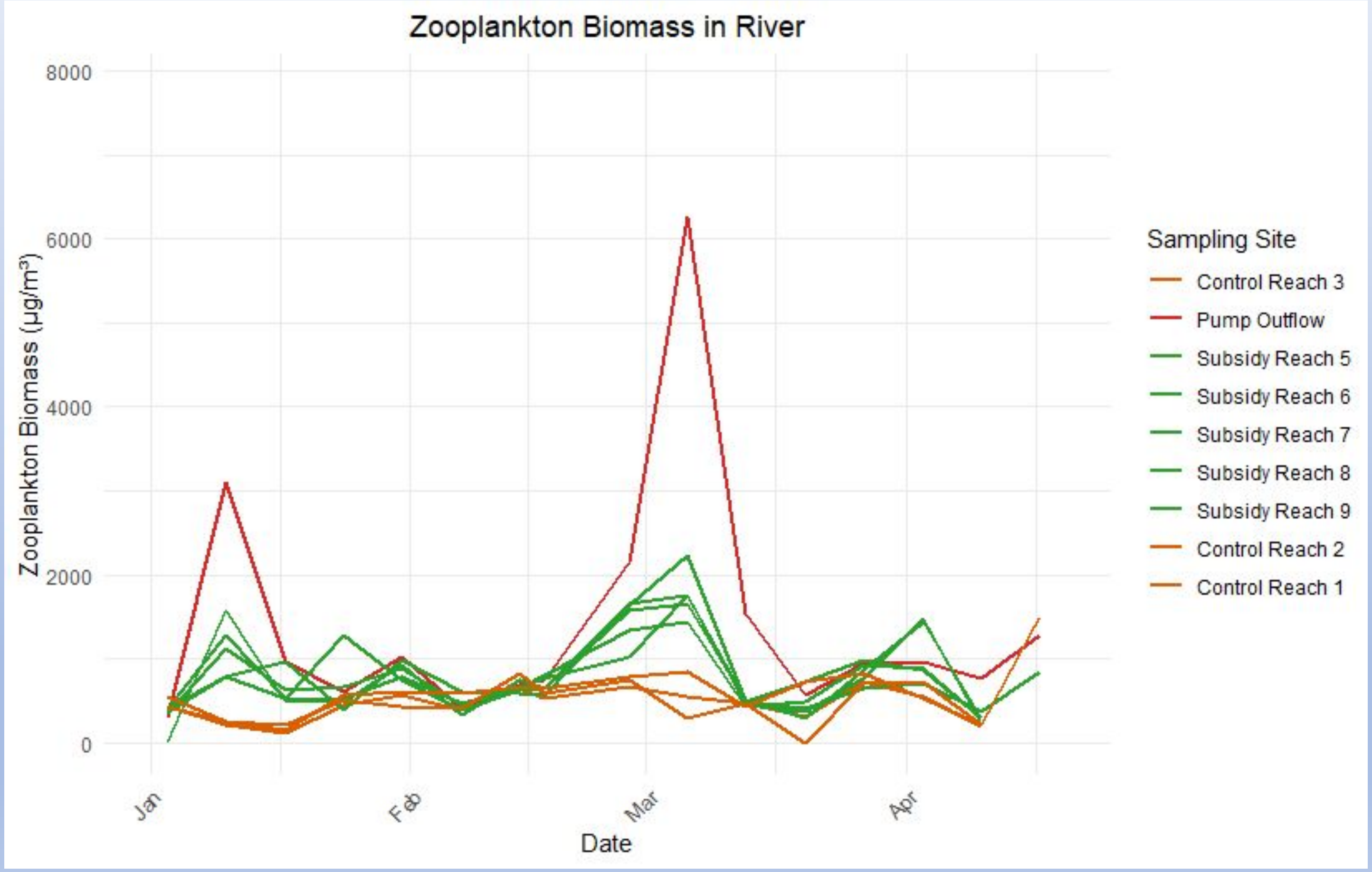
- 5 Tekno receivers (recovered)
  - 2 additional recs downloaded
- 13.18 river km long
- Deployment date: Jan 2023 Recovery date: May 2023
- 800 possible tagged fish released at Red Bluff as part of NOAA Fisheries "Seasonal Survival Hatchery Experiment"

Zooplankton Sampling

Fish Growth

2023 Preliminary Results

River Zooplankton Abundance



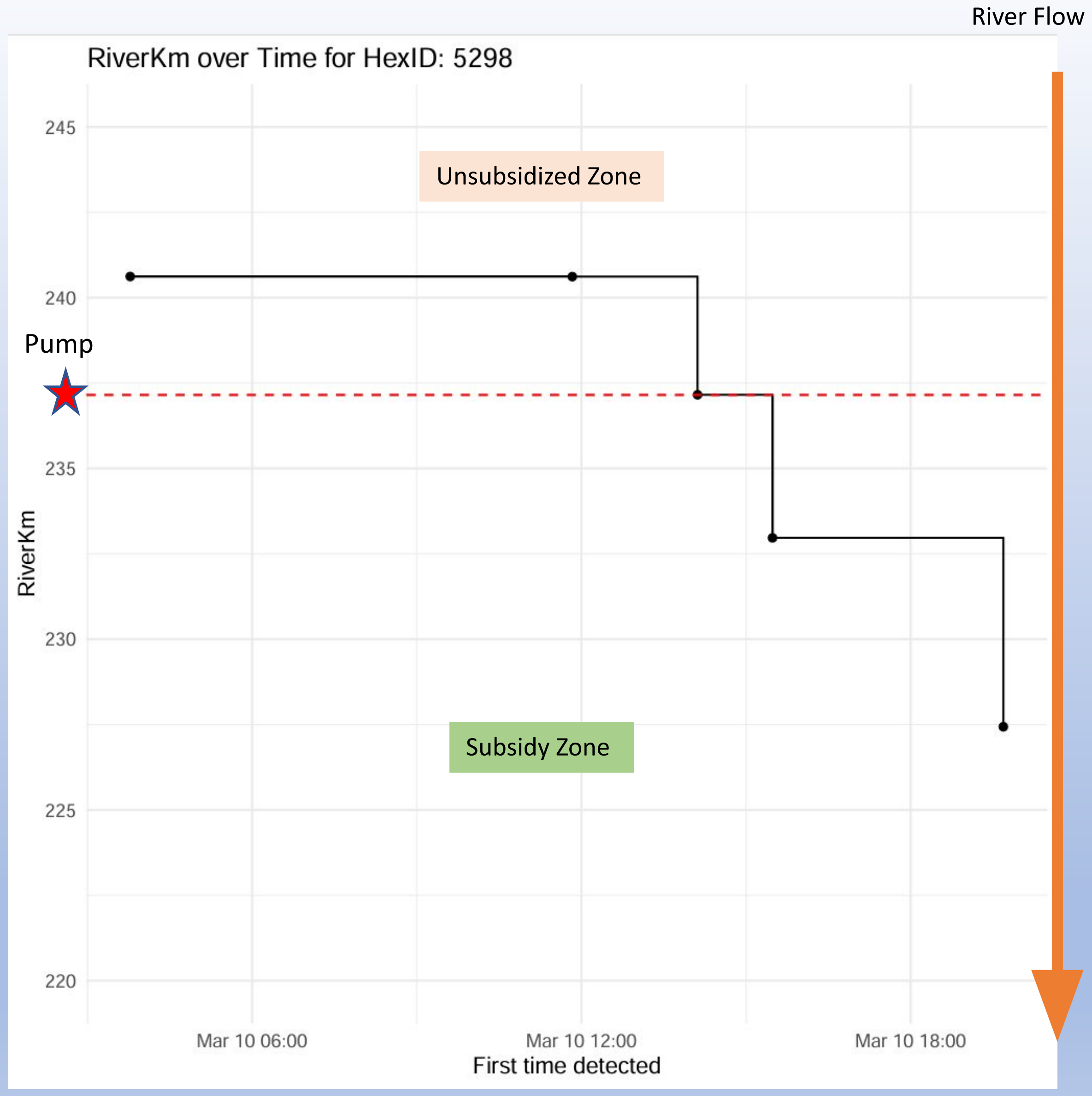
Growth Rates

Fish Ground Speeds

Over 200 different tagged fish were picked up by the array

8 hrs in array

Transit Plot (fast fish)

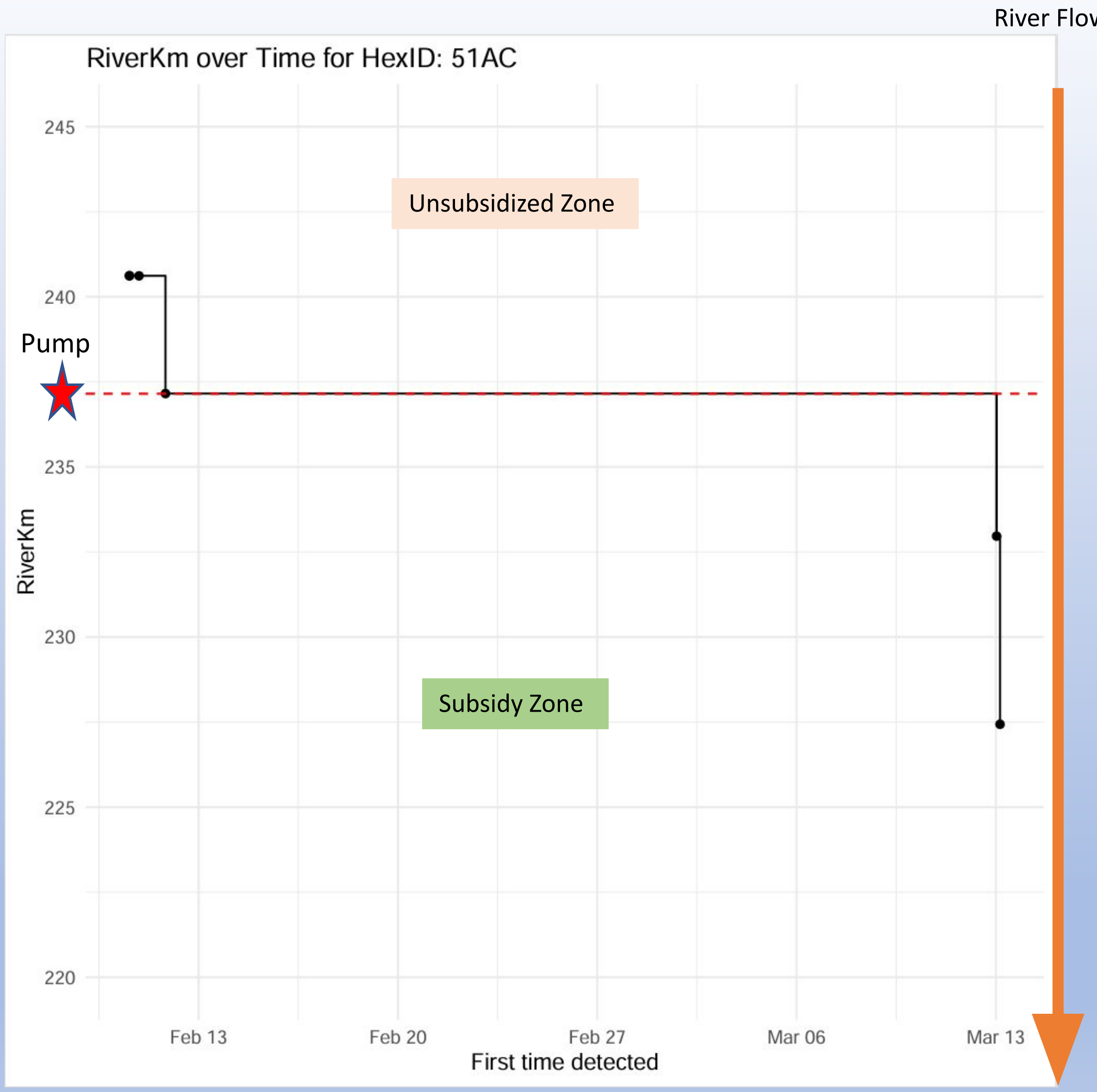


1 Day and 6 hrs in array

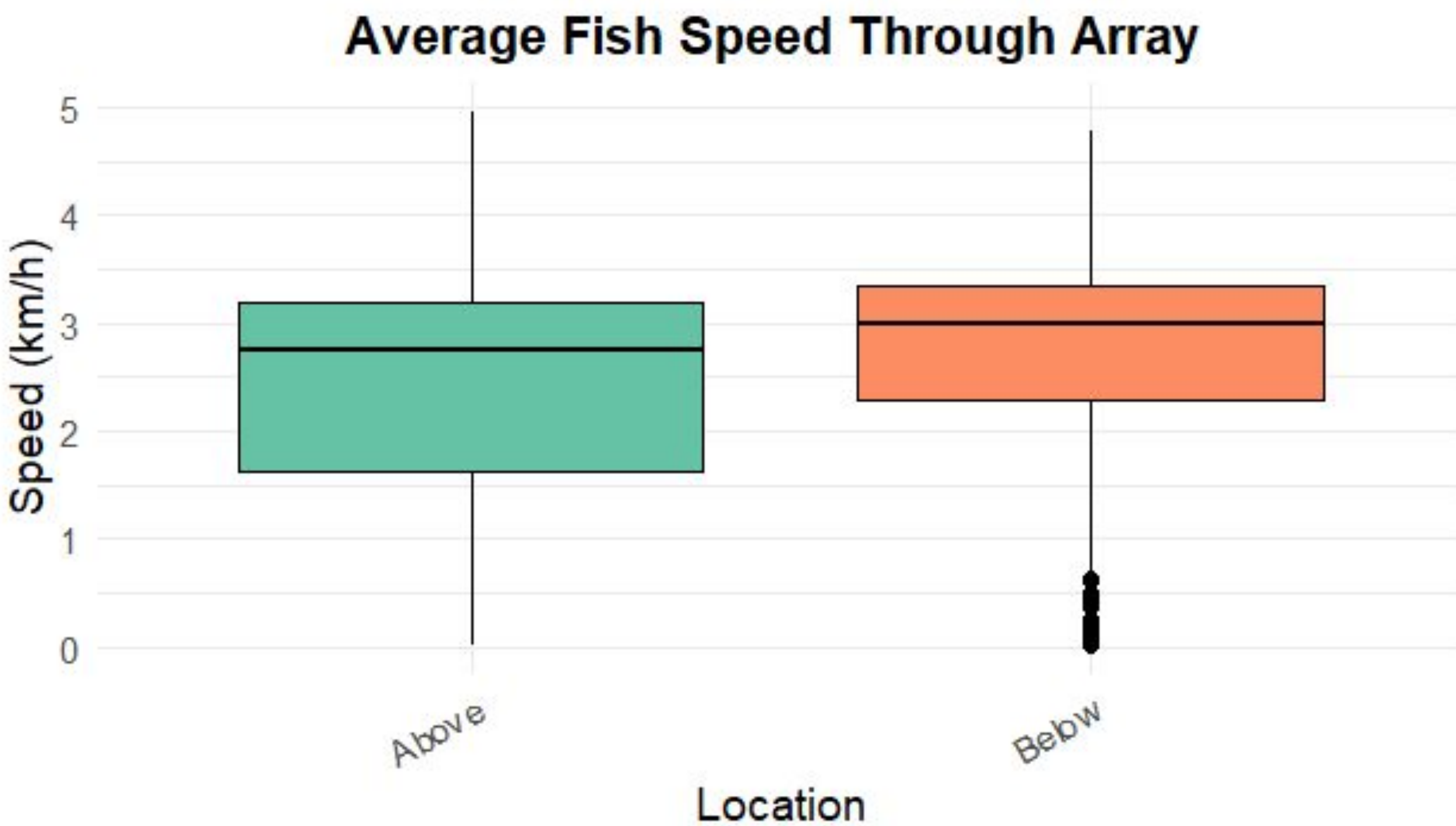
Transit Plot (medium speed)

1 month and 3 days in array

Transit Plot (slow speed)

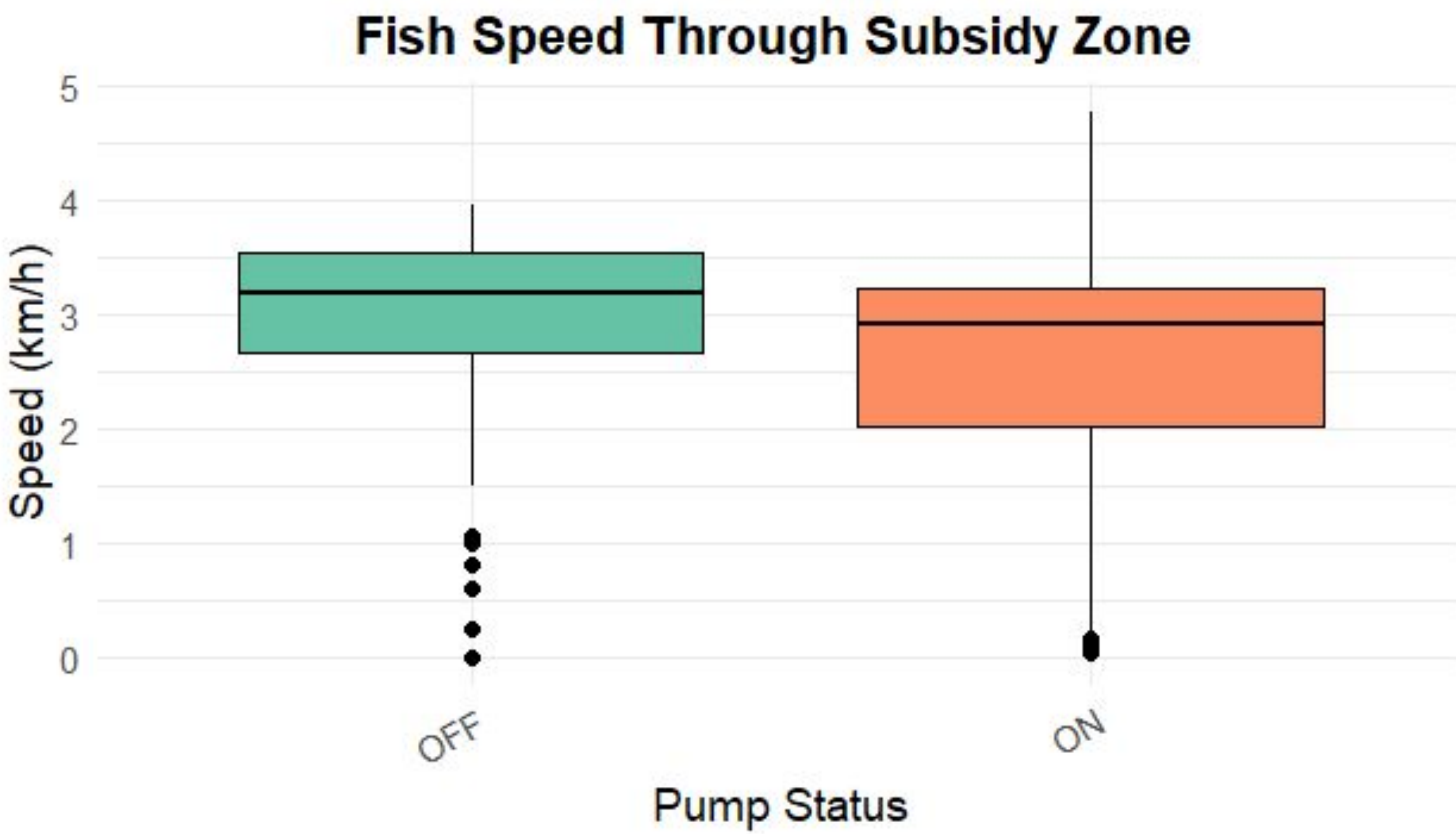


Avg speed above pump -> 2.36km/h
Avg speed below pump -> 2.63km/h



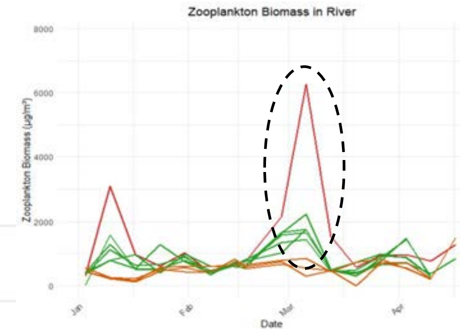
ANOVA P = 0.0267

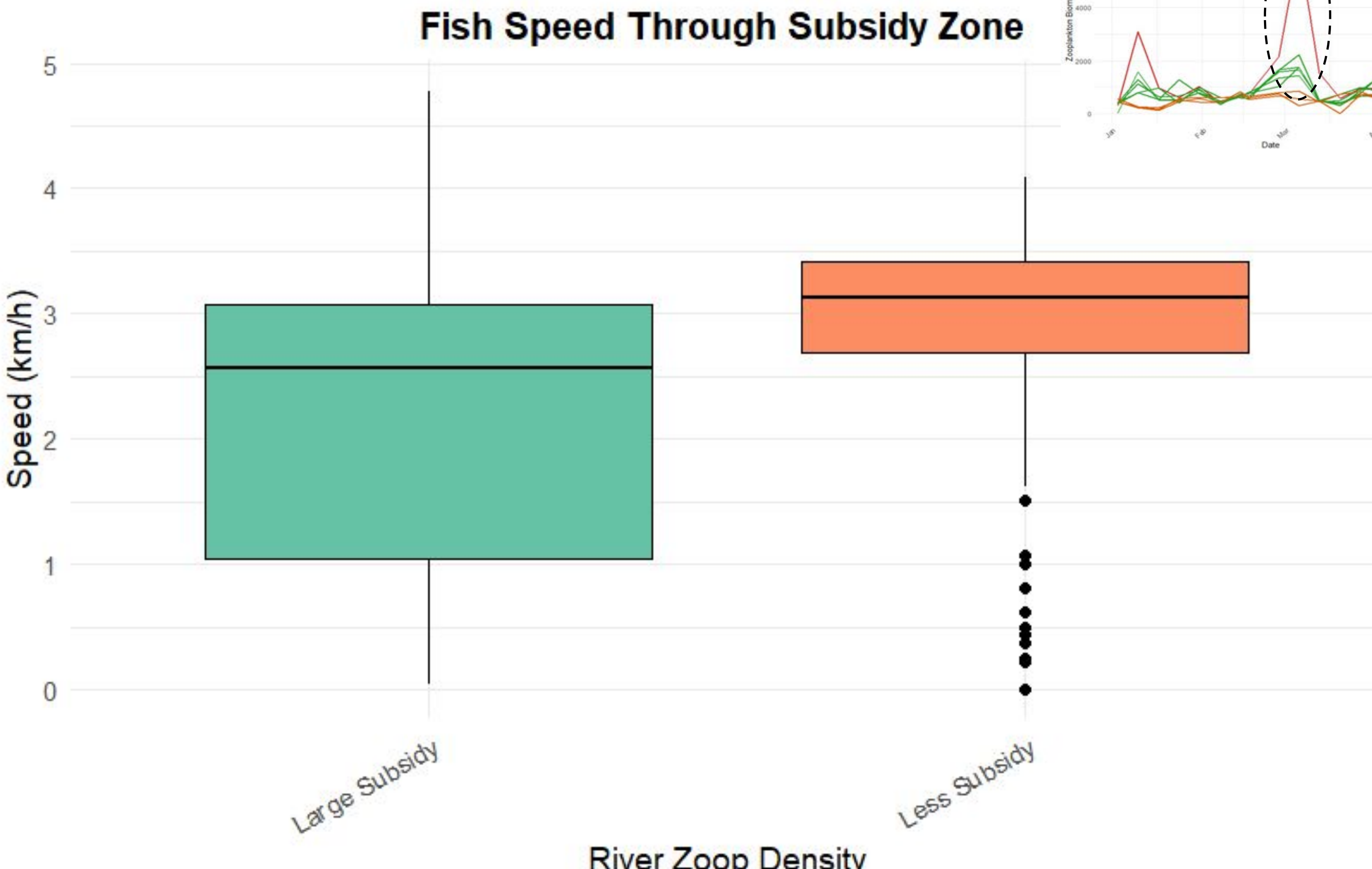
Avg speed pump ON -> 2.52km/h
Avg speed pump OFF -> 2.86km/h



ANOVA P= 0.0379

Avg speed LARGE SUB -> 2.18km/h
Avg speed LESS SUB -> 2.84km/h





ANOVA P= 1.11e^-05

Findings

Some fish do seem to be utilizing food resources

Fish seem to have lower ground speeds during large subsidies

Some extreme examples -> "51AC"

Some fish spent a large time in Fish Food subsidy zone

What’s Next

Include river flow effects in transit times

Look into if fish size at release had a possible effect. Food mode vs migration mode

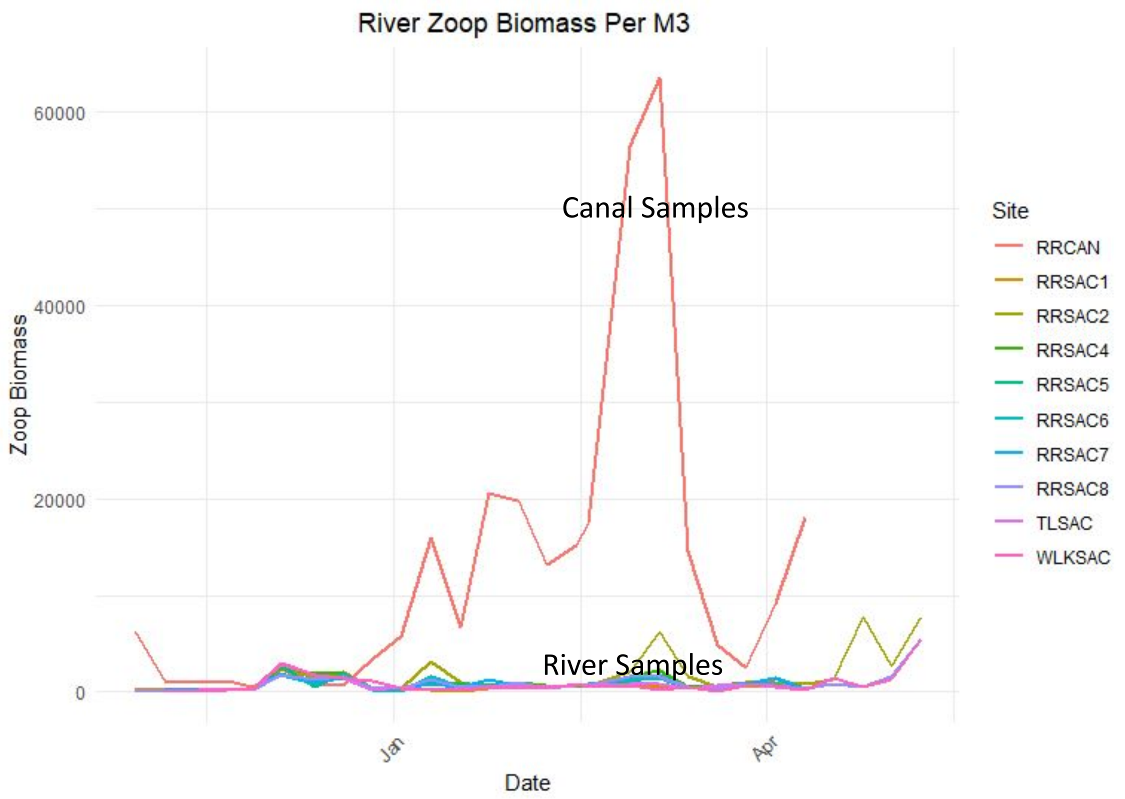
Compare outmigration success rates of fish that passed through a time of subsidy

Thank you

Telemetry Data

- 2 additional receiver detections downloaded for ERDDAP database
- Each individual fish graphed on waterfall plot
- Raw detection files downloaded into R and filtered for accuracy
    - Filters include: False Detection, Predation Events, Single detections & minimum # of receivers hit

Zooplankton Abundance



Fish Food for Thought

Foodscapes and the pivot to process

CALIFORNIA TROUT

FISH · WATER · PEOPLE

Jacob Katz – California Trout

C. Jeffres

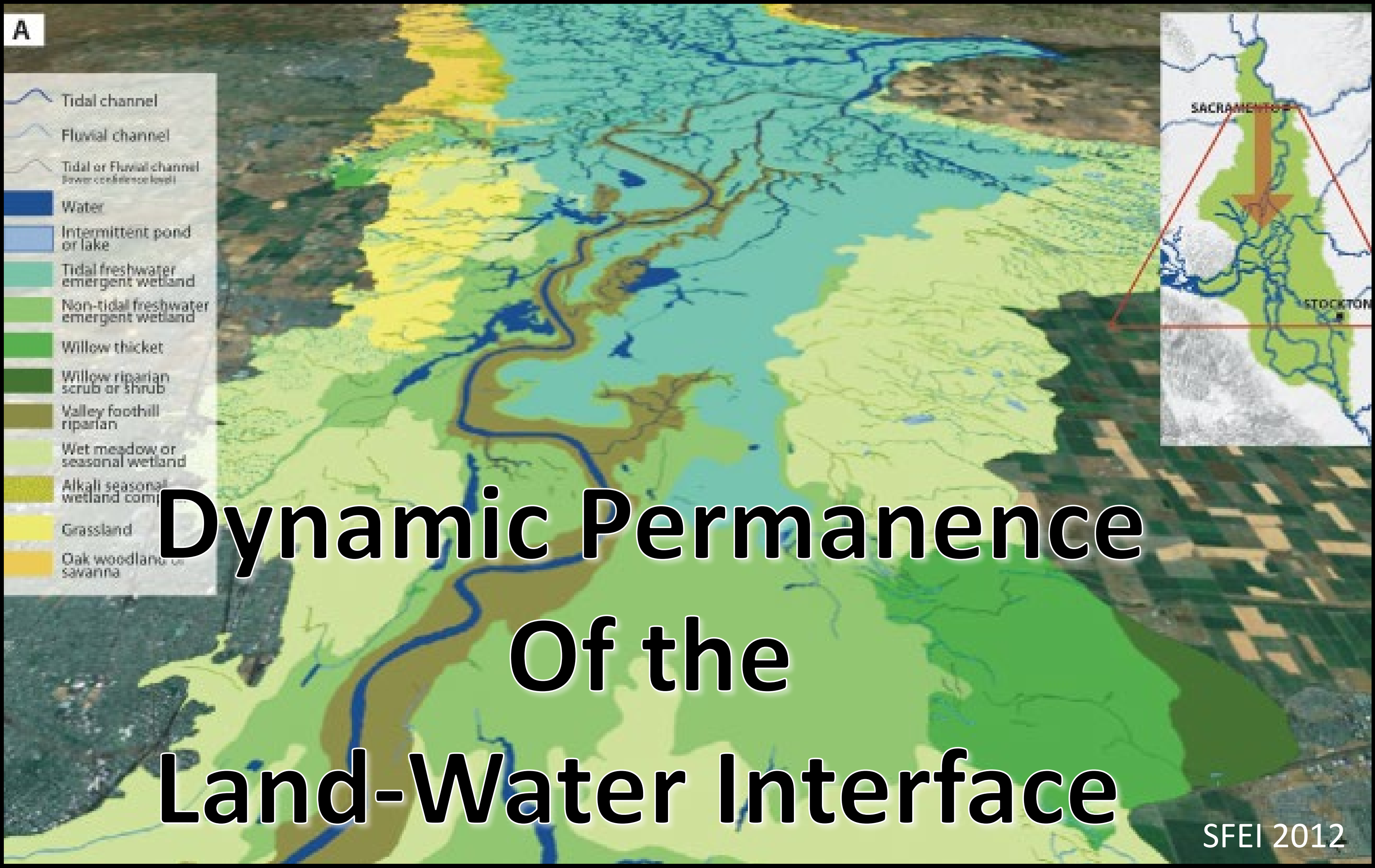
Process-Based Reconciliation

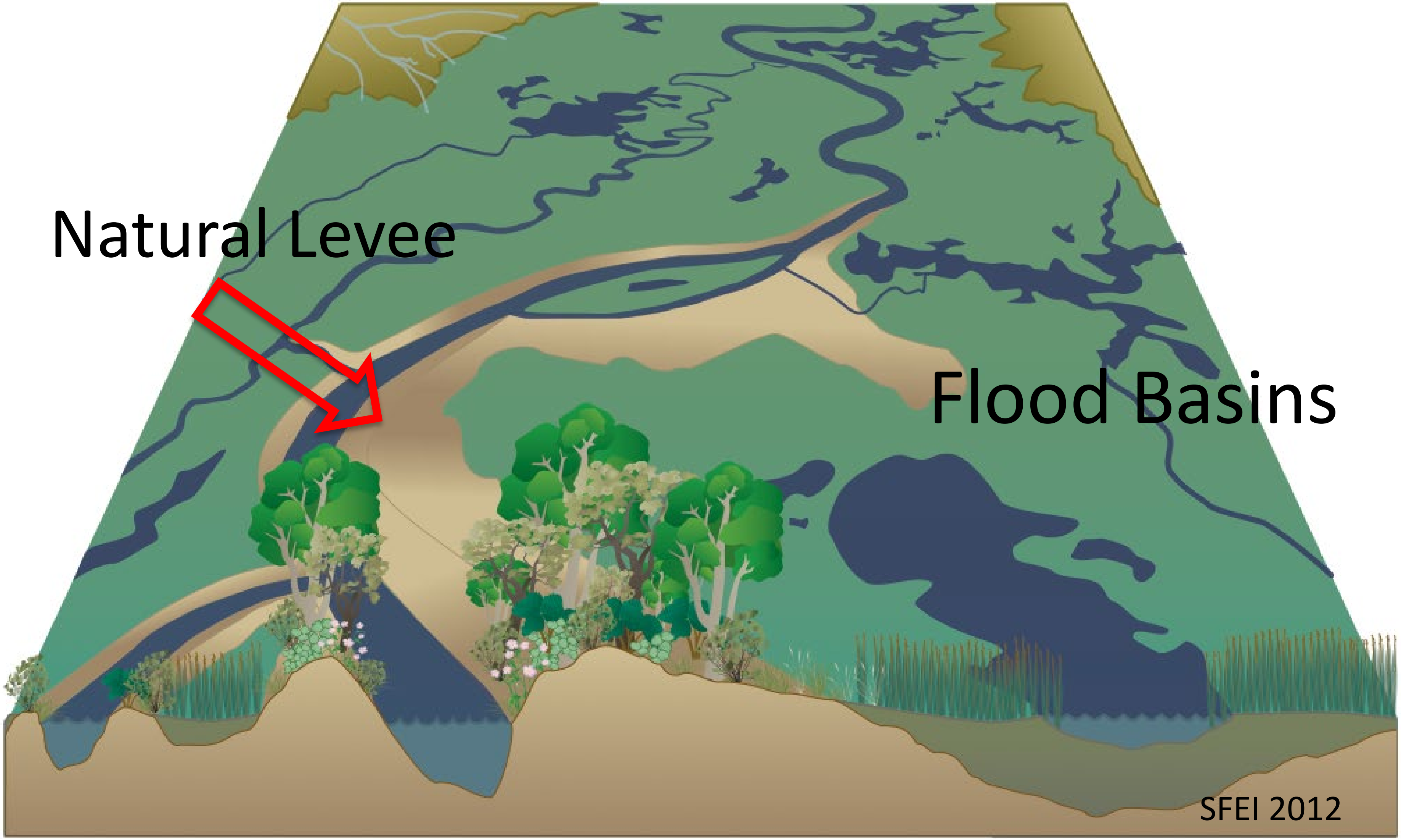
Integrating a working knowledge of natural process, into the management of natural resources




Sacramento Valley

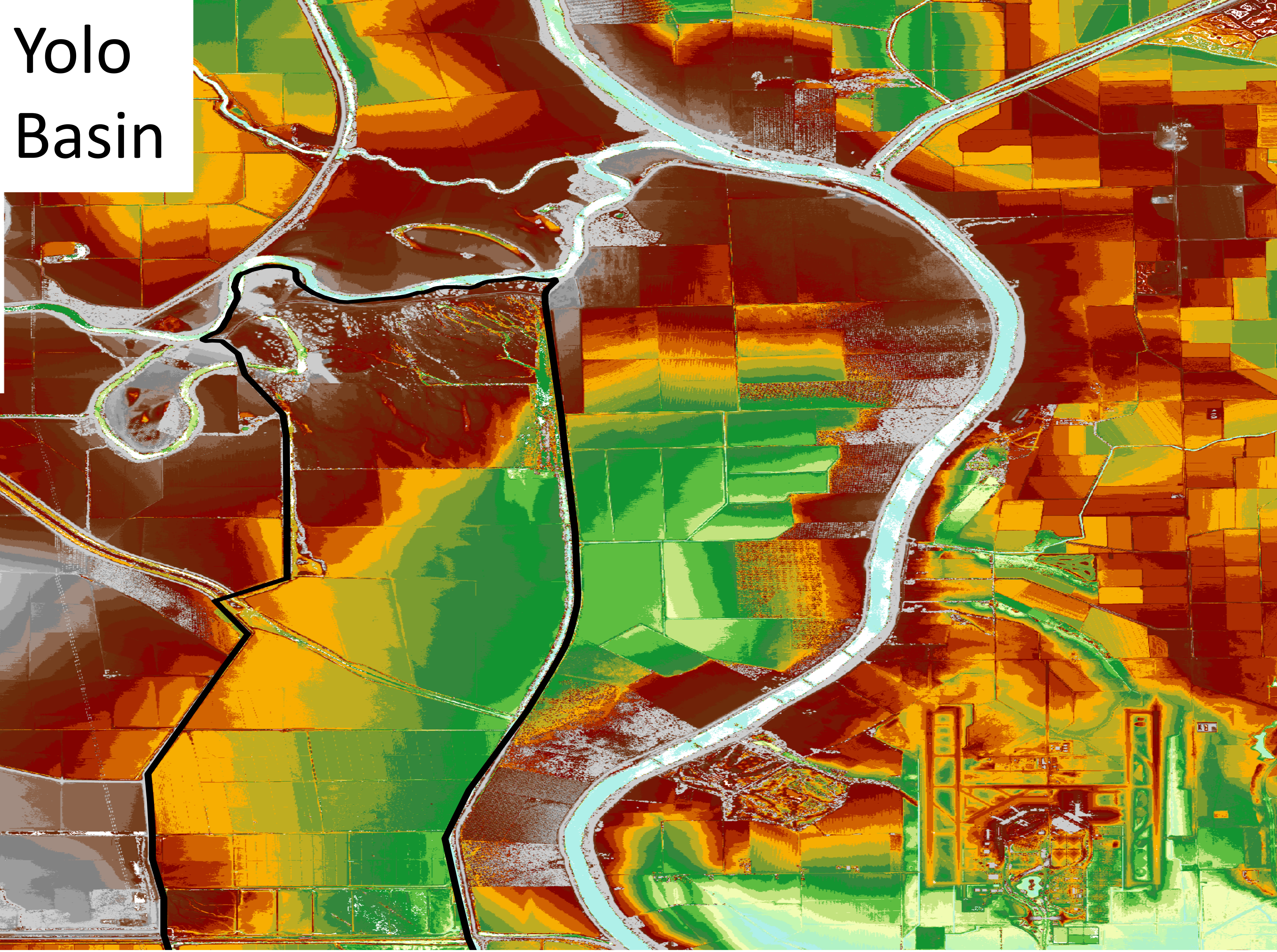
Wetland–River Corridors



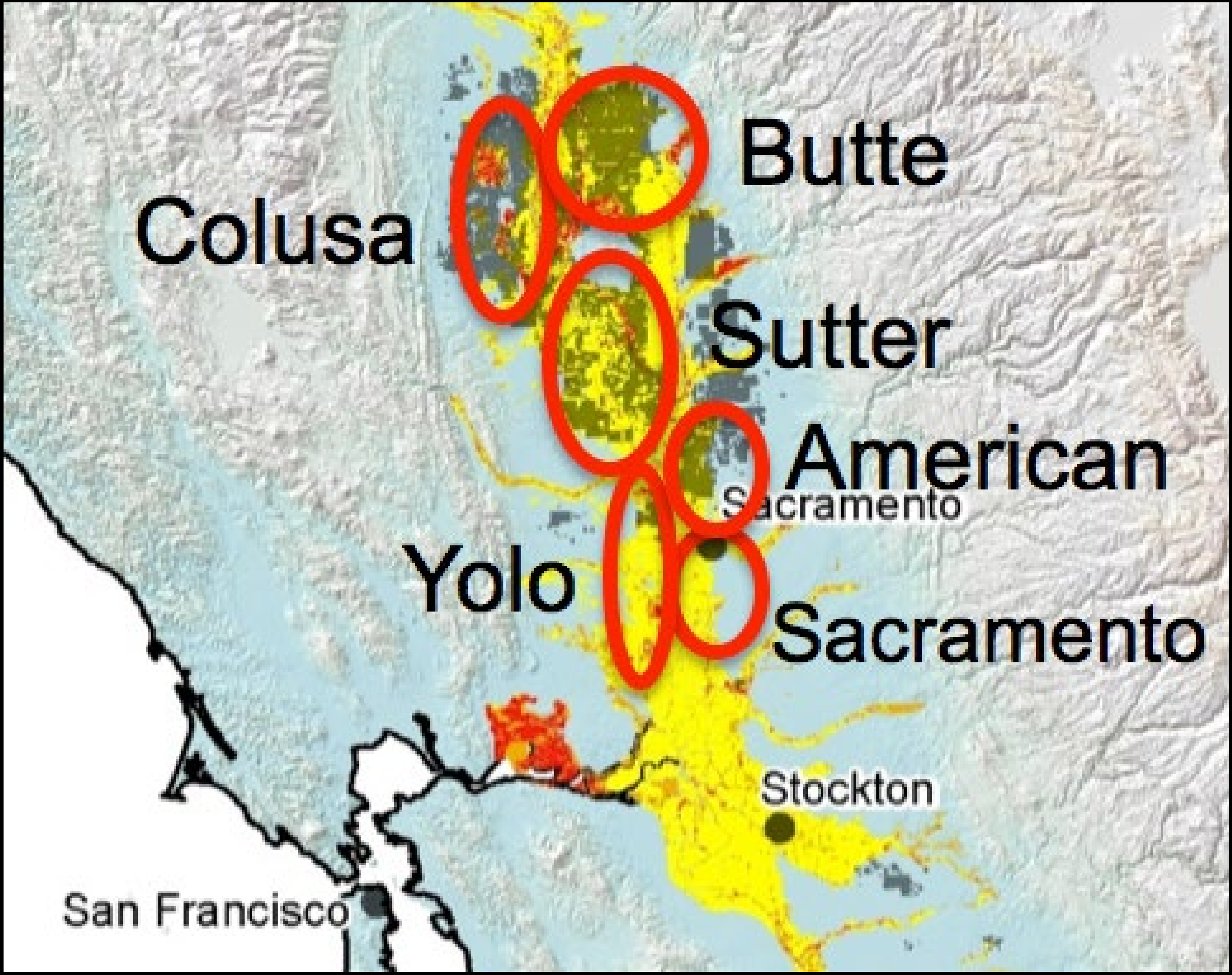


Fluvial Processes

Yolo Basin



Sac Valley Defined by its Puddles



Canalized

Thousands of miles of levees

The Land Divorced from the Water

Ubiquitous Drainage

95%

Central Valley wetlands drained

Fish belong in the river…

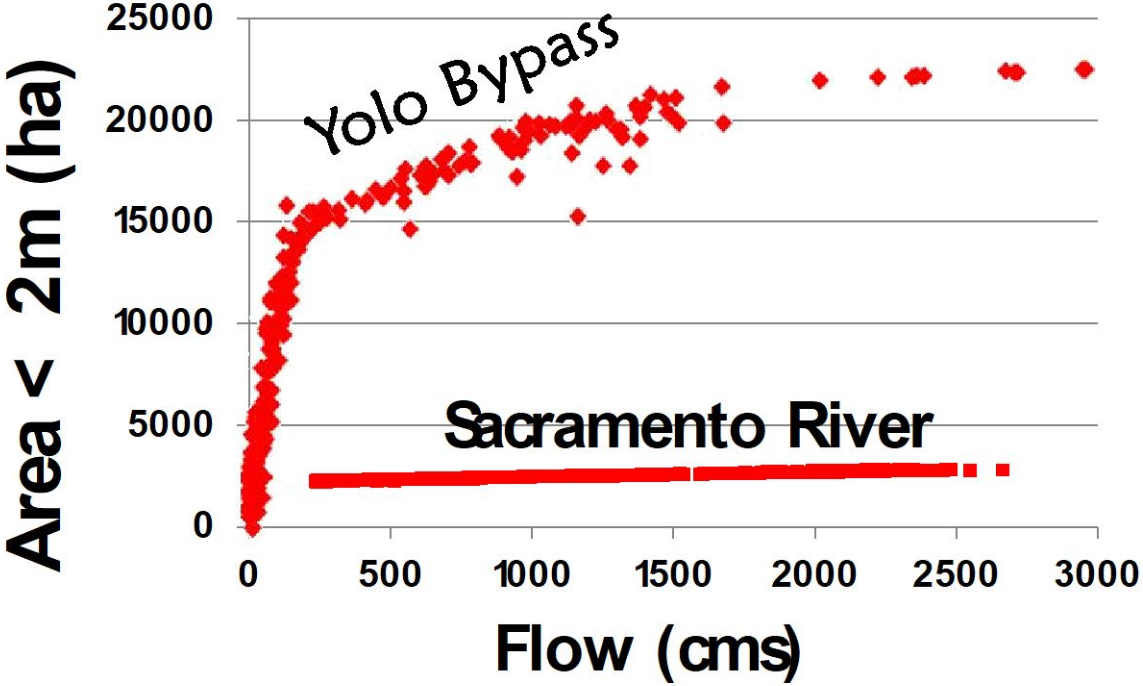
…and the river belongs in its banks.

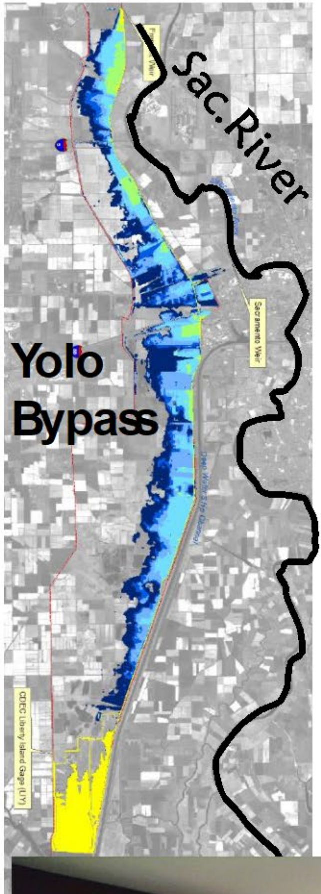
“The latest proposal to build canals or by-passes within the overflow basins, so that they will be readily drained as the river falls, would be the saving of myriads of fish, and especially of salmon fry, and should be encouraged.”

-N. Bishop Scofield, 1911

STATE OF CALIFORNIA FISH AND GAME COMMISSION FISH BULLETIN NO. 1

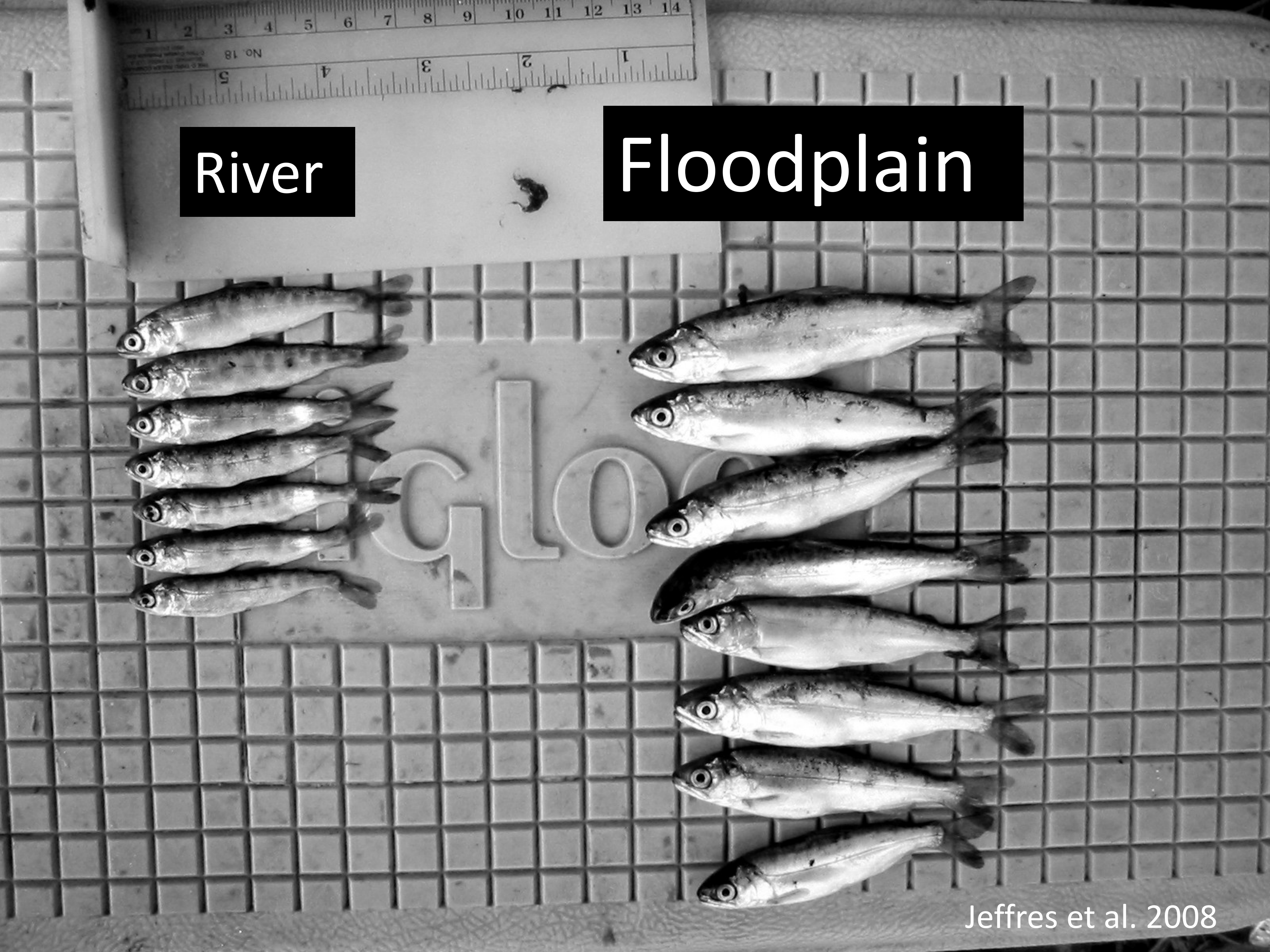
Dramatic effects of flow on habitat area

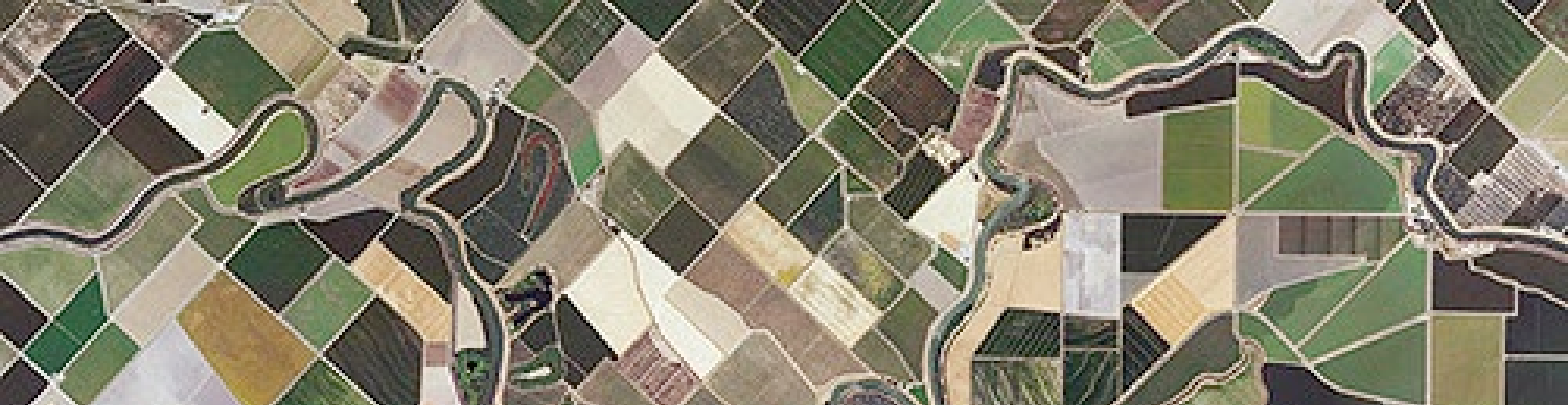




Sommer et al. (2004)

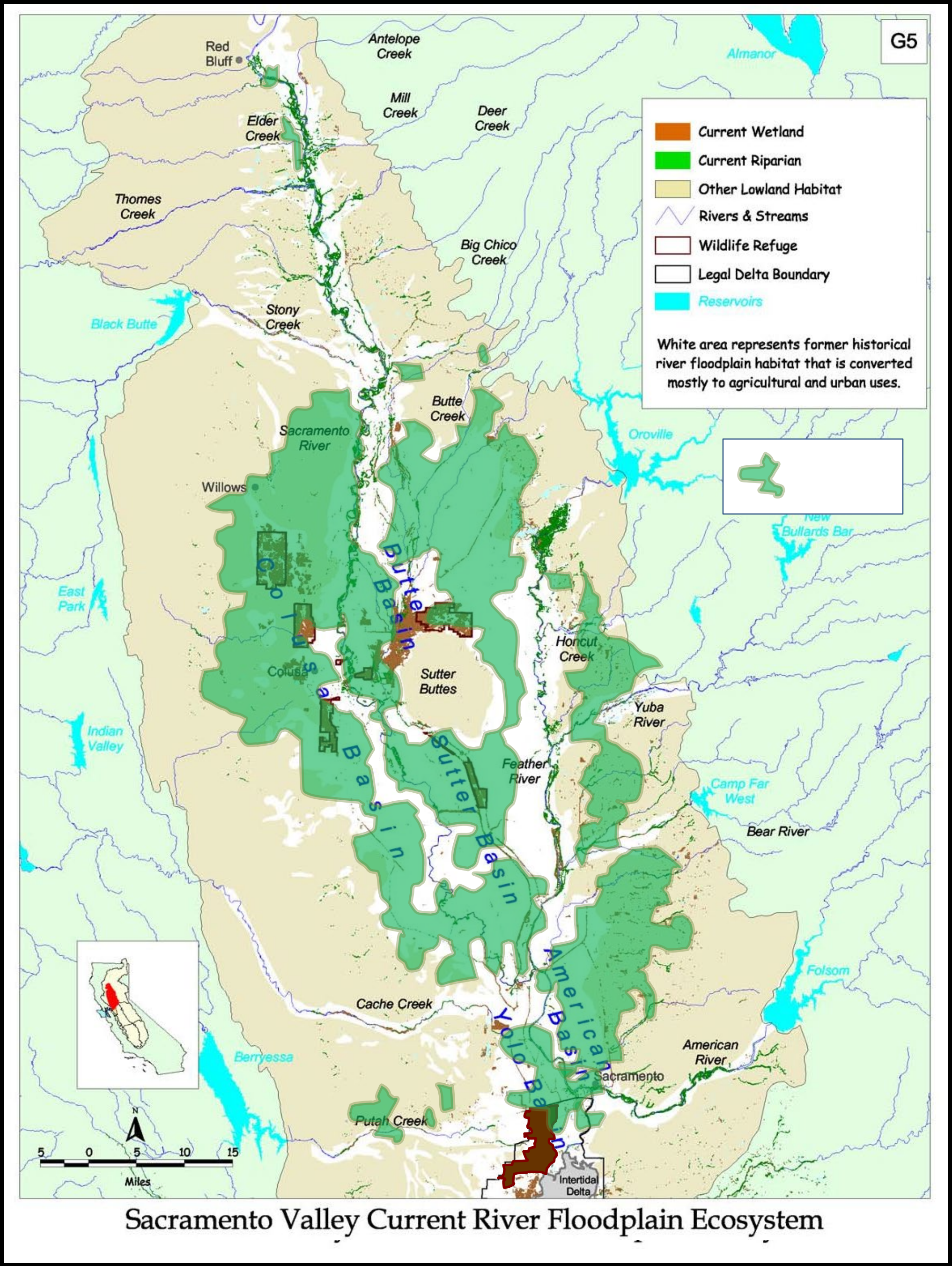
Cosumnes River


River
Floodplain
Jeffres et al. 2008

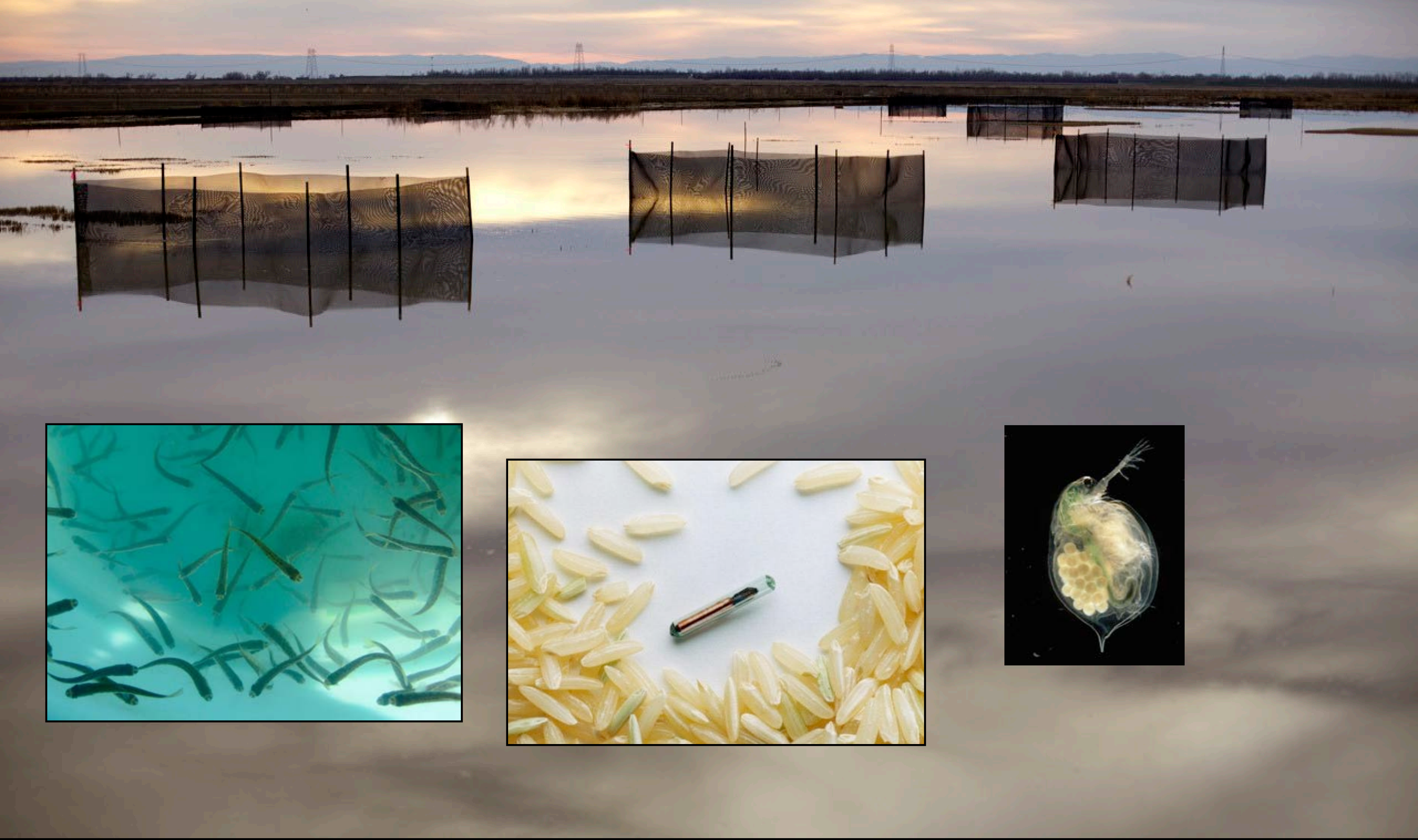


We are never going back

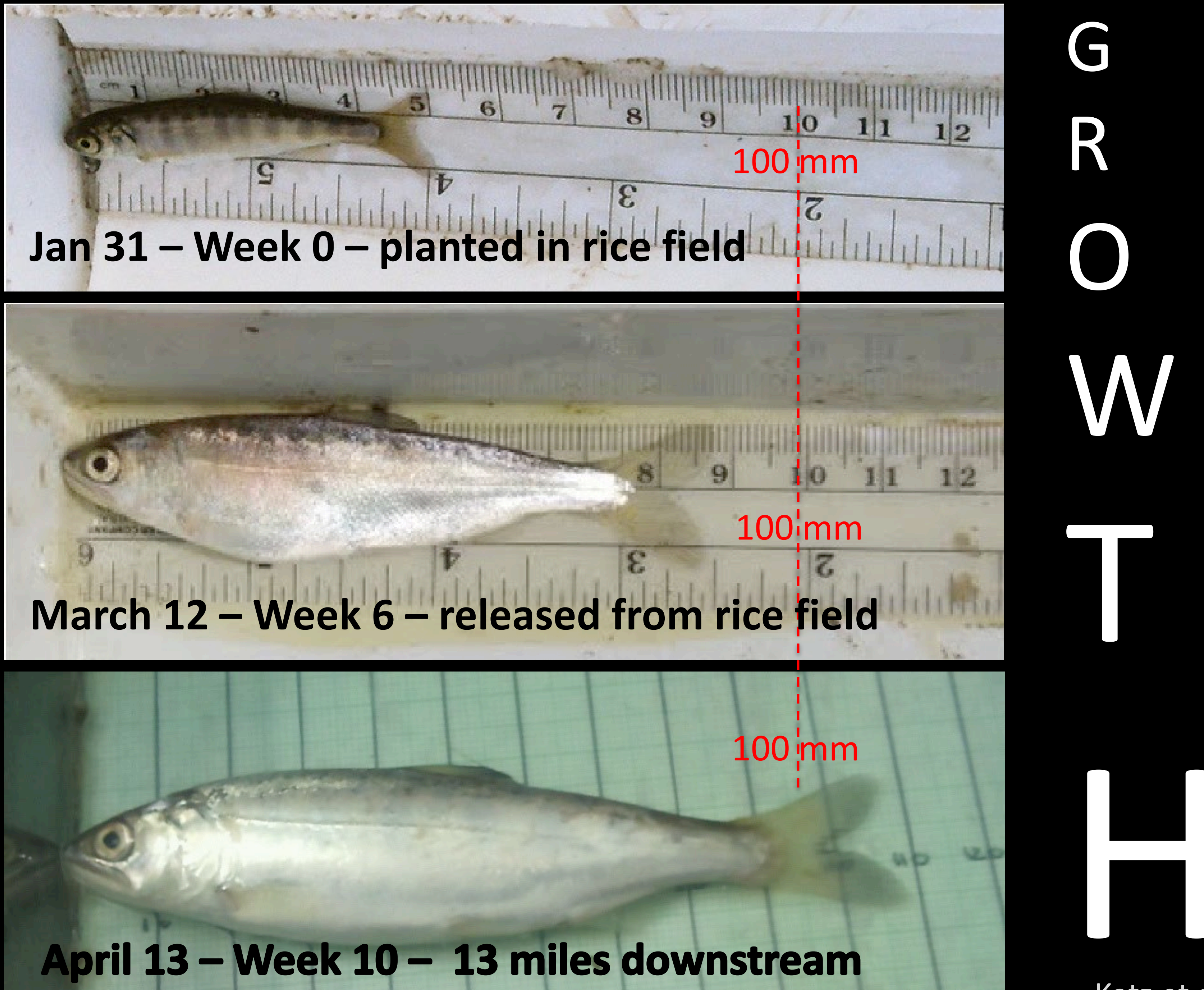
but maybe by looking back, we can reconcile the world we've inherited with the one we desire



Central Valley Waterfowl – Success Fills the Sky

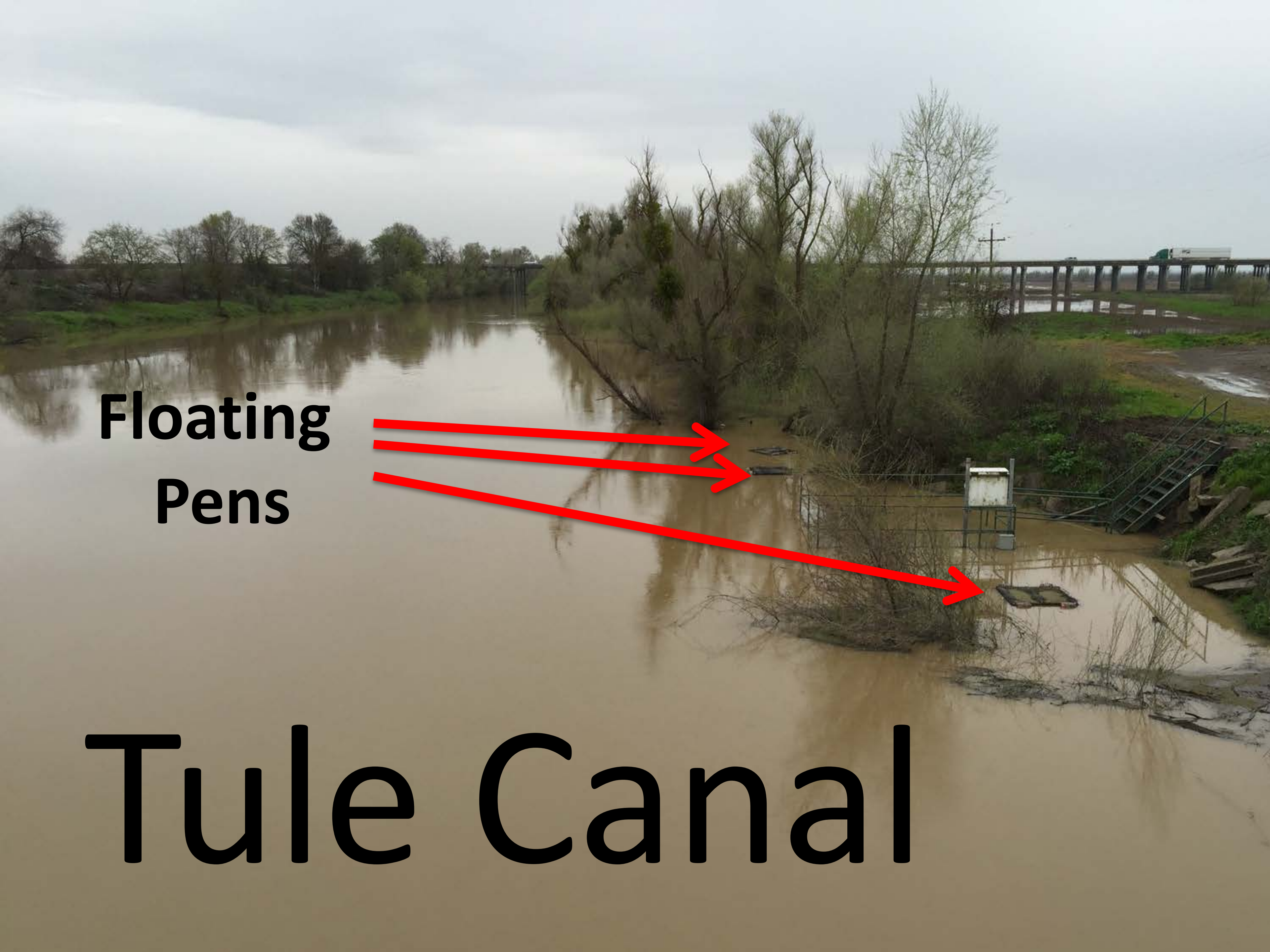


Mimicking natural floodplain processes
in post-harvest floodplain rice fields on Yolo Bypass

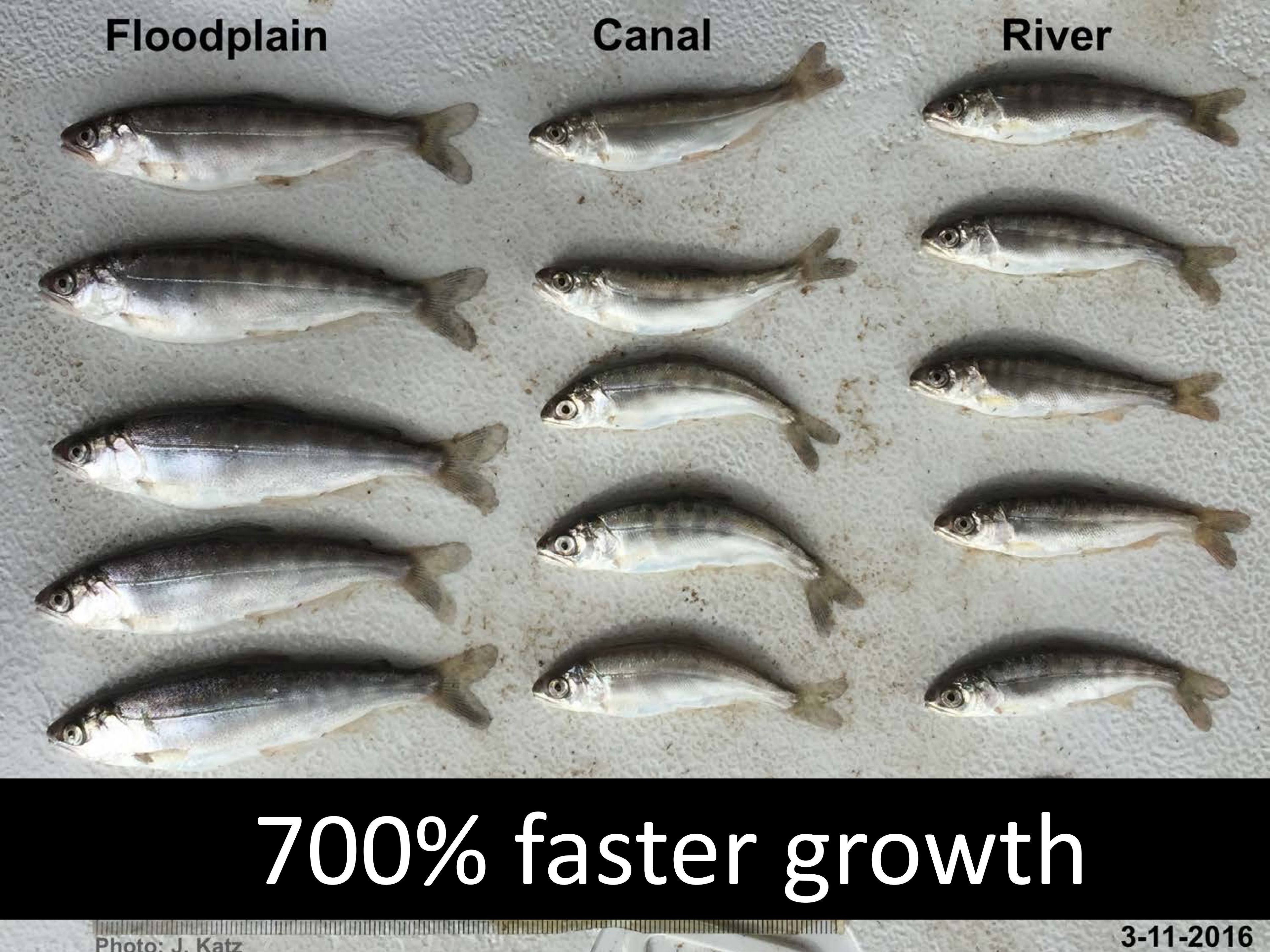


Katz et al. 2017

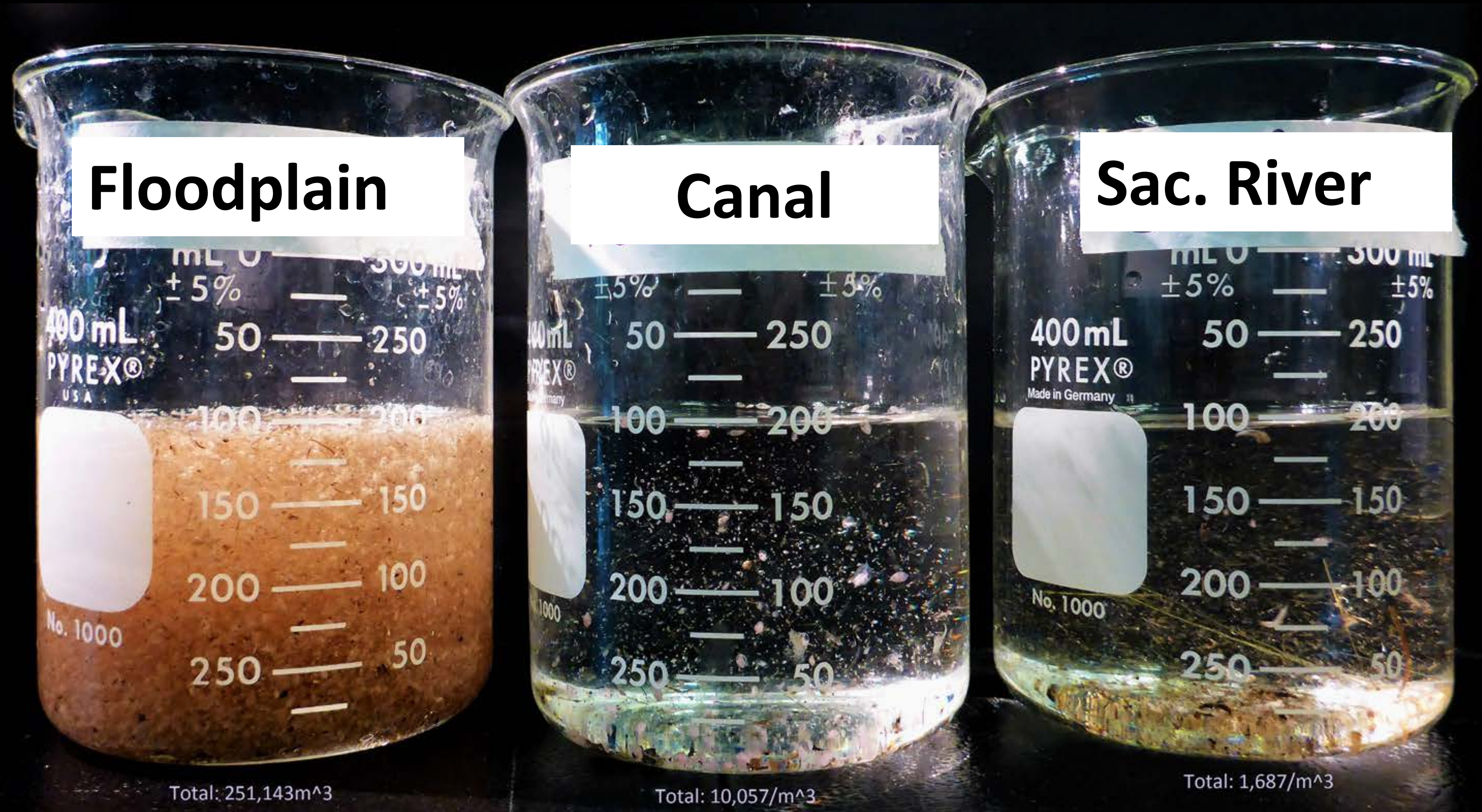

Sacramento River
10 PIT tagged fish per pen
Floating Pens


Floating
Pens
Tule Canal

Managed Agricultural Floodplain


Floodplain
Canal
River
700% faster growth
Photo: J. Katz
3-11-2016

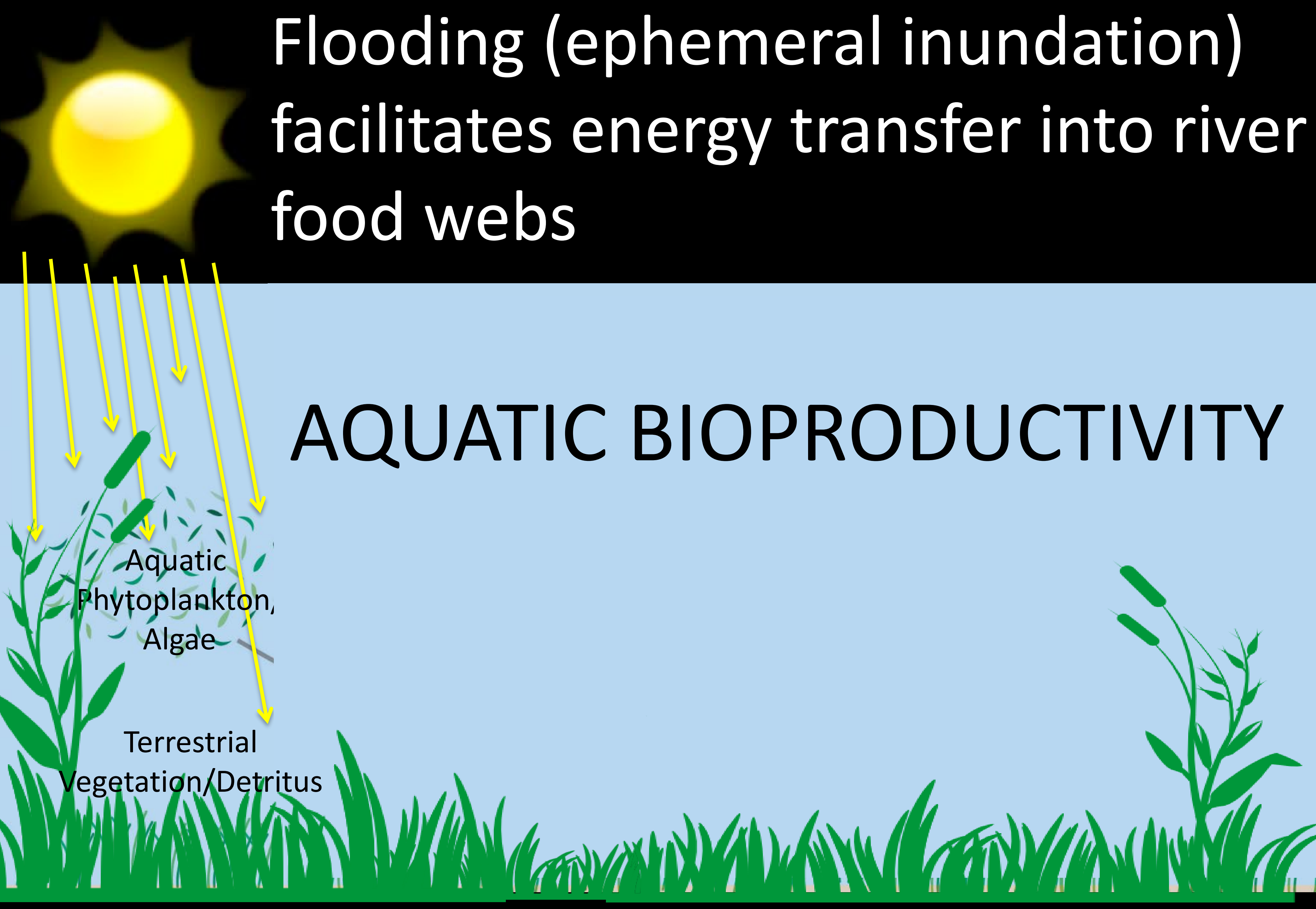
The Food is on the Floodplain



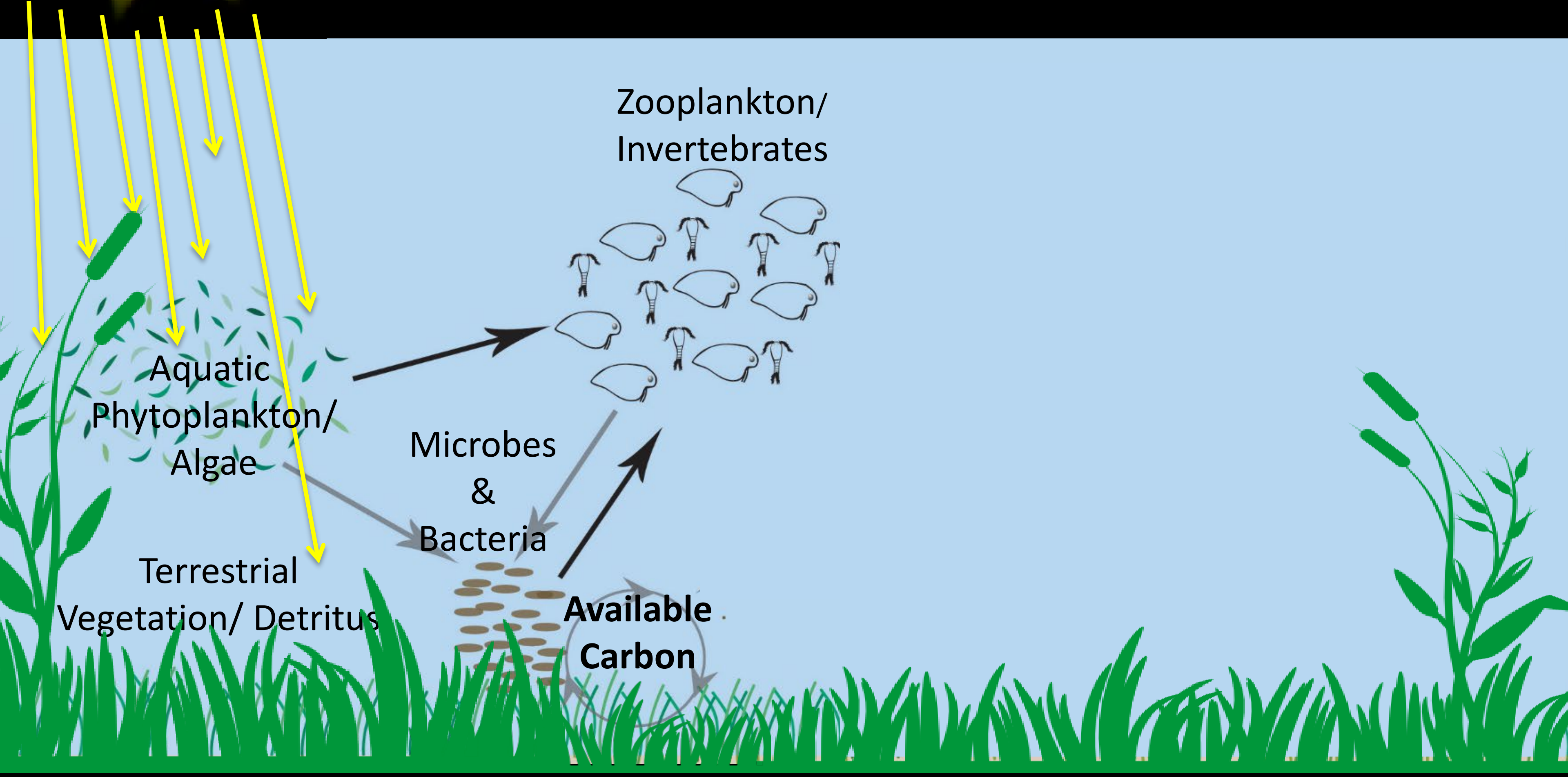
Bug Density 149x 6x x

Flooding (ephemeral inundation) facilitates energy transfer into river food webs

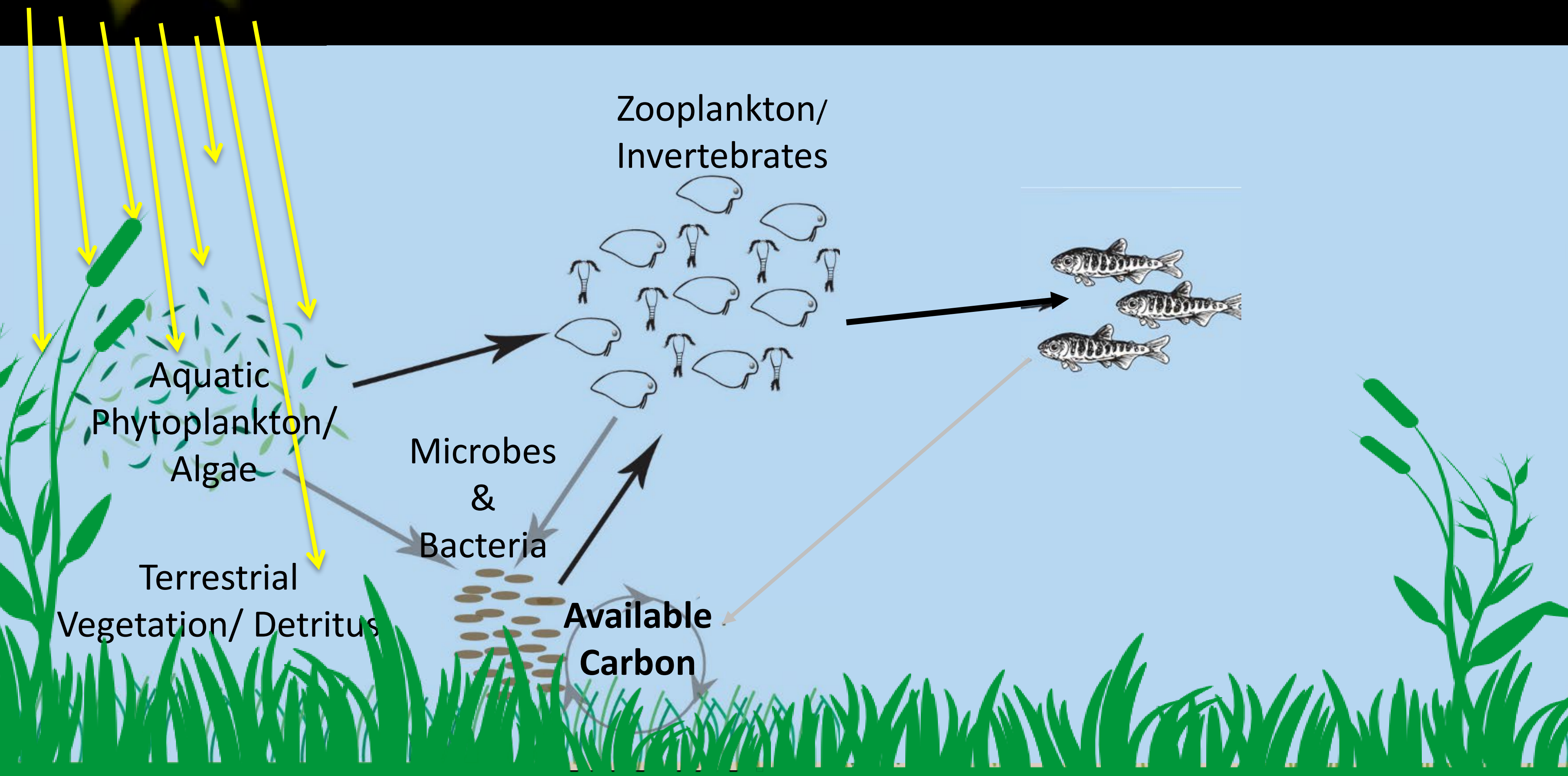
AQUATIC BIOPRODUCTIVITY



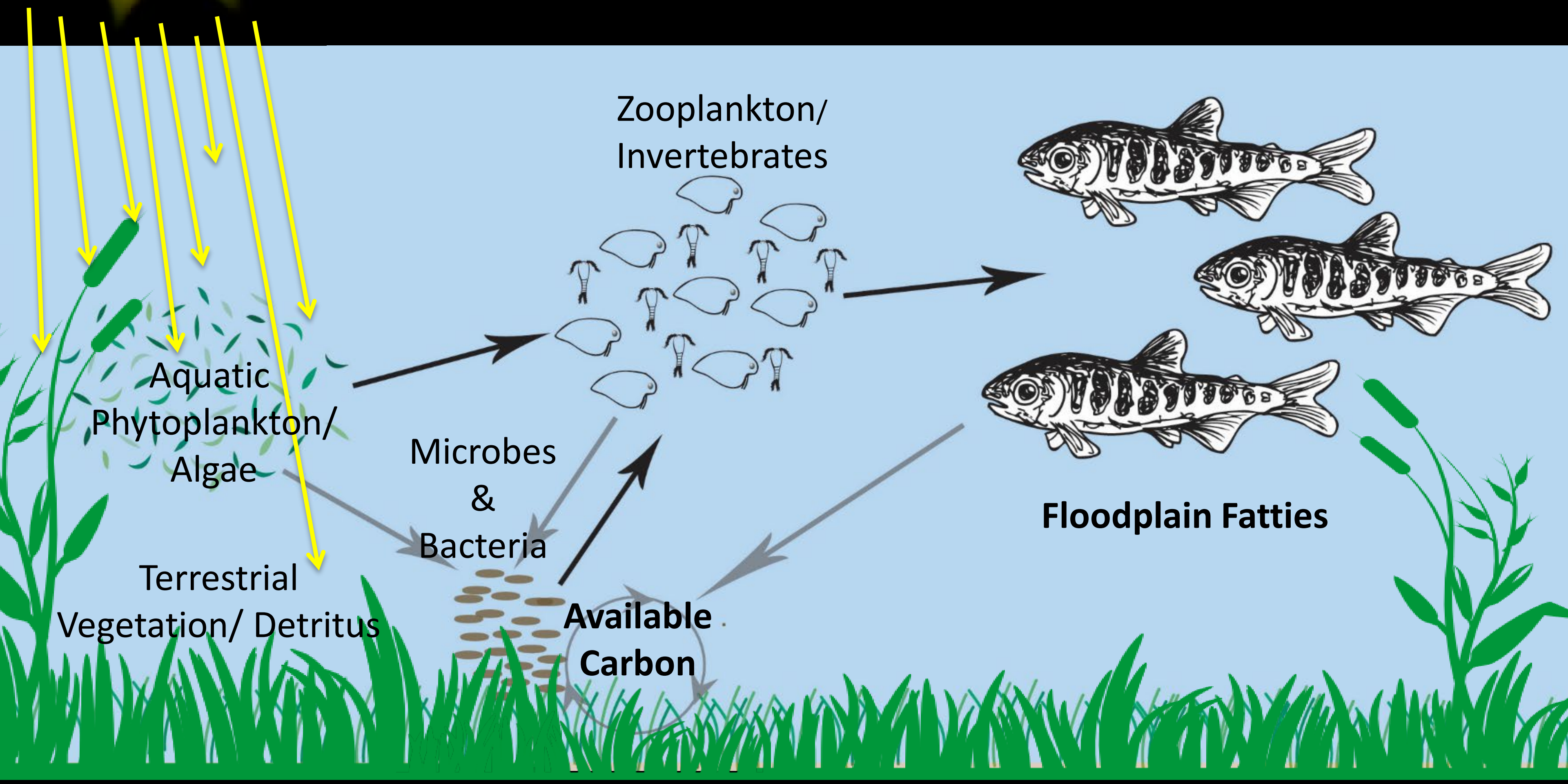
The Process Doesn't Happen Instantaneously



MAKING FISH


Zooplankton/
Invertebrates
Aquatic
Phytoplankton/
Algae
Microbes
&
Bacteria
Terrestrial
Vegetation/ Detritus
Available
Carbon

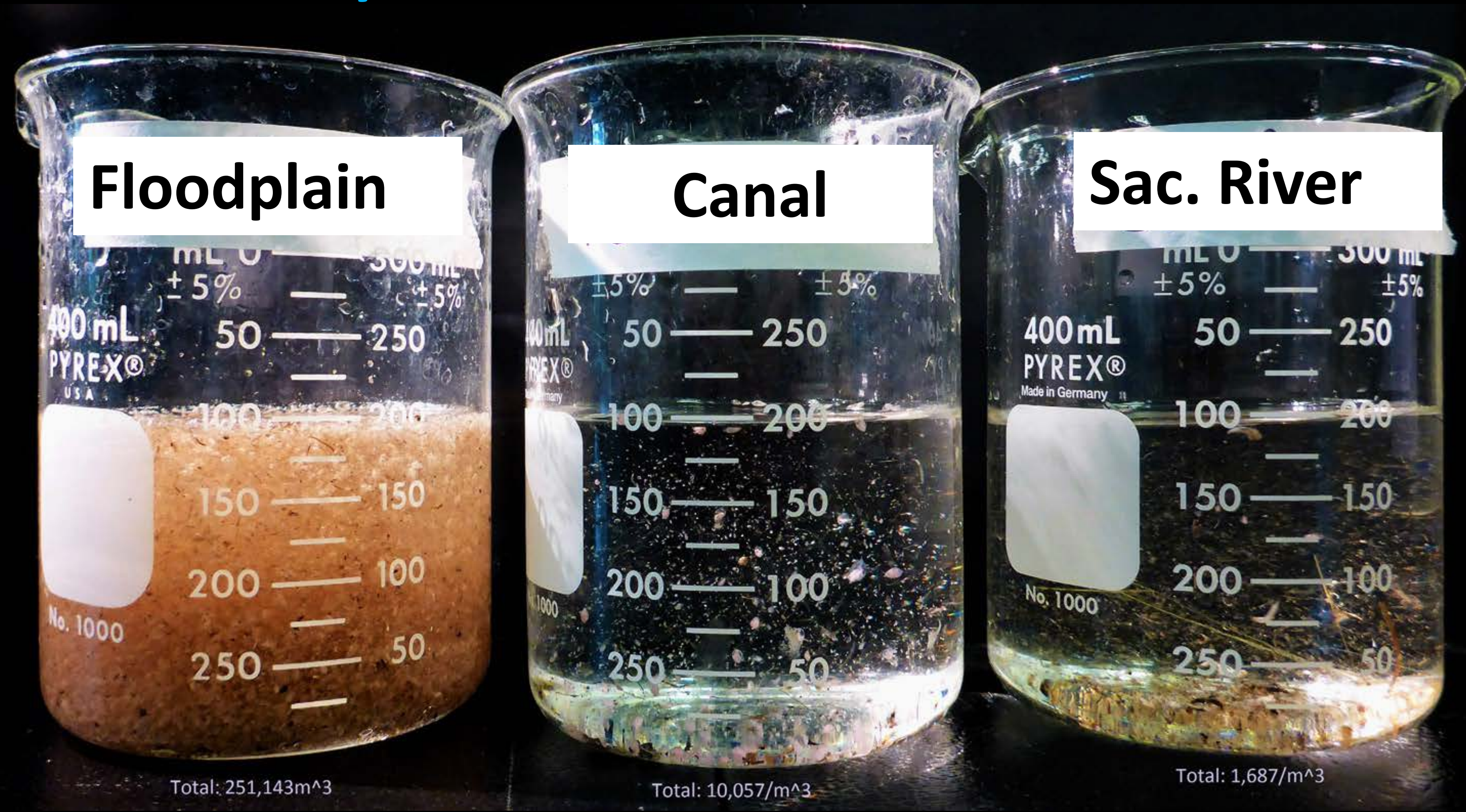
TAKES TIME!



Zooplankton/
Invertebrates
Aquatic
Phytoplankton/
Algae
Microbes
&
Bacteria
Terrestrial
Vegetation/ Detritus
Available
Carbon
Floodplain Fatties

Residence Time of Water

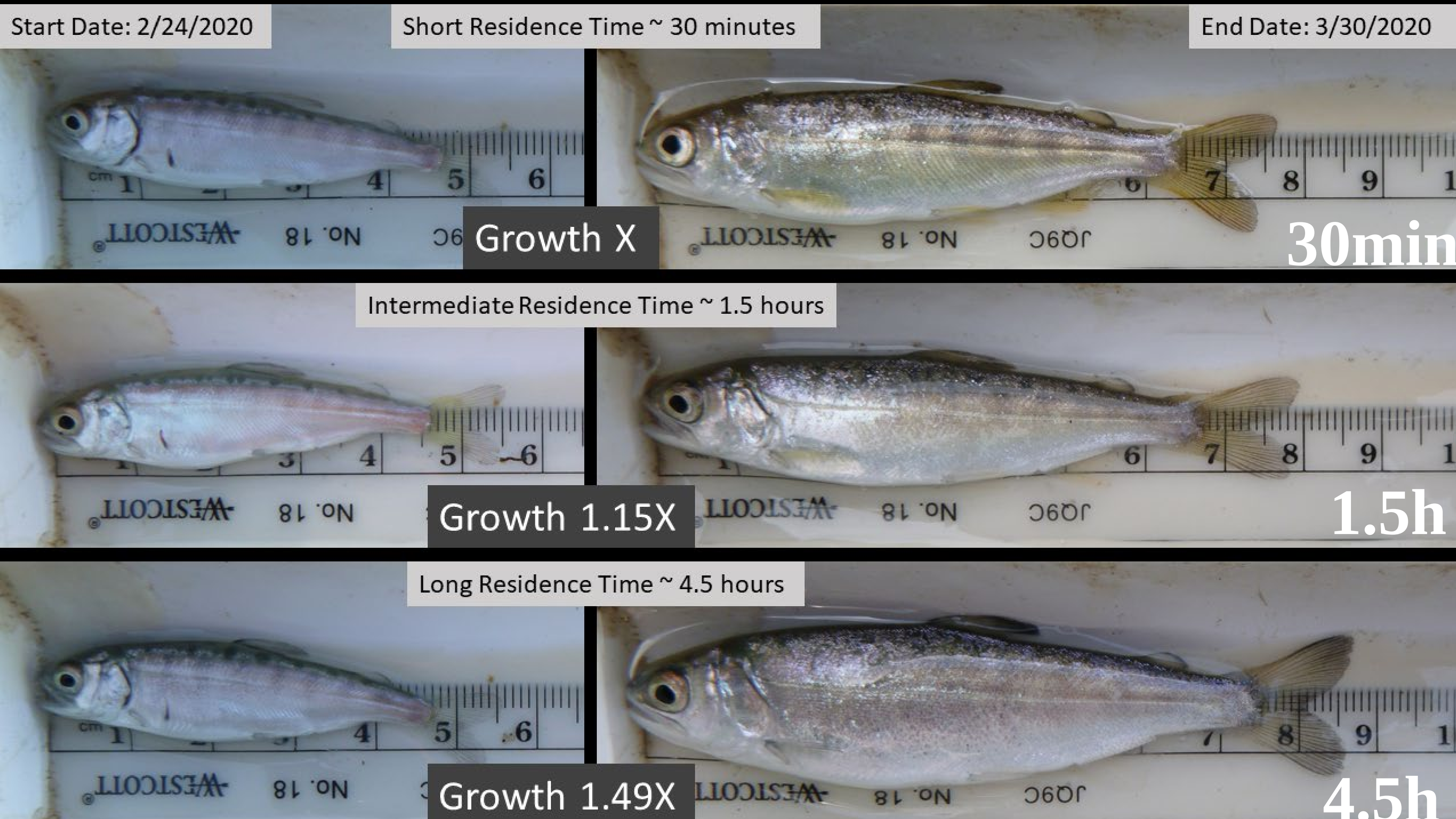
2.15 days   23.5 sec   1.7 sec



Spread it–Slow it–Sink it–Grow it

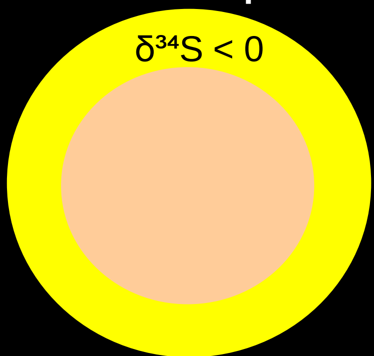
Harnessing Puddle Power

Slow it = Grow it

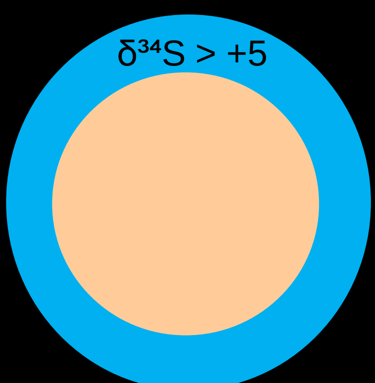


Lens formation and diet reconstructions

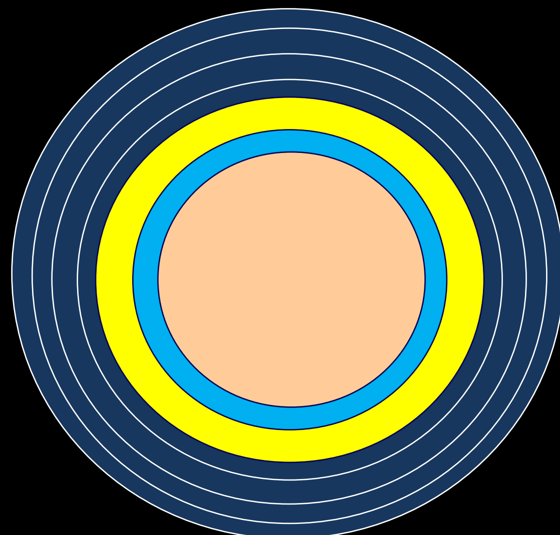
Floodplain

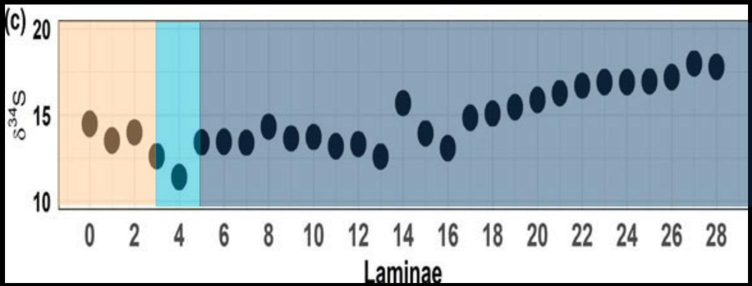


River



Multiple habitats

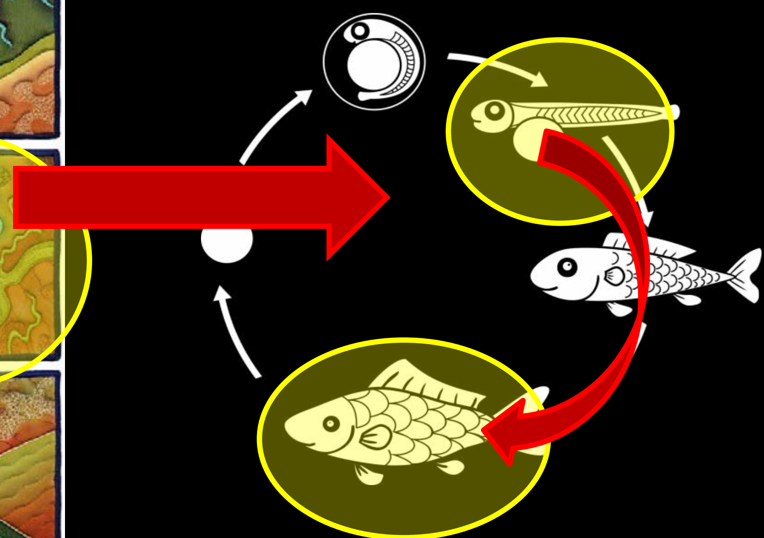


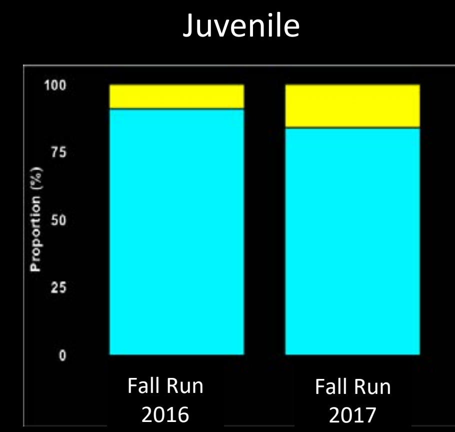


Bell-Tilcock et al. 2021

Delamination

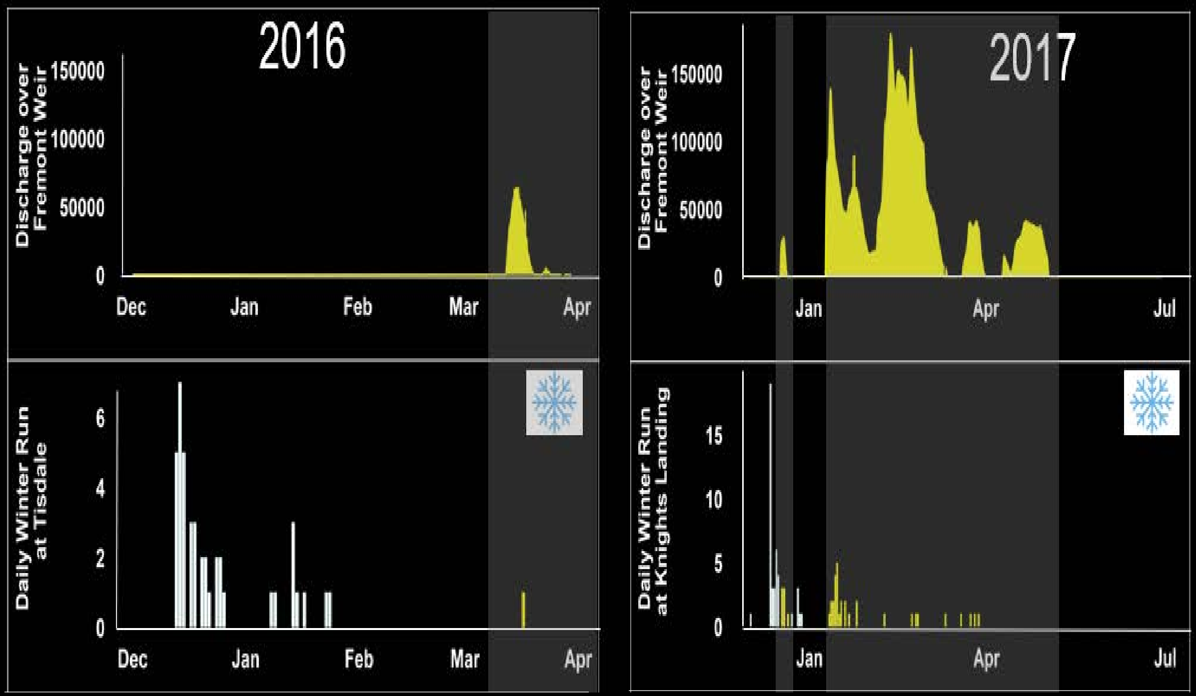
Quantifying the role of floodplains as nursery habitats for salmon populations



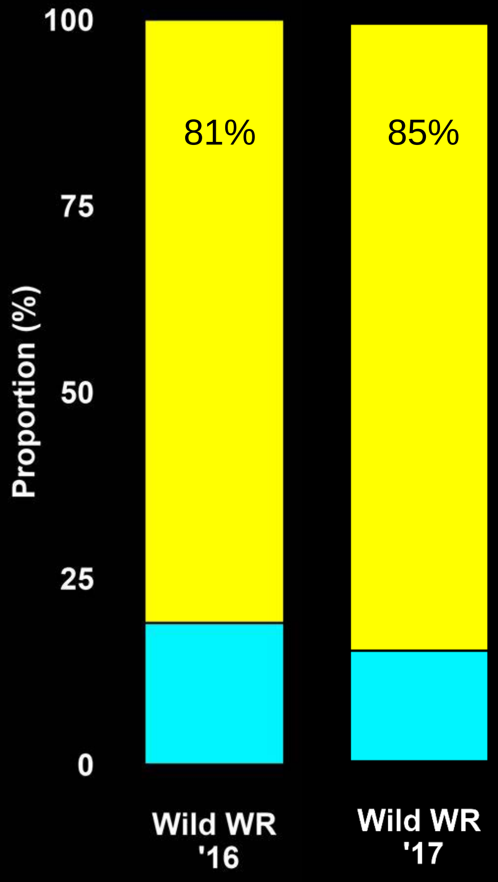


Fall run chinook

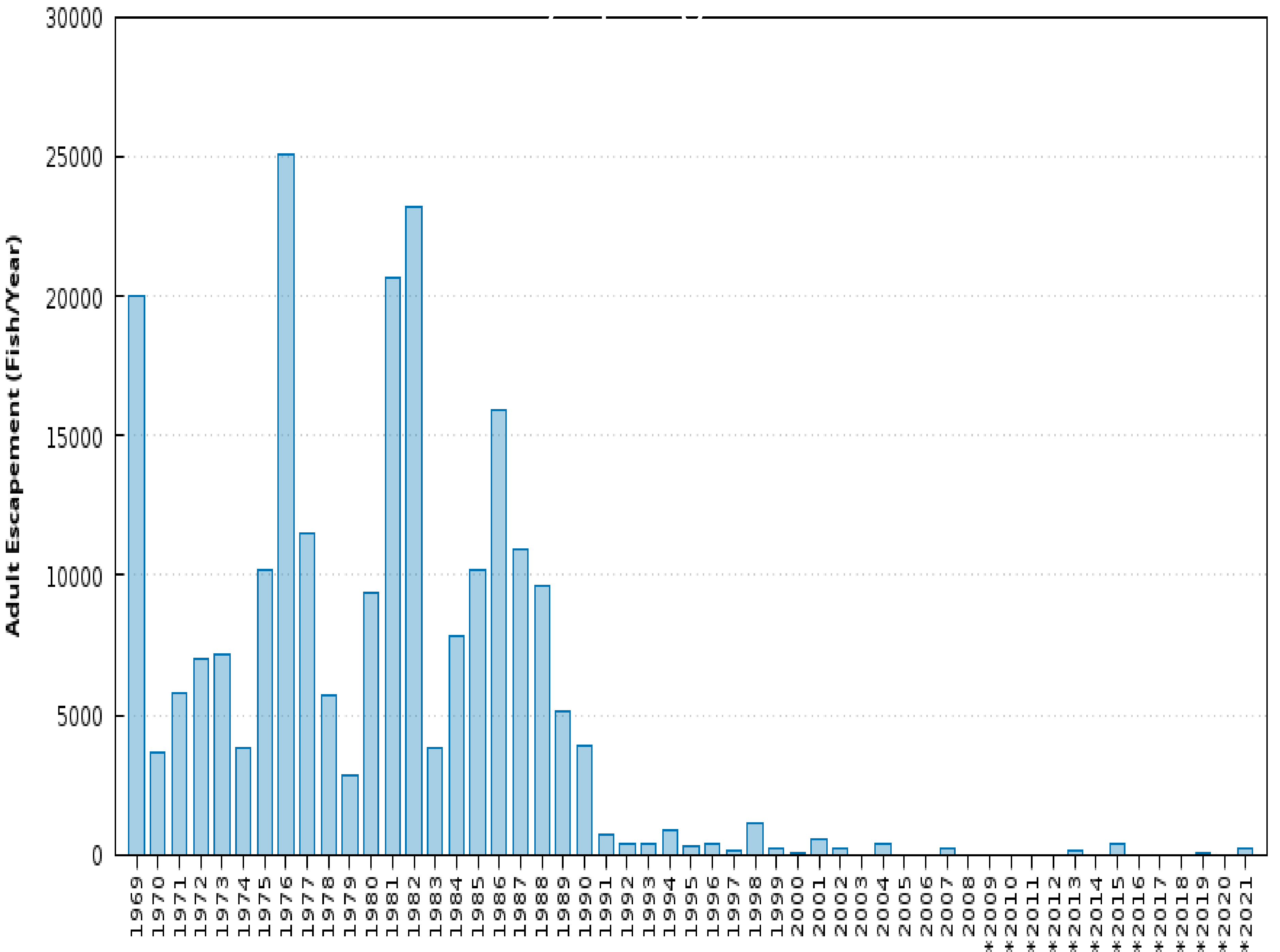
Floodplain opportunity



Survivors



Winter Run Chinook



30000
25000
20000
15000
10000
5000
0
Adult Escapement (Fish/Year)
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
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2001
2002
2003
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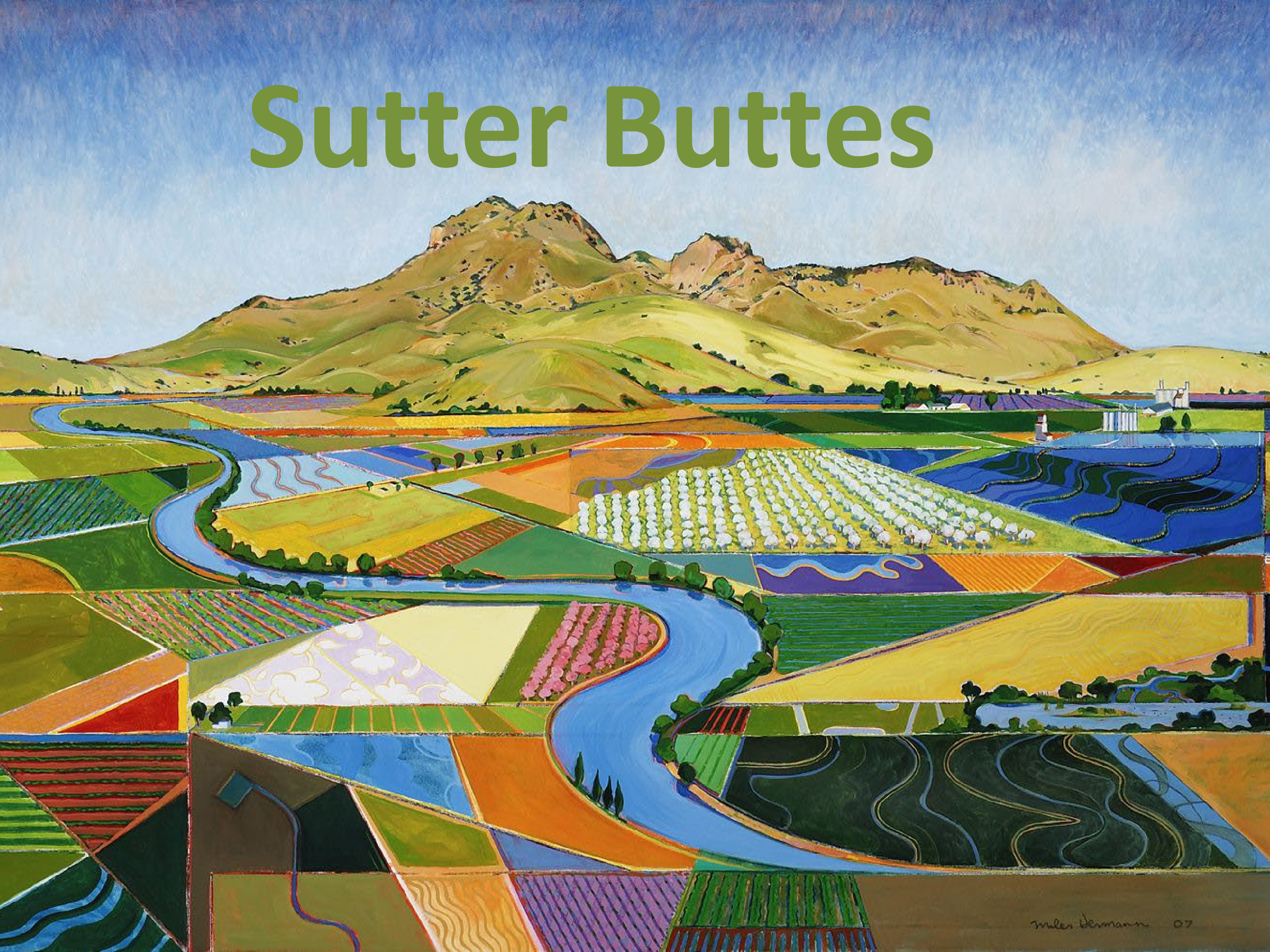
2007
2008
*2009
*2010
*2011
*2012
*2013
*2014
*2015
*2016
*2017
*2018
*2019
*2020
*2021

Sutter Buttes

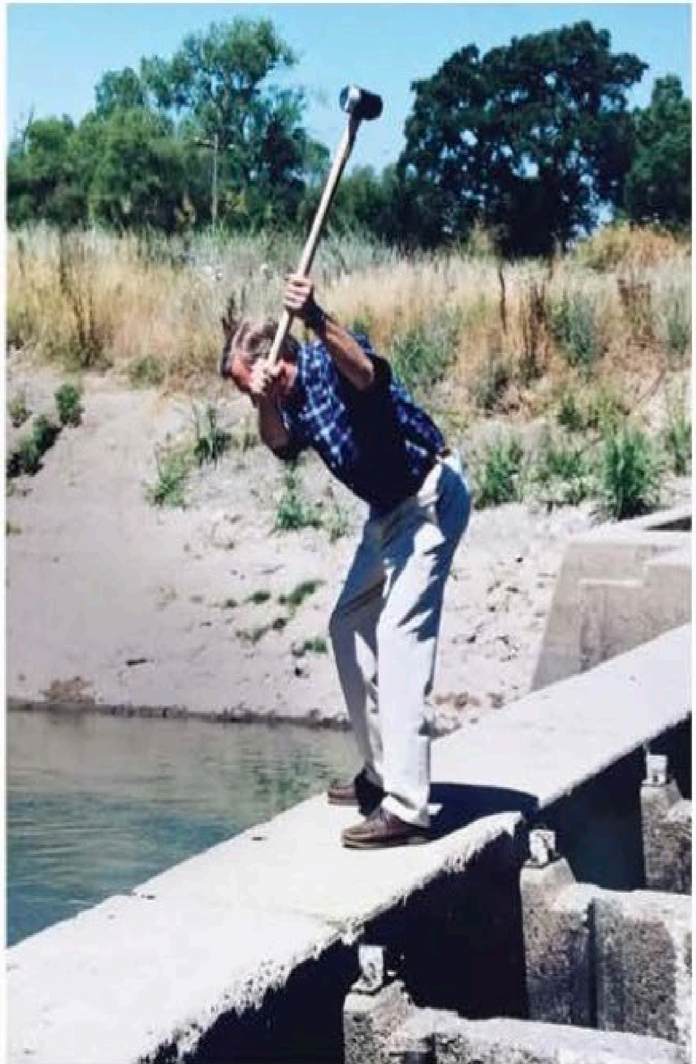


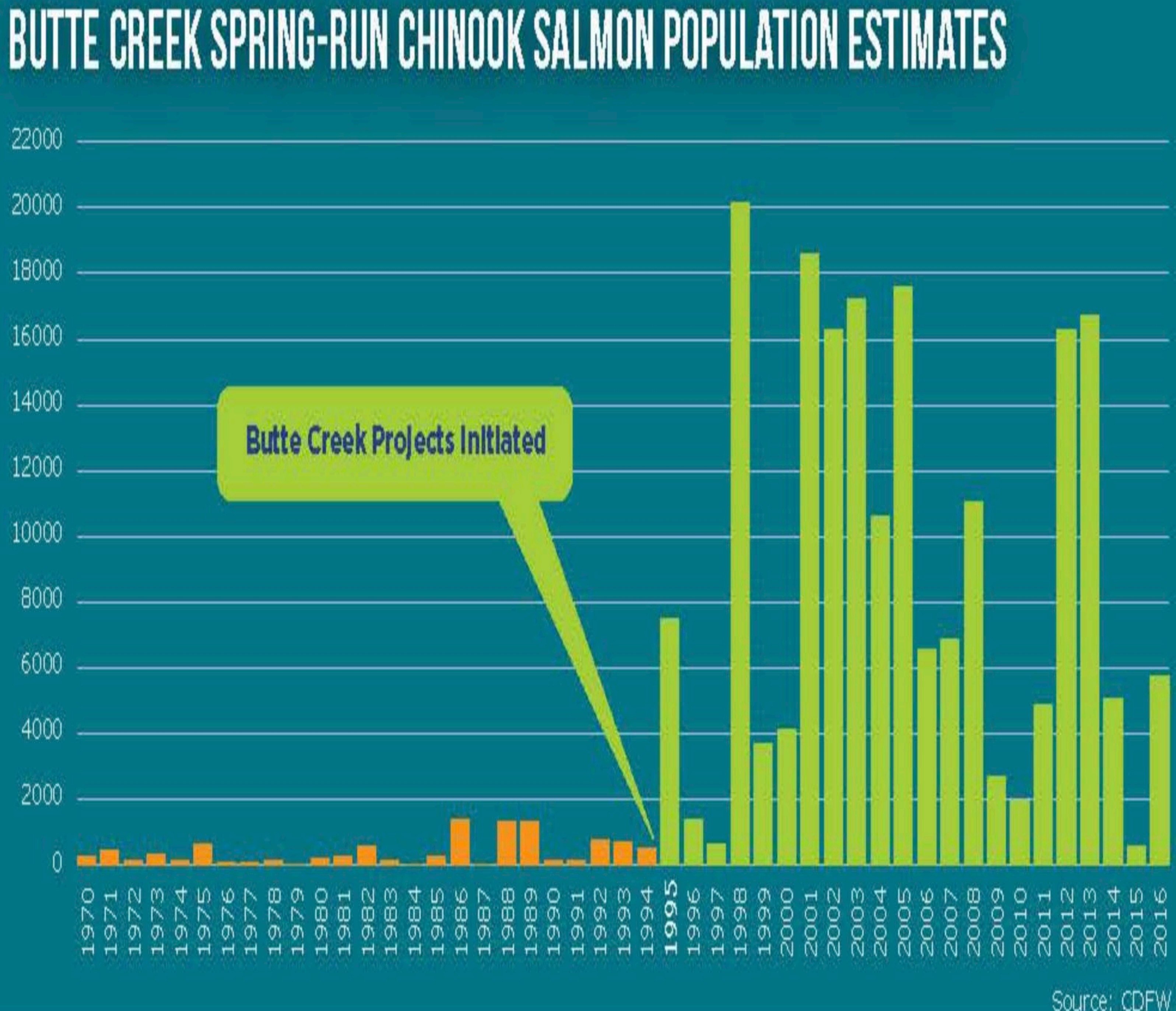
SUTTER BUTTES AND ORCHARDS IN BLOOM

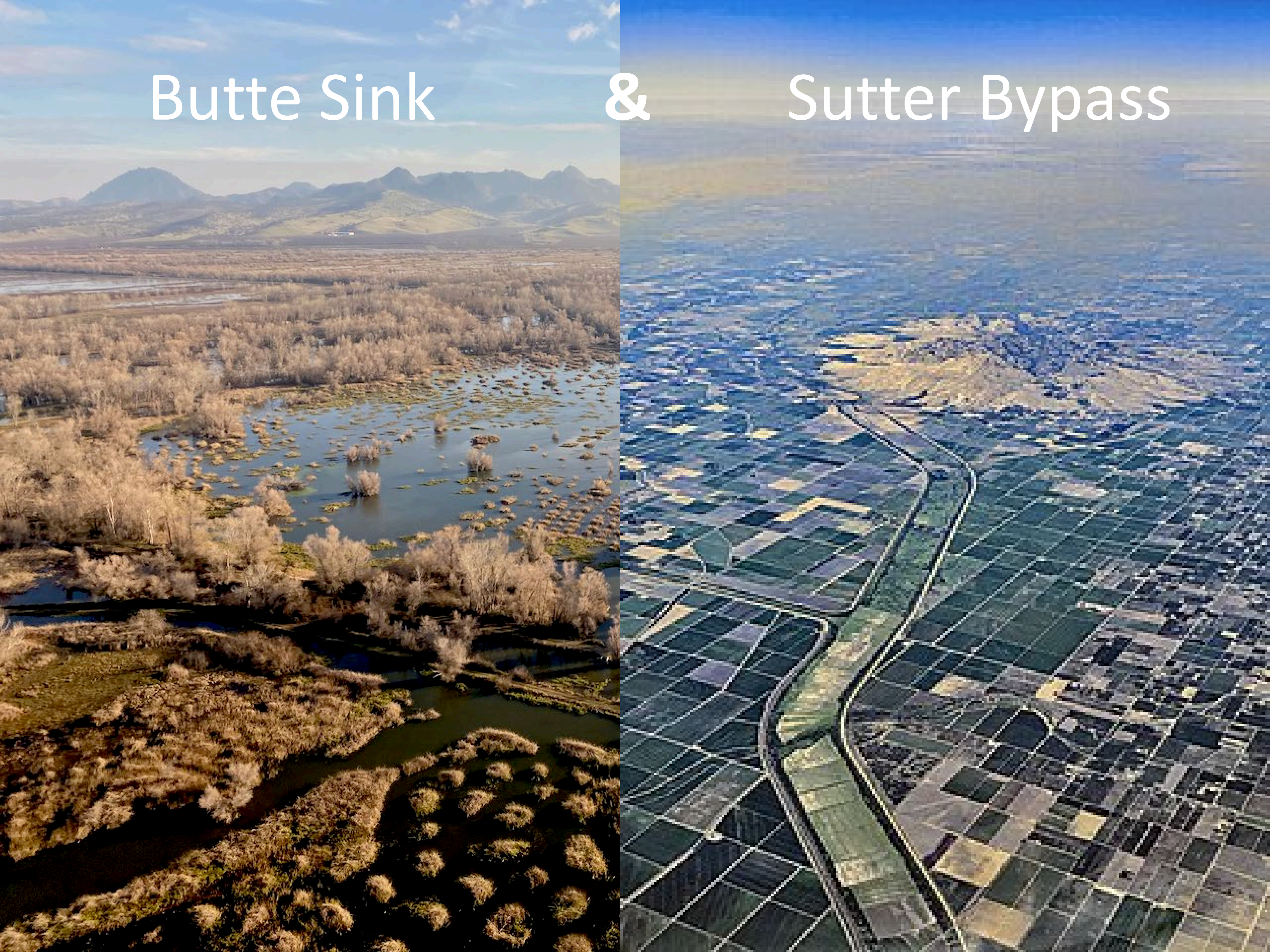
Photo: Ken "Creekman" Davis

SUCCESS ON BUTTE CREEK

Butte Creek is one of only four Sacramento River tributaries with remaining populations of the endangered spring-run Chinook salmon. Resource agencies and conservation groups value Butte Creek as a keystone in preserving and recovering spring-run salmon, which in some years had dwindled to less than a 100 returning adults from 1970 to the early 1990s. Today, as a result of the Butte Creek Fish Passage Improvement projects, in tandem with a valuable food supply and safe rearing habitat in the Sutter Bypass wetlands, more than 10,000 spring-run salmon return on average to Butte Creek. These projects all provide multiple beneficial uses, serving water for fish, farms, birds and various other species.




BUTTE CREEK SPRING-RUN CHINOOK SALMON POPULATION ESTIMATES
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Butte Creek Projects Initiated
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Source: CDFW


Butte Sink
&
Sutter Bypass

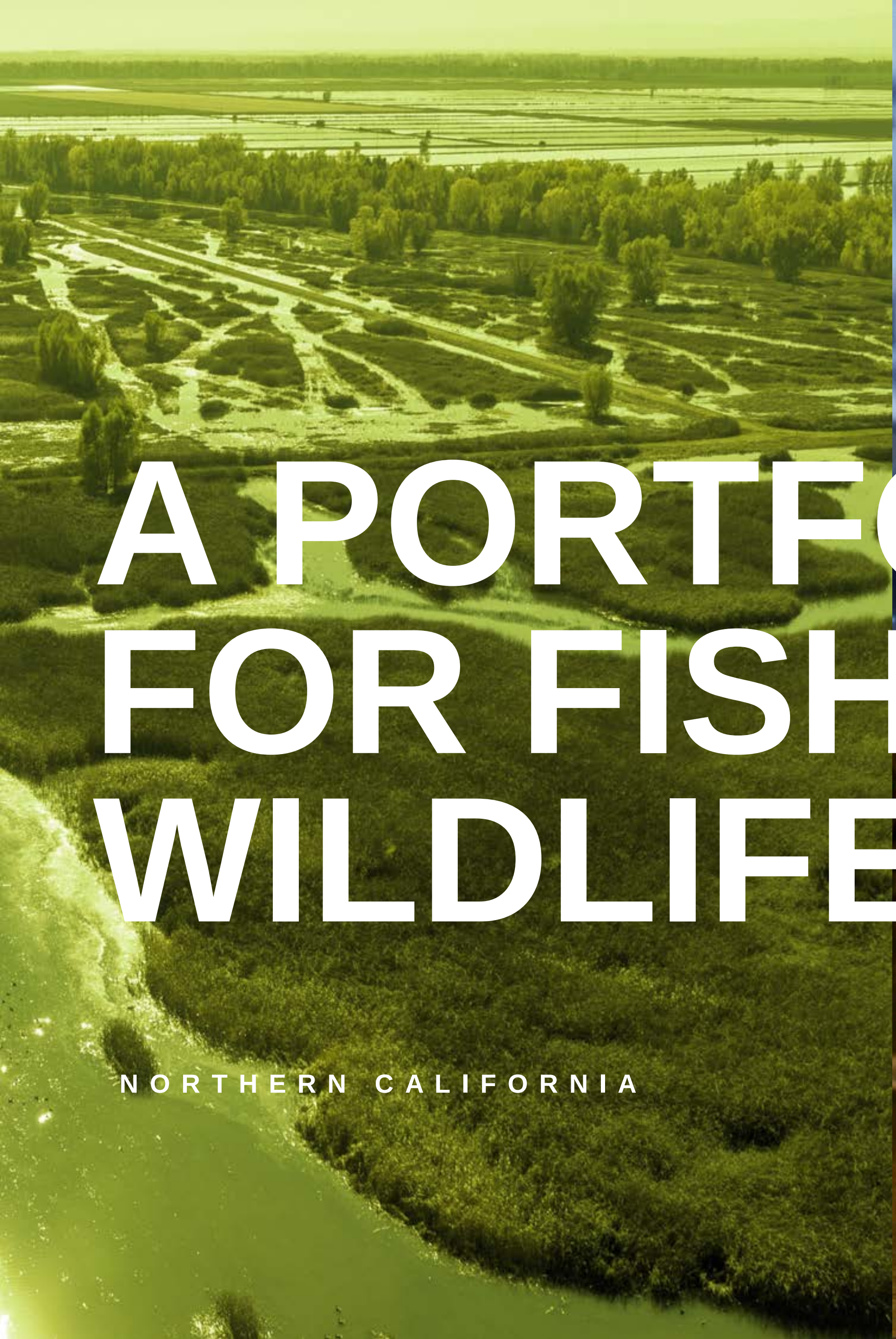
Butte Creek Spring run smolts: Floodplain Fatties

FLOODPLAIN
FORWARD

2025

FLOODPLAIN FORWARD

A 31-member organization representing landowners, irrigation districts, higher education, and conservation groups. The coalition, and the collaborative model of dynamic conservation, has resulted in farms, refuges, and managed wetlands providing essential habitat for waterfowl and shorebirds as well as potential food production for endangered fish species.



A PORTFOLIO FOR FISH & WILDLIFE

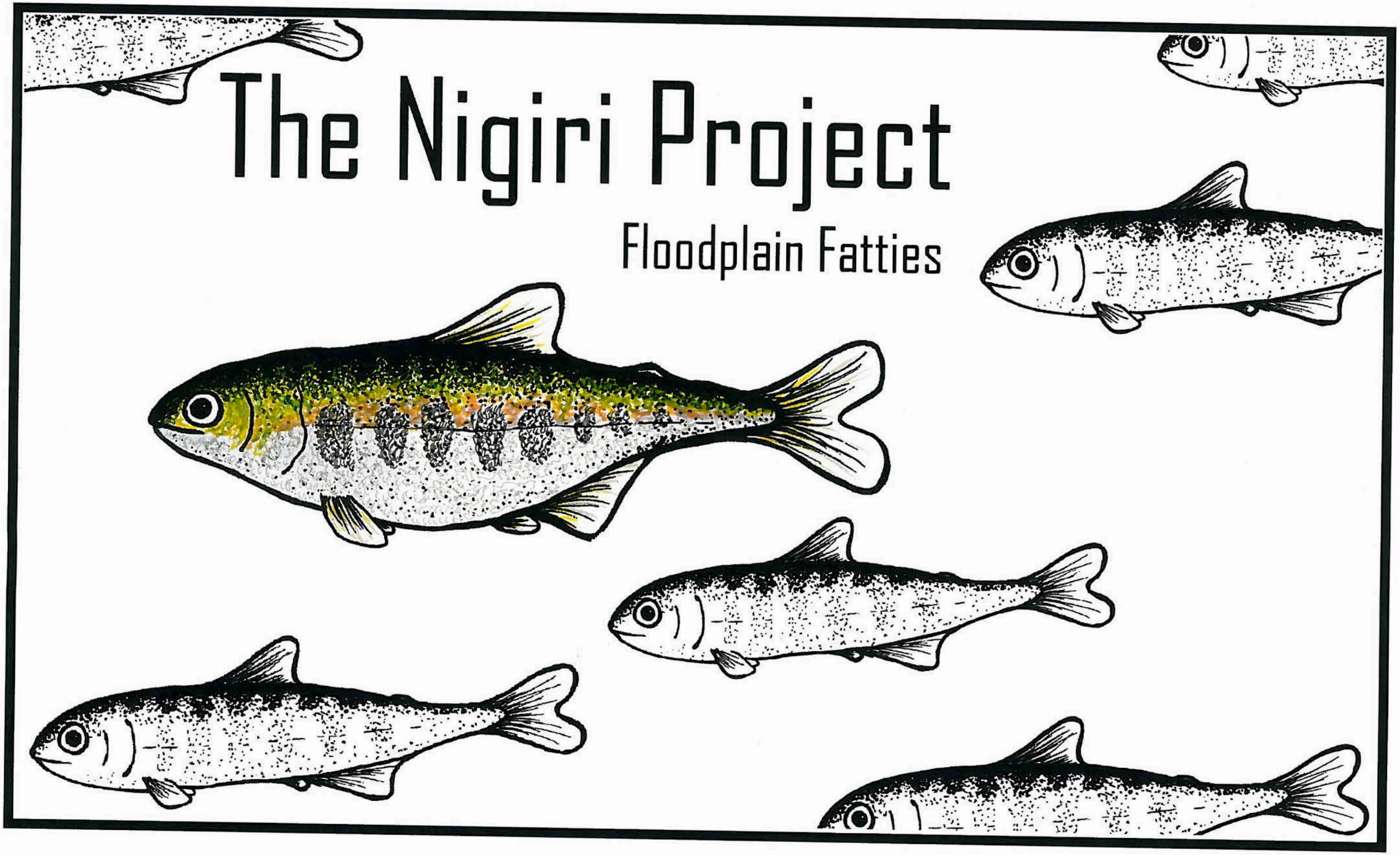
NORTHERN CALIFORNIA

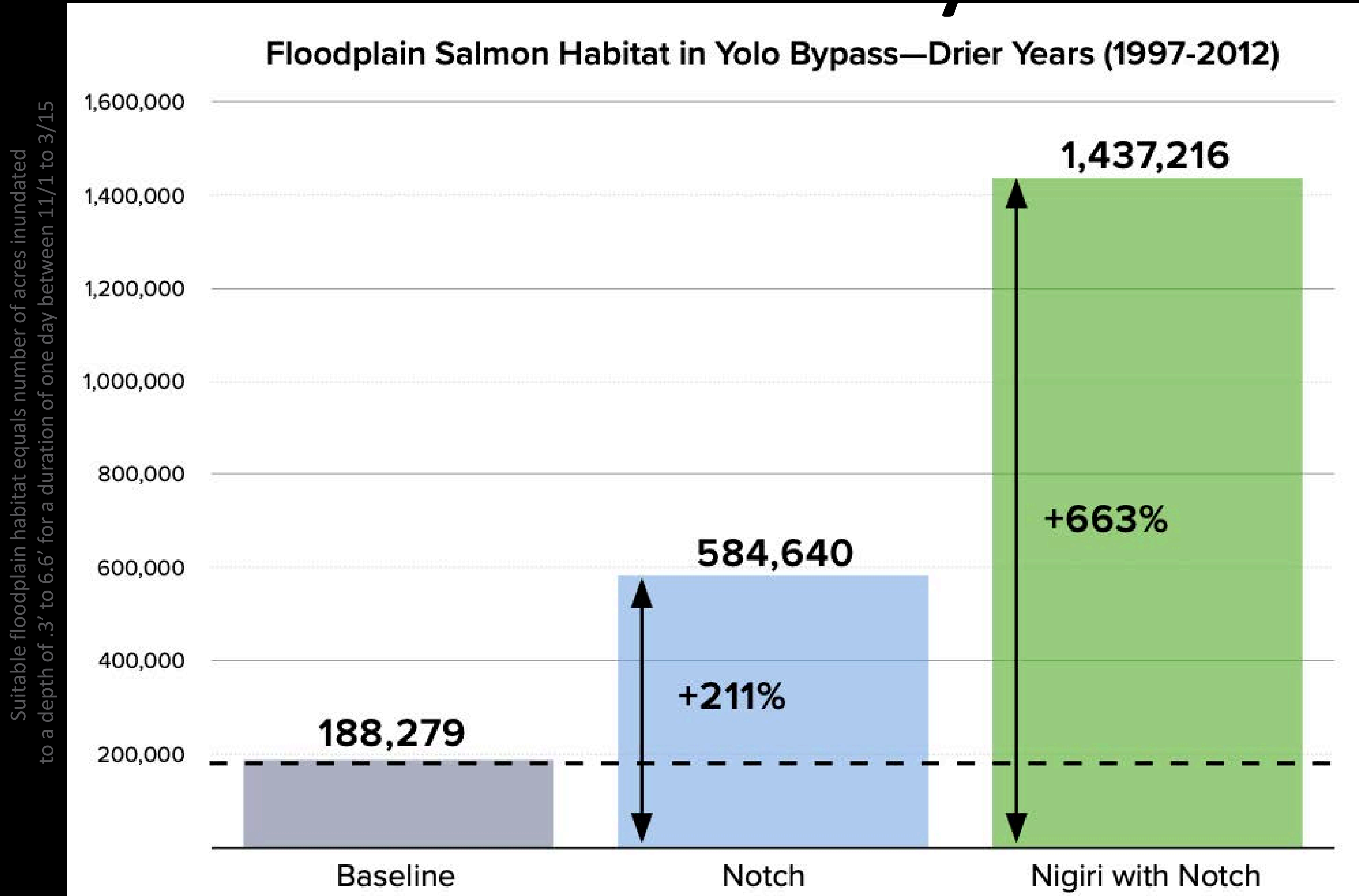
ADVANCING FLOODPLAIN REACTIVATION

In the Sacramento River Basin

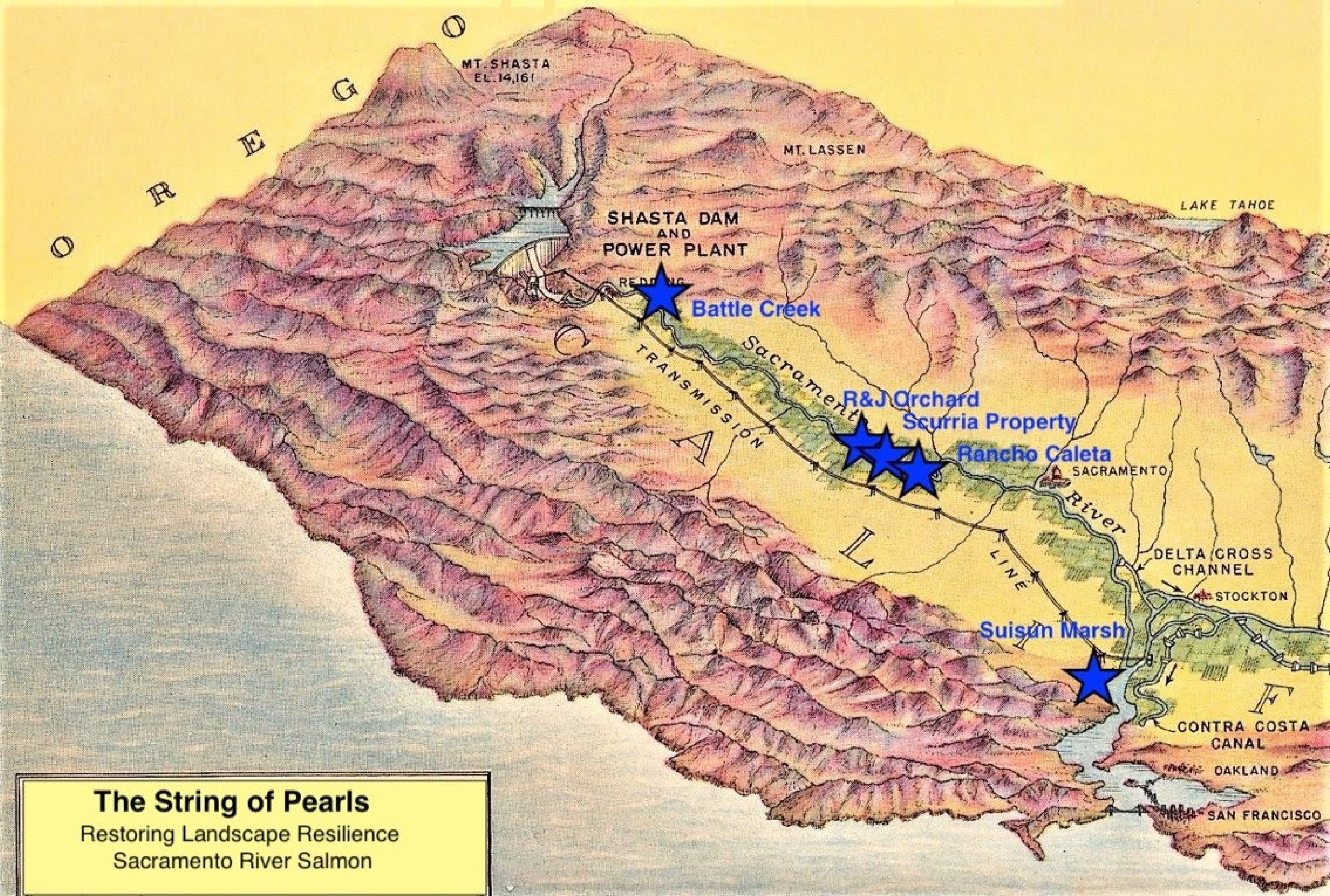
FLOODPLAIN FORWARD

Wet Side

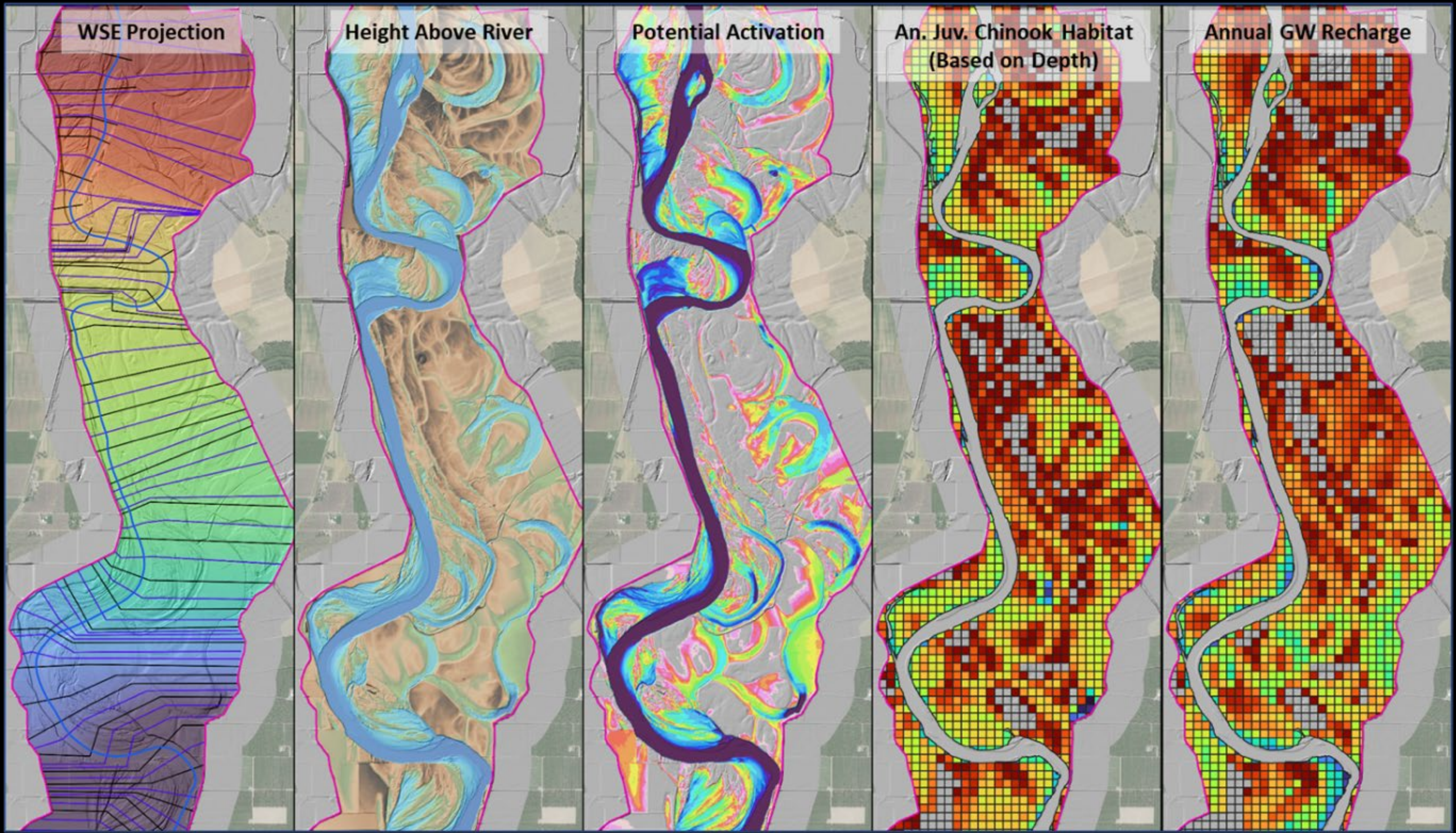

The Nigiri Project
Floodplain Fatties

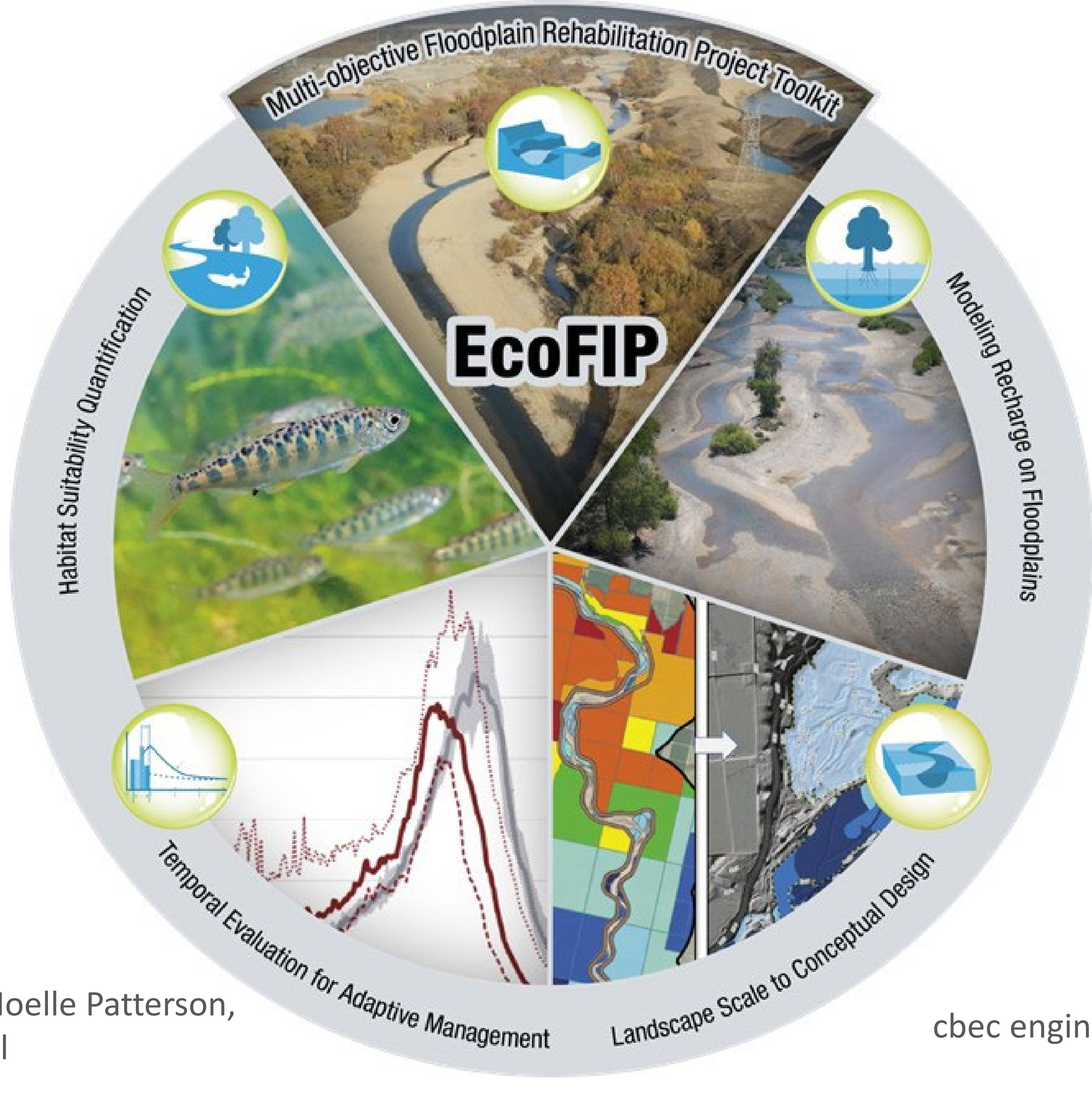

Floodplain Salmon Habitat in Yolo Bypass—Drier Years (1997-2012)
Suitable floodplain habitat equals number of acres inundated
to a depth of .3' to 6.6' for a duration of one day between 11/1 to 3/15
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
188,279
584,640
+211%
1,437,216
+663%
Baseline
Notch
Nigiri with Notch

The String of Pearls



Ecological Floodplain Inundation Potential





Luke Tillman, Noelle Patterson,
Chris Campbell

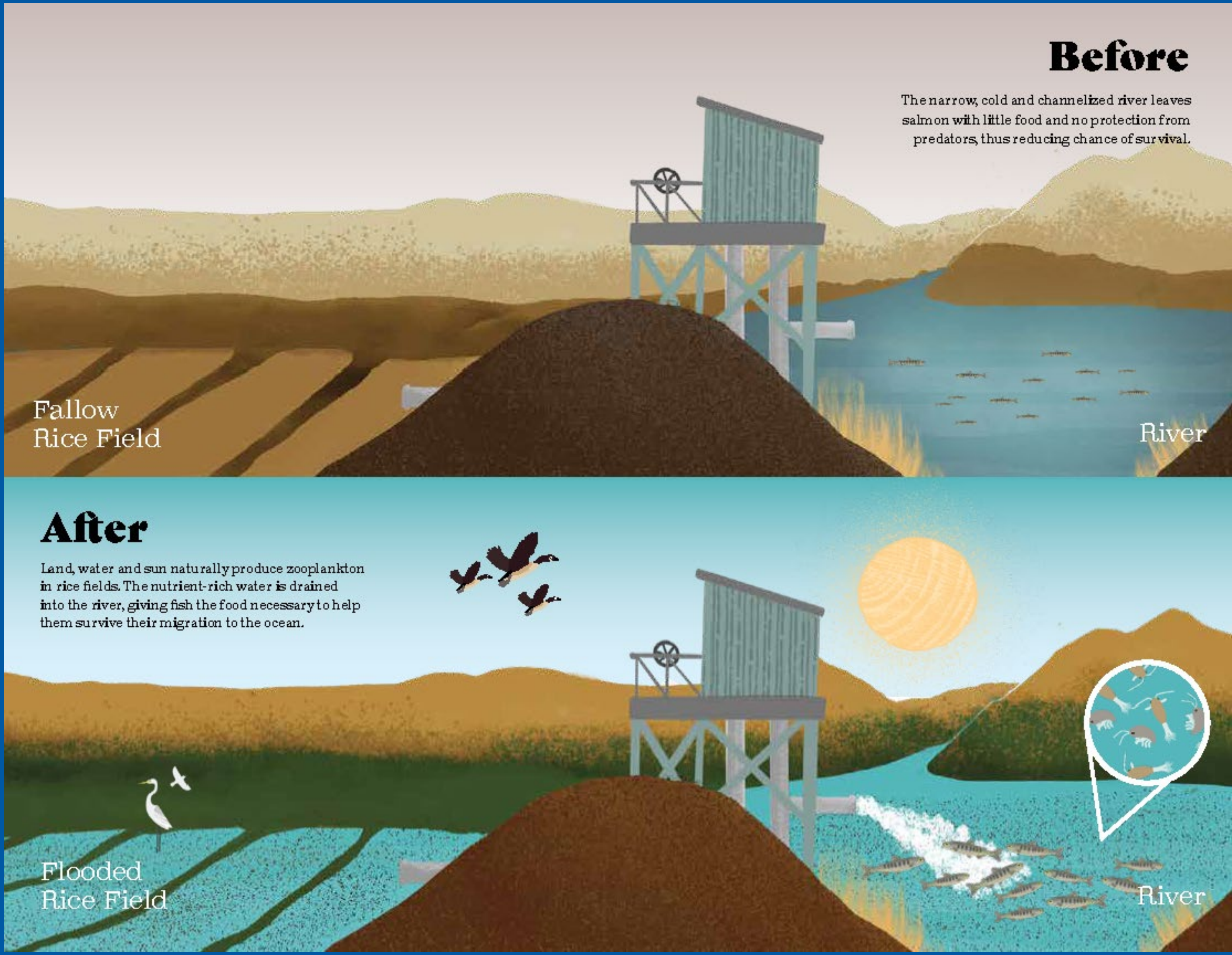
cbec engineering


Dry Side

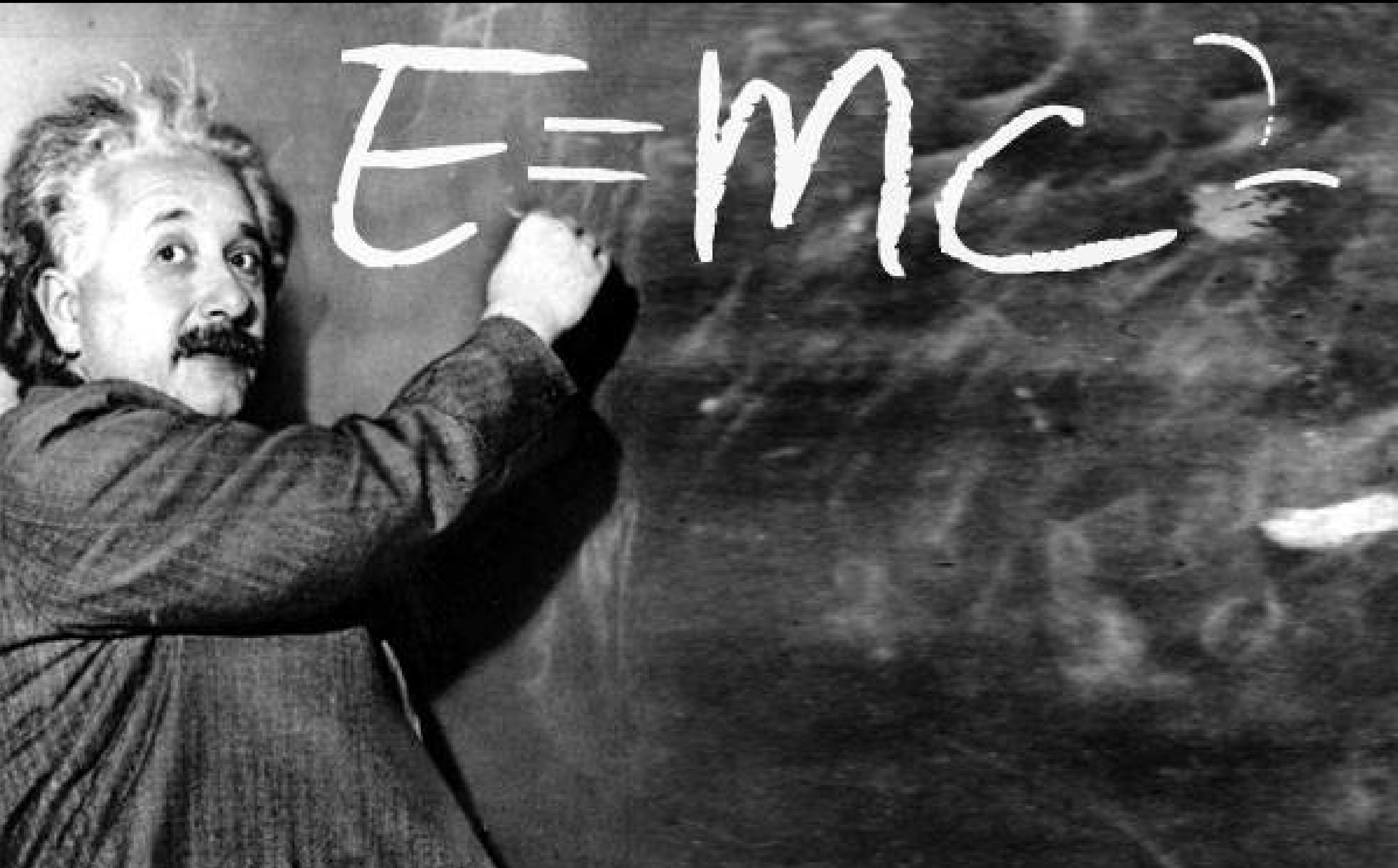

Fish Food
M.Wier


Landscape
Scale

Fish Food on Floodplain Farm Fields

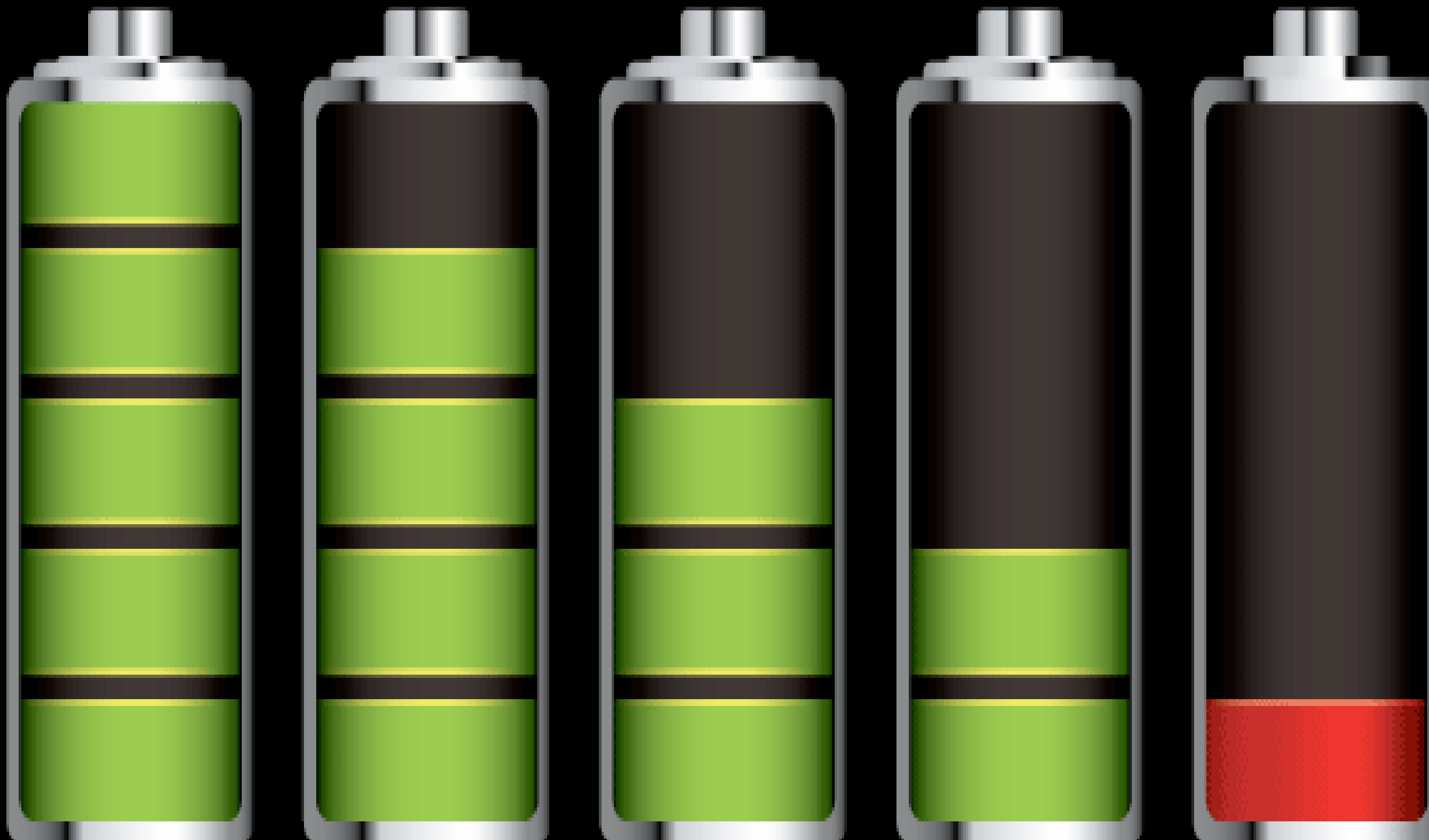


NCWA



The mathematics of recovery

Energy in **Biomass out**



Pre-development Today

Loss of Seasonally Inundated Floodplain

A process-based definition of salmon habitat:

"The spatiotemporal patterns of biophysical condition which arise (and to which salmon respond) as water interacts with the riverscape though which it flows."

The Life Cycle: Characterize each life stage (from gravel to gravel).

The Niche Cycle: Characterize the ecological function(s) required for each life stage to matriculate to the next.

The Habitat cycle: Characterize the sequence of biophysical conditions required to fulfill each link in the niche cycle.

The Process cycle: Characterize the landscape-scale biogeomorphic processes which synergistically interact to create and sustain the sequence of biophysical conditions (4-D habitat mosaic) to which individual salmon actually respond.

Process Interruption: Identify and characterize the human infrastructure and land use(s) that interrupt these biogeomorphic processes thereby limiting riverscape capacity to provision the diverse life-history trajectories from which population resilience emerges.

We don’t manage salmon.

Nor, in truth, do we manage the rivers on which they depend.

Or even the landscapes through which those rivers flow.

What we *can* manage is the behavior of people.

The *Pivot to Process* provides a means to identify where, and characterize how, human endeavor interrupts the capacity of a riverscape to provision the range of biophysical patterns required to produce resilient, abundant populations of anadromous salmonids.

Only when human endeavor no longer interrupts the landscape-scale biogeomorphic forces which create and sustain the mosaic of biophysical conditions, access to which facilitates each life stage to matriculate to the next, do we have a right to expect a population-level response – Recovery.

Puddle Power = Residence Time

Questions?

Carson Jeffres

Worldwide patterns of invertebrate drift abundance with implications for drift-feeding fishes

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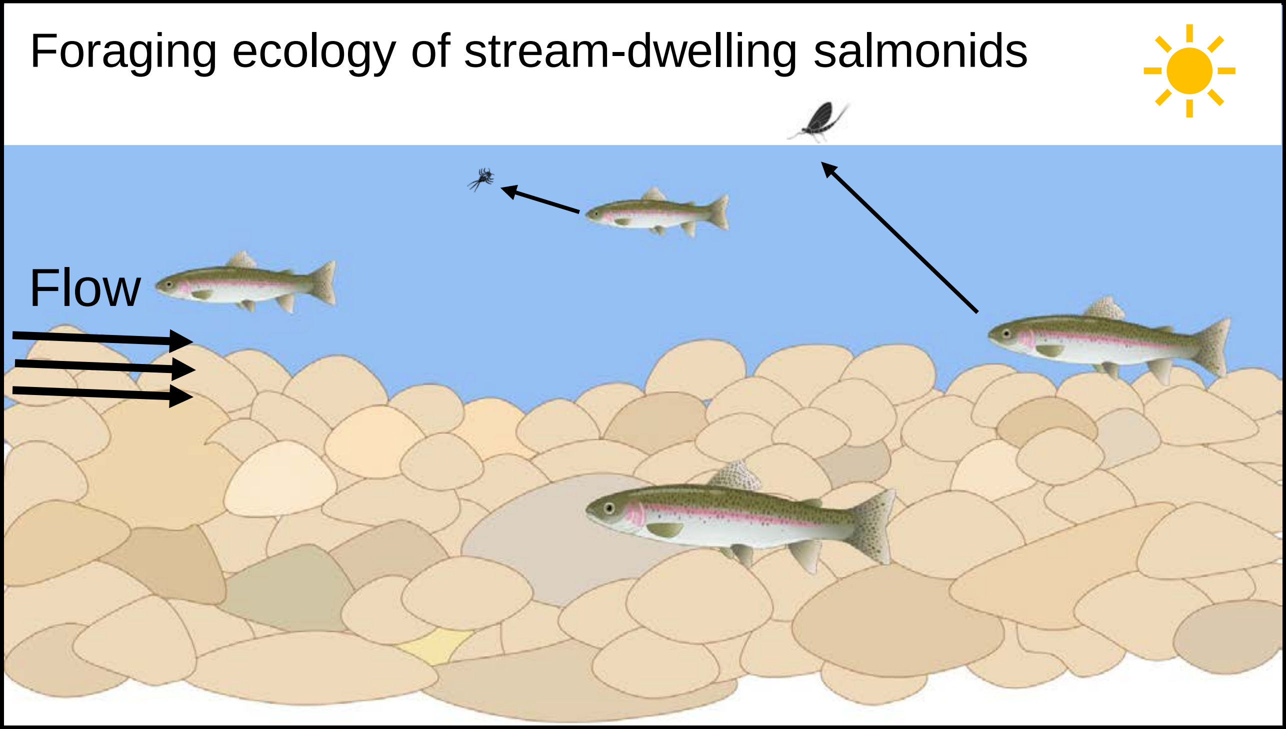
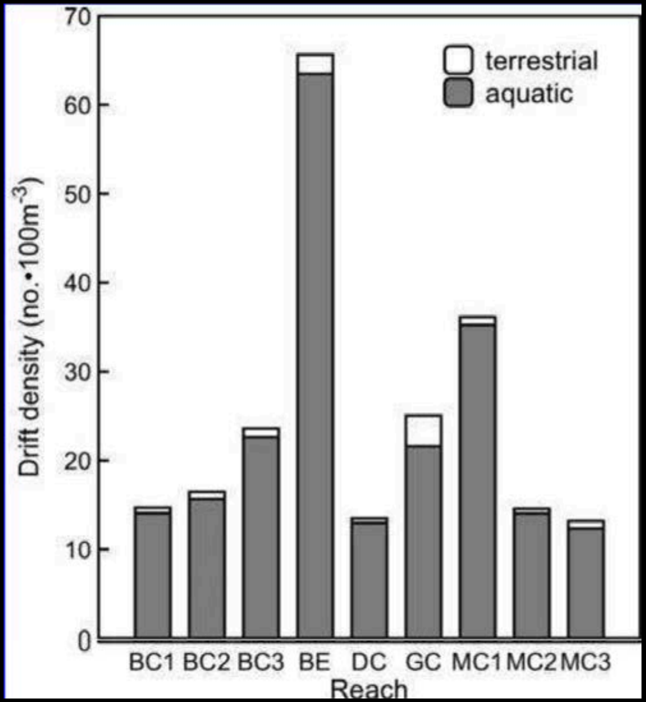
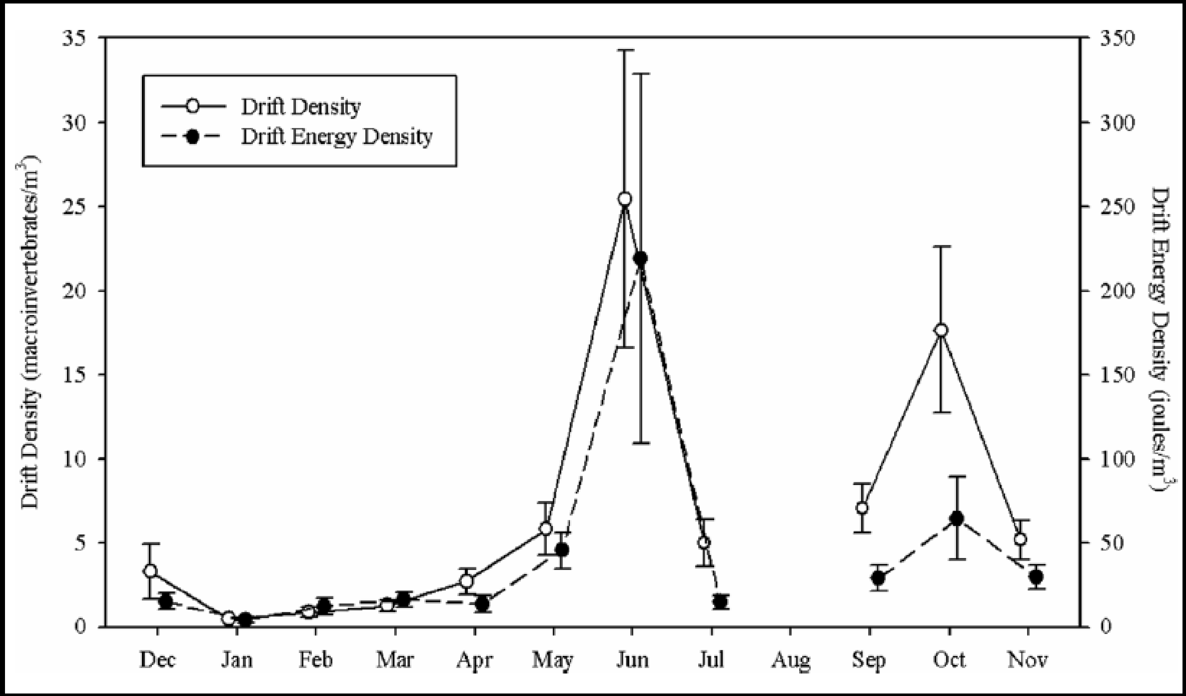
- Invertebrate drift
- Continually renewing
- Does not accumulate
- Central place foragers
    - Daytime



<u>Predation cycle for drift-feeders:</u> prey search, prey assessment, pursuit and attack, handling and ingestion of prey, then returning to search again



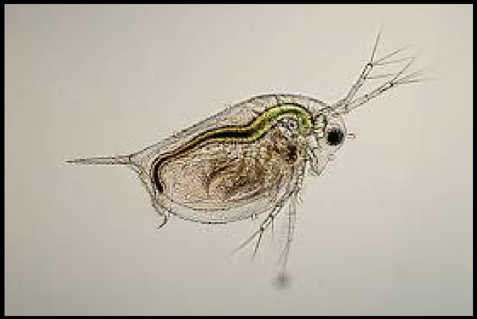


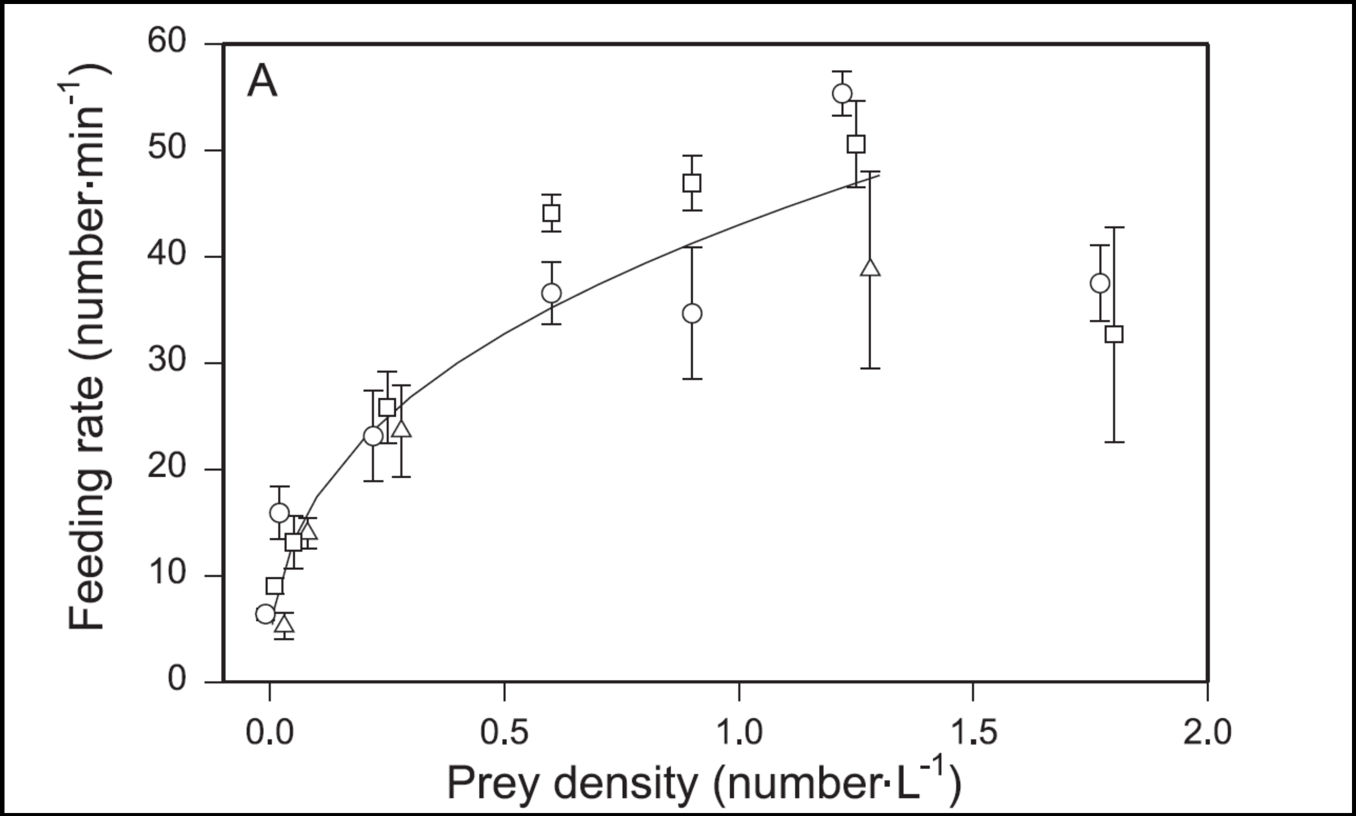
Weber et al. 2014

Kalb et al. 2017

Spatially and temporally variable within and between streams

Salmonids must capitalize on high prey densities during resource pulse





O'Brien et al., 2001

1000 L per m^3

Do fish in streams forage at similar rates when exposed to natural prey densities?

Questions

Do salmonids display a functional response to increasing prey availability in natural streams?

- Foraging rates?
- Drift densities?

Methods

Filmed cutthroat trout foraging behavior in five Idaho streams

Drift samples

Measured:

- Location of foraging attempts
  - Benthic
  - Water column
  - Surface

- Calculated foraging rates

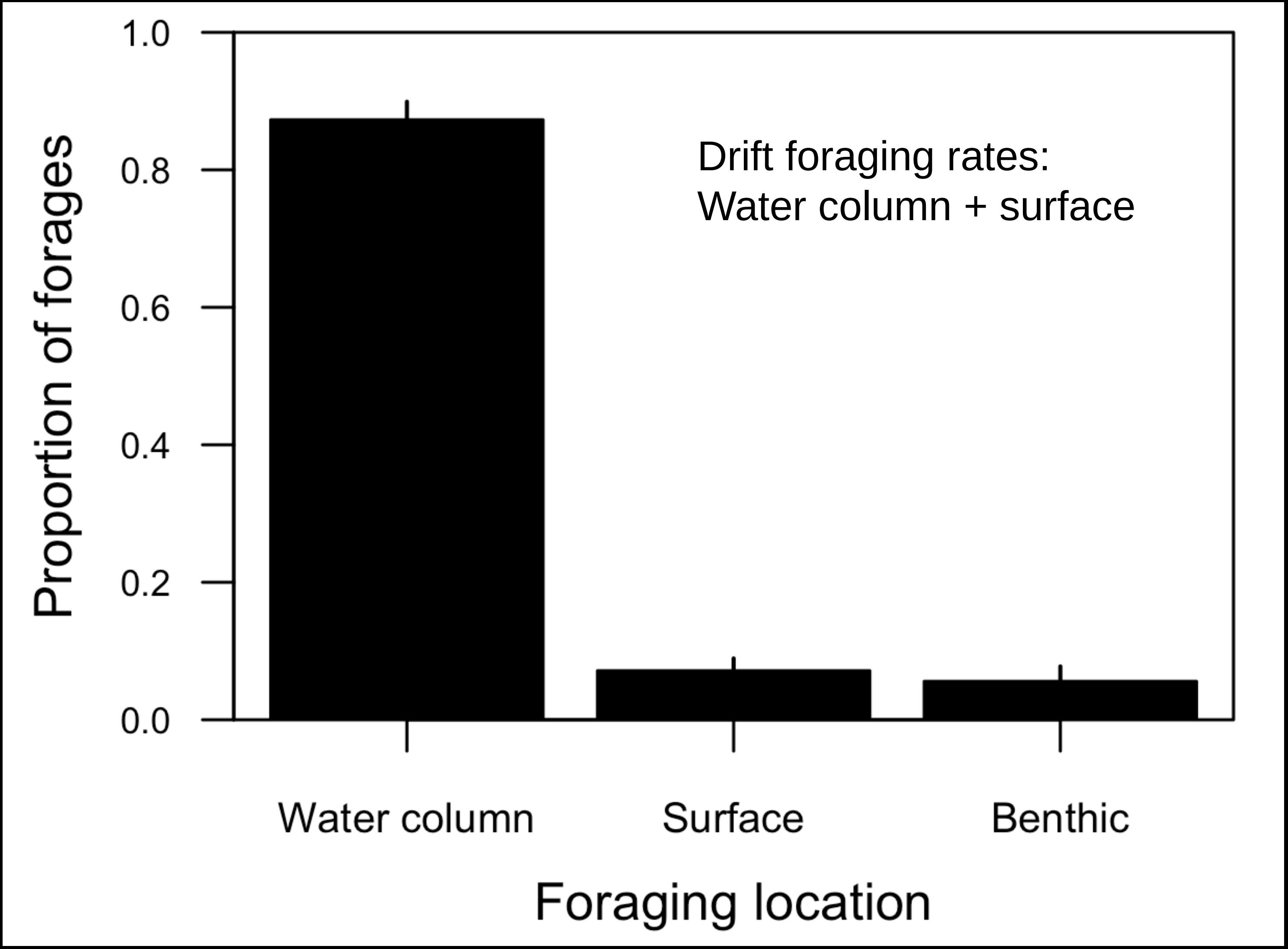
Sorted drift samples
Measured and enumerated invertebrates

prey energy content (joules · prey^{-1}) = 0.3818 (mean length of prey (mm))$^{2.46}$

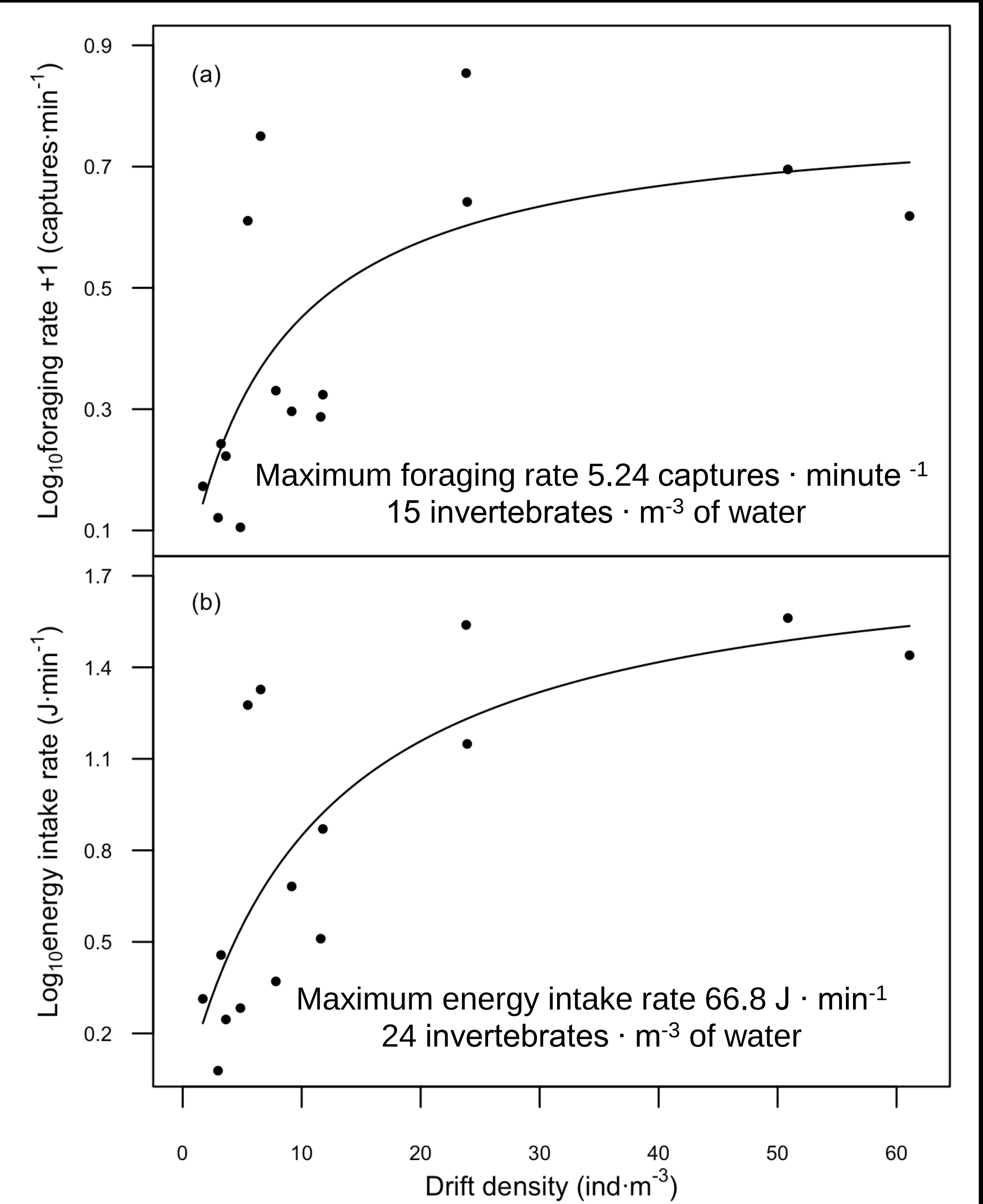
Smock, 1980

Results

- Fish filmed: 15 cutthroat trout
- Video durations: 2 min 44 sec - 36 min 52 sec
- Fish body size: 33 - 322 mm in length
- Drift density: 1.69 - 61.09 invertebrates · m^{-3}
- Foraging rates: 0.30 – 6.15 captures · min^{-3}



Hallbert & Keeley 2024



Hallbert & Keeley 2024

Questions

What is the magnitude of invertebrate drift abundance across streams?

What is the range and extent of foraging rates in drift-feeding fishes?

Do temperature, precipitation, and geographical variables predict drift abundance?

Methods

Literature survey

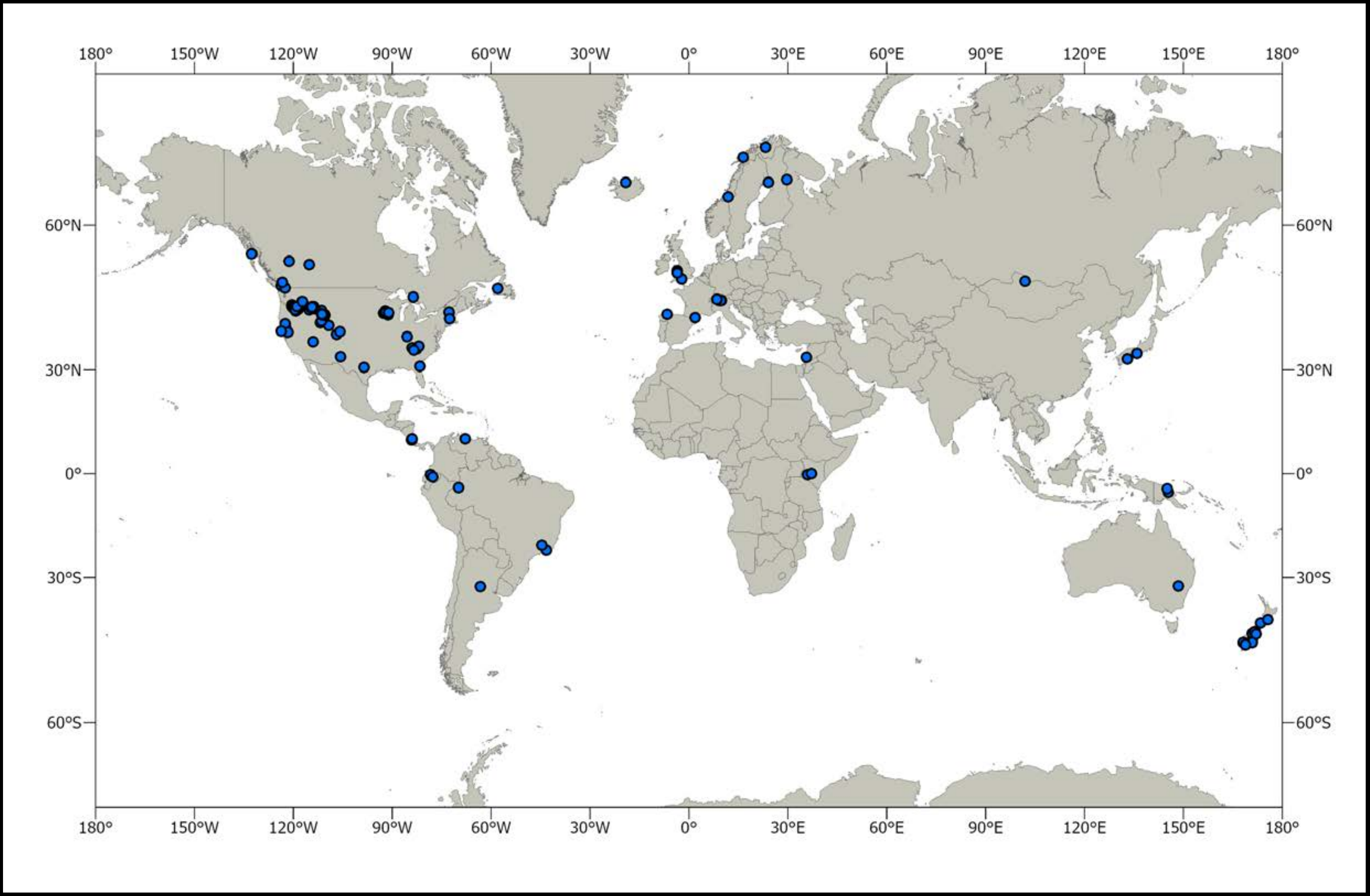
- Drift density
  - Collected during daytime
  - Units of number · m^{-3}

- Covariates
  - Latitude & longitude
  - Elevation
  - Three temperature and three precipitation variables from Worlclim
  - Net mesh size

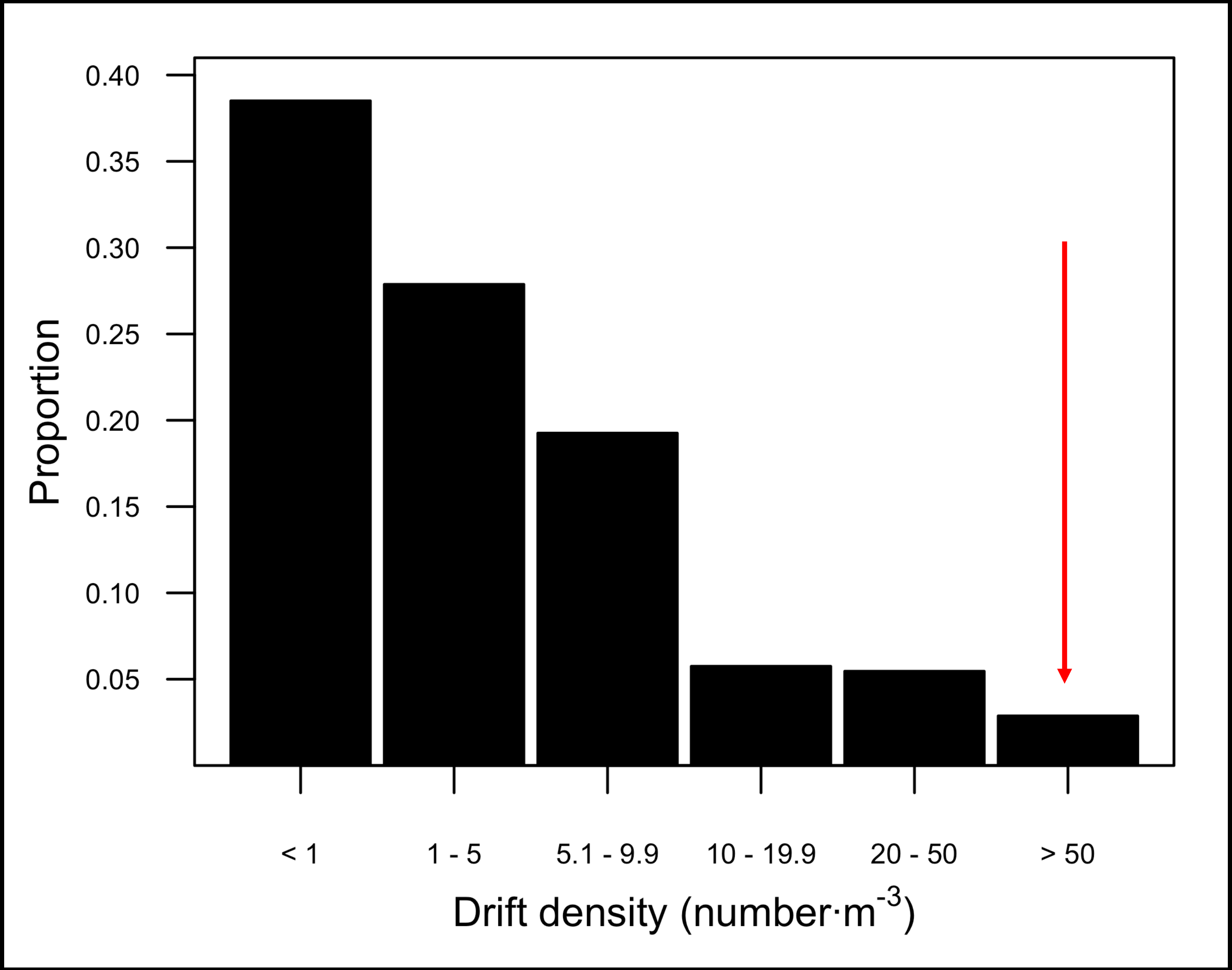
  - Stream

  - Model selection methods (mixed effects multiple regression)

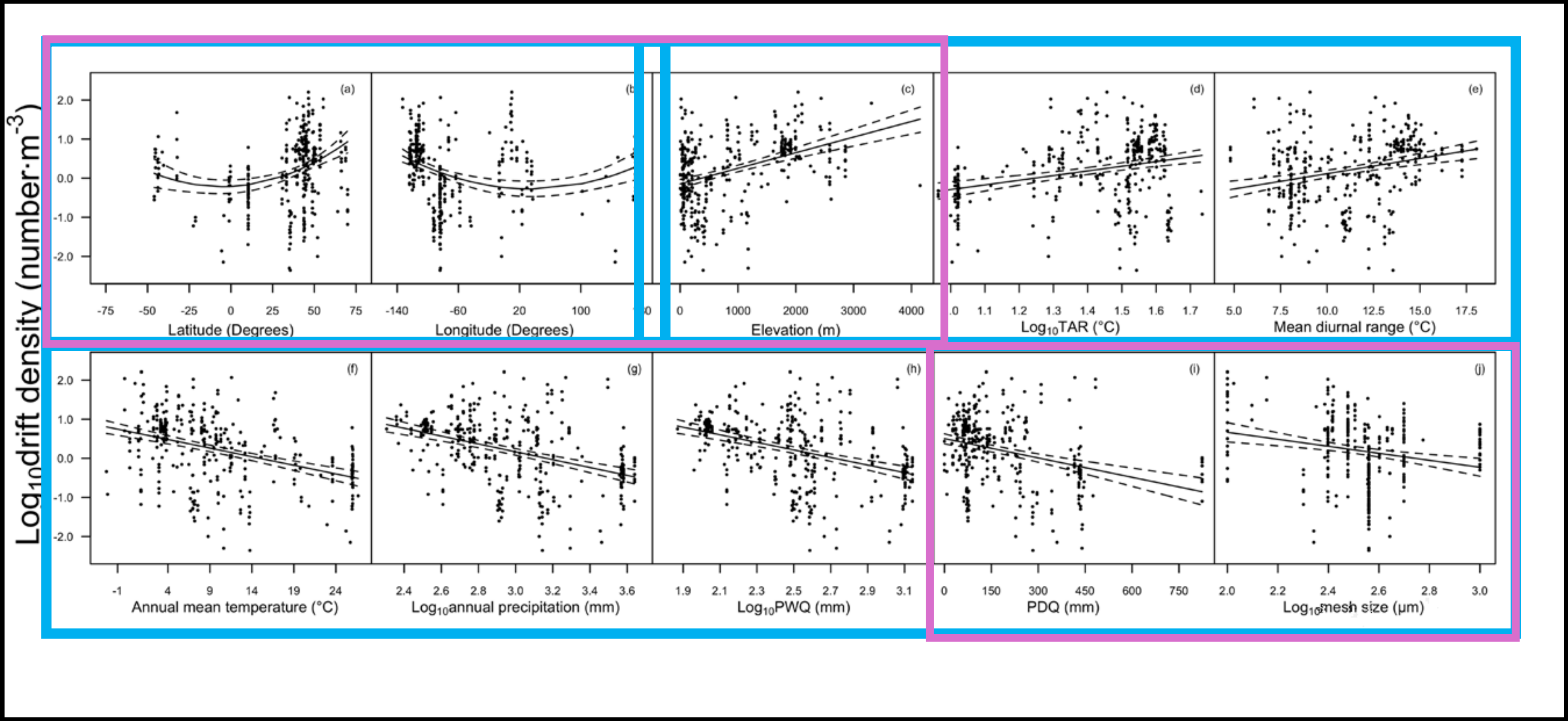
- Drift foraging rate
  - Daytime drift foraging rate in natural streams
  - Units of captures · min^{-1}



70 studies 348 drift observations from 142 streams across 23 countries within six continents



Range: 0.004 - 159.4 number · m^{-3} Mean: 7.3 number · m^{-3}

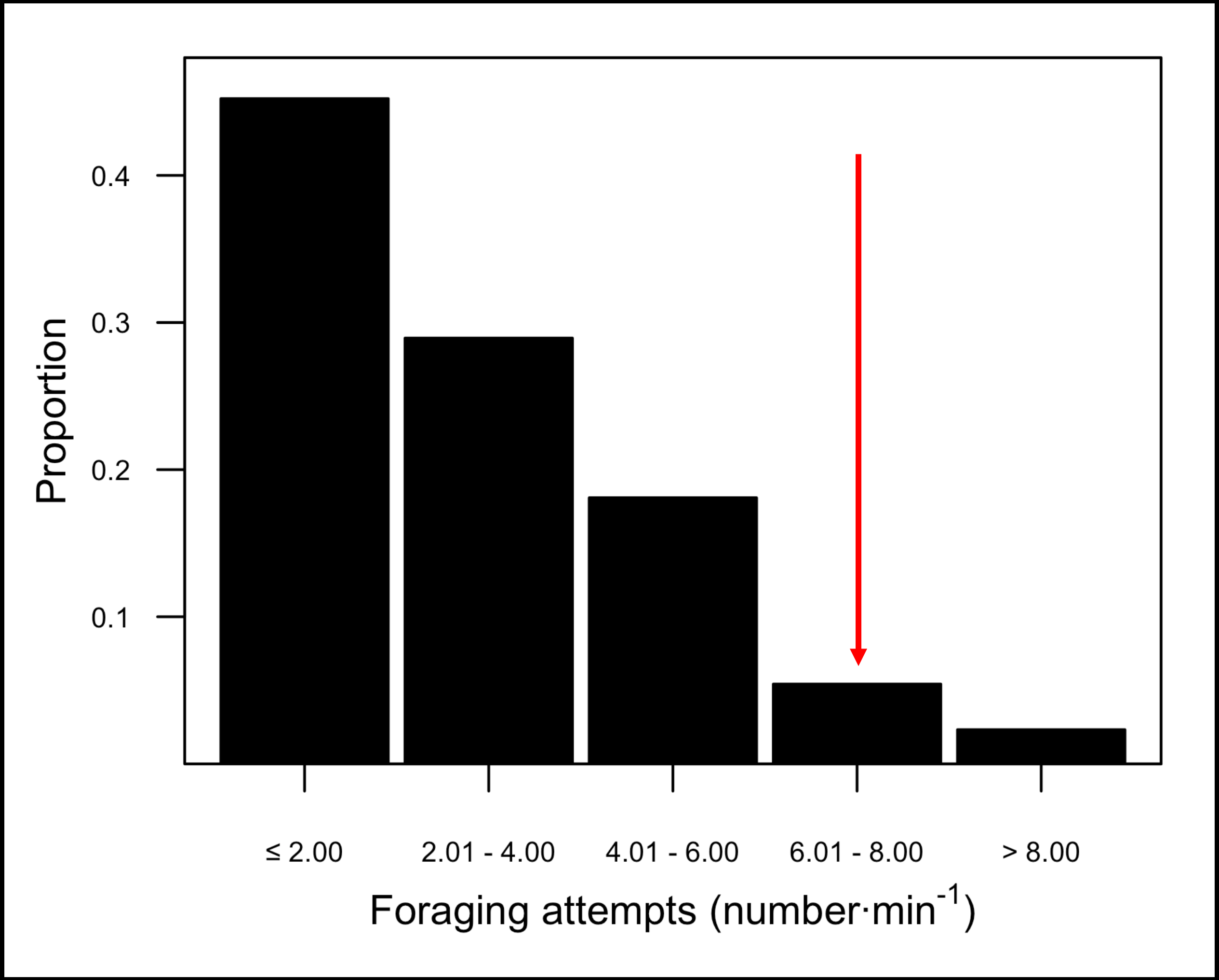


Seven models within 2 AIC_c from top model

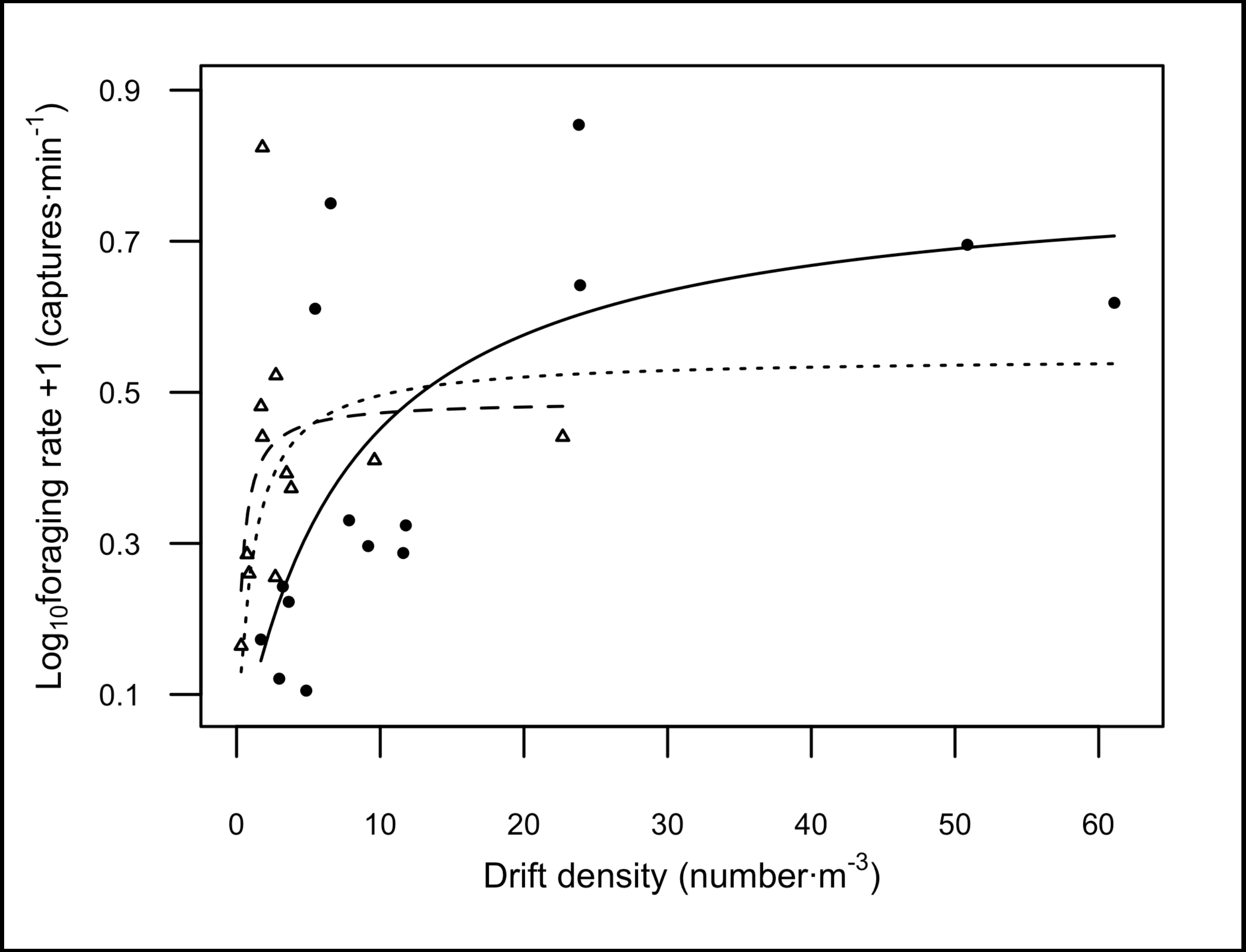
Global-model accounted for 35% (marginal $R^2 = 0.352$)

Both fixed and random effects explained 84% of variation (conditional $R^2 = 0.843$)

- 30 studies
- 385 observations
- 19 species
- 14 salmonid



Drift foraging rates: 0.06 - 12 captures · min^{-1}



0.9
0.7
0.5
0.3
0.1
Log10foraging rate +1 (captures·min-1)
0
10
20
30
40
50
60
Drift density (number·m-3)

Conclusions

- Most reported drift densities were low

  Food availability likely limits productivity in many populations

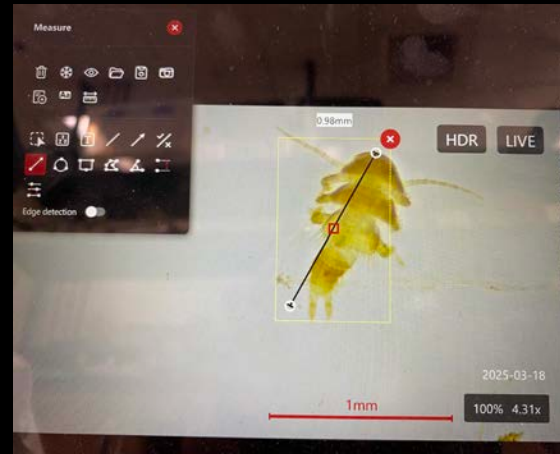
- Foraging rates for drift-feeding fishes were low

  Foraging rates paralleled drift densities

- $Latitude^2$, elevation, net mesh size, and PDQ were top predictors of drift density

  Mid-latitude regions where many drift-feeders are native to had higher drift abundance

Future directions



Size

Seasonality

Energetic contributions of alternative foraging modes

Habitat thresholds and switching

Questions?

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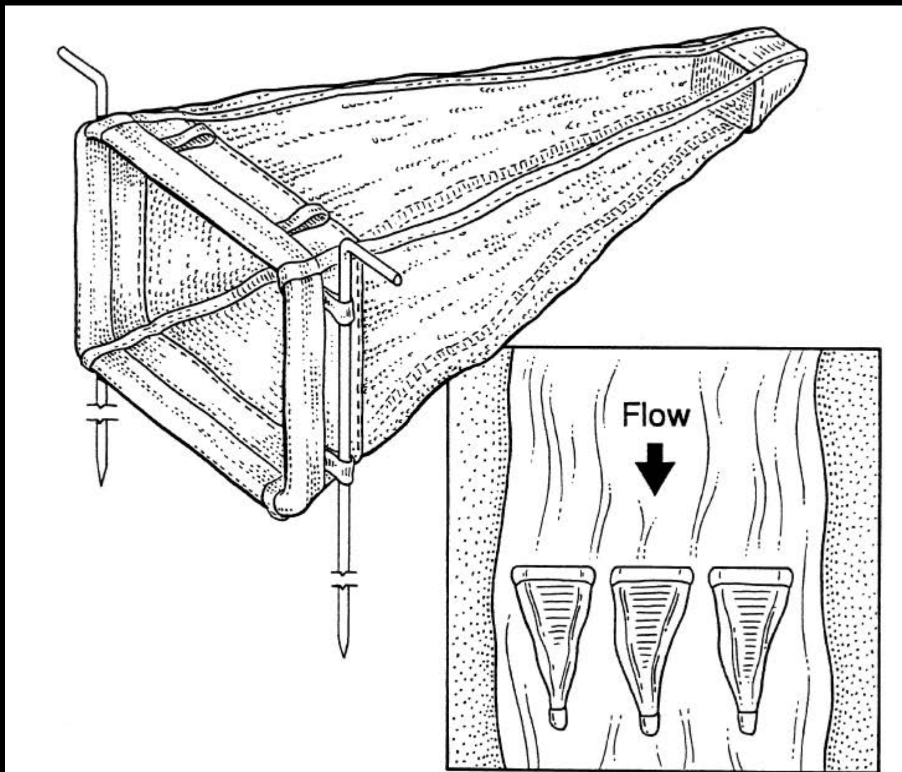
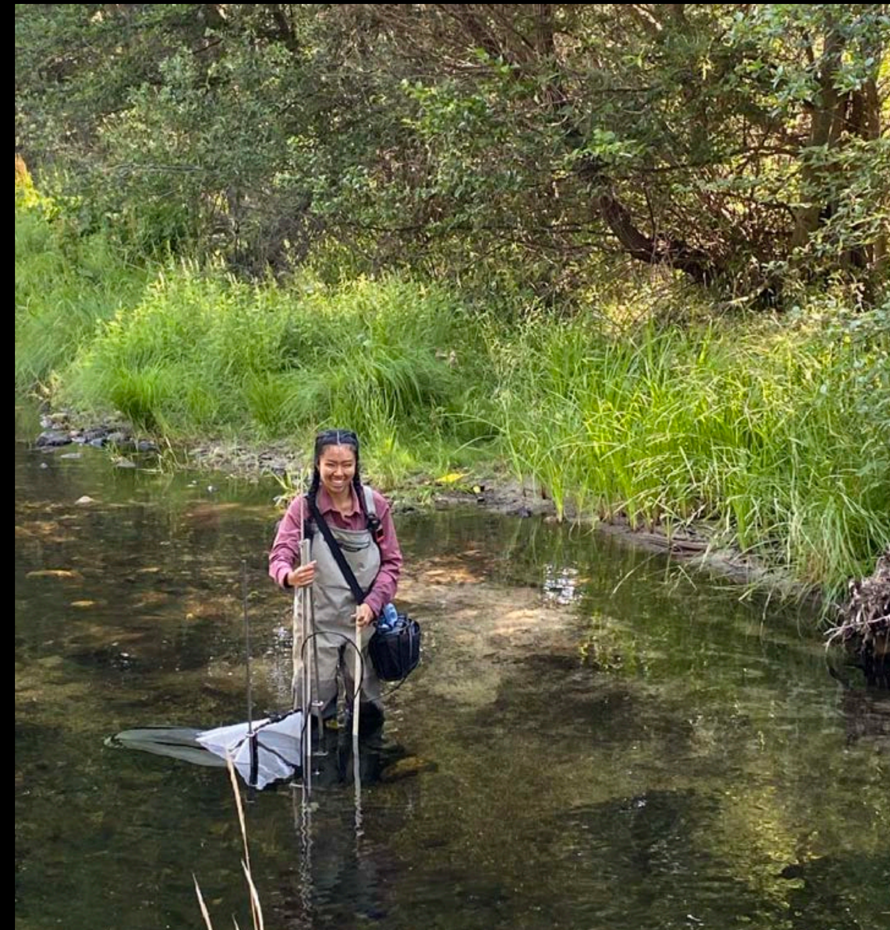
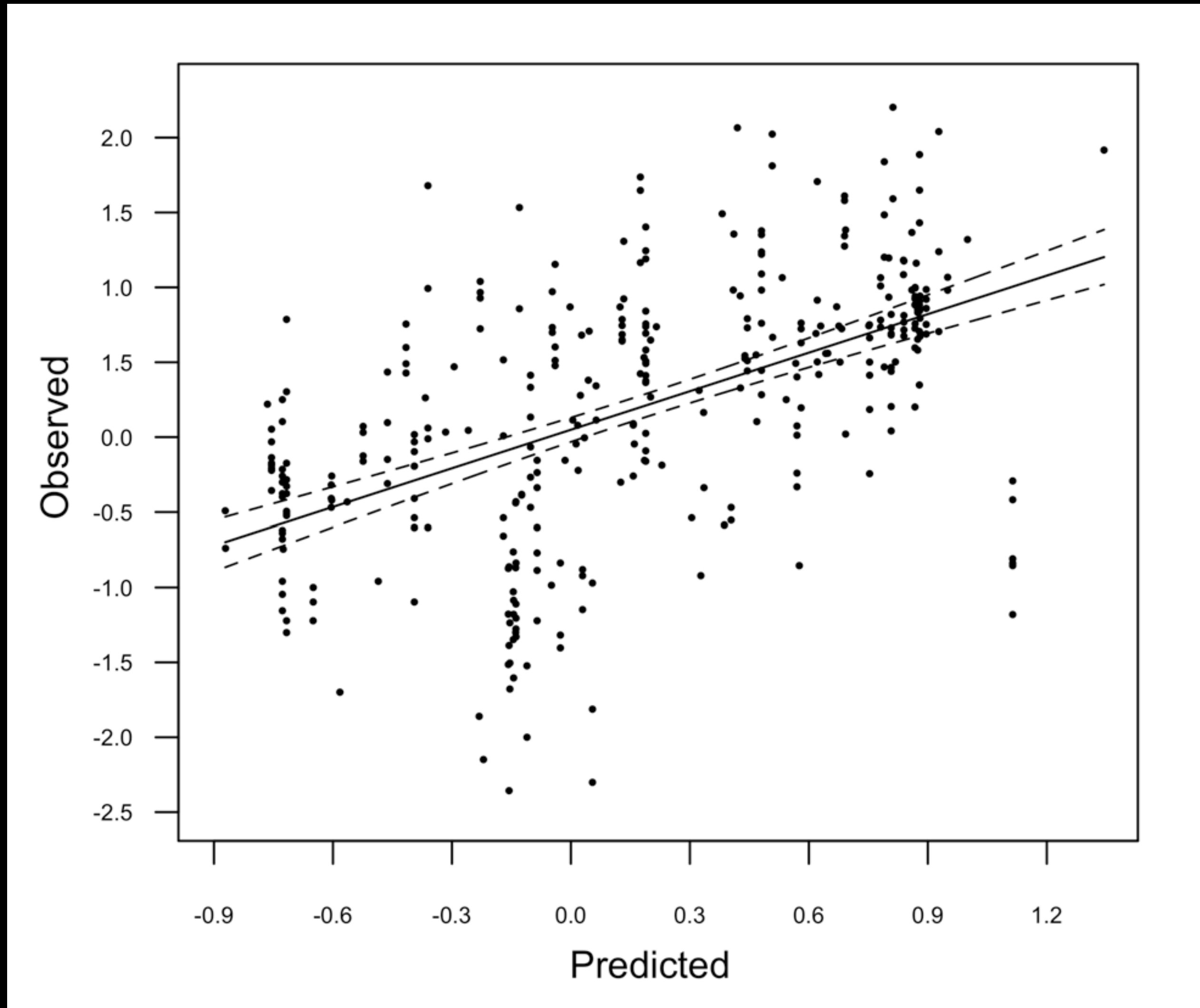




Drift density = individuals / w · d · v · t

$R^2 = 0.288$



2.0
1.5
1.0
1.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Observed
-0.9
-0.6
-0.3
0.0
0.3
0.6
0.9
1.2
Predicted