Beyond Physical Habitat; Session 1: The Importance of Prey Availability

A Concurrent Session at the 39th Annual Salmonid Restoration Conference held in Santa Cruz, California from April 19 – 22, 2022.

- **Session Coordinators:**
  - Robert Lusardi, Ph.D., *UC Davis Center for Watershed Sciences*

This session will delve into understanding how prey availability may influence the growth and fitness of salmonids and will identify productive ecosystems or habitats that may assist in the recovery of imperiled populations. We will also explore ecosystems, including highly managed ecosystems, that have the ability to improve productivity or prey availability at broader spatial scales and in an overall effort to improve habitat heterogeneity across the landscape.

Presentations

Slide 4 - **Putting Fish and Fish Food in the Framework: Using Drift-Foraging Bioenergetics to Make Flow Recommendations,** Suzanne Kelson, Ph.D., *University of Nevada, Reno and McBain Associates*

Slide 34 - **The Effects of Prey Density and Water Velocity on Capture Success of a Juvenile Salmonid,** Kwanmok Kim, *UC Santa Cruz and NOAA Affiliate*

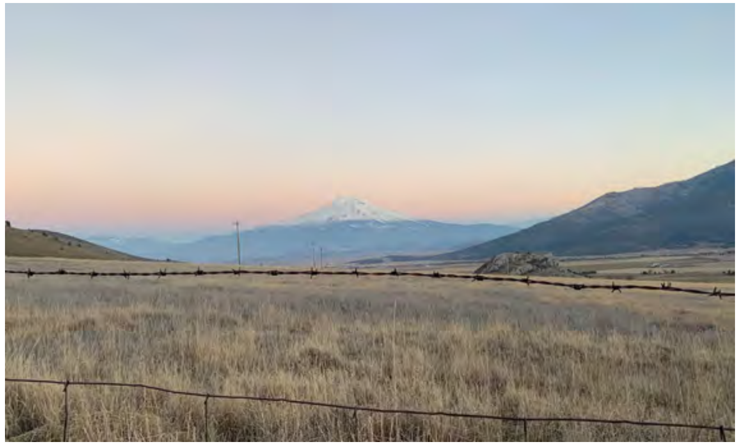
Slide 66 - **Salmonids Return to Montezuma Wetlands after 150 Years: Fish Use and Productivity Trends in a Sediment Beneficial Reuse Restoration Site,** Cassie Pinnell and Chris Jasper, *Vollmar Natural Lands Consulting*

Slide 100 - **Does "Wilding" Juvenile Chinook Salmon on Agricultural Floodplains Boost Survivorship in California's Central Valley?,** Rachelle Tallman, Graduate Student, *UC Davis*

Slide 125 - **How Do Beaver Dam Analogues (BDAs) Change Stream Food Webs: What Stable Isotopes Can Teach Us about Food Webs in BDAs,** Brandi Goss, *Graduate Group in Ecology, UC Davis*

Slide 154 - **Past, Present, and Future Coho Habitat Restoration in the Scott River, Tributary to the Klamath River,** Michael Pollock, Ph.D., *NOAA Fisheries*

Putting Fish and Fish Food in the Framework: Using Drift-Foraging Bioenergetics to Make Flow Recommendations



Suzanne Kelson,[1,2] PhD

Tim Caldwell[1,2], PhD, Sudeep Chandra[1], PhD , Scott McBain[2], Natalie Stauffer-Olsen[3], PhD, Rene Henery[3], PhD, Tara McKinnon[1]

[1]Global Water Center & Biology Dept, University of Nevada, Reno, [2]McBain Associates, [3]Trout Unlimited

Human-driven stream flow reduction is common in arid regions like California

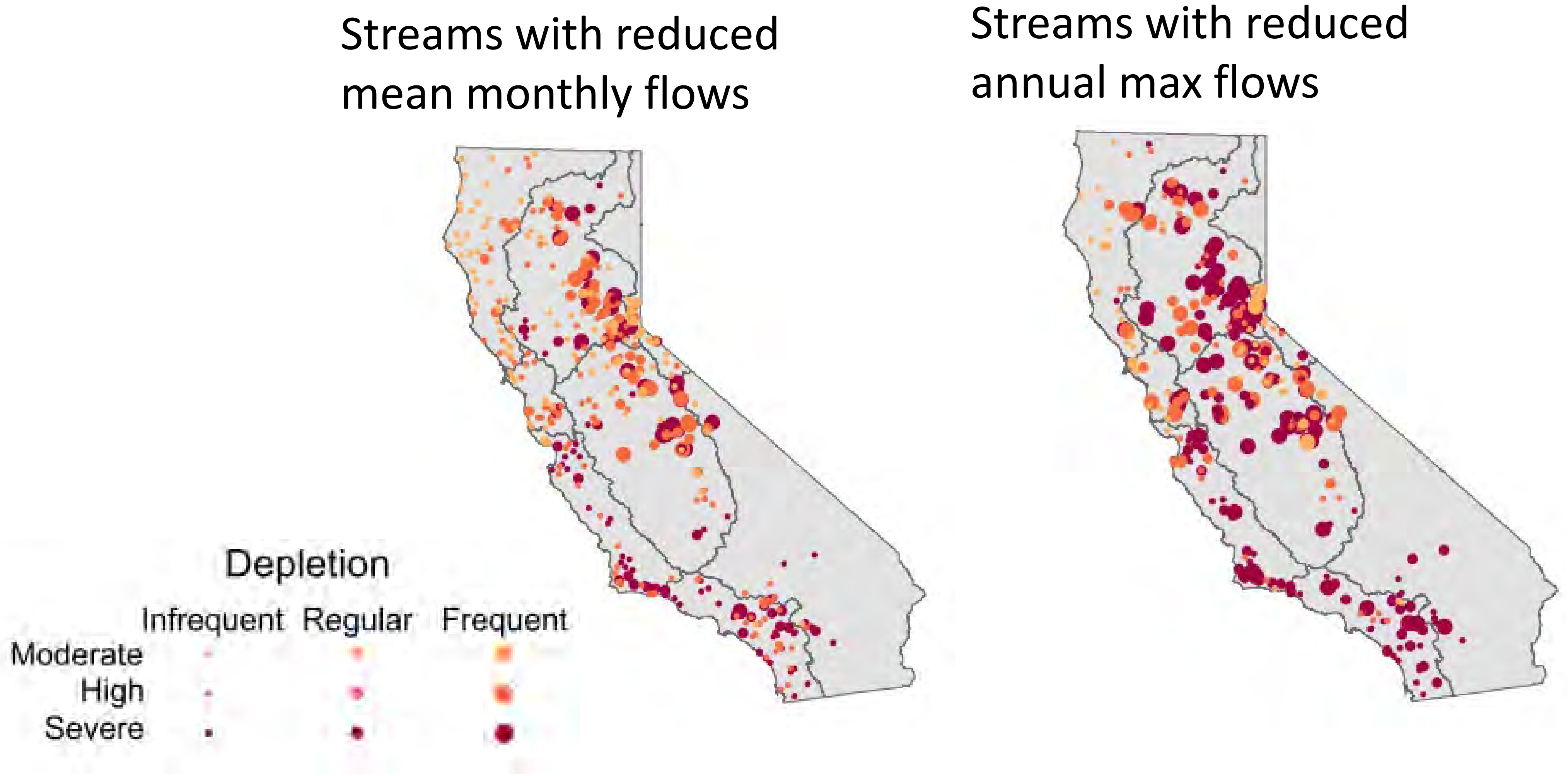
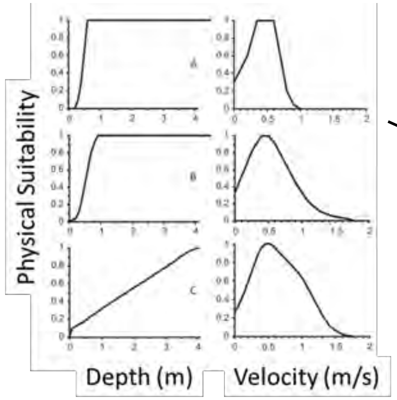


Figure adapted from Zimmerman et al. 2018

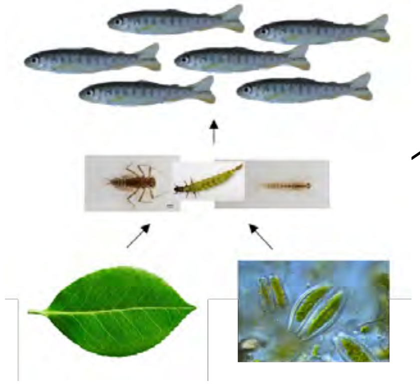
How much water does a trout need in a river, and when?

Stream flows influence **habitat** and **food** availability to influence trout condition

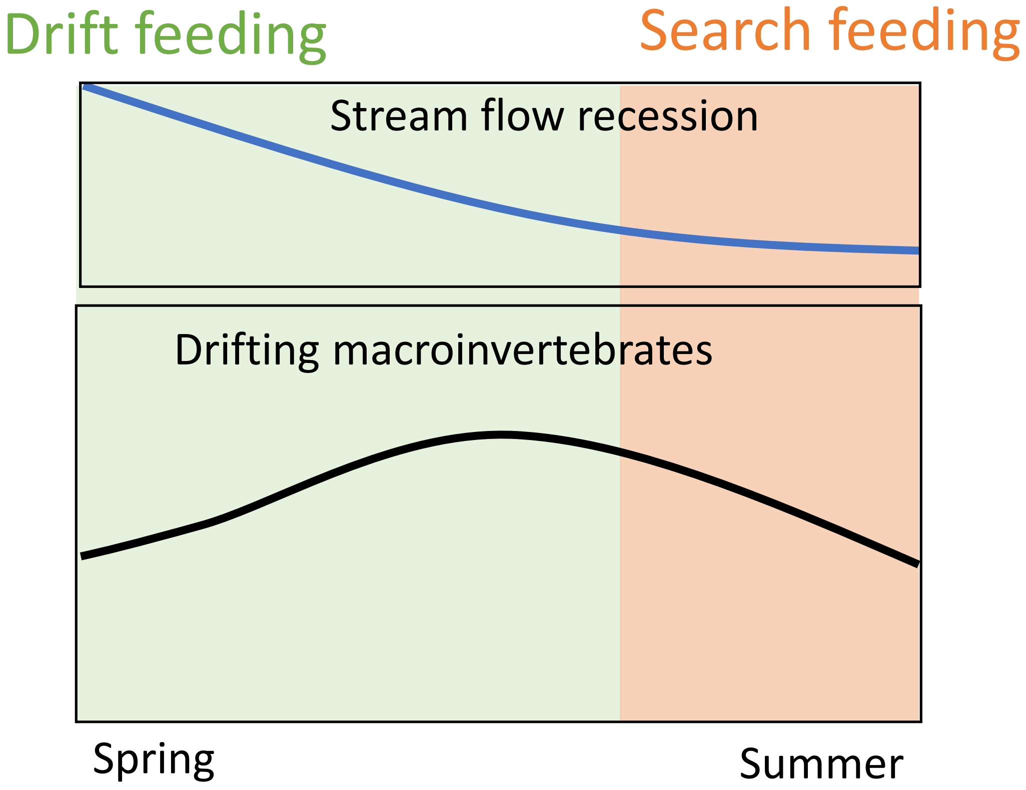
Hydraulic habitat (e.g., habitat suitability curves)



Food availability



Fish bioenergetics



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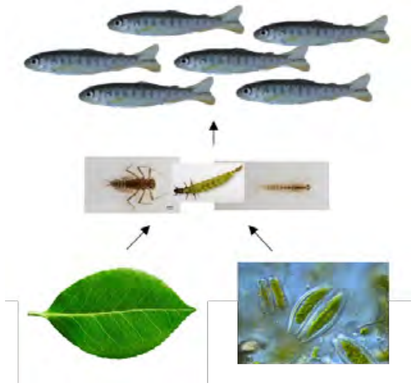
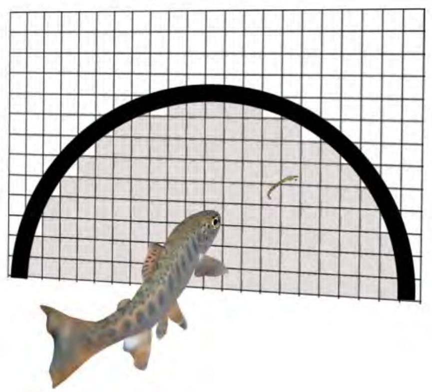


1. How does stream flow recession influence trophic level productivity that fuels fish?



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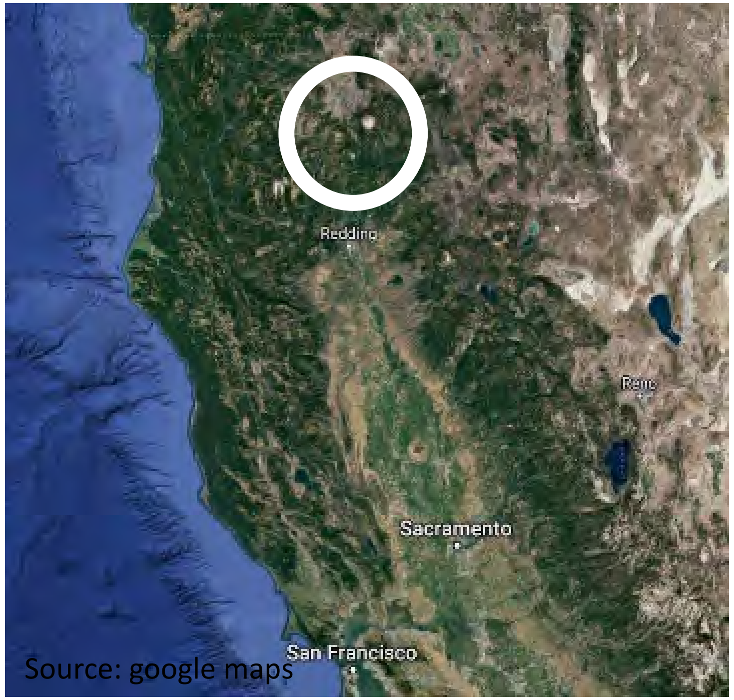
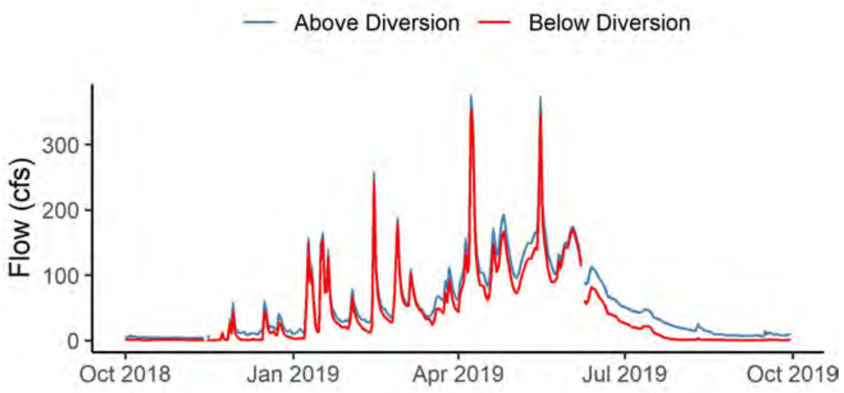
2. How can we use bioenergetics to synthesize changes in flow and food to make stream flow recommendations?

Flows for fish in the Upper Shasta River, CA



- Hydrologic inputs from rainfall, snowmelt, springs
- Stream temperatures remain cool (<20ºC) in the summer
- Rainbow trout are native species of interest (above Dwinelle dam)
- Up to 98% (30 cfs) of stream flows are diverted in the summer months at one major diversion point



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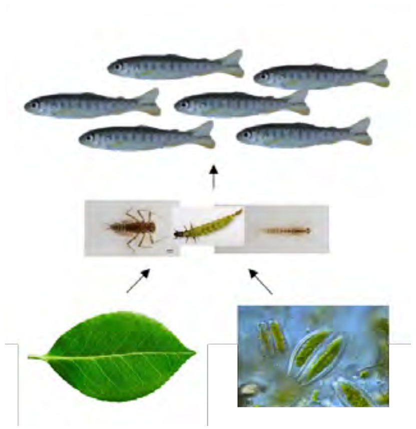


1. How does stream flow recession influence trophic level productivity that fuels fish?

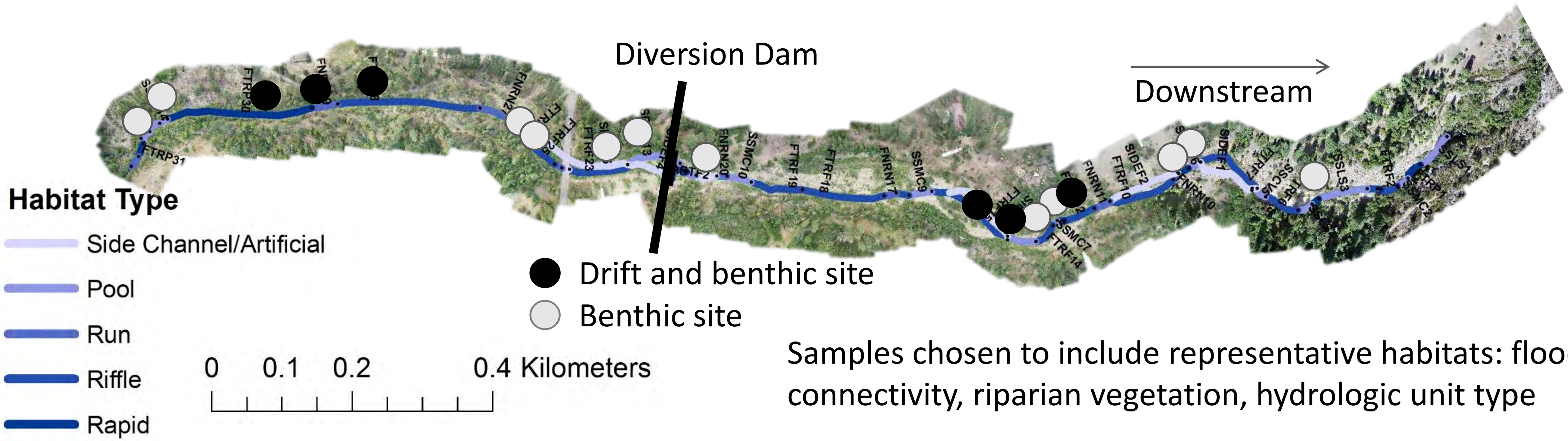
   - *Are primary productivity, benthic invertebrates, and drifting invertebrates in synchrony in the summer?*

   - *Can we predict drifting invertebrate concentration from streamflow and benthic invertebrates?*

   - *How do fish respond behaviorally to changes in food resources and flows?*

Methods: How does stream flow recession influence productivity above and below diversion?

- Productivity of benthic biofilms (in-situ chambers)
- Drifting invertebrates at 6 sites
- Benthic invertebrate density at 18 sites
- Fish foraging behavior in 2 focal pools



Samples chosen to include representative habitats: floodplain connectivity, riparian vegetation, hydrologic unit type

Predictions: Decline in primary and secondary productivity and drift with stream flows at end of summer

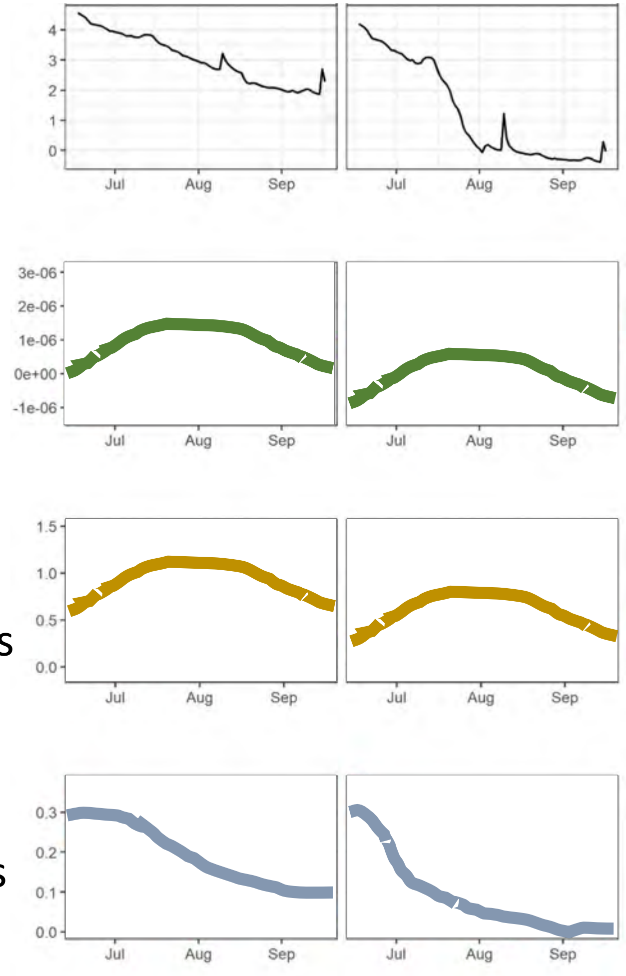
Above diversion Below diversion

Stream flow (cfs)

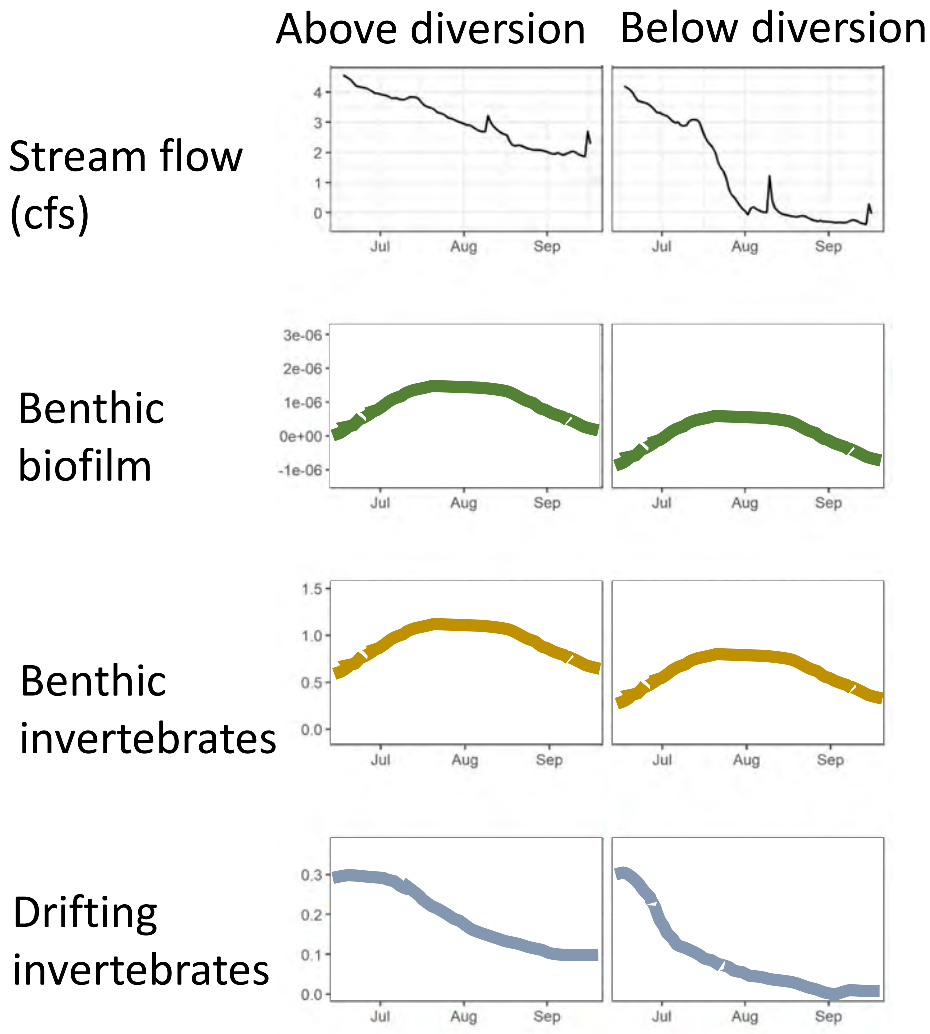
Benthic biofilm

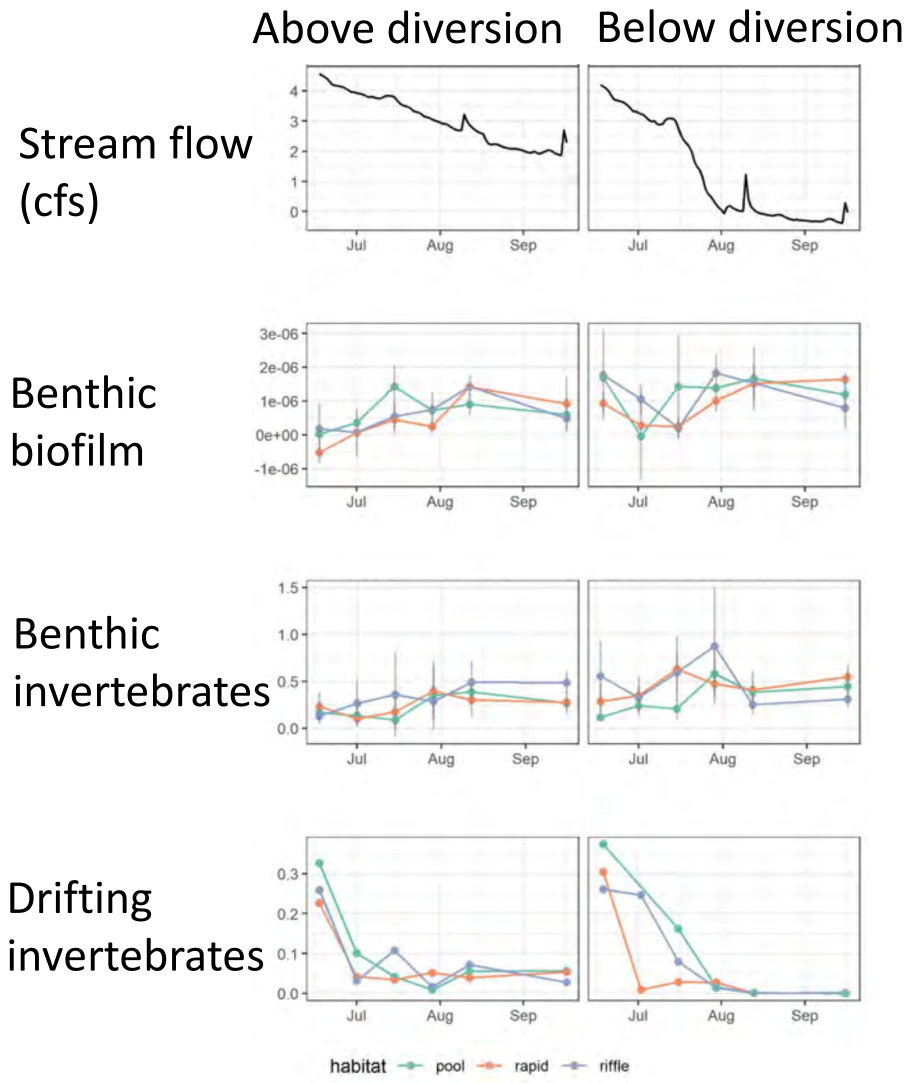
Benthic invertebrates

Drifting invertebrates



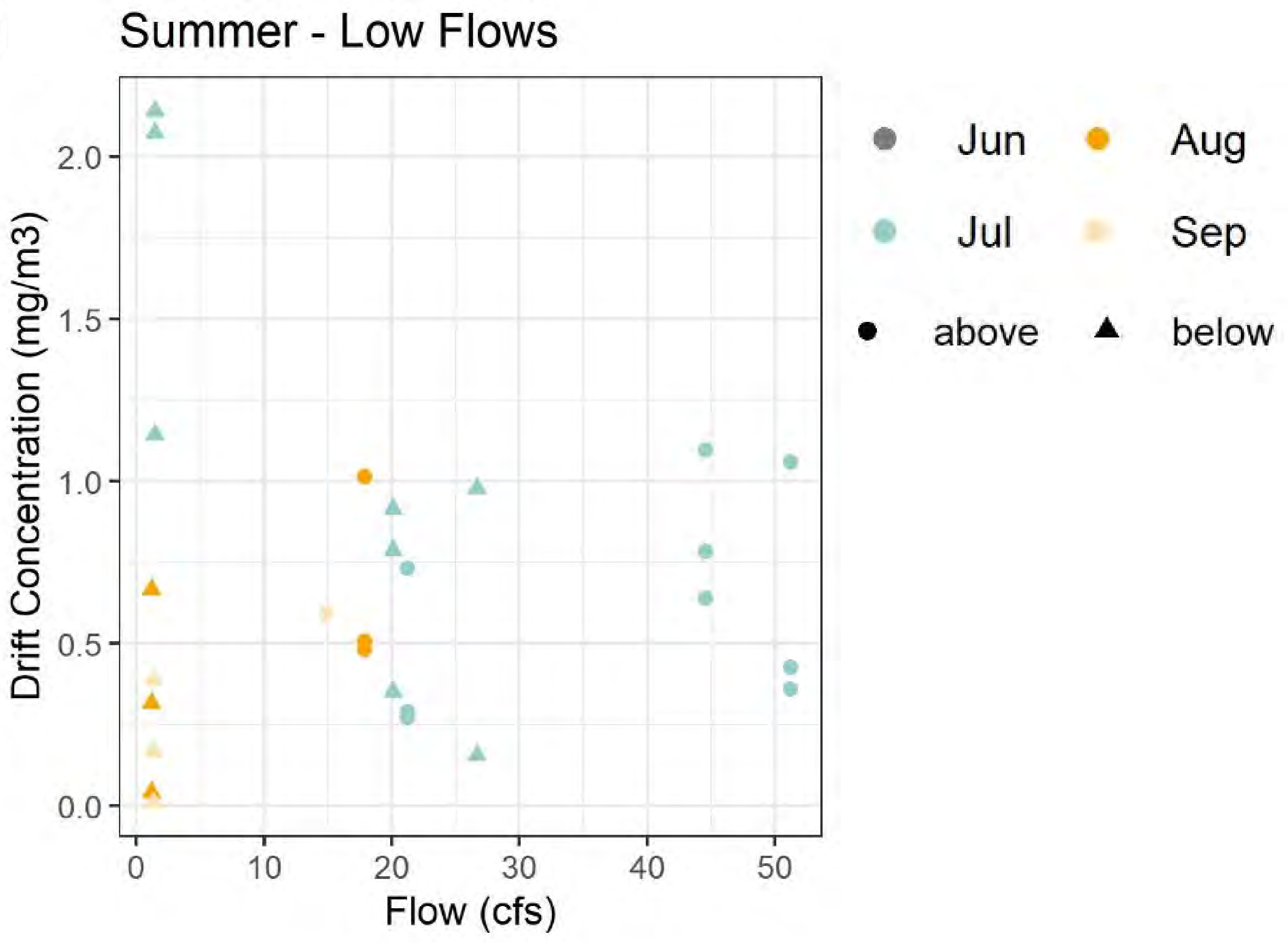
Results: Primary and benthic invertebrate production increased while drift flux decreased through the summer





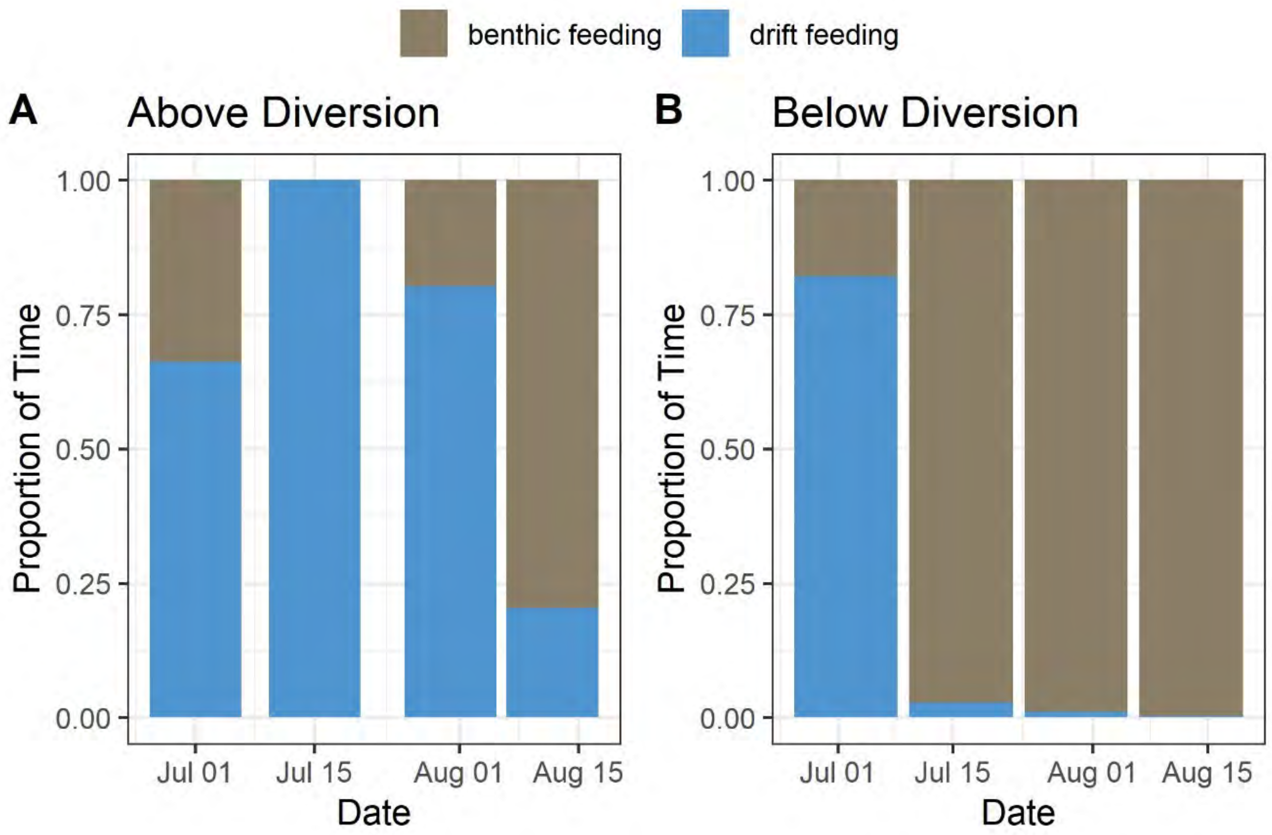
Results: streamflow does not predict summer drift concentration

- Relationship between flow and drift concentration is not significant



Results:

- Trout switched to benthic foraging **one month earlier** below the diversion



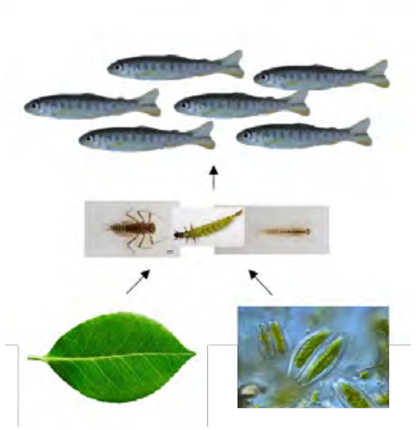
Summary: Trophic level productivity

- Benthic biofilms and benthic invertebrates **increased** throughout the summer, and especially so below the diversion

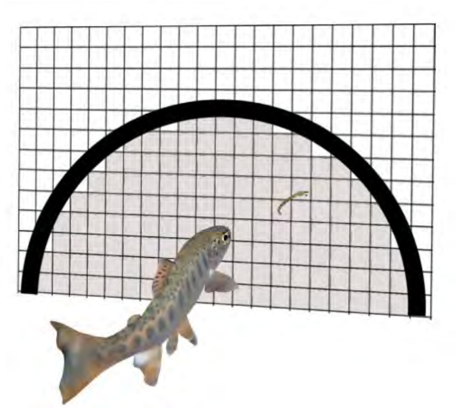
- Decline in flows were accompanied by **a loss of drift flux but not drift concentration**

- Drift flux dropped to nearly **zero** below the diversion, accompanied by change in feeding behavior of trout

Today:



1. How does stream flow recession influence trophic level productivity that fuels fish?



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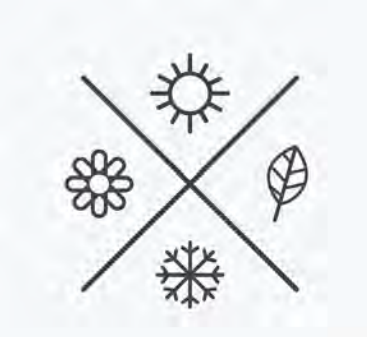
2. **Can we use bioenergetics to synthesize changes in flow and food to make stream flow recommendations?**

Bioenergetics modelling approach:

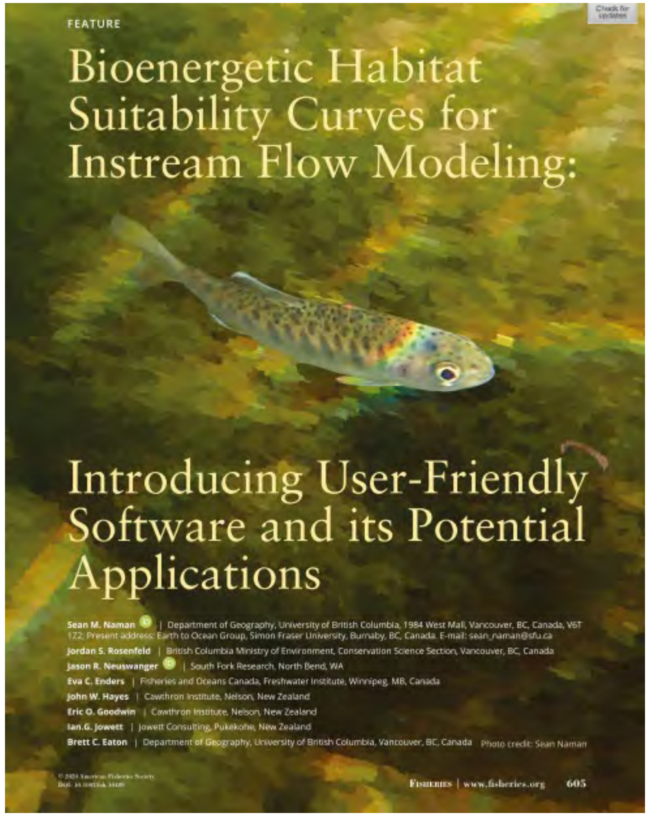


1. When are water diversions most impactful on fish energetics?

2. What is the maximum flow diversion rate would provide protection for fish energetics in over the course of >50 years?

Bioenergetics modelling approach:

- **Bioenergetics HSC:** User-friendly software to estimate energetics and of drift-foraging fish
- Can generate habitat suitability curves that incorporate fish energetics
- Output is **Net Rate of Energetic Intake (NREI)**


FEATURE

Bioenergetic Habitat Suitability Curves for Instream Flow Modeling:

Introducing User-Friendly Software and its Potential Applications

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John W. Hayes | Cawthron Institute, Nelson, New Zealand
Eric O. Goodwin | Cawthron Institute, Nelson, New Zealand
Ian.G. Jowett | Jowett Consulting, Pukekohe, New Zealand
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Photo credit: Sean Naman

Naman et al 2020, Fisheries

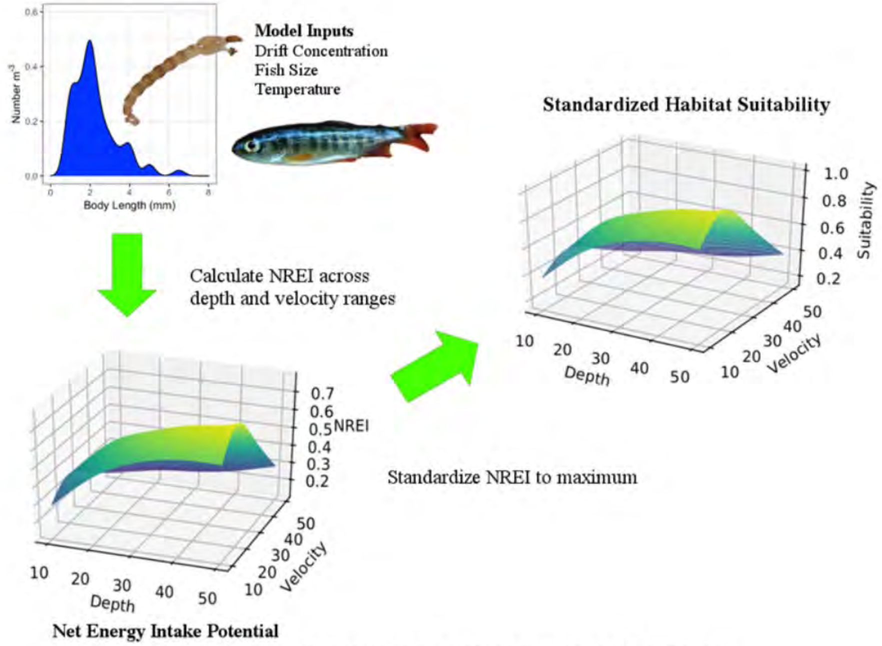


Figure 1 Overview of modelling procedure used in the software

Part 1 Inputs to Bioenergetics HSC:

- Mean monthly water temperature
- Empirical drift data from Oct 2018 – Dec 2019 (density, size classes of invertebrates)
- Depth and velocity transects from 2-D Hydraulic model
  - 5 riffle transects
  - 5 pool transects

Upstream of Diversion

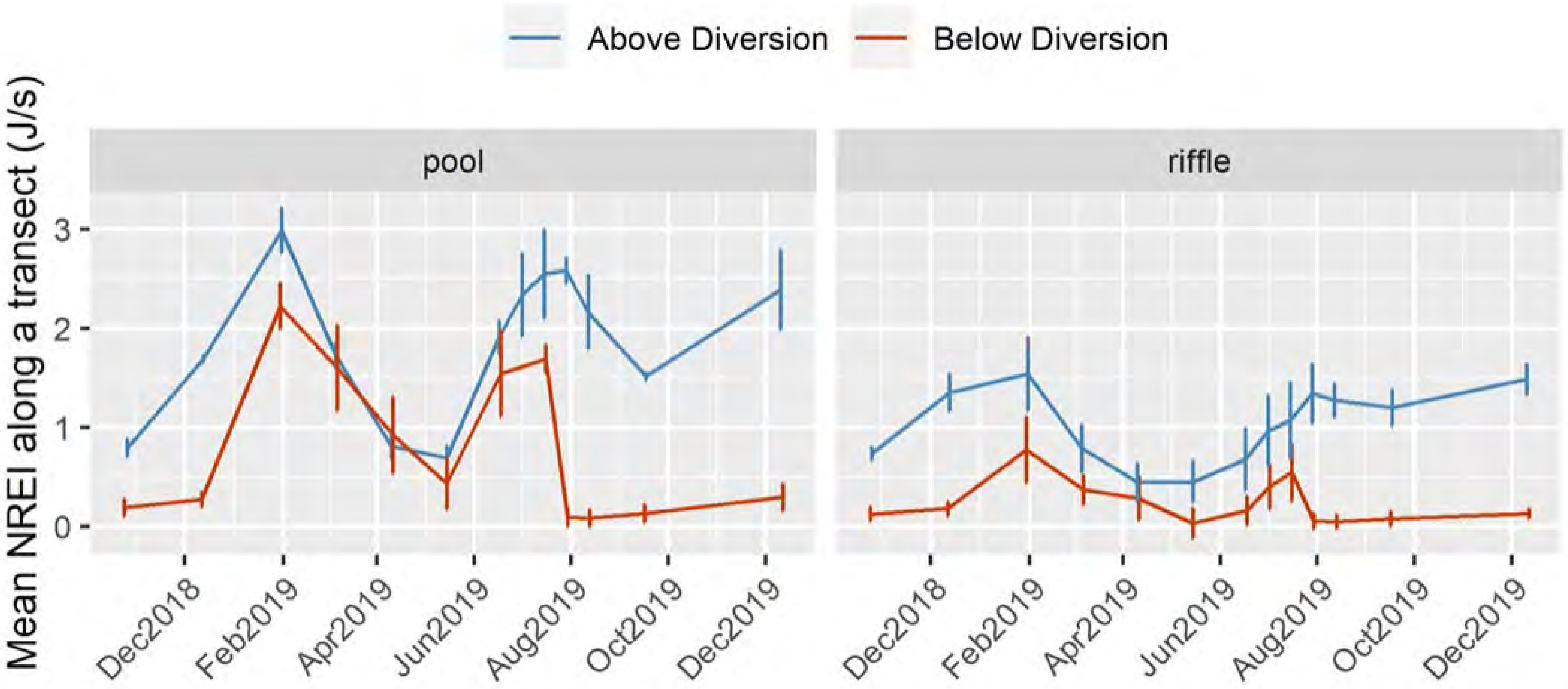
Downstream of Diversion

○ Drift sample

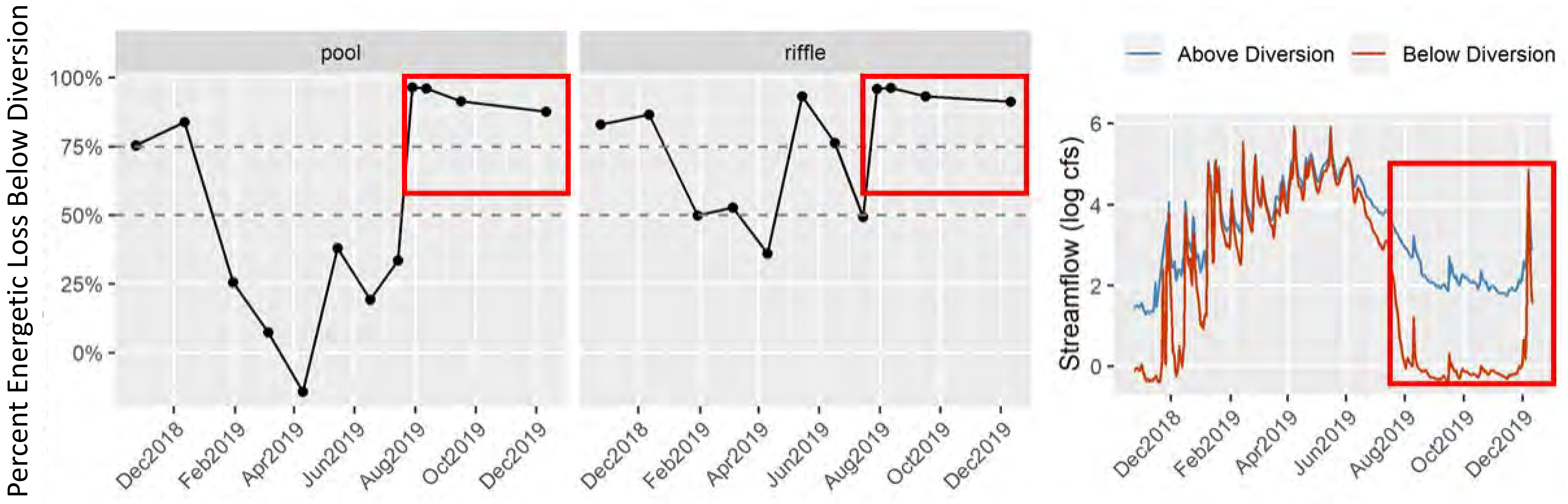
▬ ▬ Depth and velocity transect

Results:

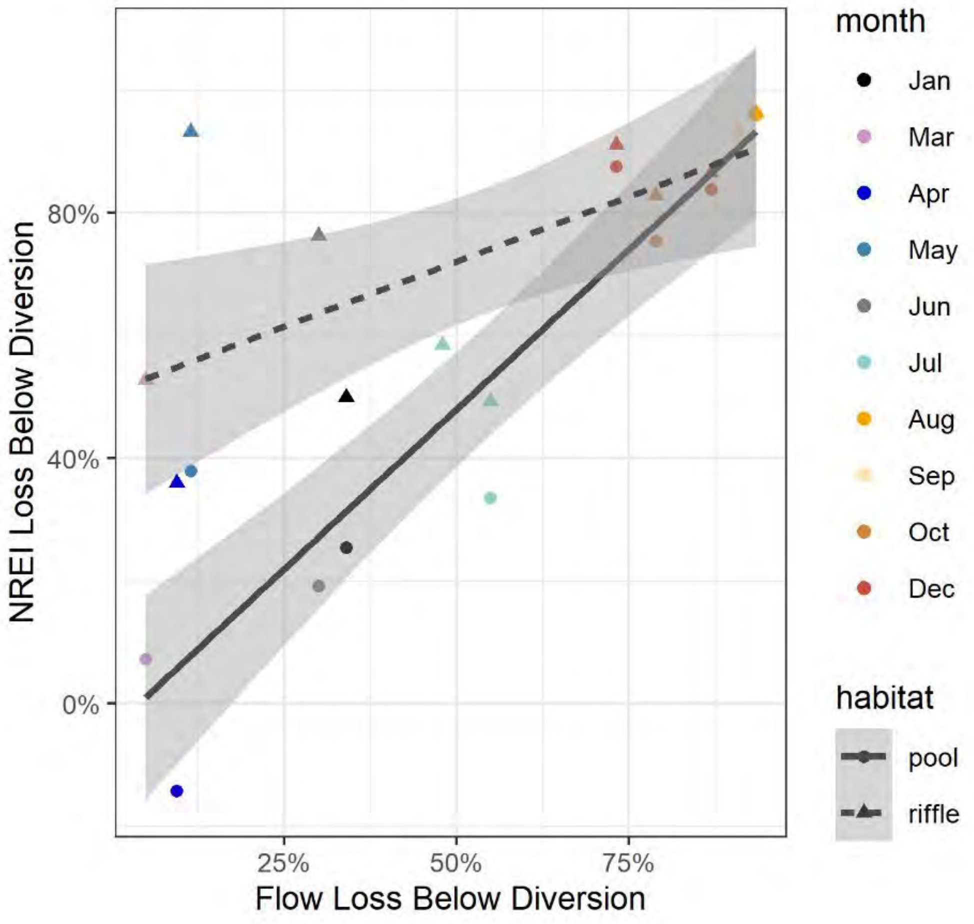
- NREI is highest in late summer and spring (before snowmelt recession)
- Energetics are much lower below diversion in summer
- Pools are more profitable than riffles



Results: Greatest % energetic loss occurs July – December, when diversion has most impact on streamflow



Results: In pool habitats, flow loss is proportional to energetic loss



Riffles:

Y = 0.42 x + 0.51

Adj R2 = 0.39

Analysis of variance on linear fit:

F1,11 = 8.74, P = 0.01

Pools:

Y = 1.04 x - 0.04

Adj R2 = 0.86

Analysis of variance on linear fit:

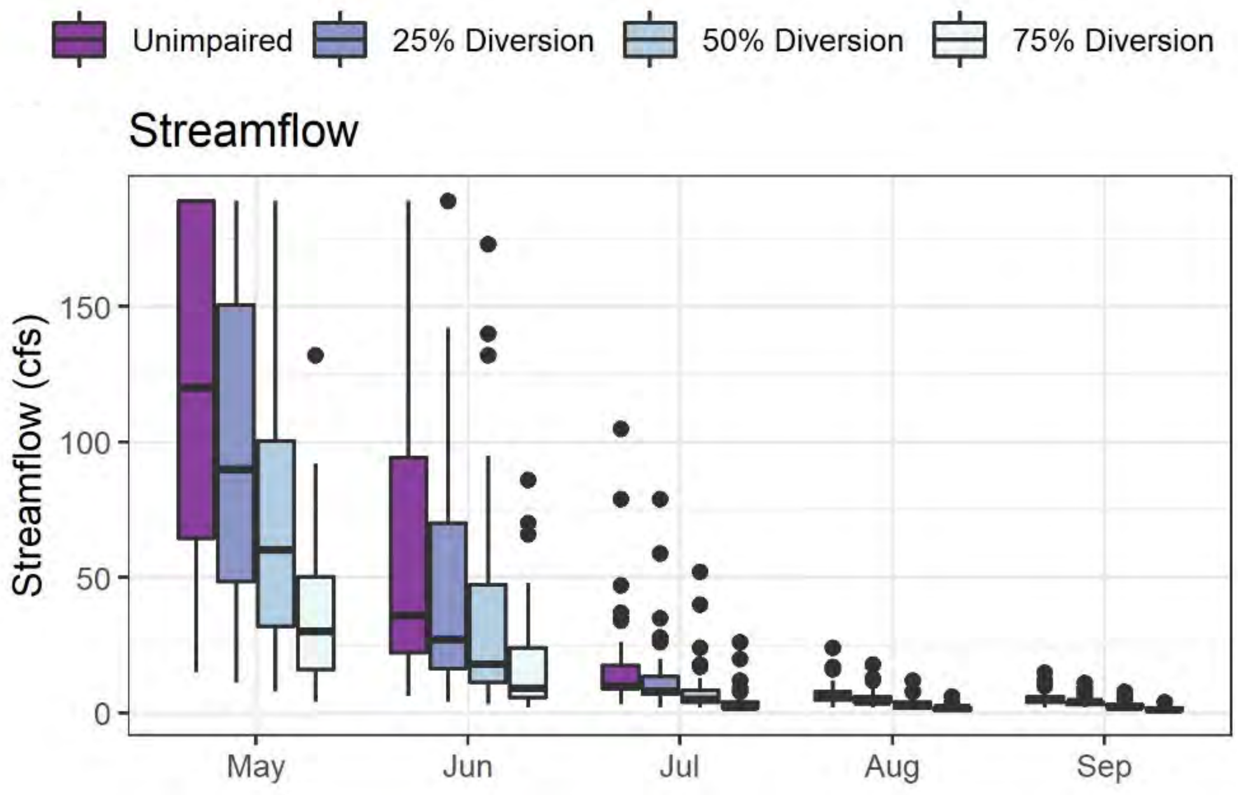
F1,10 = 71.0, P < 0.001

Part 2 Inputs to Bioenergetics HSC:

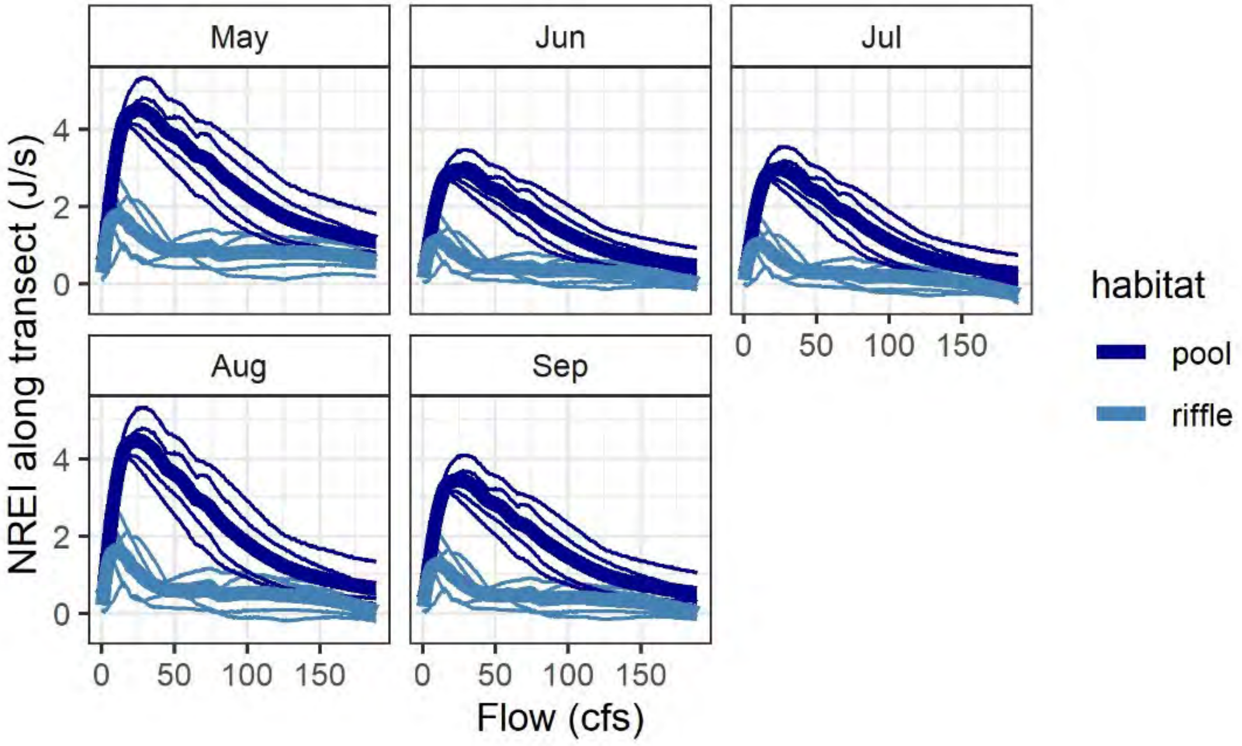
Goal is to understand maximum allowable diversion that would protect fish energetics, given natural variation in flows among years

- Flow scenarios include:
  - Unimpaired flows above and below the diversion
  - Percent of flow diversion from 1% to 75%
- Simulated stream flows
  - Estimated long-term unimpaired flow record at Upper Shasta from Trinity R above Coffee Creek
  - Use the daily flow on the 15th of every month (May 15, June 15, July 15, Aug 15, Sept 15) for all 62 years (1958-2020)
- Depth and velocity transects from 2D Hydraulic model
- Drift file with the mean density by size class of invertebrates for every month, combining data from 2019 (wet year, this study) and 2015 (dry year, in Caldwell et al 2018)
- Water temperature – mean monthly temperatures from 2013-2020
  - Ranged from 10.5 C in May to 17.6 C in August
- Models were run for 5 cm, 10 cm, and 15 cm fish

Flows included in simulated scenarios



Results: Intermediary flows predict the highest NREI

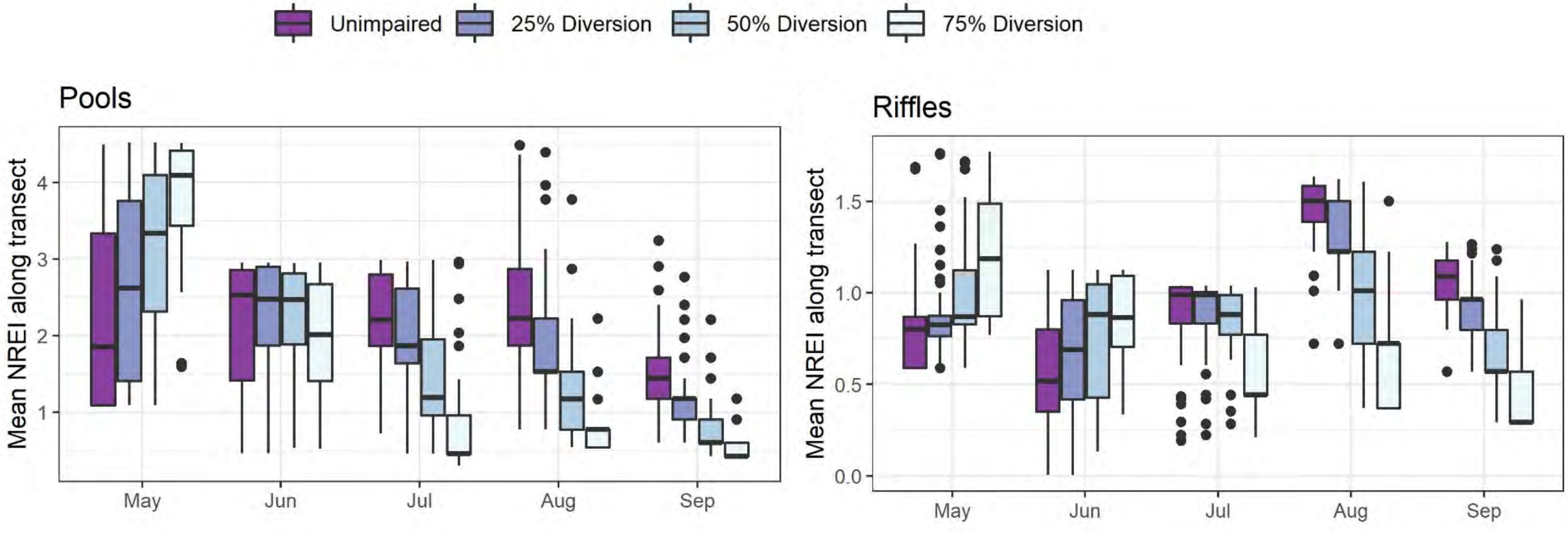


Bold line is the mean of 5 transects

- Low flows deliver fewer drifting invertebrates
- Prey capture success decreases quickly with high velocities

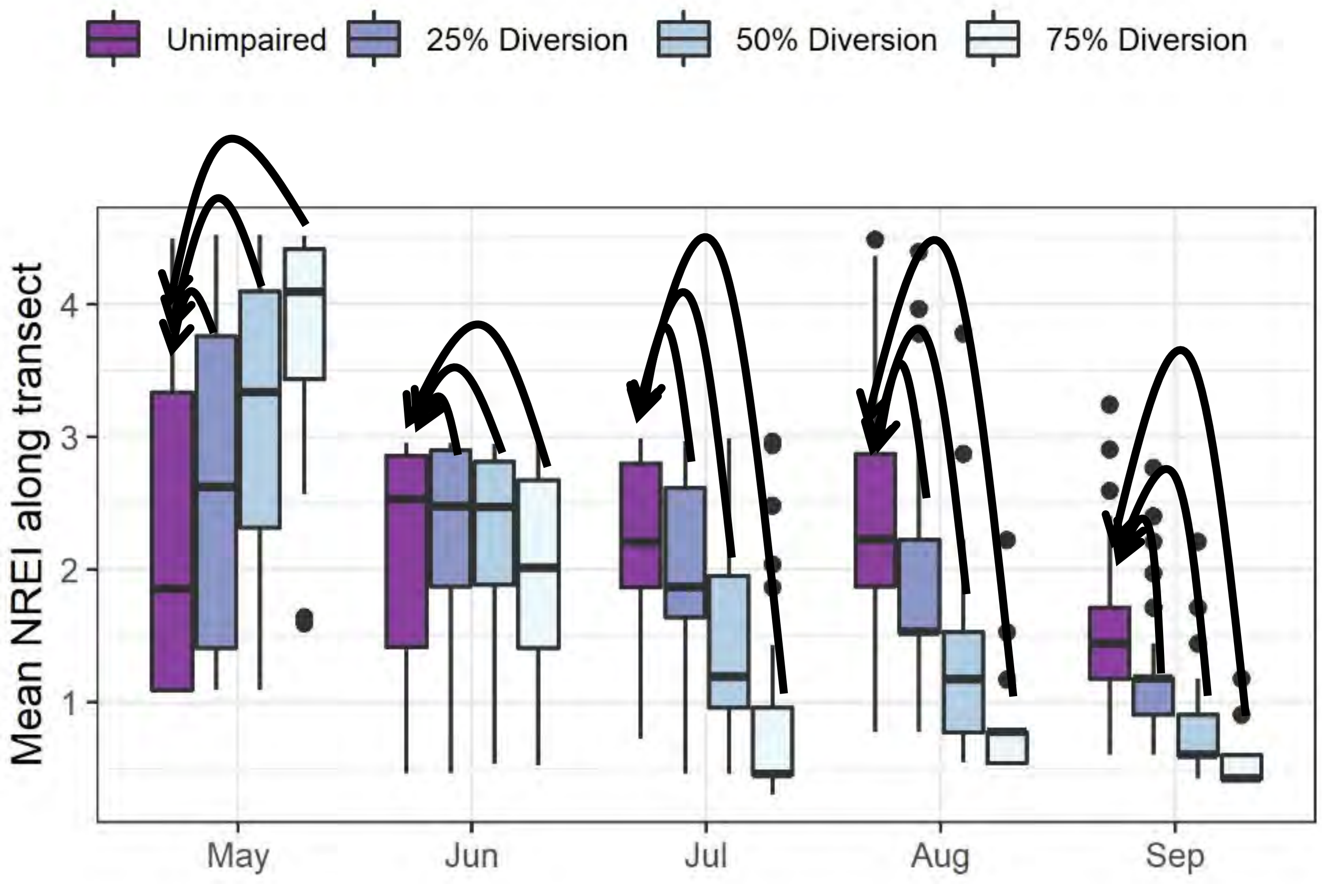
Results: NREI differs between % diversion and unimpaired flow scenarios

- In May and June, diverting more water leads to higher predicted NREI
- Pools create more energetically favorable habitat



What is the maximum allowable diversion rate?

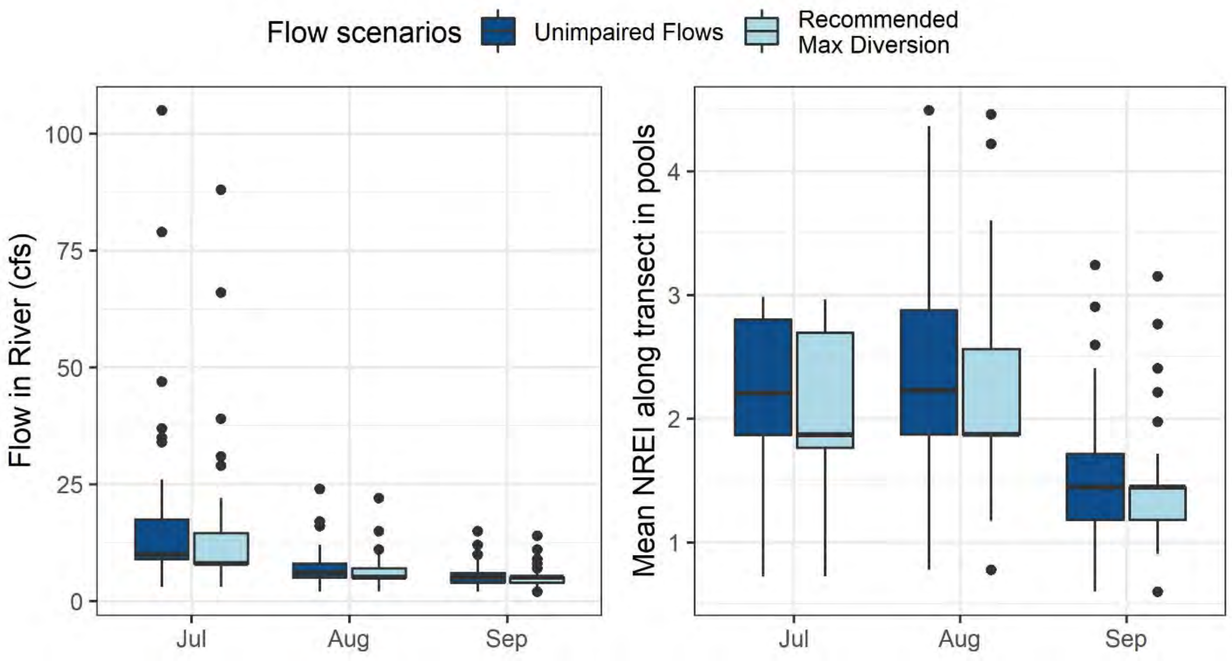
- Pairwise comparisons between the % diversion flow and unimpaired flow



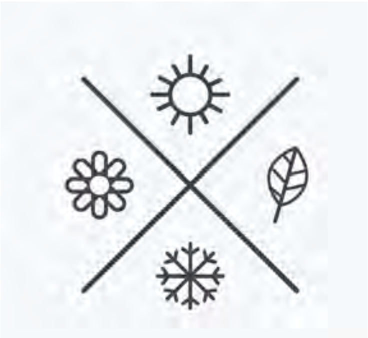
Results: What is the maximum allowable diversion rate?

- Implementing the maximum % of diversion creates flows and NREI that are not significantly lower than unimpaired conditions

Maximum Percent of Diversion					
	May	Jun	Jul	Aug	Sep
Pools 5 cm	>75%	>75%	18%	9%	9%
10 cm	>75%	>75%	**16%**	**9%**	**9%**
15 cm	>75%	68%	16%	12%	10%
Riffles 5 cm	>75%	>75%	>75%	30%	12%
10 cm	>75%	>75%	54%	9%	9%
15 cm	>75%	>75%	**38%**	**9%**	**9%**



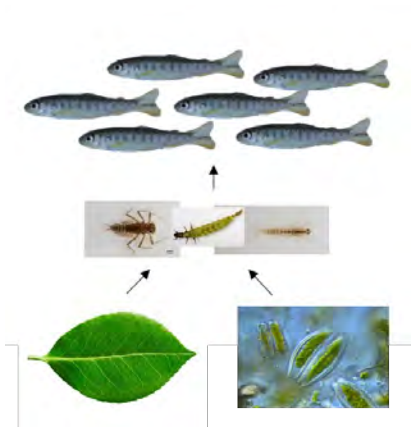
Summary: Bioenergetics modeling for instream flow recommendations

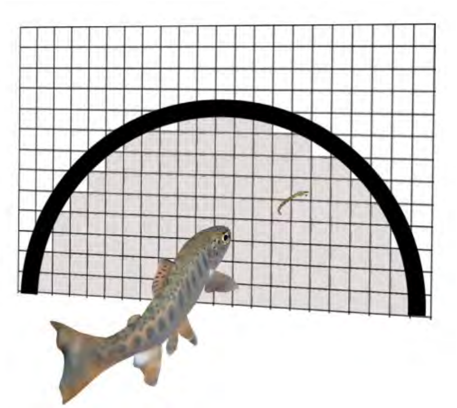


1. When are water diversions most impactful on fish energetics?
   - Energetic condition is reduced **most in the summer months**
   - Percent of flow loss is **proportional** to percent energetic loss in pool habitats

2. Can we use bioenergetics models to estimate the maximum flow diversion rate would provide protection for fish energetics in over the course of >50 years?
   - We used pairwise comparisons with energetic conditions to make flow recommendations in **low flow months**
   - This process interfaces well with percent-of-flow scenarios

Conclusions





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- Predicting drifting invertebrates is elusive, but it is an important input to bioenergetics models
- Bioenergetics models are process-based way of incorporating fish and food in the flow recommendations process
- Bioenergetics models are likely to be most useful in determining low flow recommendations

Thank you funders and partners

NATIONAL FISH AND WILDLIFE FOUNDATION
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TROUT UNLIMITED

Global Water Center
University of Nevada, Reno
Solutions for sustainability℠
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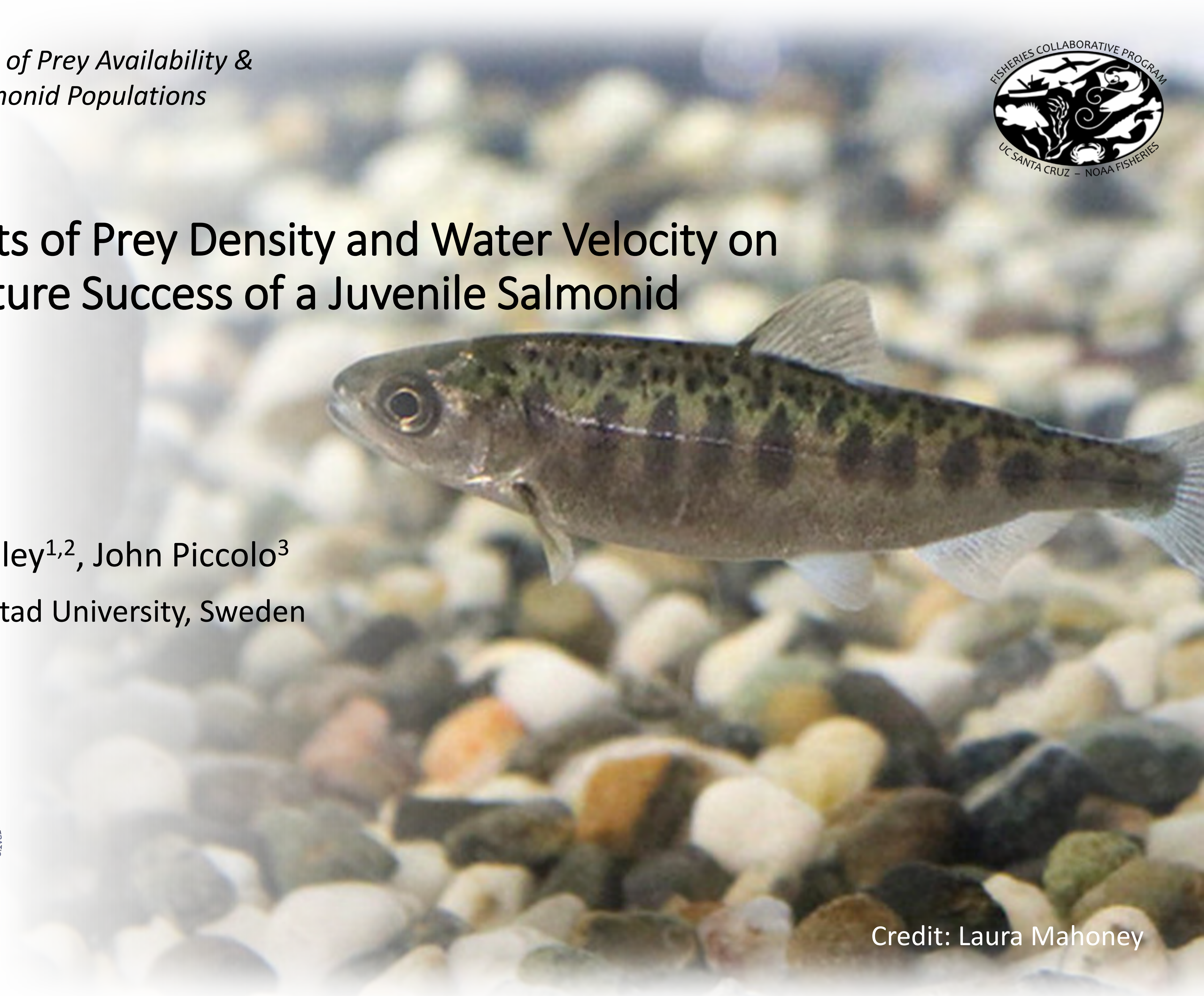
Trout underwater videography

Beyond Physical Habitat: the Importance of Prey Availability & Productivity in Recovering Imperiled Salmonid Populations

The Effects of Prey Density and Water Velocity on Capture Success of a Juvenile Salmonid

Kwanmok Kim[1,2], Peter Dudley[1,2], John Piccolo[3]

[1]UC Santa Cruz , [2]NOAA, [3]Karlstad University, Sweden

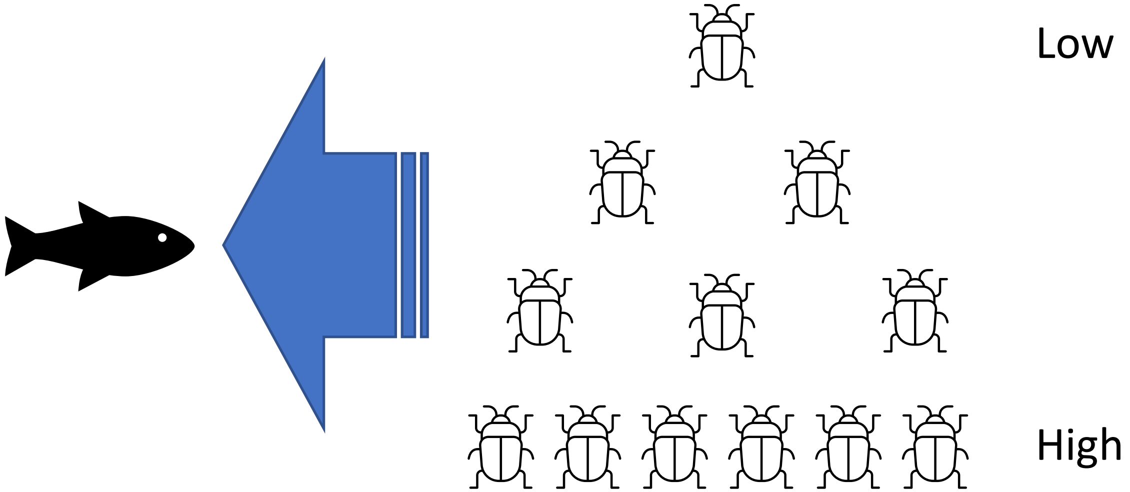


Credit: Laura Mahoney

Why are prey densities and velocities important for juvenile salmonids?

- Drift feeders.
- Velocity and prey density affects the prey encounter rate.

Why are prey densities and velocities important for juvenile salmonids?



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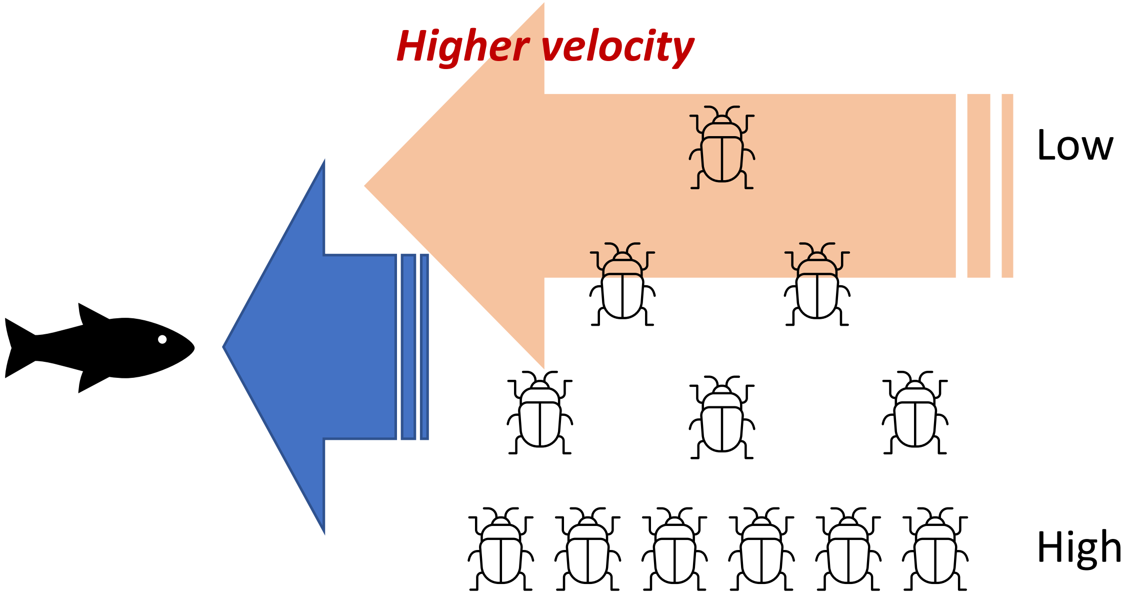
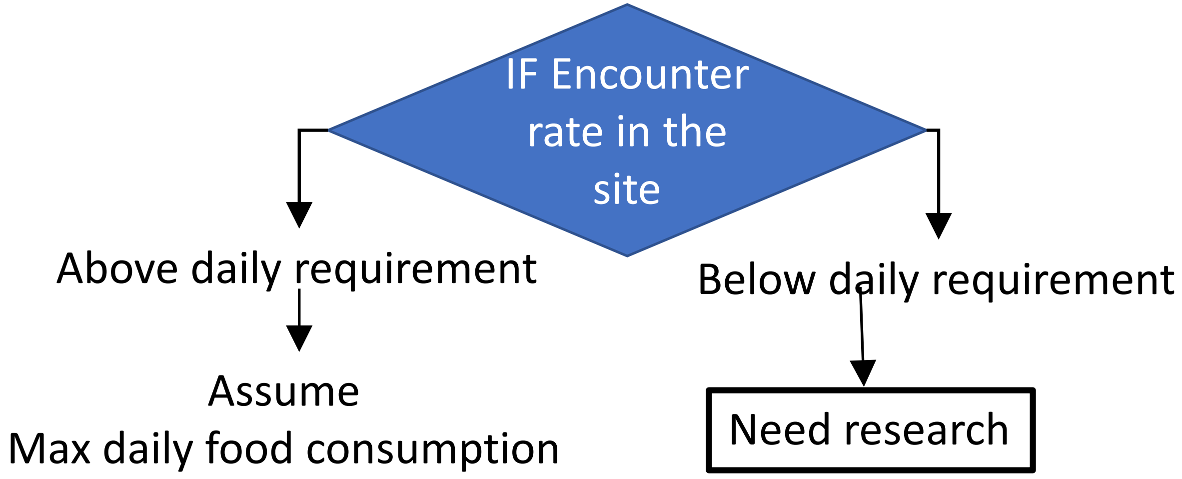


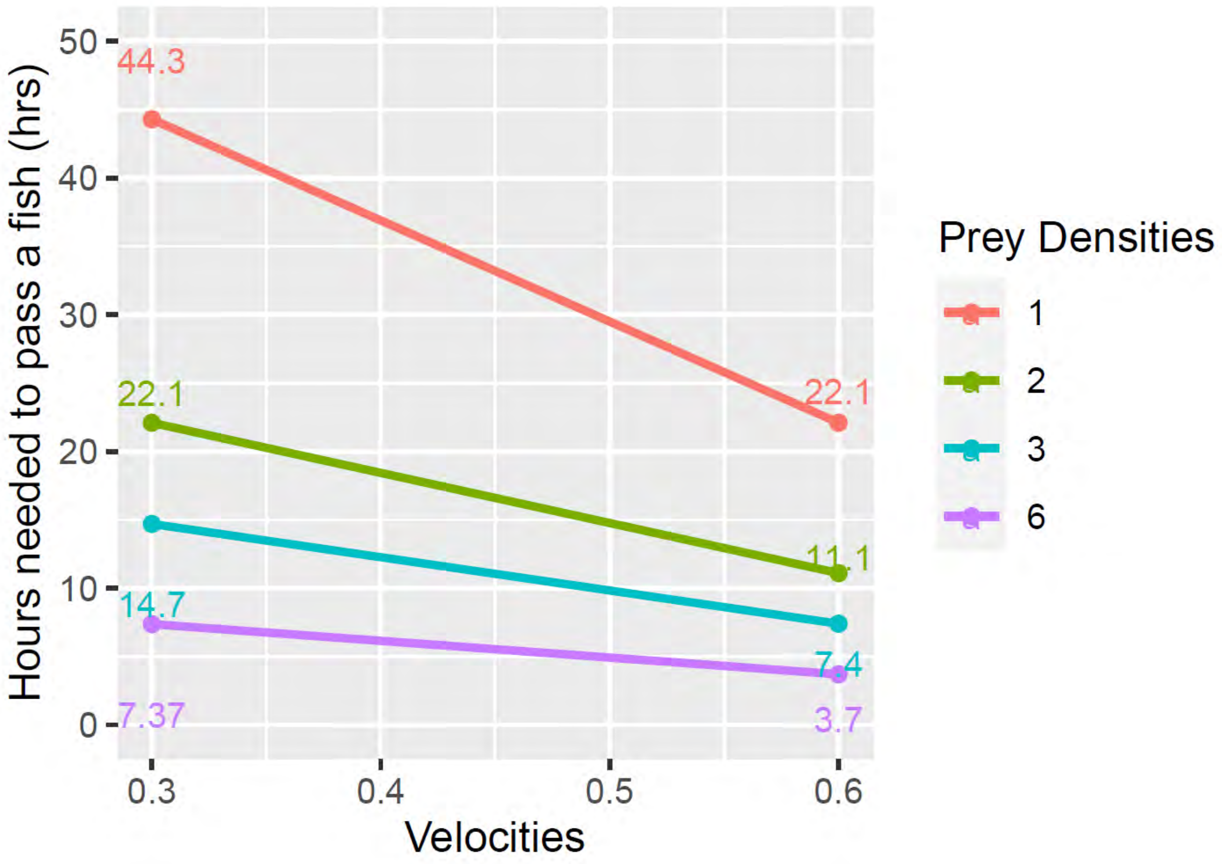
- Drift feeders.
- Velocity and prey density affects the prey encounter rate.
- **Prey encounter rate affects prey consumption.**

Are juvenile salmonids encountering enough prey?



Sacramento River	Juvenile salmonid
2.55grams (ft/day)	2.94grams max (ft/day)

- Daphidae and Copepoda (0.04mg) are the main food source.
- 63,750 prey passes ft^2 per day



Are juvenile salmonids encountering enough prey?

IF

Above daily requirement → Assume Max daily food consumption

Below daily requirement → **Need research**

Sacramento River	Juvenile salmonid
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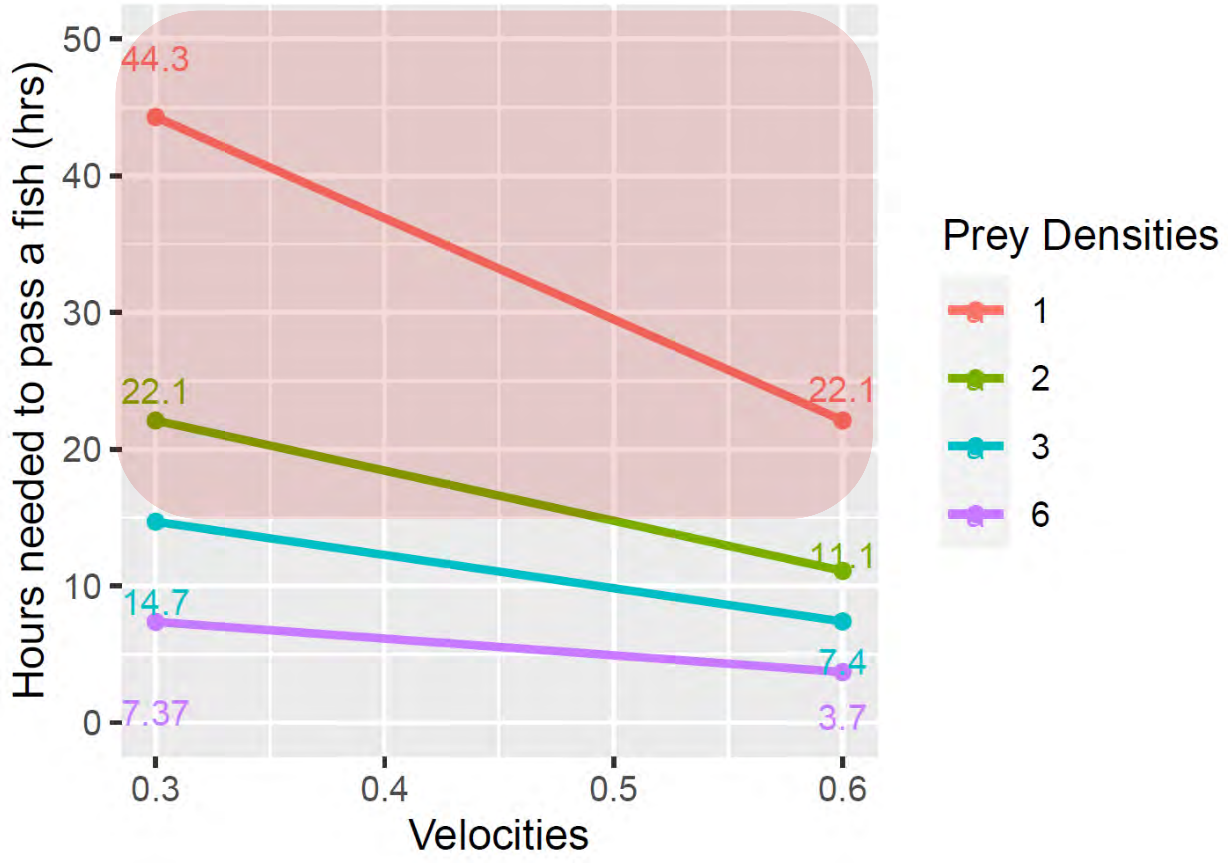
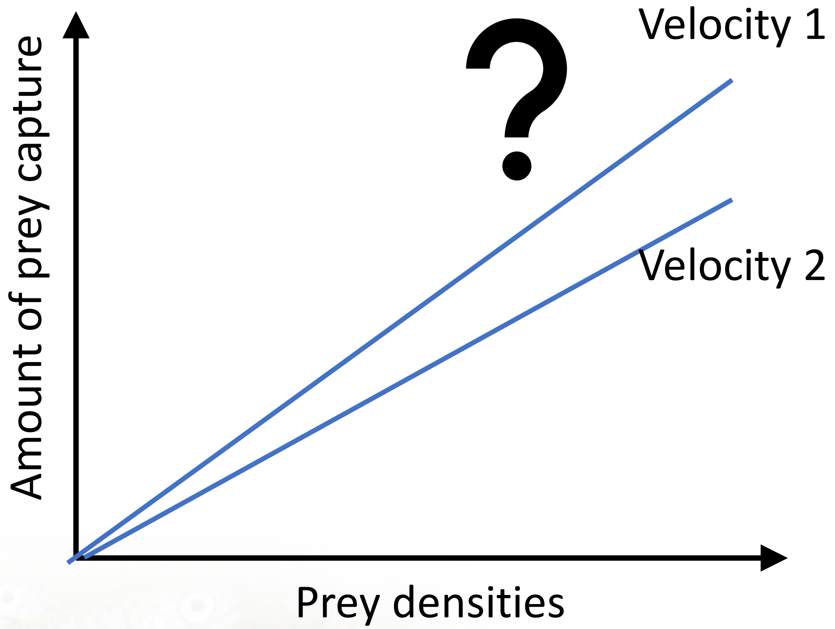


Research needed!

Linear response of prey density and velocity to prey capture success?



Current models:
Increase in prey density leads to a linear increase of capture success

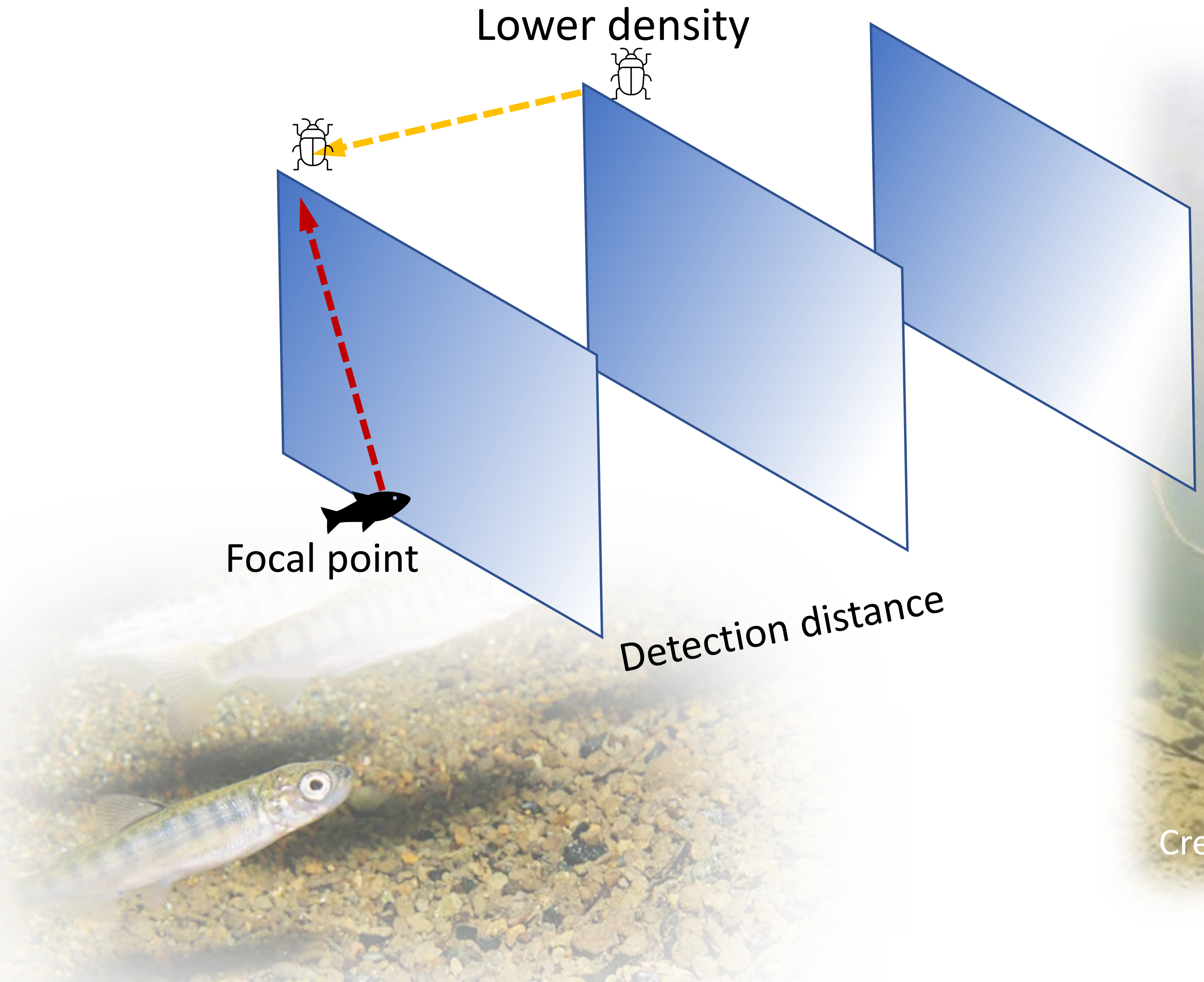
↓

Overestimation of prey capture success

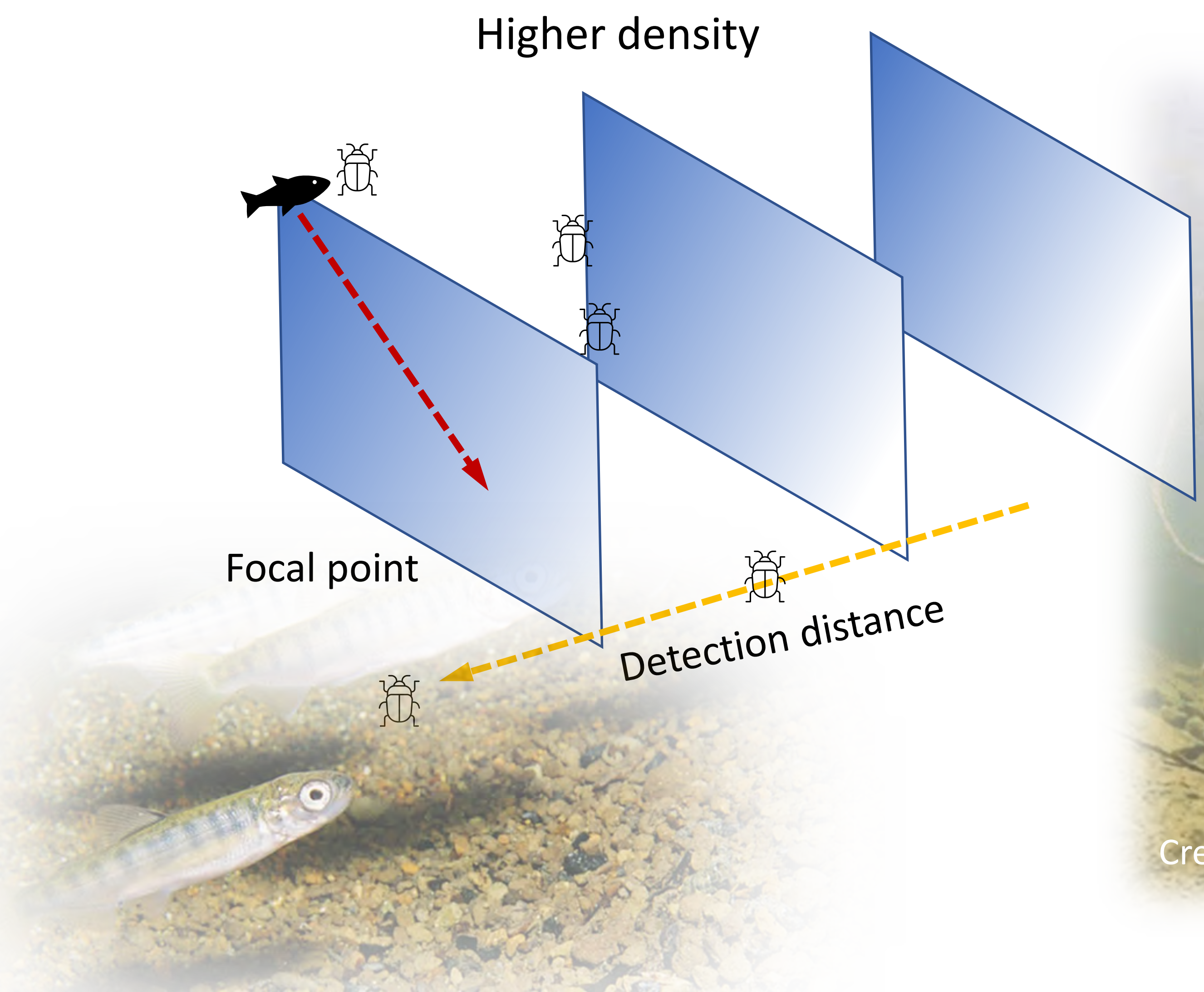
Higher density brings more capture success?

Dodge ball example

Fish playing dodgeball

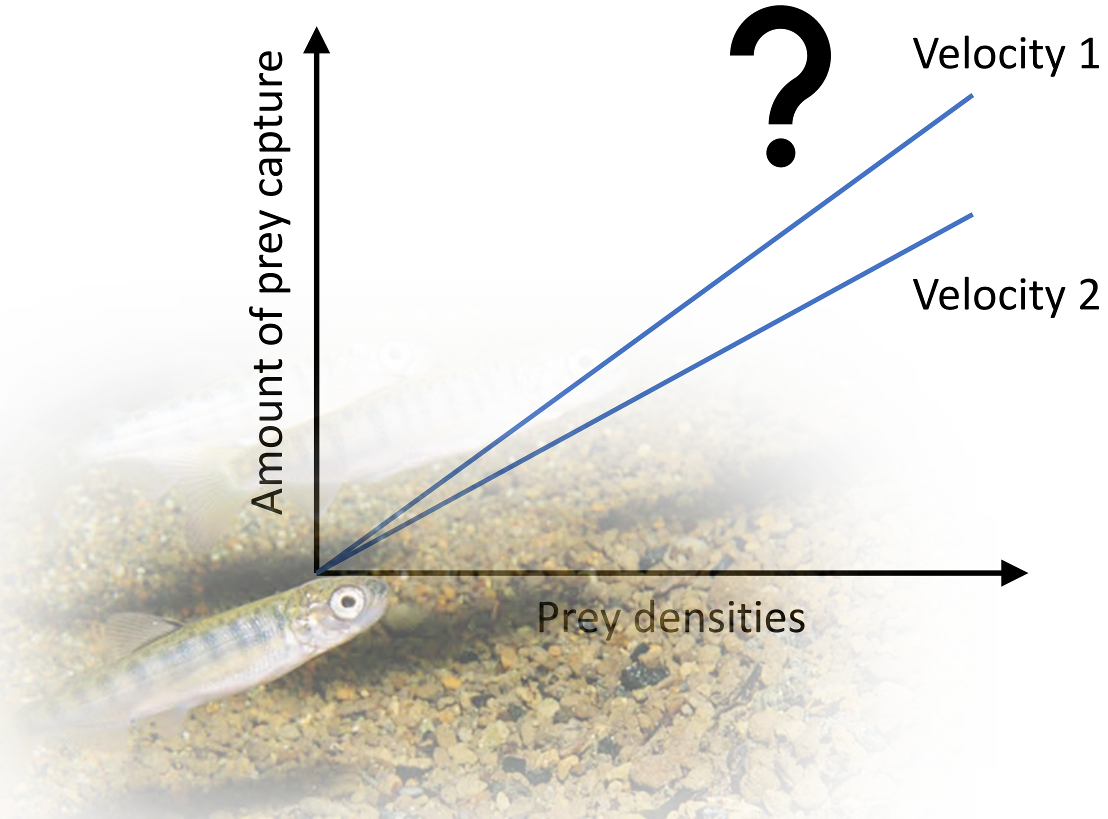


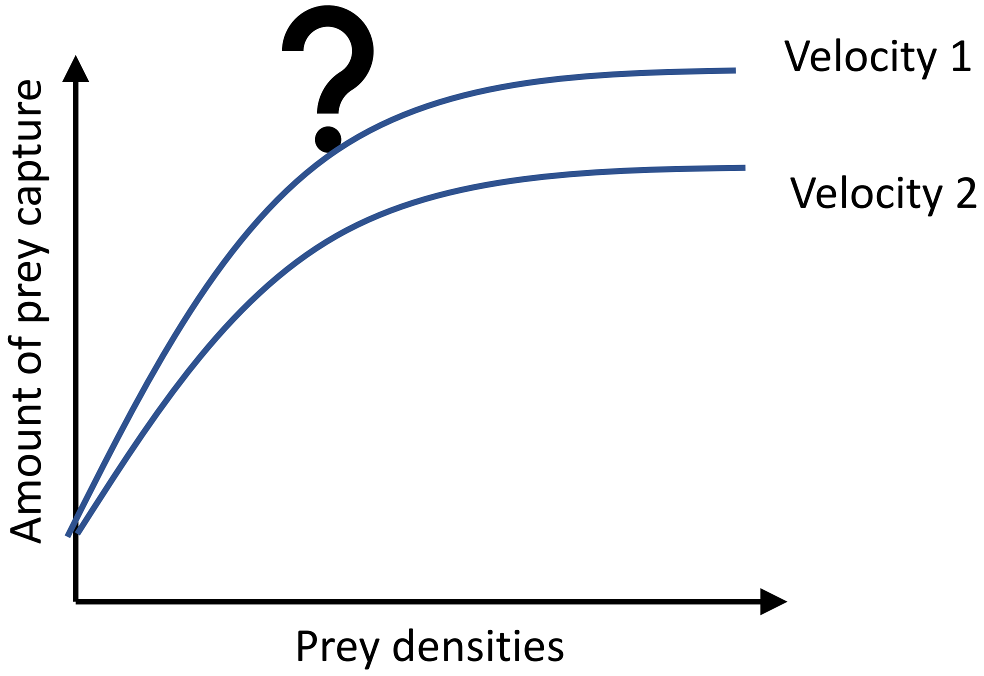
Fish playing dodgeball



Goal of the study

- Test the relationship between the prey density, velocity and the capture success.





Goal of the study

- Test the relationship between the prey density, velocity and the capture success.

Objective

- Make a mechanistic model that is realistic to fish behavior.

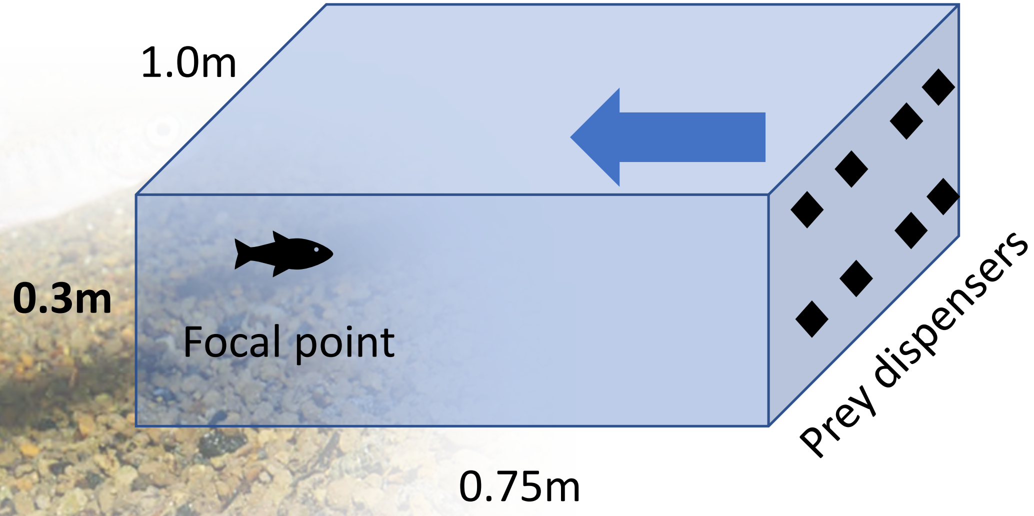
Approach

- Simulate fish behavior based on an existing data (Piccolo et al. 2007 and 2008).

Methods

Types of data we need:

- Juvenile salmonid capture success
- 3D Fish location
- 3D Prey location
- Fish maneuver speed
- Fish return speed
- Fish maximum detection distance
- Velocity



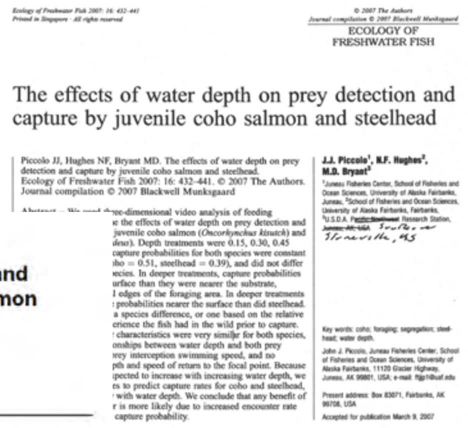
Vary Depths

Piccolo et al. 2007

Add data

Vary Velocities

Piccolo et al. 2008



Ecology of Freshwater Fish 2007: 16: 432–441

ECOLOGY OF FRESHWATER FISH

The effects of water depth on prey detection and capture by juvenile coho salmon and steelhead

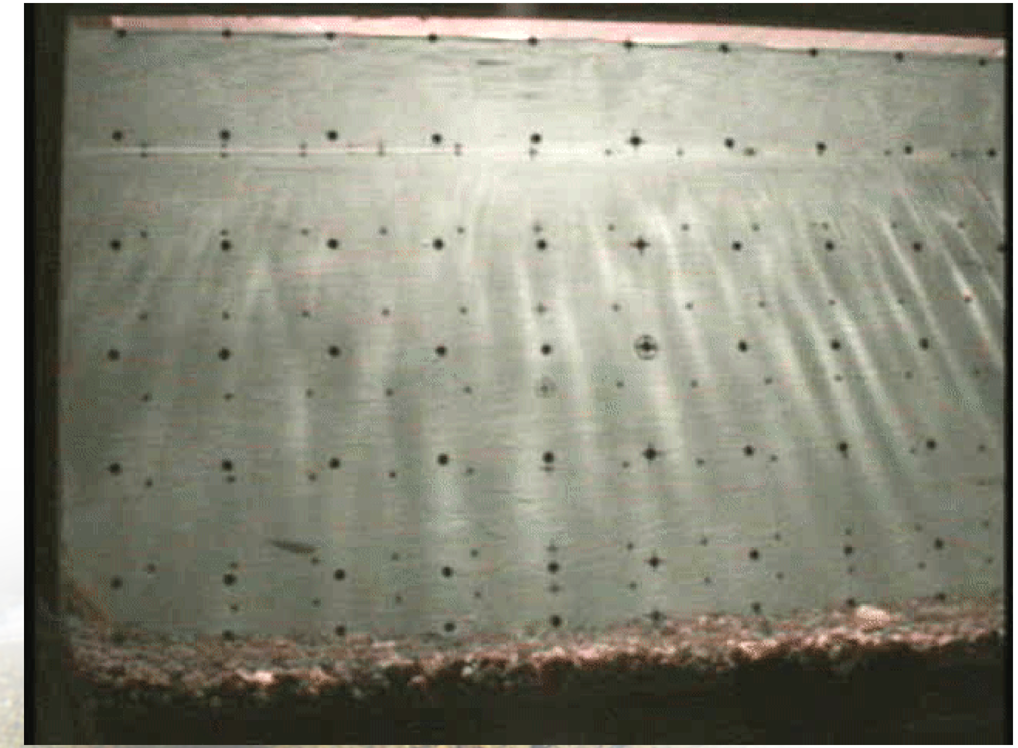
Water velocity influences prey detection and capture by drift-feeding juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss irideus*)

John J. Piccolo, Nicholas F. Hughes, and Mason D. Bryant

Introduction

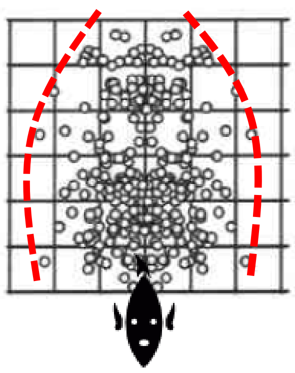
Piccolo et al. 2008 data

Actual film of the experiment.

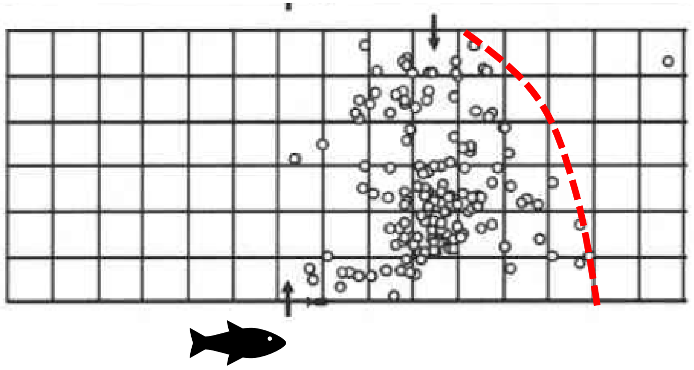


Prey detection areas

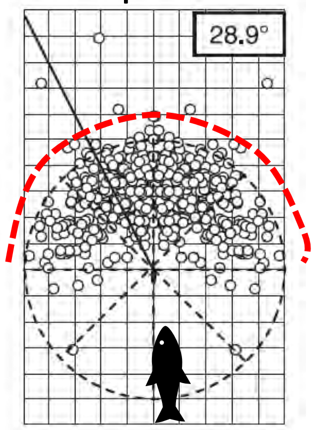
Front view



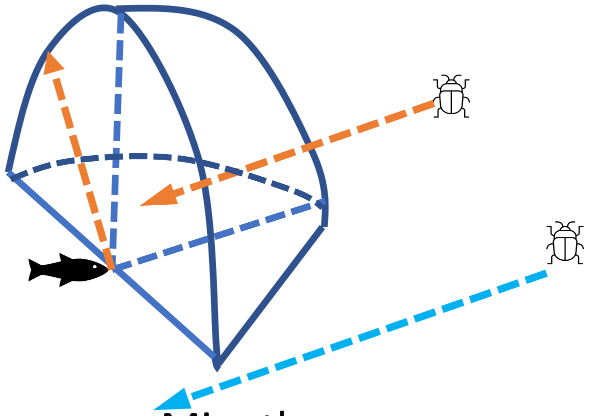
Side view



Top view



Ellipsoid shape detection area?

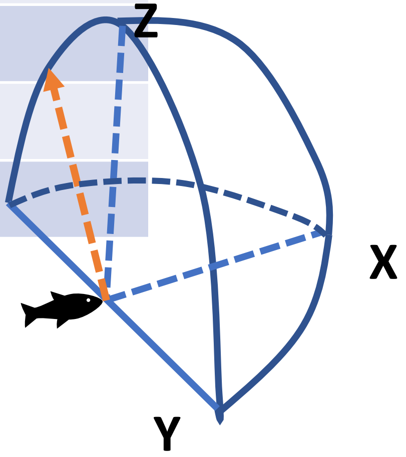


What affects the detection distance?

- GLMM with gamma distribution
- Fixed effects: Feeder locations, **Fish length, Velocity**
- Random effects: Experiment (paper 2007 vs 2008), Fish ID
- Model selection criteria: lowest AIC value

Sampling bias from two different experiments

X-axis	Y-axis	Z-axis
Feeder width location	Feeder depth location	Feeder depth location
Depth	Feeder width location	Feeder width location
Fish length	Depth	**Velocity**
Velocity	**Fish length**	
	Velocity	



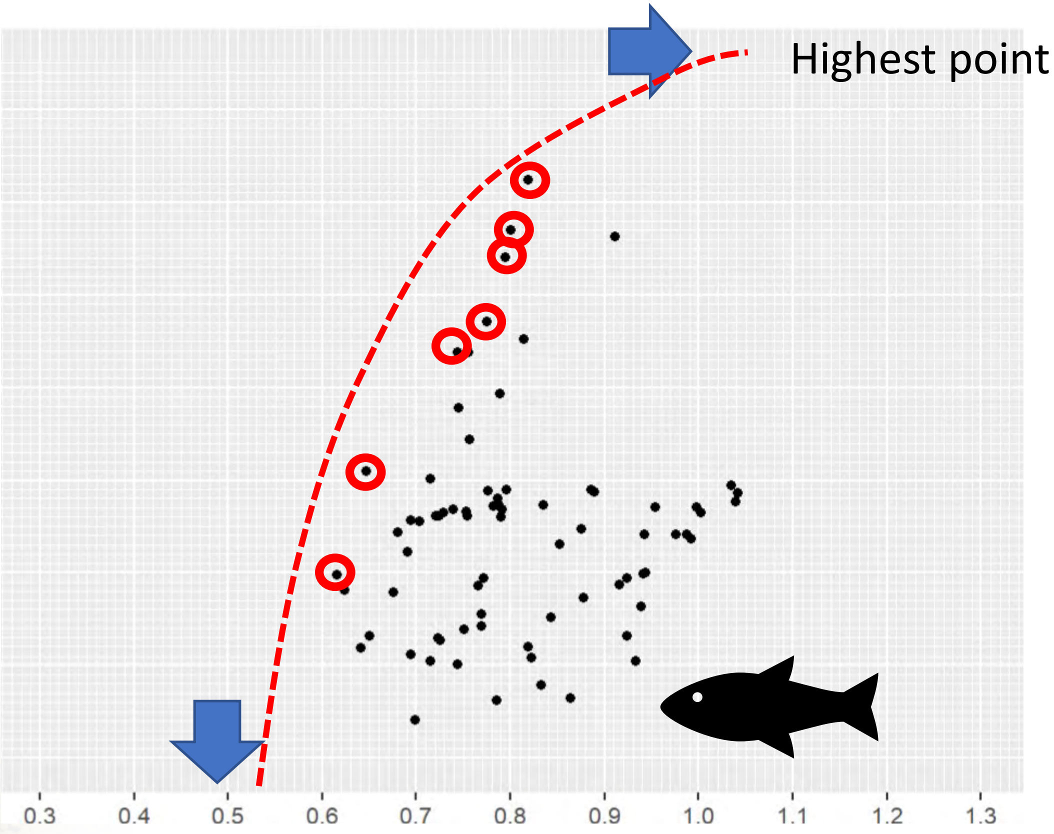
Maximum detection distance of X,Y, and Z ?

Extract furthest points

Linear regression

Predict max XYZ intercepts

1) Extract contour points of detection points from all directions

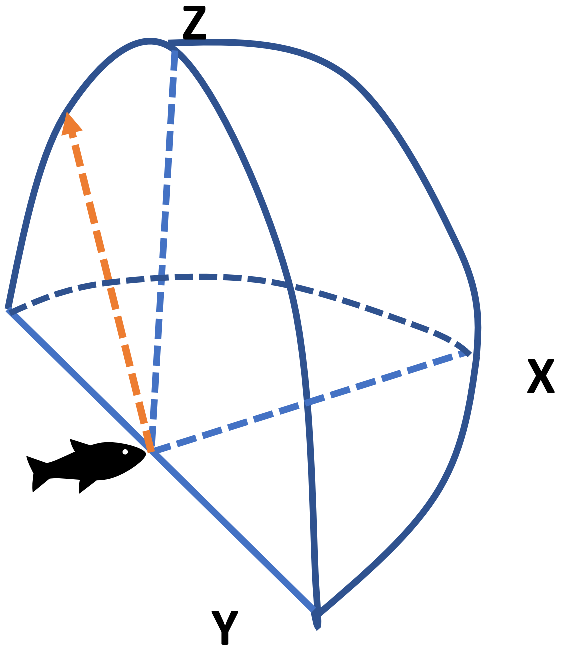


Maximum detection distance of X,Y, and Z ?

2) Fit linear regression models

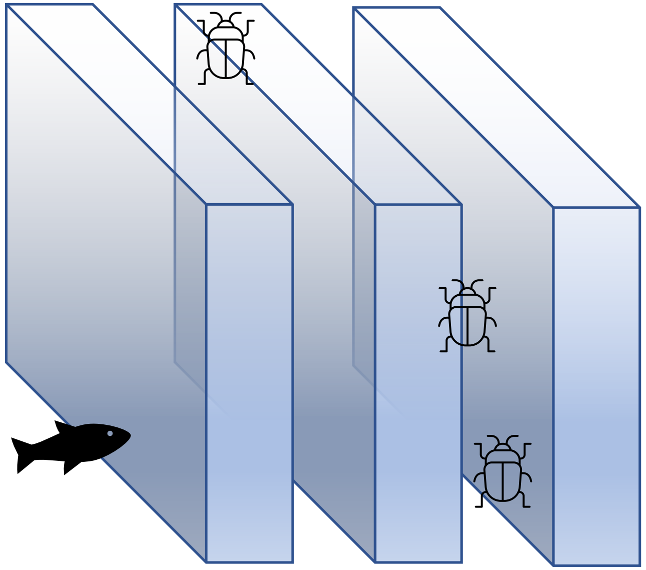
- Linear regression with normal distribution
- Factors: Fish length, velocity, polynomial transform
- Random effect: Experiment and Fish ID
- Model averaging (AICc values with cumulative weight up to 95%)

Max upstream distance (X)
Max side distance (Y)
Max depth distance (Z)

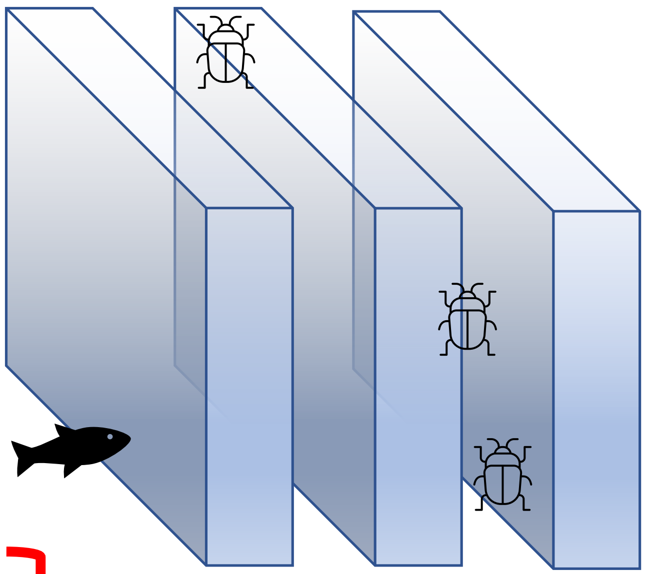


2D simulation feeding model

1. 2D model. This model does not consider the distance the fish moves back and forth.
2. Fish gets one prey and attacks the next prey immediately (no delay of handling).
3. Fish attempts to attack every prey rather than strategically attacking a few prey.



2D simulation feeding model

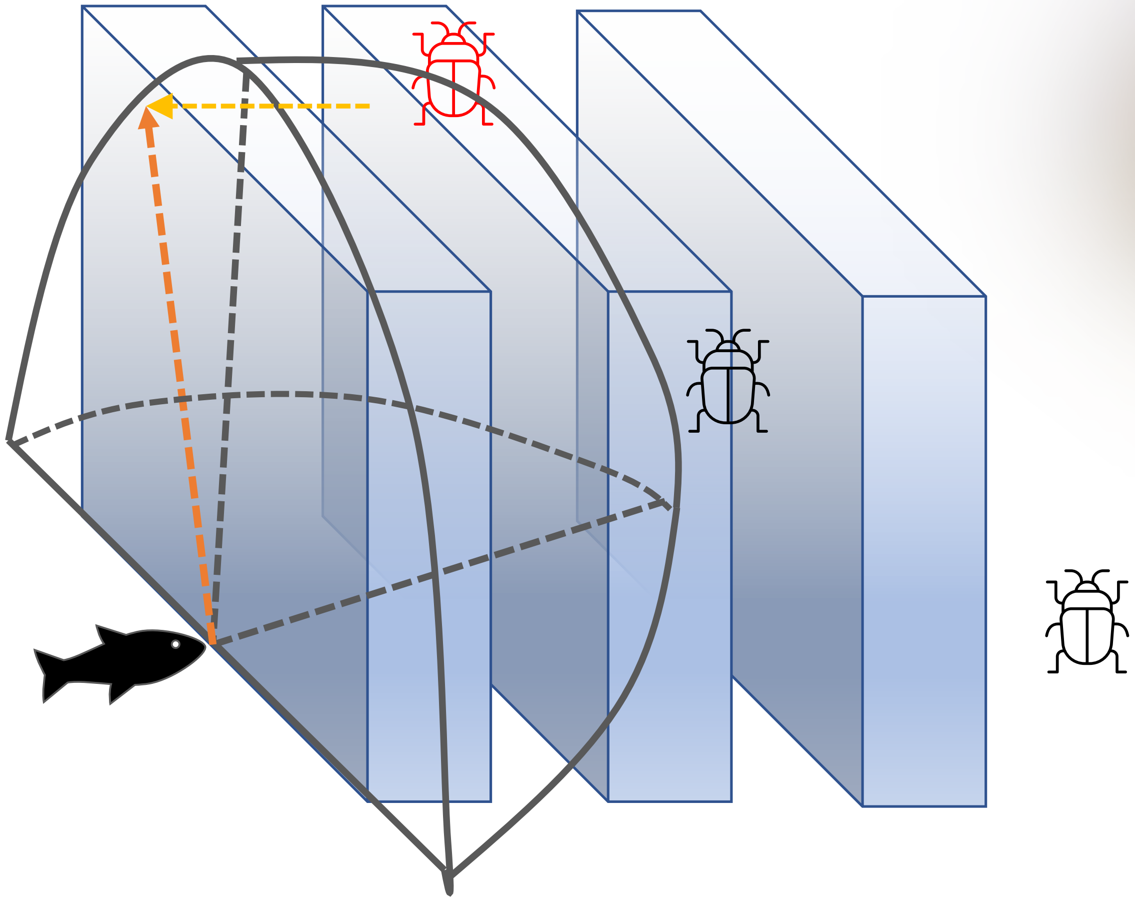


1. 2D model. This model does not consider the distance the fish moves back and forth.
2. Fish gets one prey and attacks the next prey immediately (no delay of handling).
3. Fish attempts to attack every prey rather than strategically attacking a few prey.
4. Return and attack speed is based on the formula presented in Piccolo et al. 2008.
5. Prey distribution: random distribution.
6. Fish starts at the bottom focal point. (0,2)
7. Distance from feeder is 0.75 meters.
8. Prey feeder: a prey within 15 seconds interval.
9. Prey density range 1 to 6: average 4.47 individual preys per cubic square in Sacramento River.

Piccolo et al. 2008

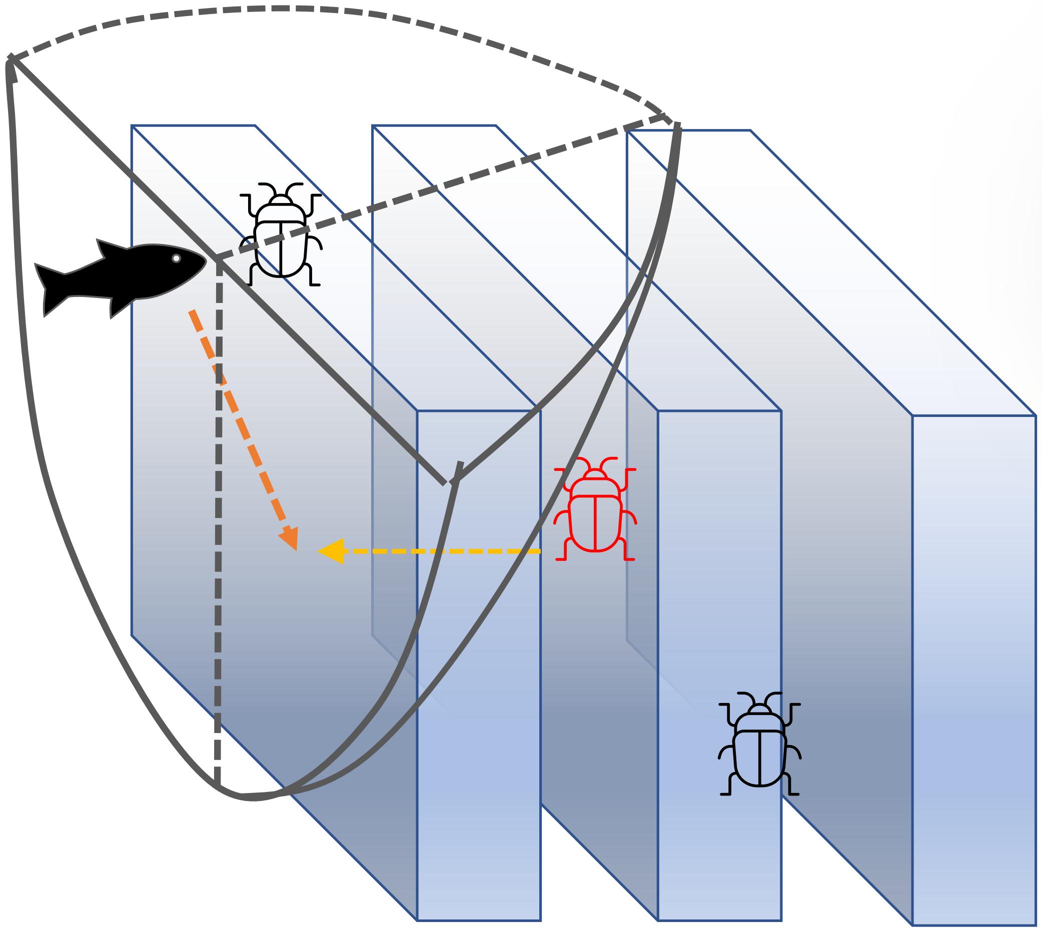
2D simulation feeding model

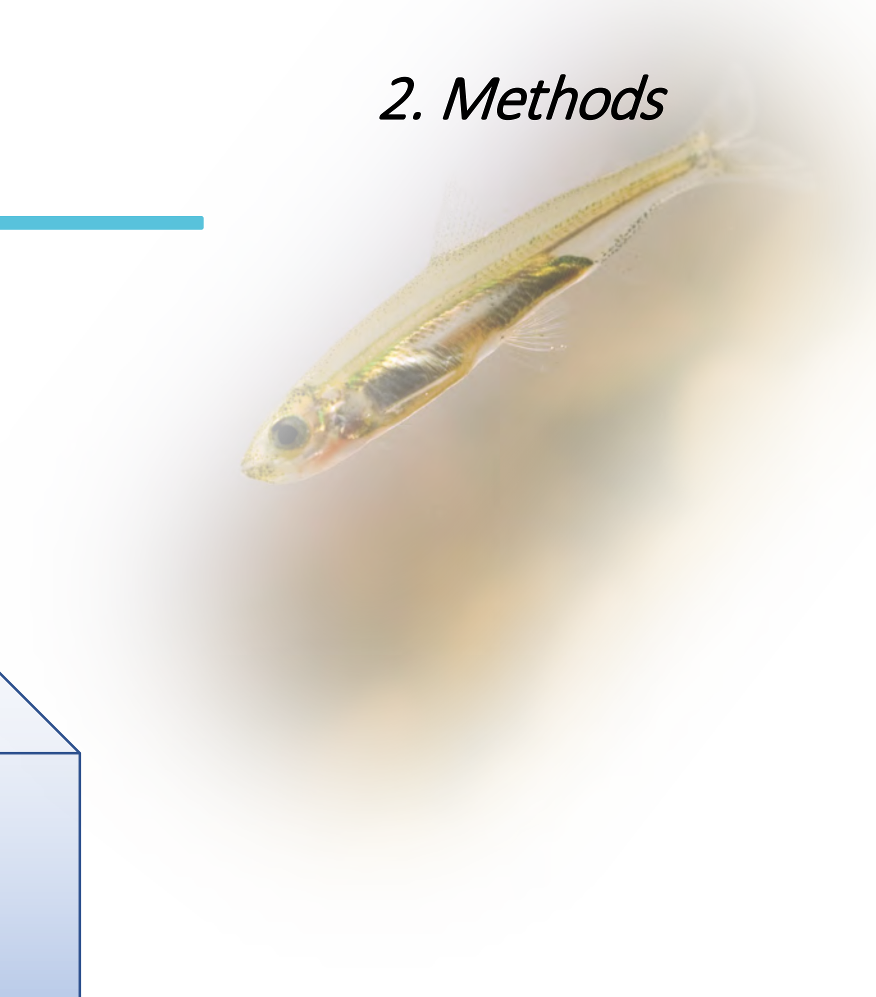
Detects a prey and respond



2D simulation feeding model

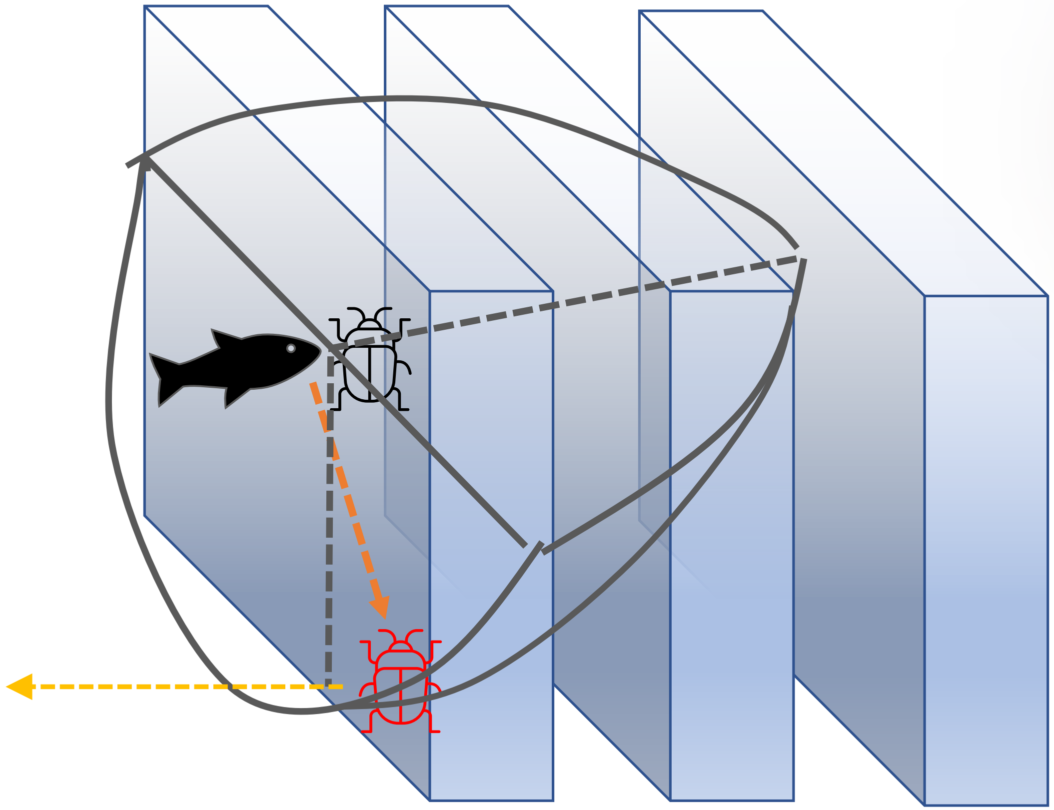
Detects the next prey and respond





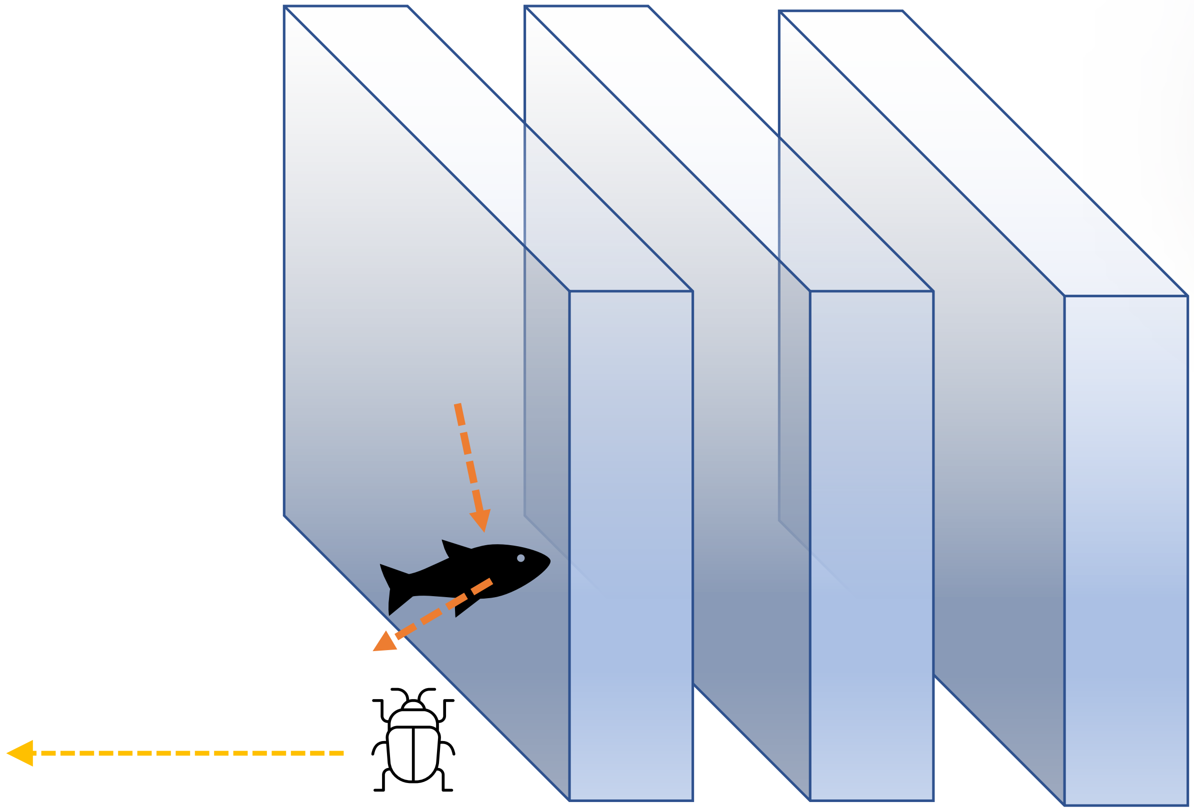
2D simulation feeding model

Moves to the next prey



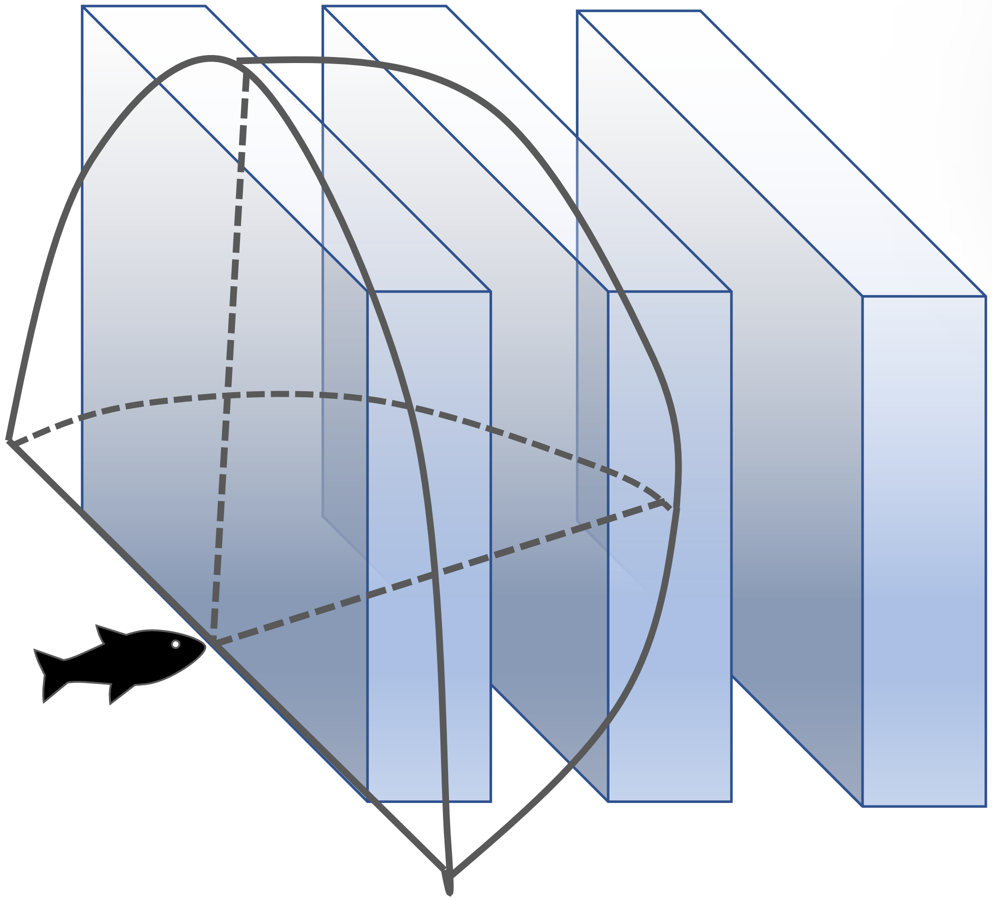
2D simulation feeding model

Moves back to the focal point



2D simulation feeding model

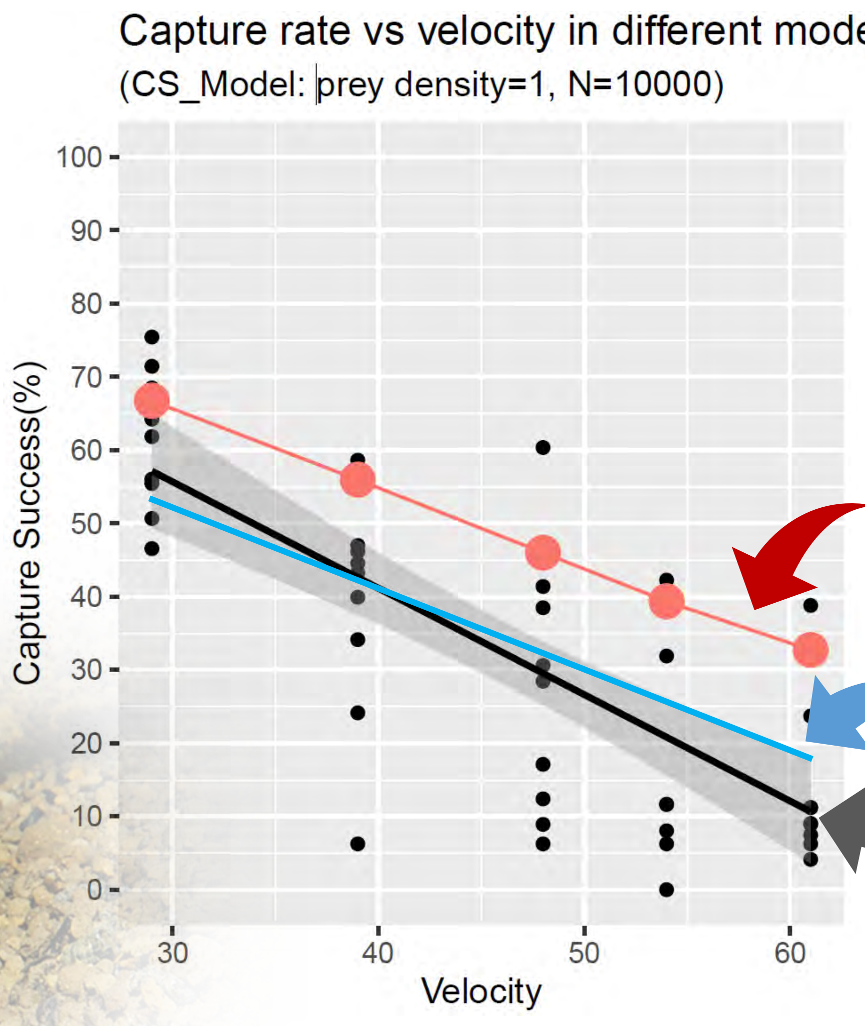
Waits for the next prey



Results; Model validation

Validation of the 2D simulation model compared to the results from Piccolo et al. 2008

Prey abundance: 10,000



Prediction based on Piccolo et al. 2007 and 2008

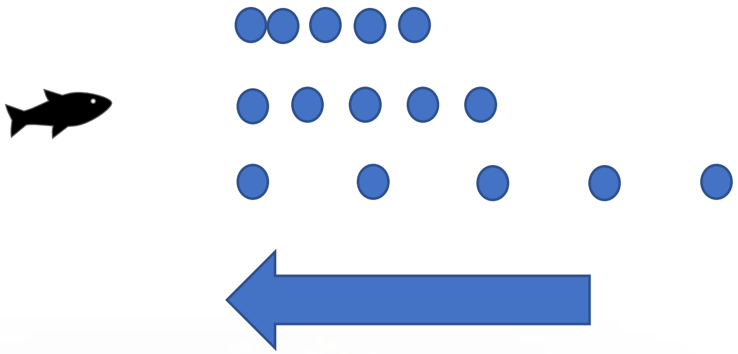
Prediction based on Piccolo et al. 2008

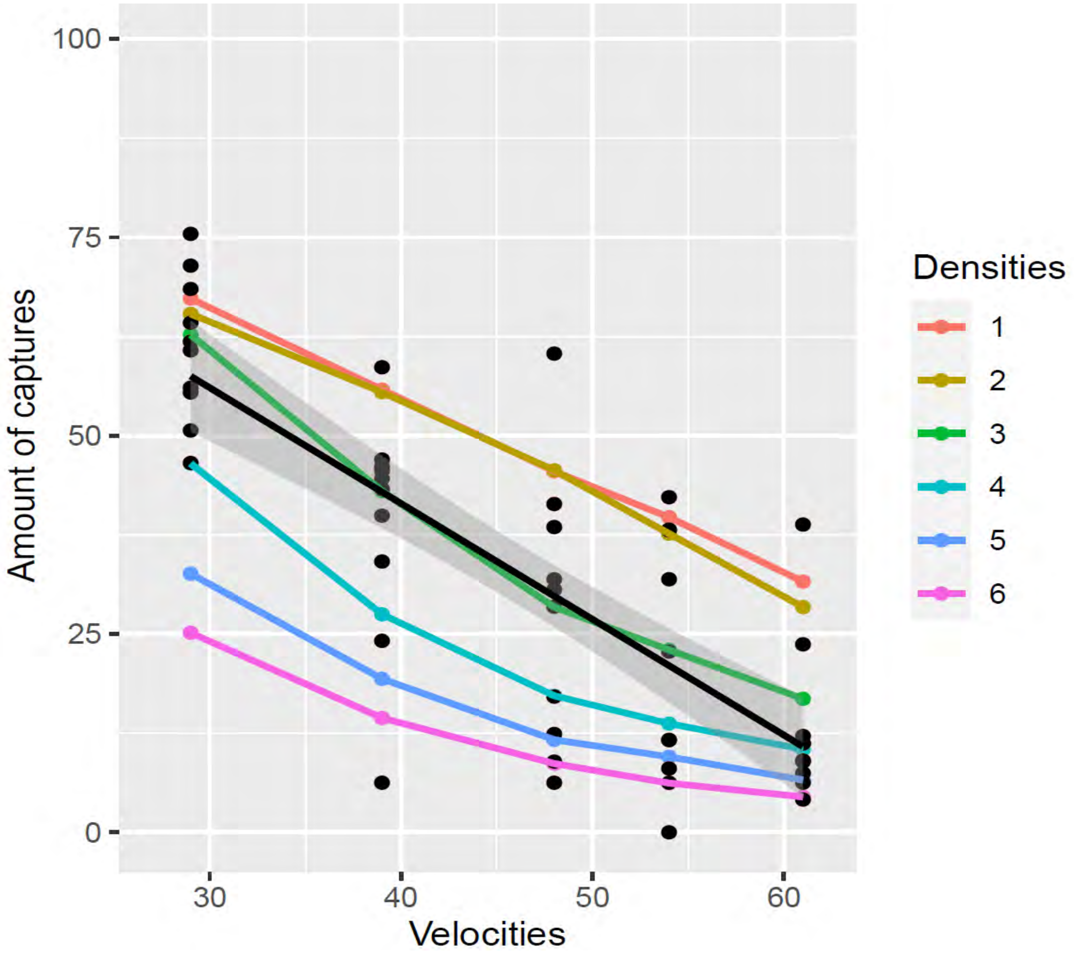
True data from Piccolo et al. 2008

Results

Capture success decreases as velocities and densities increase

- Prey abundance: 10,000
- *Different prey densities*
- ***Time is different***

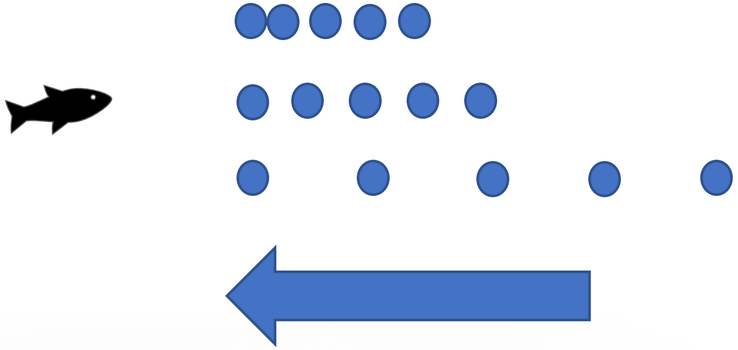


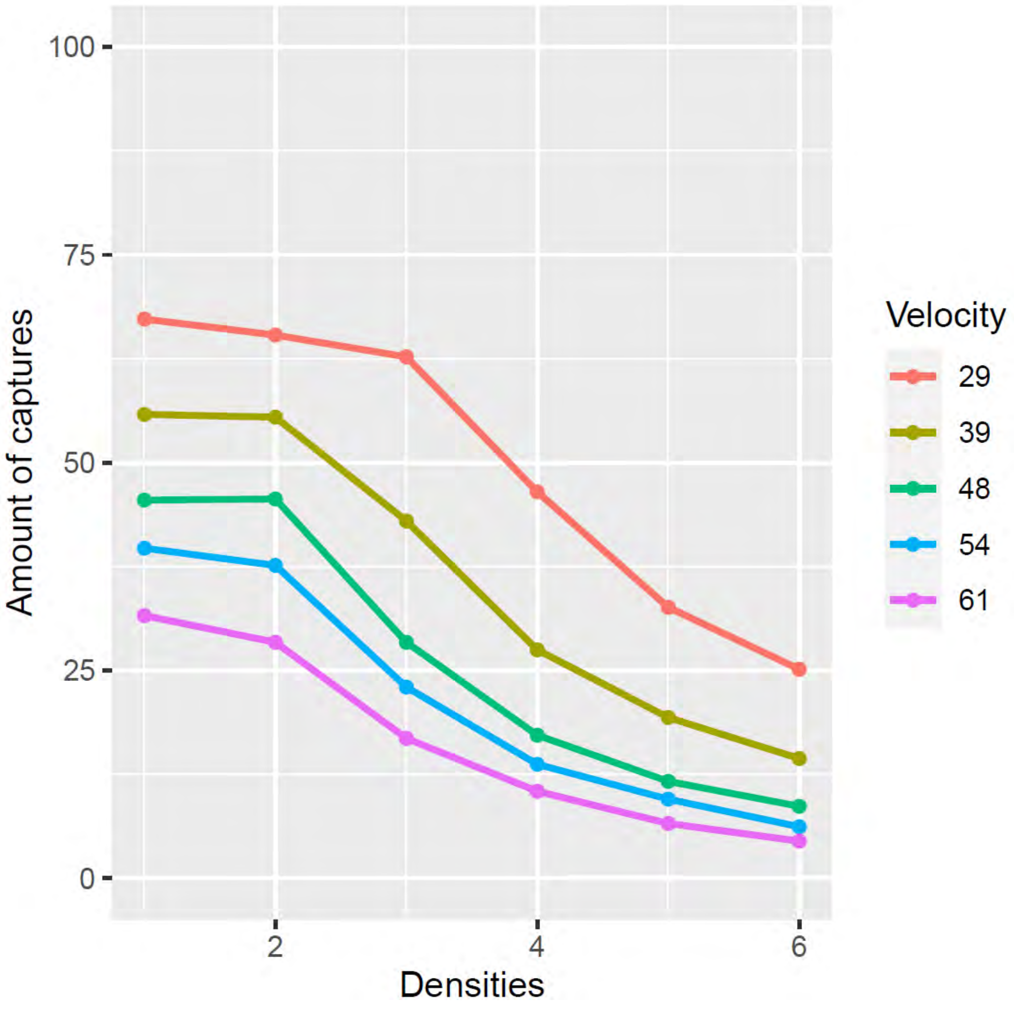


Results

Capture success decreases as velocities and densities increase

- Prey abundance: 10,000
- *Different prey densities*
- ***Time is different***

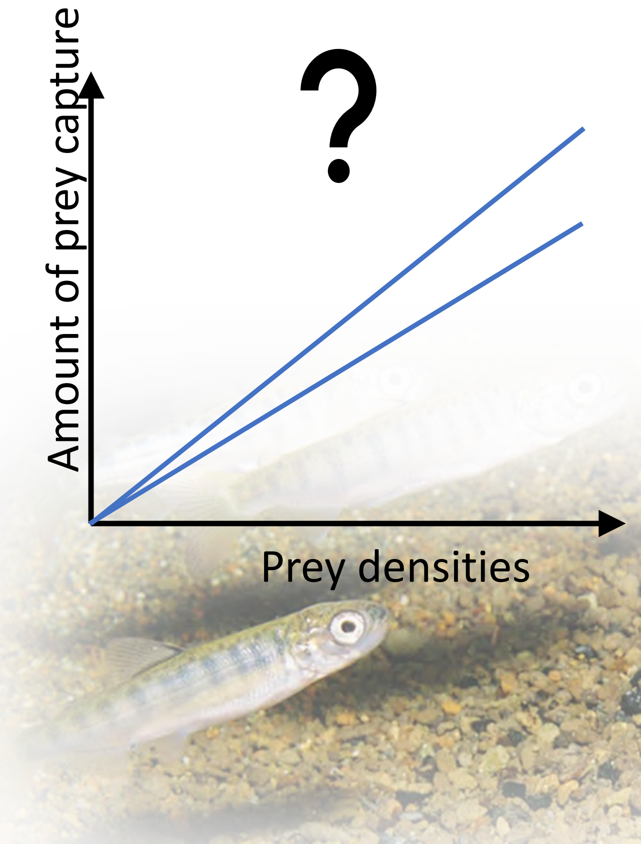


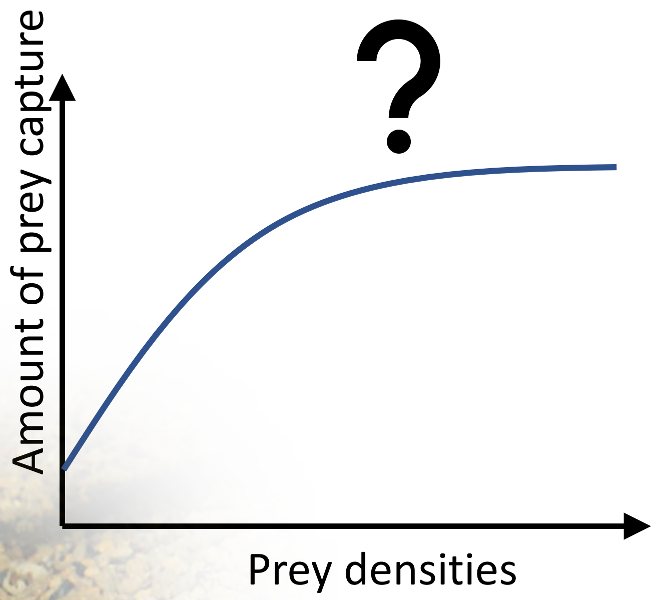


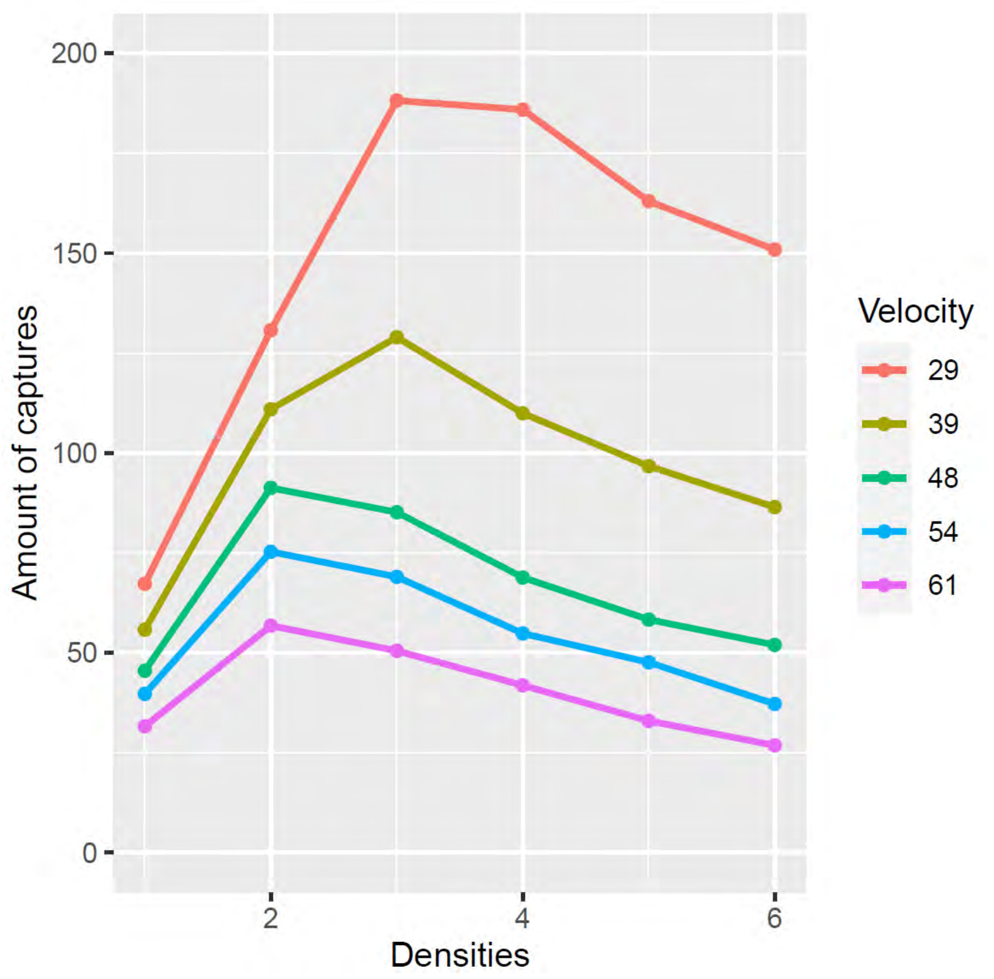
Results

Capture success levels off and decreases as velocities and densities increase

Preys unlimited
Equal amount of time







Discussions

1. A combination of prey density and velocity can affect the prey capture success.
2. Relationship between the capture success and the density is closer to a non-linear (or asymptote) rather than a liner relationship.
3. Our methods and results can help improve feeding models and metabolism models.
4. Maximum distance parameters will be made available in linear regression formula.
5. We can further improve our model by having the fish to behave more strategically.

References

Grossman and Newuswanger "Development and testing of mechanistic fitness-based models to predict habitat choice, behavior, and recruitment of juvenile Chinook salmon in the Arctic-Yukon-Kuskokwim region." North Pacific Research Board Project 1424

Piccolo, J. J., Hughes, N. F., & Bryant, M. D. (2008). Water velocity influences prey detection and capture by drift-feeding juvenile coho salmon (Oncorhynchus kisutch) and steelhead (Oncorhynchus mykiss irideus). Canadian Journal of Fisheries and Aquatic Sciences, 65(2), 266-275.

Piccolo, J. J., Hughes, N. F., & Bryant, M. D. (2007). The effects of water depth on prey detection and capture by juvenile coho salmon and steelhead. Ecology of Freshwater Fish, 16(3), 432-441.

Canale, R. P., Breck, J. E., Shearer, K. D., & Neely, K. G. (2013). Validation of a bioenergetic model for juvenile salmonid hatchery production using growth data from independent laboratory feeding studies. Aquaculture, 416, 228-237.

Questions?

Peter Dudley

FISHERIES COLLABORATIVE PROGRAM
UC SANTA CRUZ – NOAA FISHERIES

Ted Herman

Jesse Black

Alli Cramer

Chris John

End of presentation

Salmonids Return to Montezuma Wetlands after 150 Years

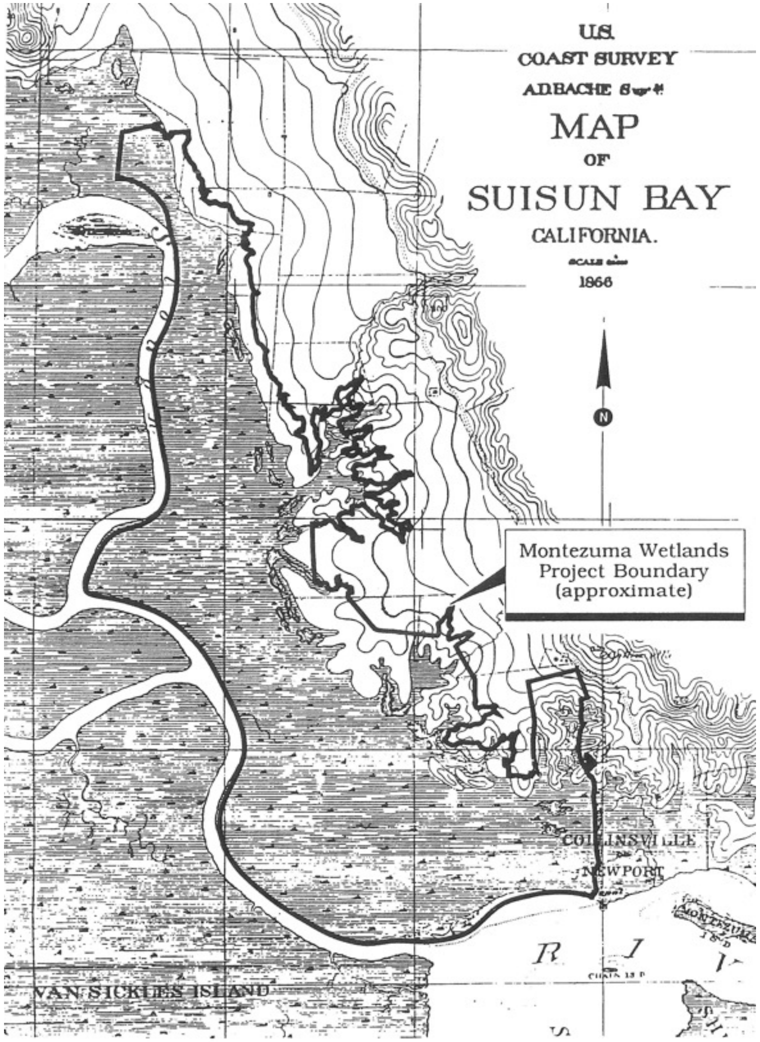
Fish Use and Productivity Trends in a Sediment Beneficial Reuse Restoration Site

Salmonid Restoration Federation Conference
April 22, 2022

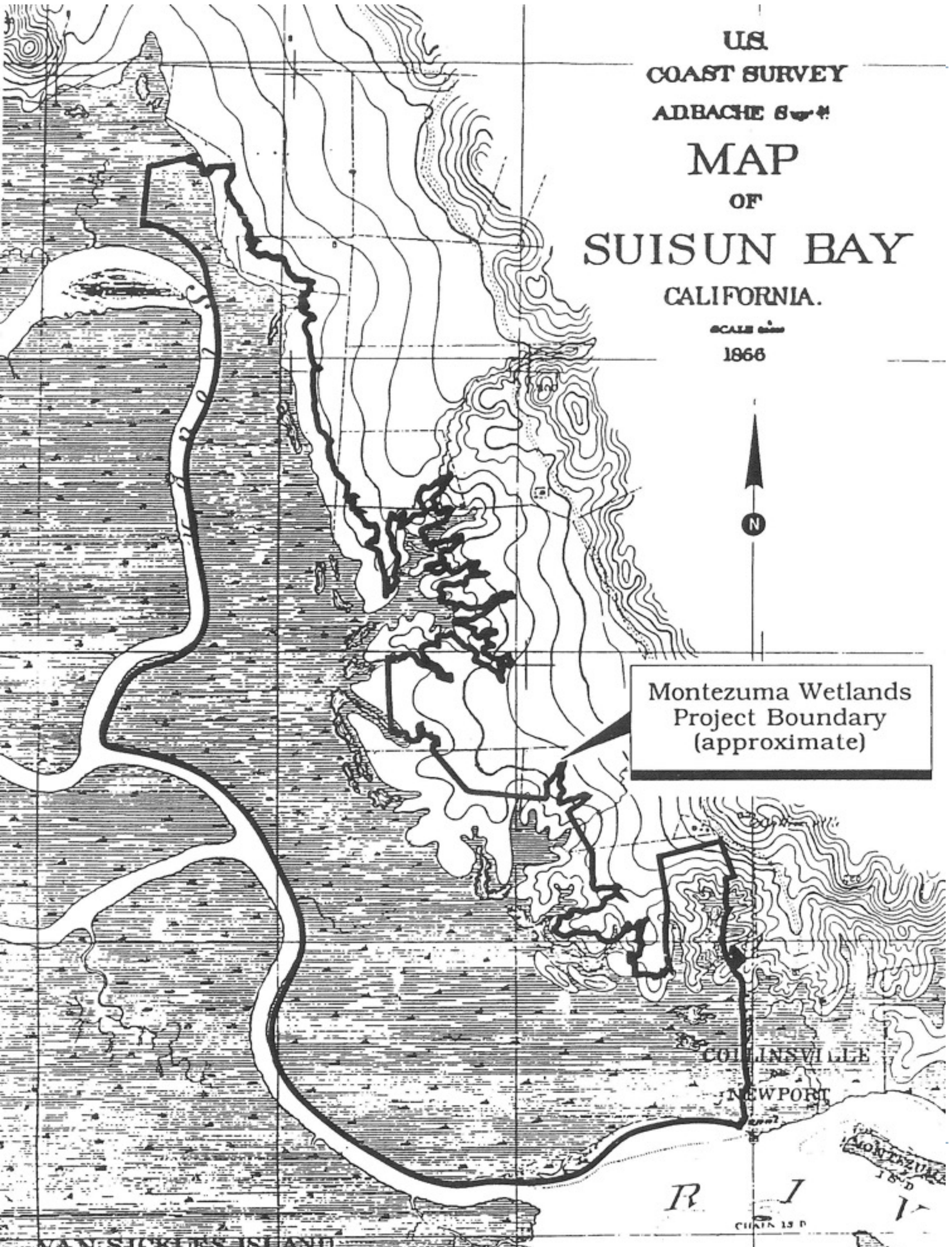
Cassie Pinnell and Chris Jasper, Vollmar Natural Lands Consulting

Suisun City
Hill Slough
Nurse Slough
Rush Ranch
Montezuma Slough
Grizzly Bay
Montezuma Wetlands Project
Honker Bay
Suisun Bay
Sacramento River
Browns Island
San Joaquin River
10
Kilometers
Miles
8
Redding
Reno
Sacramento
Montezuma Wetlands
San Francisco
San Jose
Fresno
CALIFORNIA
Bakersfield
Los Angeles

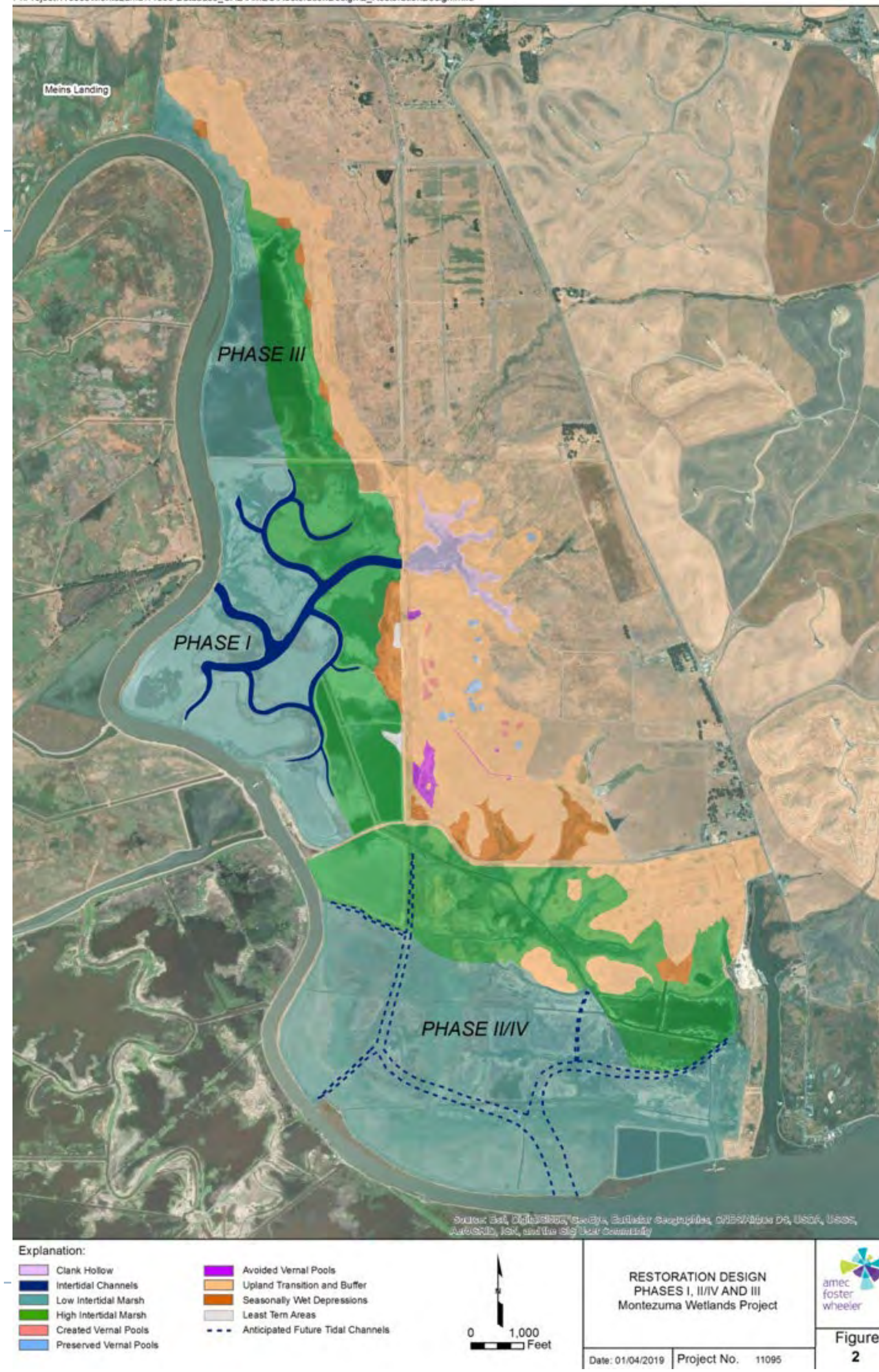
Site History



Site Design



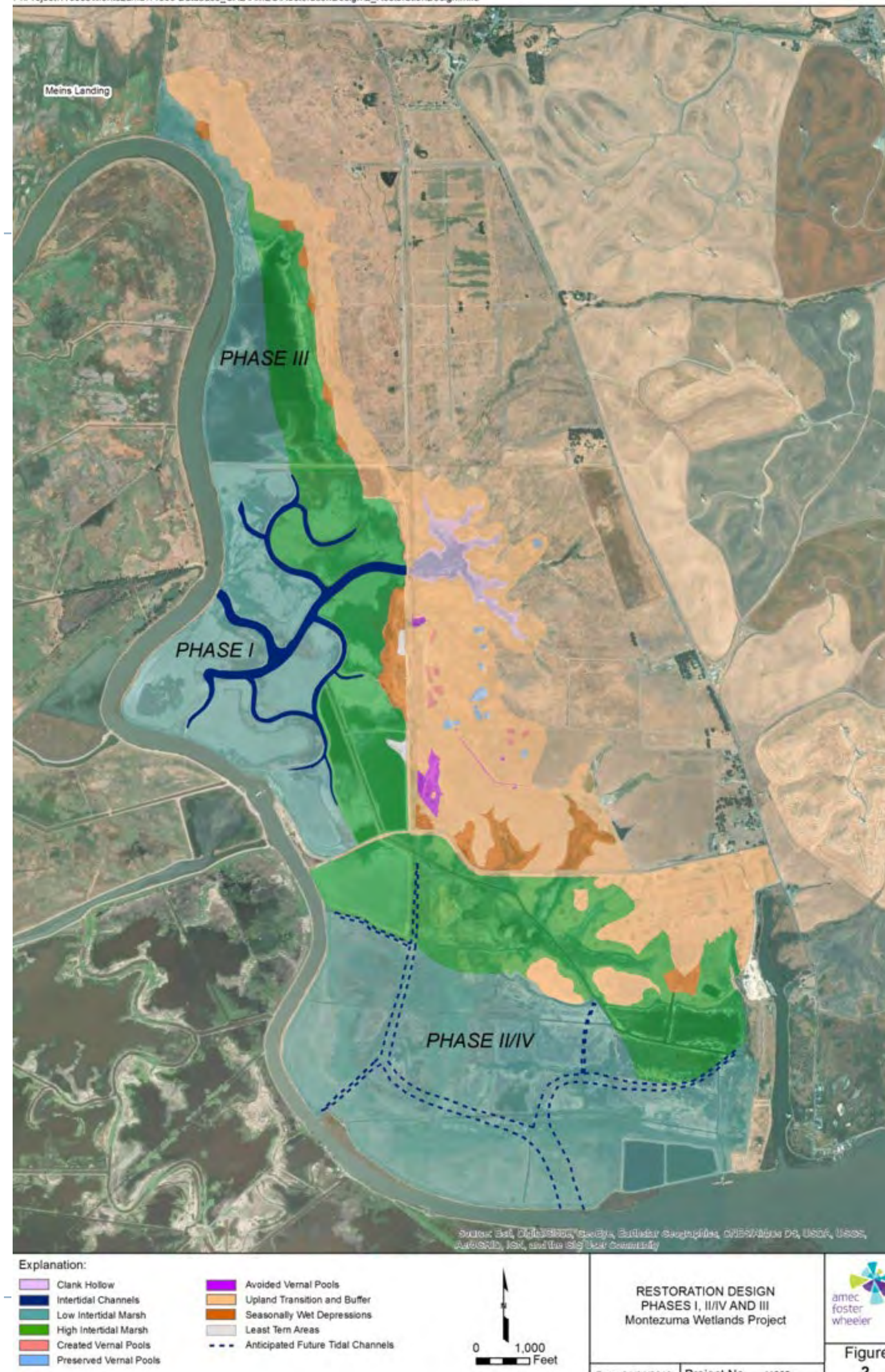
U.S.
COAST SURVEY
A.D.BACHE
MAP
OF
SUISUN BAY
CALIFORNIA.
1866
N
Montezuma Wetlands
Project Boundary
(approximate)
COLLINSVILLE
NEWPORT



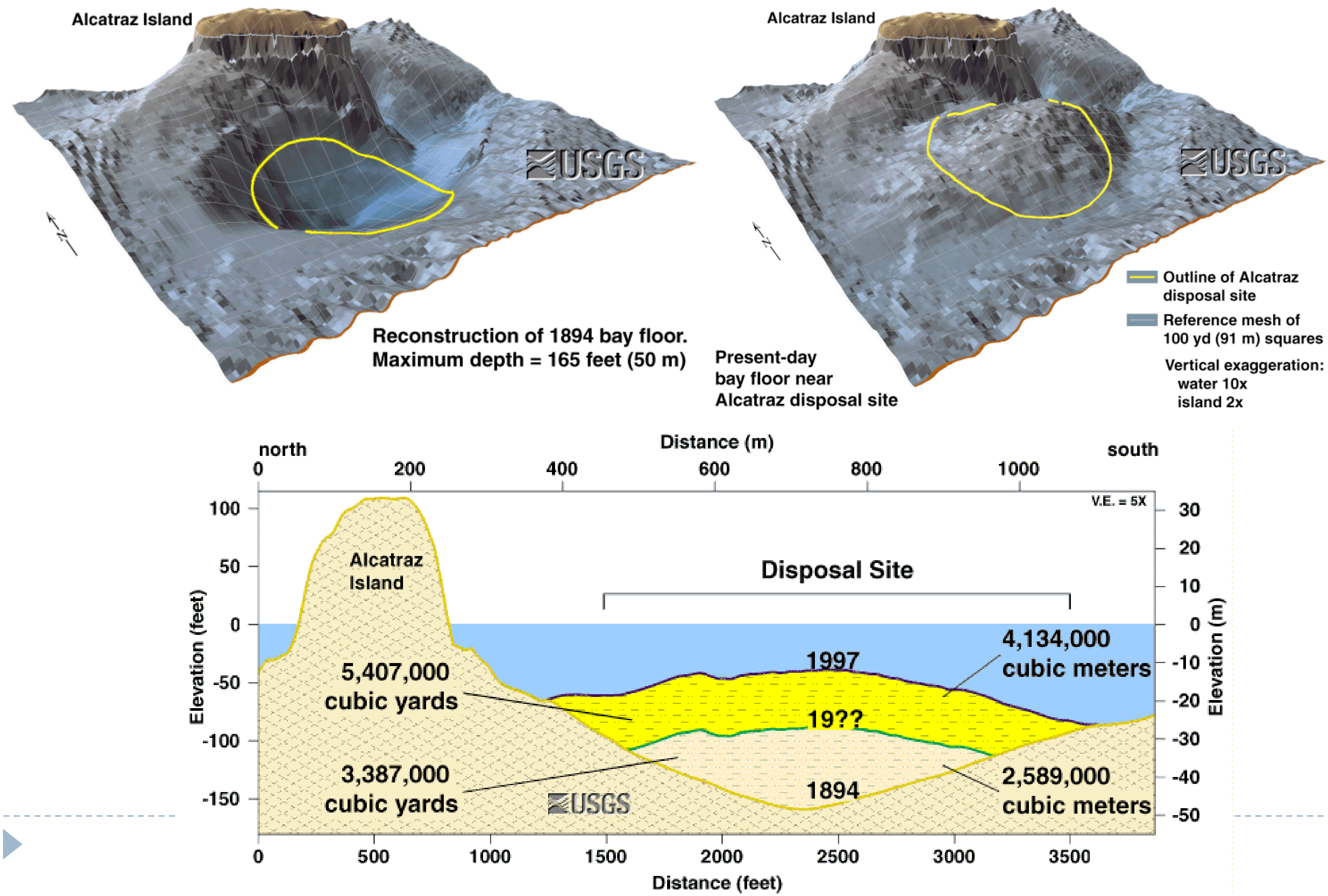
Meins Landing
PHASE III
PHASE I
PHASE II/IV
Explanation:
Clank Hollow
Intertidal Channels
Low Intertidal Marsh
High Intertidal Marsh
Created Vernal Pools
Preserved Vernal Pools
Avoided Vernal Pools
Upland Transition and Buffer
Seasonally Wet Depressions
Least Tern Areas
Anticipated Future Tidal Channels
0
1,000
Feet
RESTORATION DESIGN
PHASES I, II/IV AND III
Montezuma Wetlands Project
amec
foster
wheeler
Figure
2
Date: 01/04/2019
Project No. 11095

Project Elements

- Low marsh
- High marsh
- Intertidal Channels
- Seasonal Wetland
- CA Least Tern and Snowy Plover Habitats
- Clank Hollow
- Vernal Pools



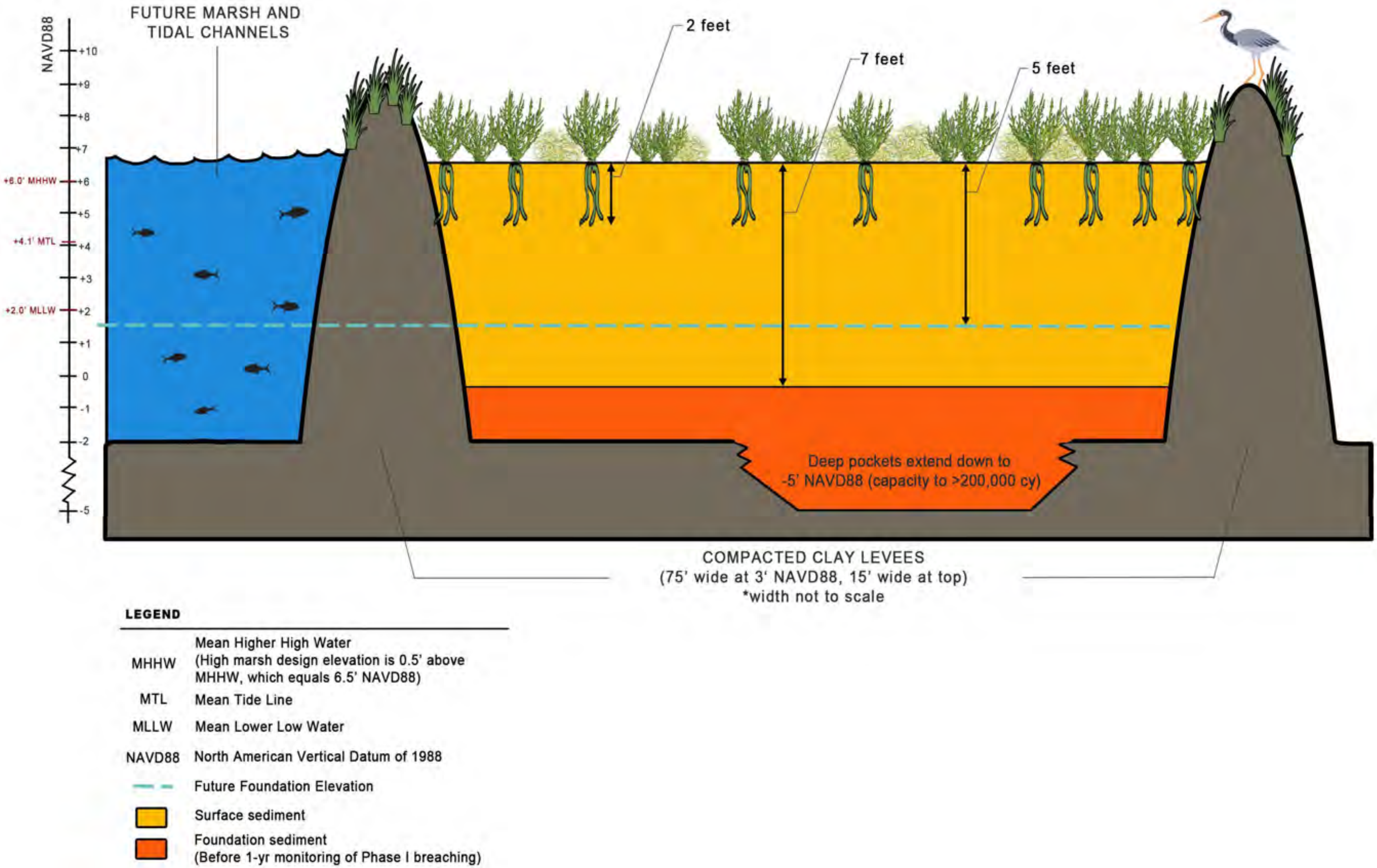
Previous Sediment Disposal



Sediment Offloading System


Sediment Pumped

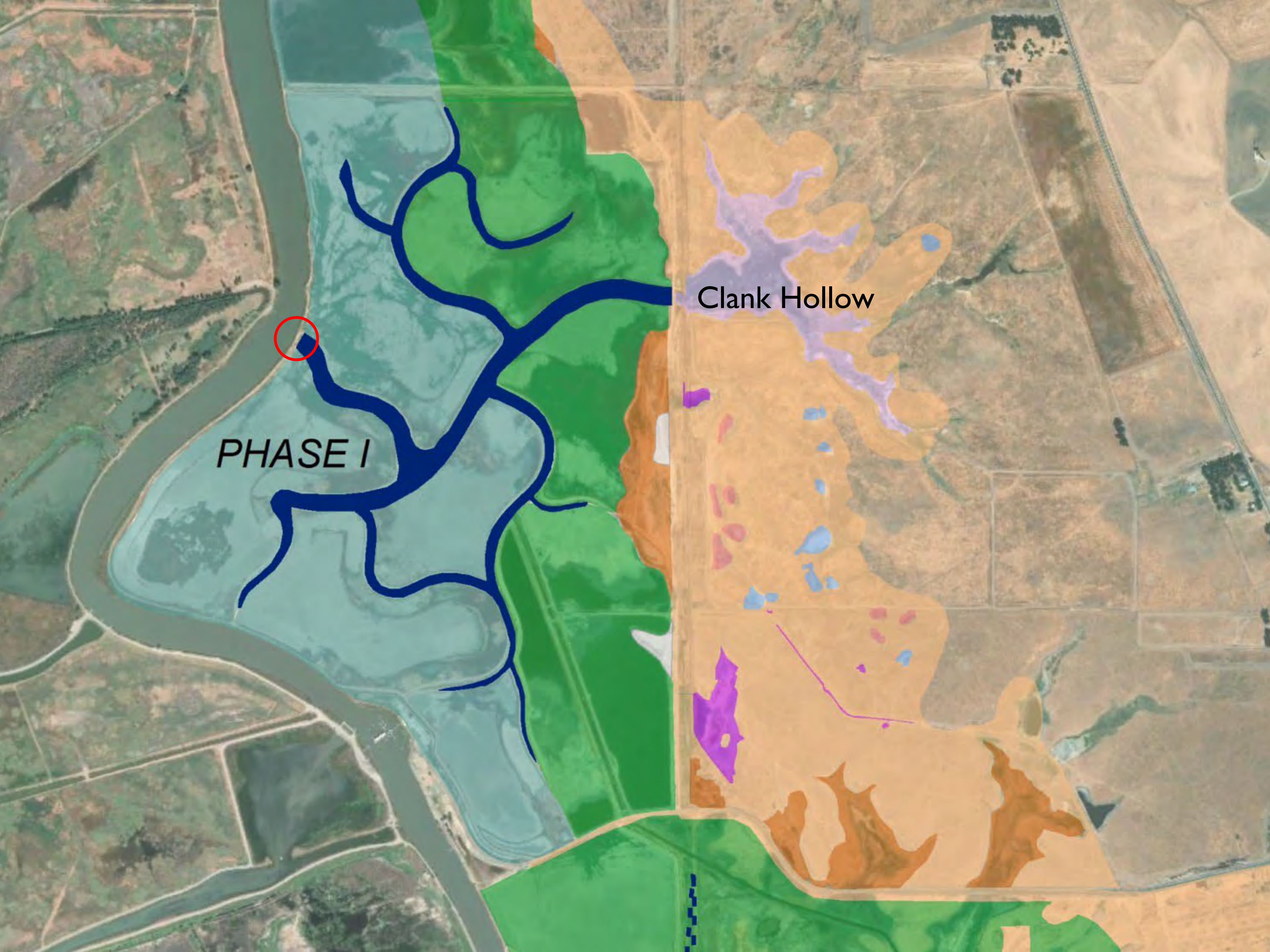
Cell Design


NAVD88
FUTURE MARSH AND TIDAL CHANNELS
+10
+9
+8
+7
+6.0' MHHW
+6
+5
+4.1' MTL
+4
+3
+2.0' MLLW
+2
+1
0
-1
-2
-5
2 feet
7 feet
5 feet
Deep pockets extend down to -5' NAVD88 (capacity to >200,000 cy)
COMPACTED CLAY LEVEES
(75' wide at 3' NAVD88, 15' wide at top)
*width not to scale
LEGEND
MHHW Mean Higher High Water (High marsh design elevation is 0.5' above MHHW, which equals 6.5' NAVD88)
MTL Mean Tide Line
MLLW Mean Lower Low Water
NAVD88 North American Vertical Datum of 1988
Future Foundation Elevation
Surface sediment
Foundation sediment (Before 1-yr monitoring of Phase I breaching)

Science and Oversight

- Technical Review Team (chair: SFEI)
- Project Team (Sediment, Engineering, Biology, Chemistry)
- Technical Specialists – Monitoring
- Resource Agencies (Permits, Review, and Support)

Phase 1 Breach: Oct 27, 2020


Clank Hollow
PHASE I

Early Results

Birds


Figure 1
Birds Observed in Restored Tidal Marsh Plain: June 2020 - June 2021
Low Tidal Marsh Plain 1
Low Tidal Marsh Plain 2
Low Tidal Marsh Plain 3/4
# of birds obs'd per monitoring event
0
100
200
300
400
500
600
700
800
900
Breach of Restoration Site on 10/27/20
6/15/2020
7/15/2020
8/15/2020
9/15/2020
10/15/2020
11/15/2020
12/15/2020
1/15/2021
2/15/2021
3/15/2021
4/15/2021
5/15/2021
6/15/2021

Tidal Channel Formation

Vegetation

Special-status Species

Salt marsh harvest mouse, burrowing owl, western pond turtle, CA least tern, western snowy plover

Photo credits: Anne Wallace, Joseph DiDonato

Additional Monitoring

- Rare Plants
  - Annual surveys
- Vegetation Development
  - UAV, Field
- Invasive Species
  - Early Detection- Rapid Response
- Overall Marsh Condition
  - CRAM
- Biosentinel
  - Bioaccumulative COCs

Collaborating with the UC Davis Suisun Marsh Fish Study (SMFS)

- SMFS has been sampling Suisun Marsh since 1980.
- Several long-term sampling locations within Montezuma Slough
- Sampling Montezuma Wetlands began November 2020
- Frequency: Monthly for 5 years
- Habitat sampled: Intertidal channels, Low marsh, High marsh, Clank Hollow

Recent UC Davis Center for Watershed Sciences Suisun Marsh Projects

- Recent research out of the Durand Lab at UCD Center for Watershed Sciences has:
  - Explored Chinook salmon rearing in managed wetland vs. tidal sloughs
  - Studied a recent restoration and explored how design caveats favor non-native fishes

Estuaries and Coasts
https://doi.org/10.1007/s12237-020-00880-4

Managed Wetlands Can Benefit Juvenile Chinook Salmon in a Tidal Marsh

Nicole M. Aha[1,2] · Peter B. Moyle[1,2] · Nann A. Fangue[2] · Andrew L. Rypel[1,2] · John R. Durand[1,2]

Received: 9 April 2020 / Revised: 25 November 2020 / Accepted: 2 December 2020

RESTORATION ECOLOGY
The Journal of the Society for Ecological Restoration
SER

RESEARCH ARTICLE

Tidal restoration of a managed wetland in California favors non-native fishes

Brian O. Williamshen[1,2], Teejay A. O'Rear[1], Melissa K. Riley[3,4], Peter B. Moyle[1,3], John R. Durand[1]

On-going UC Davis Center for Watershed Sciences Suisun Marsh Projects

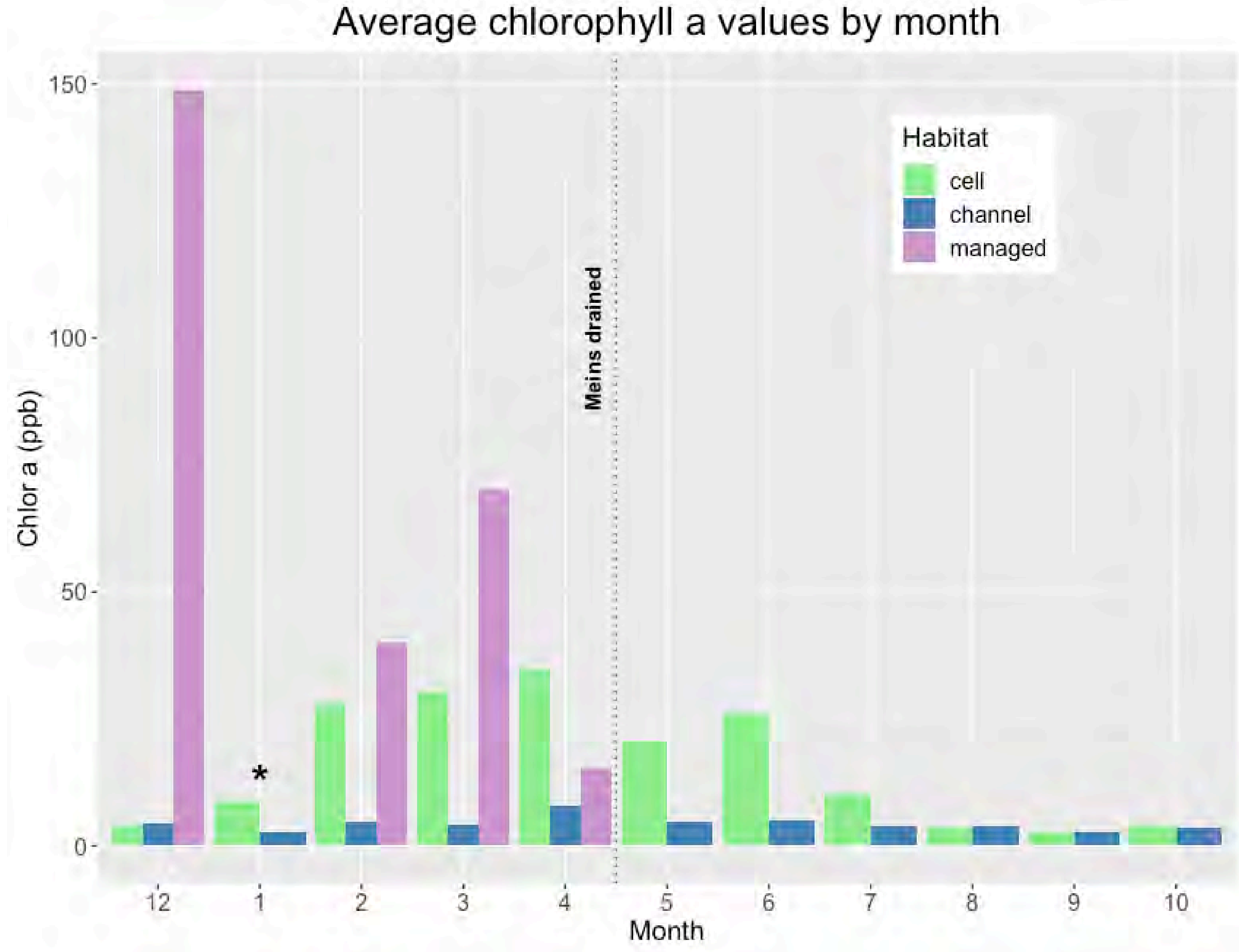
- **On-going research out of the Durand Lab at UCD Center for Watershed Sciences:**
  - Examining food web drivers and trends in managed wetlands across Suisun Marsh
  - Exploring food web processes and fish communities in a recently breach tidal restoration and a managed wetland…

Ponds Study - Alice Tung (left) and Kyle Phillips (right)

Montezuma Wetlands Study - Elsie Platzer

Water Quality Sampling

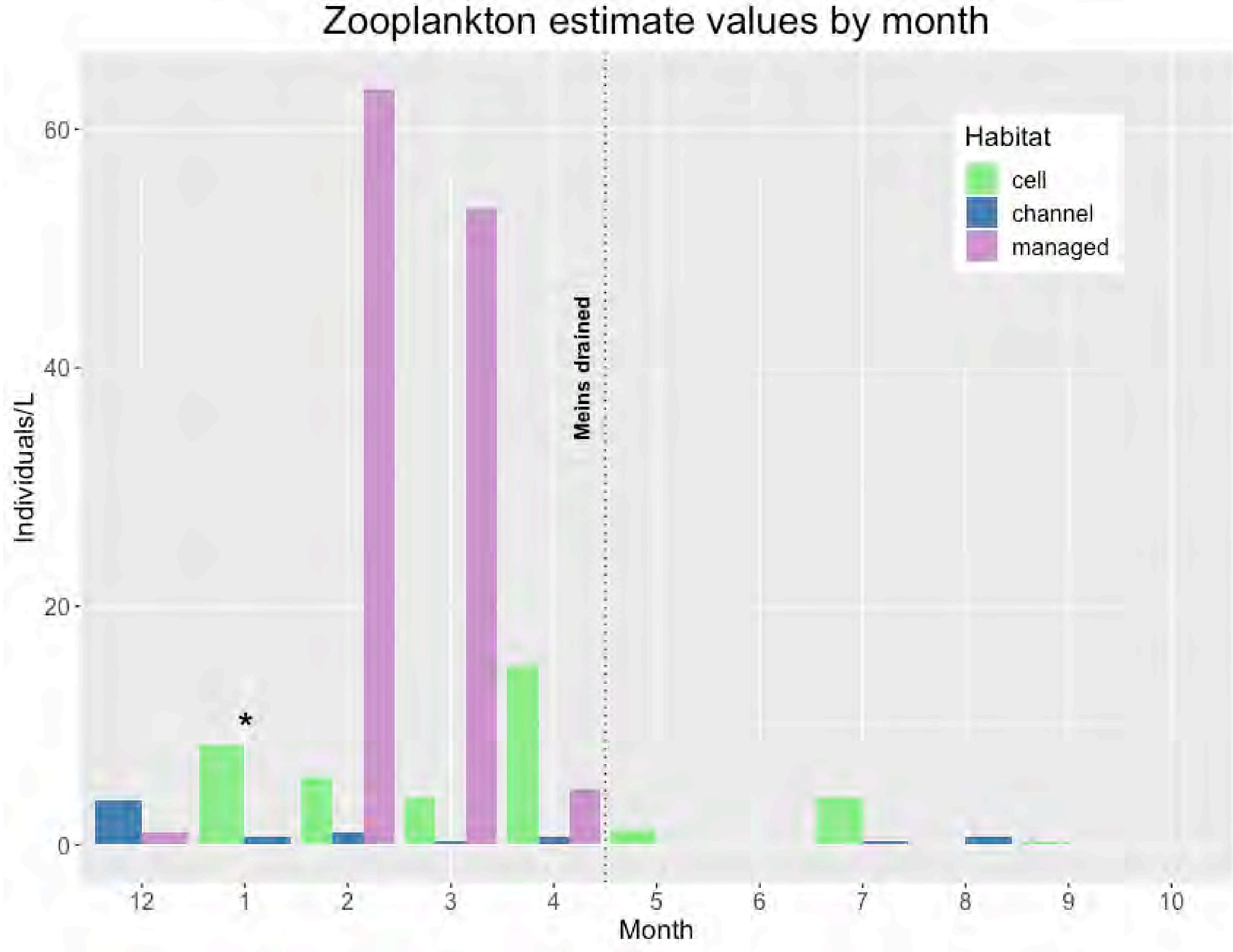
- Point samples collected in channels, cells, and at reference site (nearby managed wetland)
- YSI EXO2 multiparameter sonde:
  - temperature (°C),
  - salinity (ppt)
  - specific conductance (µS)
  - dissolved oxygen (both mg/L and % saturation)
  - pH
  - fluorescent dissolved organic matter (FDOM)
  - **chlorophyll *a***
  - phycocyanin (BGA-PC)



Average chlorophyll a values by month
Chlor a (ppb)
150
100
50
0
Meins drained
*
Habitat
cell
channel
managed
12
1
2
3
4
5
6
7
8
9
10
Month

Zooplankton Sampling

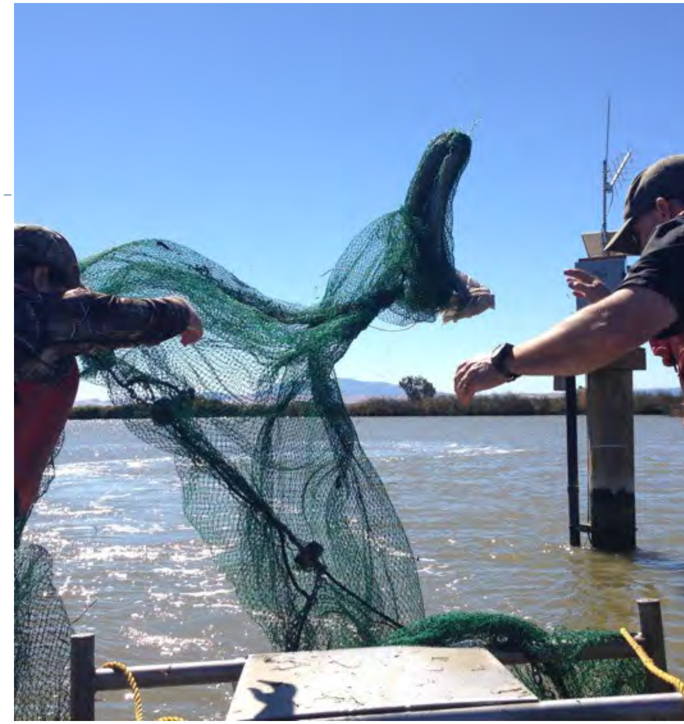
- Rapid-assessment technique adopted in December 2020
  - collected three water grabs measuring 1 L
  - filtered through a 50-mm-micron mesh
  - visually examined for zooplankton
  - recorded numbers of adult *Daphnia*, copepods, and ostracods per liter of water
  - summed for total individuals/L
- Method allows to quickly gauge zooplankton densities across multiple habitat types and larger spatial distributions

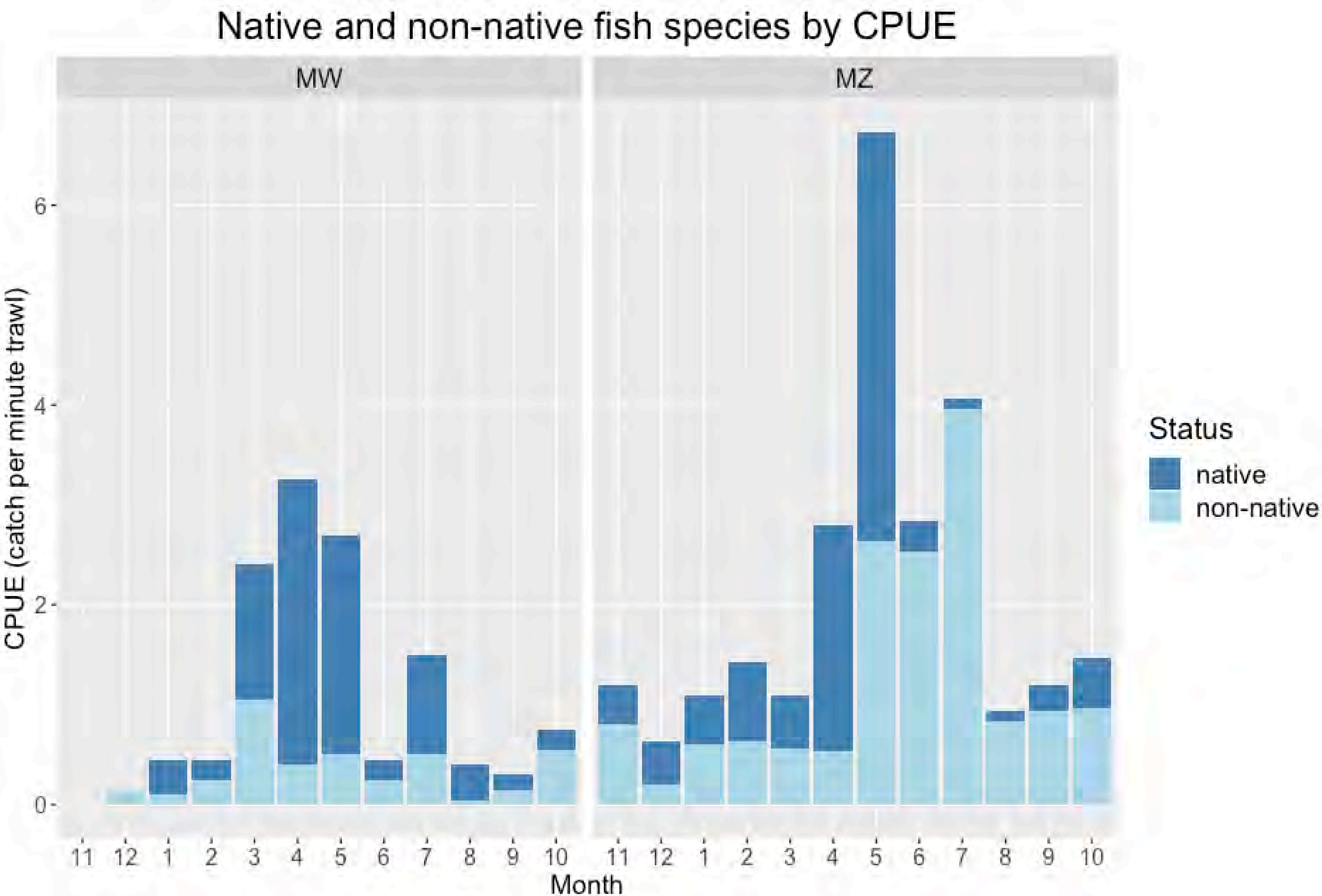


Zooplankton estimate values by month
Habitat
cell
channel
managed
Meins drained
Individuals/L
0
20
40
60
*
12
1
2
3
4
5
6
7
8
9
10
Month

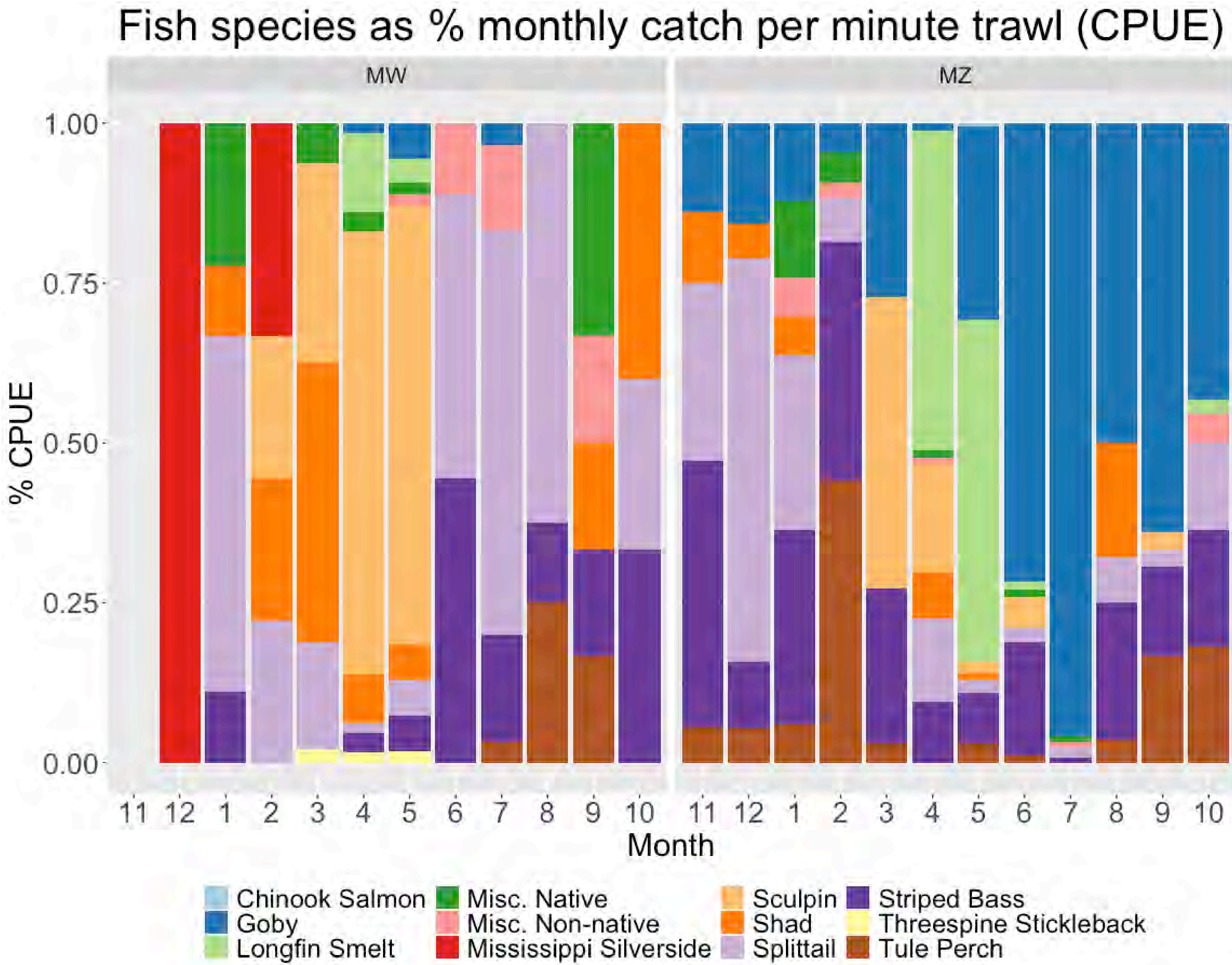
Otter Trawl Sampling

- Trawls cover the four main slough segments of Montezuma Wetlands (MW)
- Trawl stations located in Montezuma Slough were selected as comparison sites (MZ)
- Trawling was conducted using a four-seam otter trawl
  - 1.5-m X 4.3-m opening
  - a length of 5.3 m
  - 35-millimeter (mm) mesh size





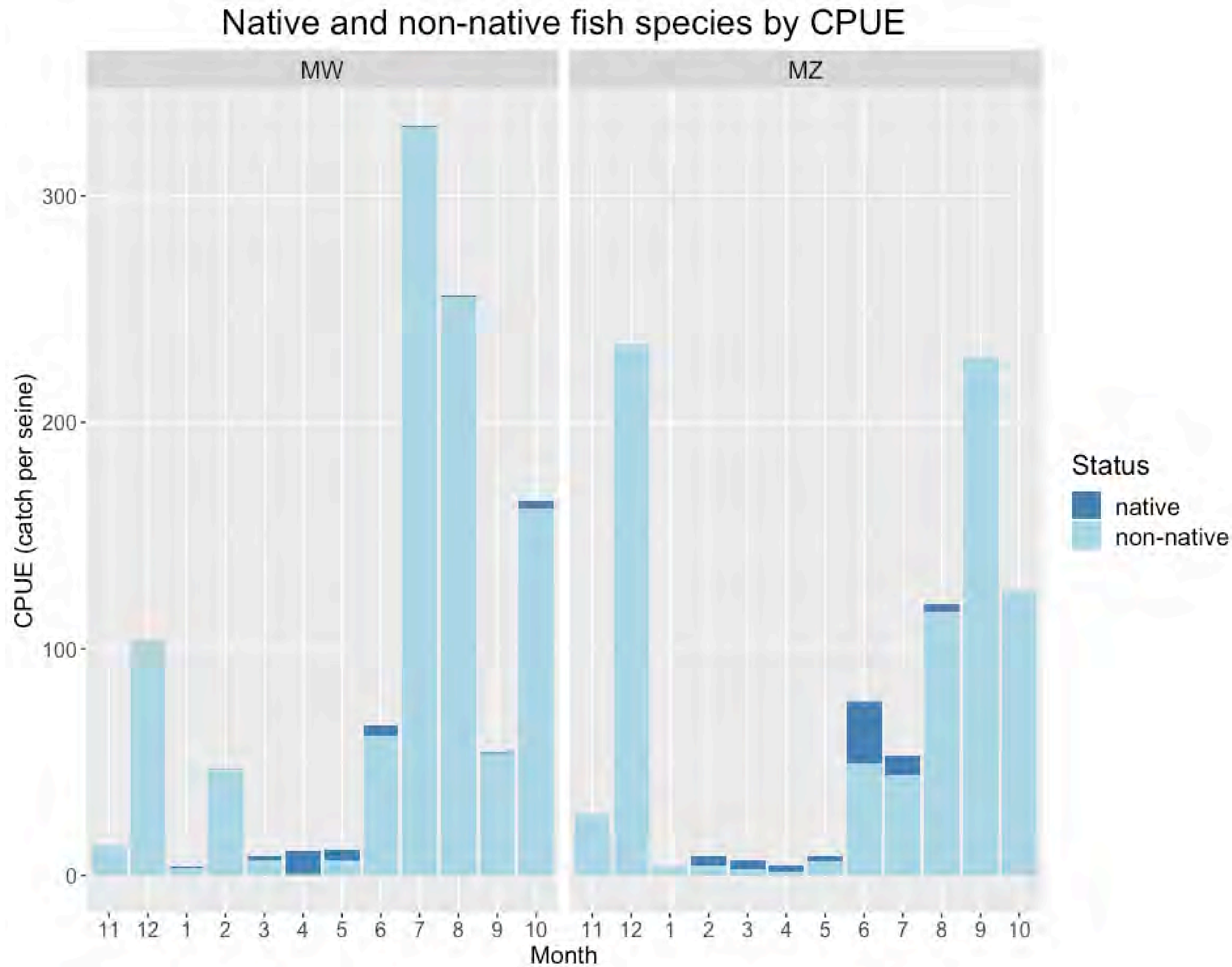
Native and non-native fish species by CPUE
MW
MZ
CPUE (catch per minute trawl)
0
2
4
6
11
12
1
2
3
4
5
6
7
8
9
10
Month
Status
native
non-native

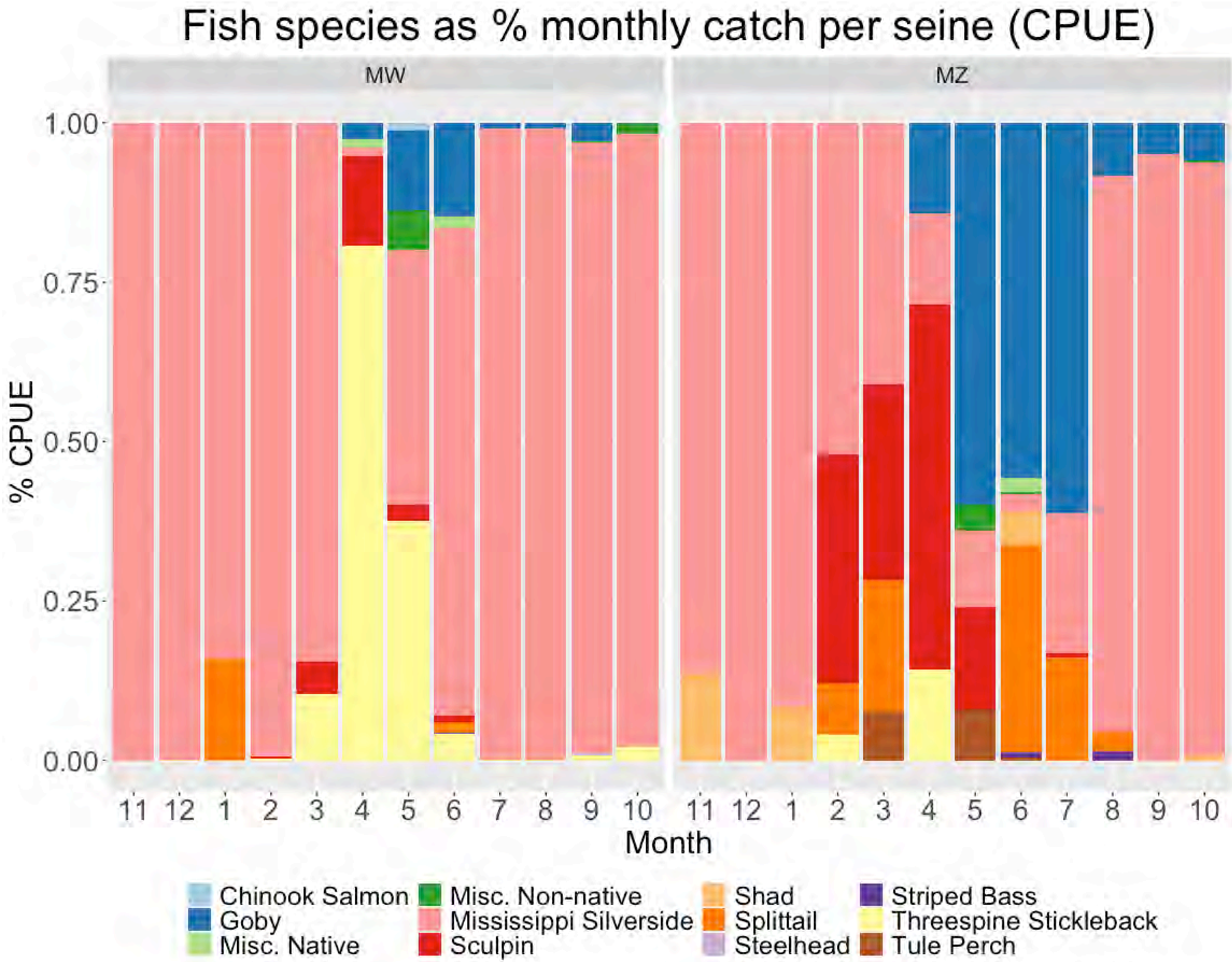


Fish species as % monthly catch per minute trawl (CPUE)
MW
MZ
1.00
0.75
0.50
0.25
0.00
% CPUE
11 12 1 2 3 4 5 6 7 8 9 10
11 12 1 2 3 4 5 6 7 8 9 10
Month
Chinook Salmon
Goby
Longfin Smelt
Misc. Native
Misc. Non-native
Mississippi Silverside
Sculpin
Shad
Splittail
Striped Bass
Threespine Stickleback
Tule Perch

Seine Sampling

- Seines are conducted cover the four main slough segments and within several tidal cells of Montezuma Wetlands (MW)
- Seine stations located in Montezuma Slough (MZ) were selected as comparison sites
- Seining was conducted using 10-mm seine with a 6mm mesh size


Native and non-native fish species by CPUE
MW
MZ
CPUE (catch per seine)
300
200
100
0
11 12 1 2 3 4 5 6 7 8 9 10
11 12 1 2 3 4 5 6 7 8 9 10
Month
Status
native
non-native



Fish species as % monthly catch per seine (CPUE)
MW
MZ
1.00
0.75
0.50
0.25
0.00
% CPUE
11
12
1
2
3
4
5
6
7
8
9
10
Month
Chinook Salmon
Goby
Misc. Native
Misc. Non-native
Mississippi Silverside
Sculpin
Shad
Splittail
Steelhead
Striped Bass
Threespine Stickleback
Tule Perch

Key Findings from First Year of Survey

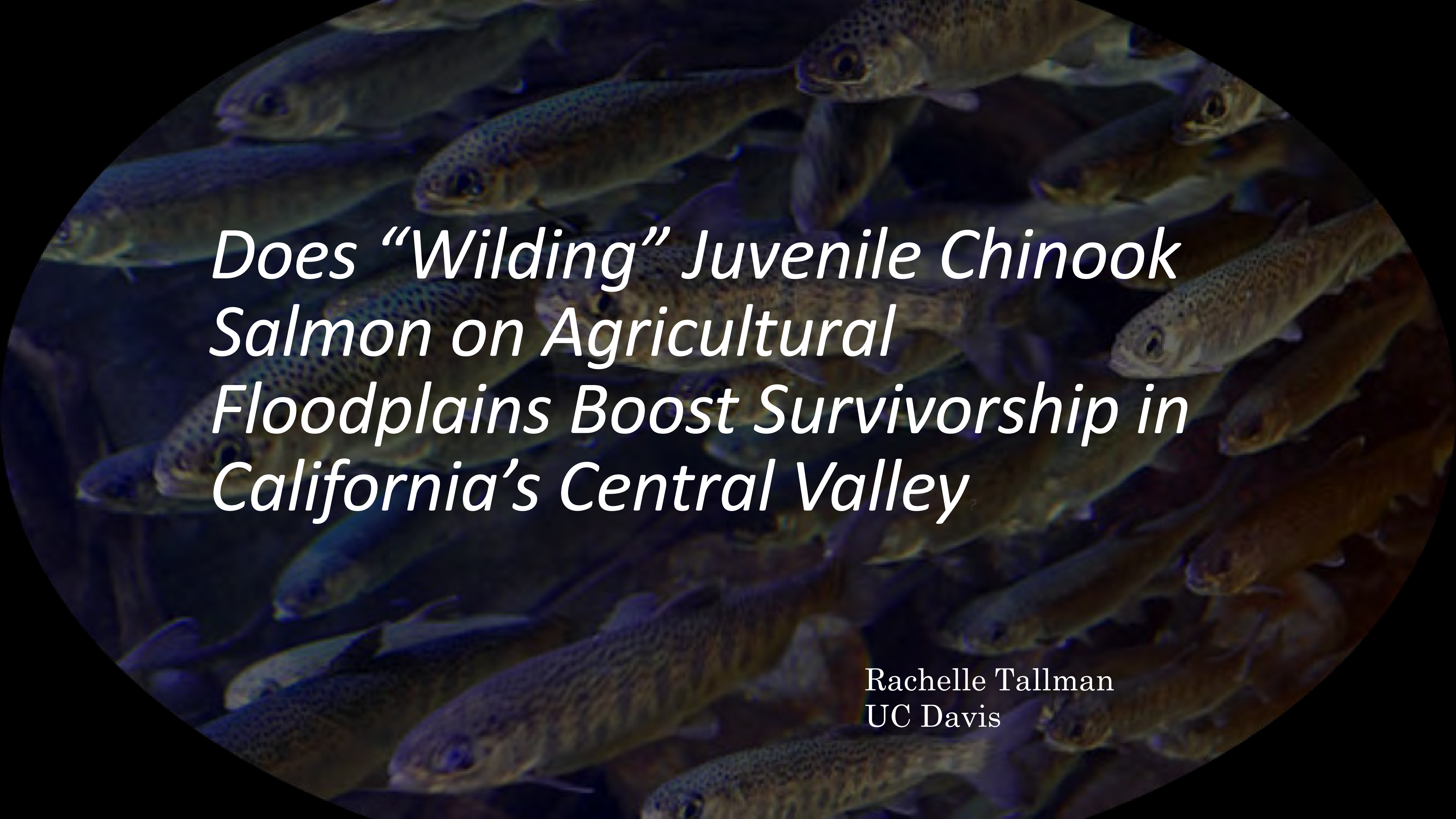
- Montezuma Wetlands displays seasonal benefits for native fishes
- Chlorophyll and zooplankton densities are highest in spring months
- Salmonids are present Montezuma Wetlands, but more surveys and research is required to understand extent of use
- Early successional invaders such as silversides are prevalent throughout – a common trend for new restorations in Suisun Marsh

Future Studies

- Four more years of monthly monitoring by the SMFS will aid in understanding of:
  - successional processes of restoration
  - changes in food web dynamics
  - changes in fish community dynamics
  - salmonid use of the restoration
- The UC Davis Genomic Variation Laboratory will begin refining eDNA methodology to:
  - understand special-status fish use of the restoration
  - understand non-native fish use of the restoration
  - explore novel novel food web pathways

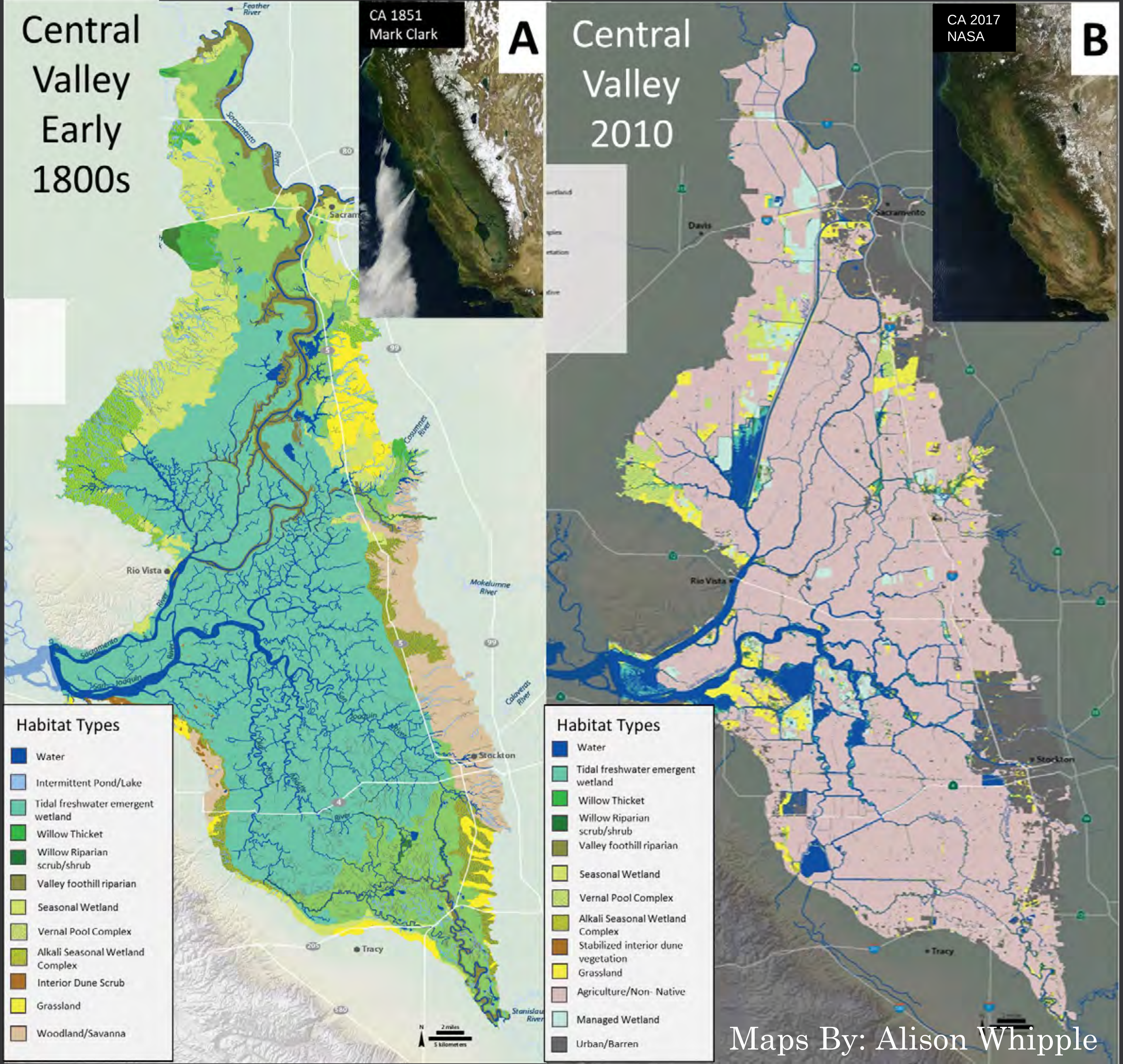
- www.montezumawetlands.com
- Cassie Pinnell: cpinnell@vollmarconsulting.com
- Chris Jasper: cjasper@vollmarconsulting.com
- Doug Lipton, PhD: docterre@sonic.net

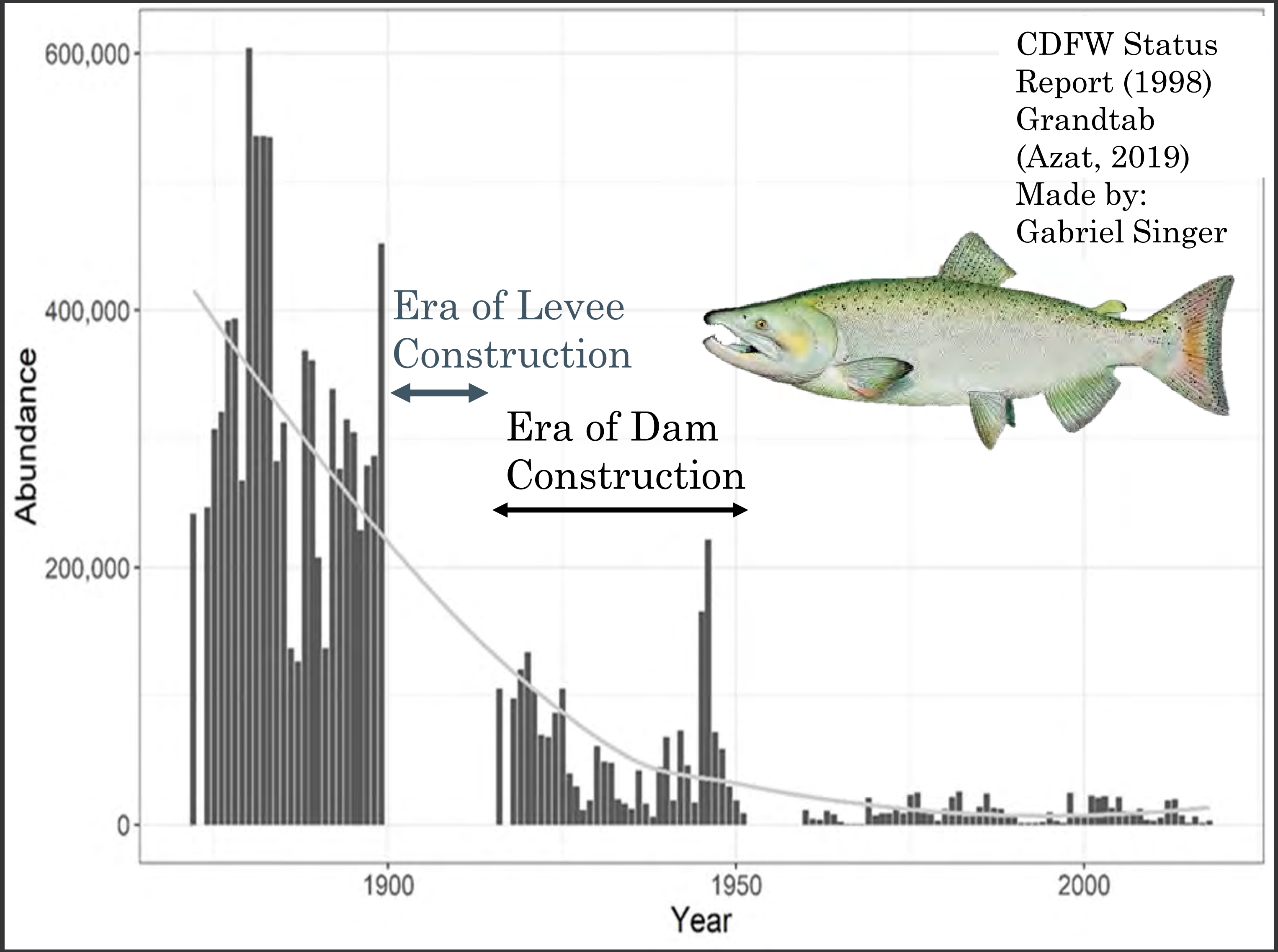
Thank you to Montezuma Wetlands LLC, SF Bay Restoration Authority, SFEI, Montezuma Technical Review Team, UC Davis Center for Watershed Sciences, Far West Restoration, Lipton Environmental Group, Vollmar Natural Lands Consulting, The Dutra Group, and our larger team of researchers and agency partners for decades of work and support.

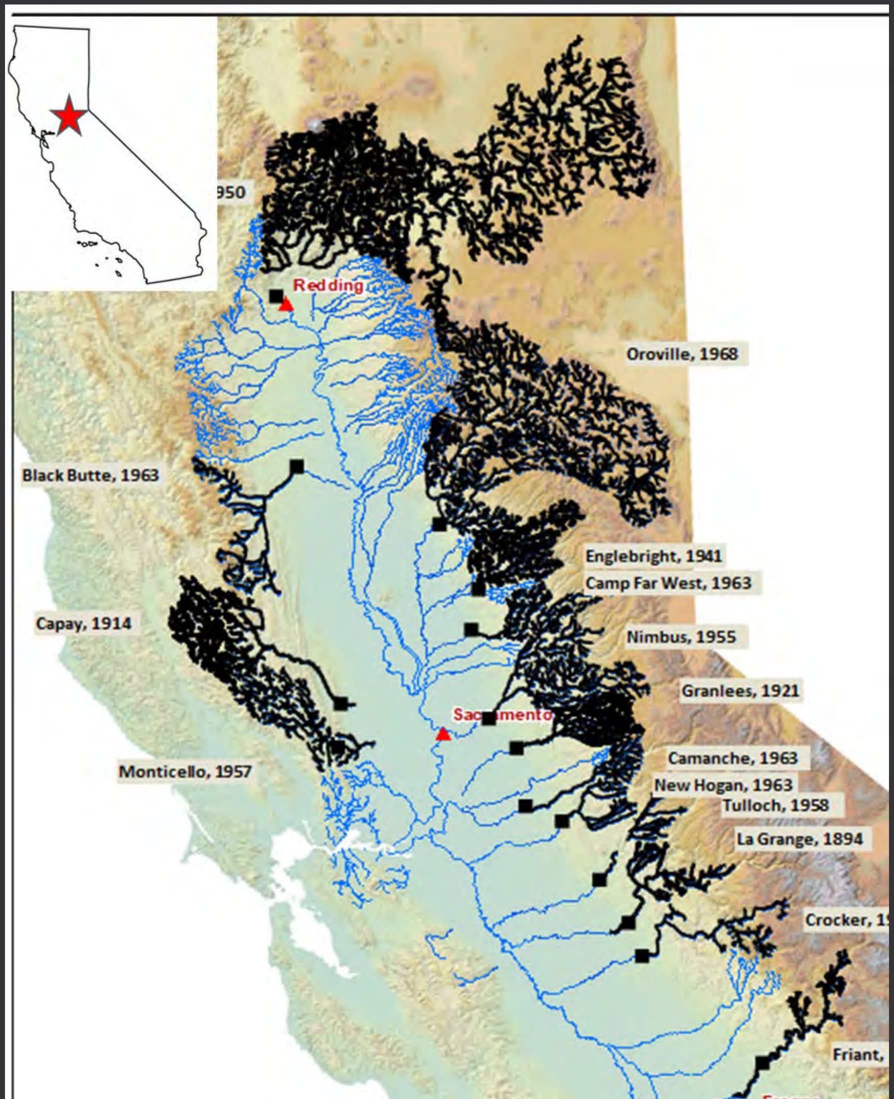


Does "Wilding" Juvenile Chinook Salmon on Agricultural Floodplains Boost Survivorship in California's Central Valley

Rachelle Tallman
UC Davis


Central Valley Early 1800s
CA 1851
Mark Clark
A
Central Valley 2010
CA 2017
NASA
B
Habitat Types
Water
Intermittent Pond/Lake
Tidal freshwater emergent wetland
Willow Thicket
Willow Riparian scrub/shrub
Valley foothill riparian
Seasonal Wetland
Vernal Pool Complex
Alkali Seasonal Wetland Complex
Interior Dune Scrub
Grassland
Woodland/Savanna
Habitat Types
Water
Tidal freshwater emergent wetland
Willow Thicket
Willow Riparian scrub/shrub
Valley foothill riparian
Seasonal Wetland
Vernal Pool Complex
Alkali Seasonal Wetland Complex
Stabilized interior dune vegetation
Grassland
Agriculture/Non- Native
Managed Wetland
Urban/Barren
Rio Vista
Stockton
Tracy
Davis
Sacramento
Mokelumne River
Maps By: Alison Whipple

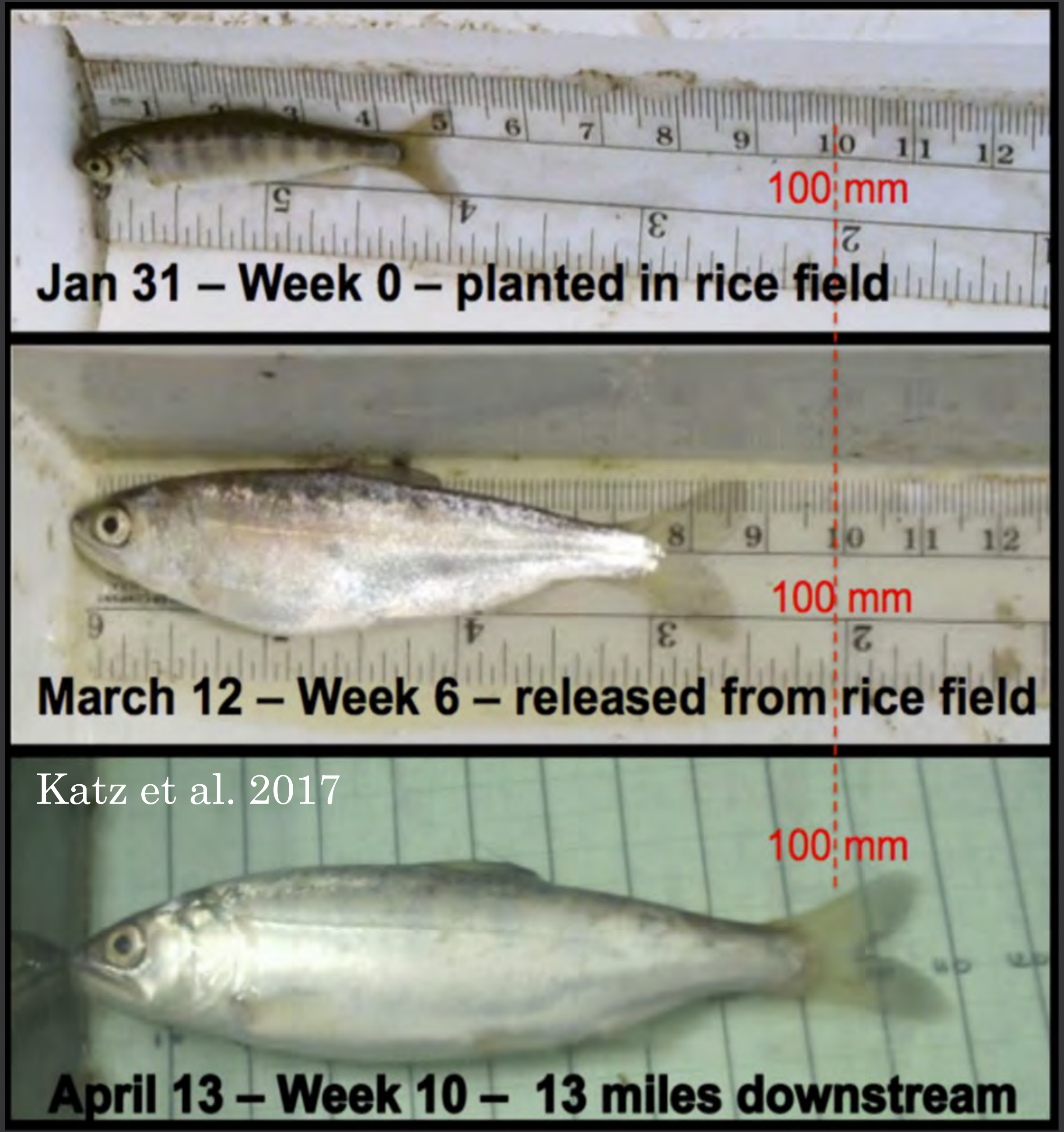




Lindley et al. 2006


River
Rice Field

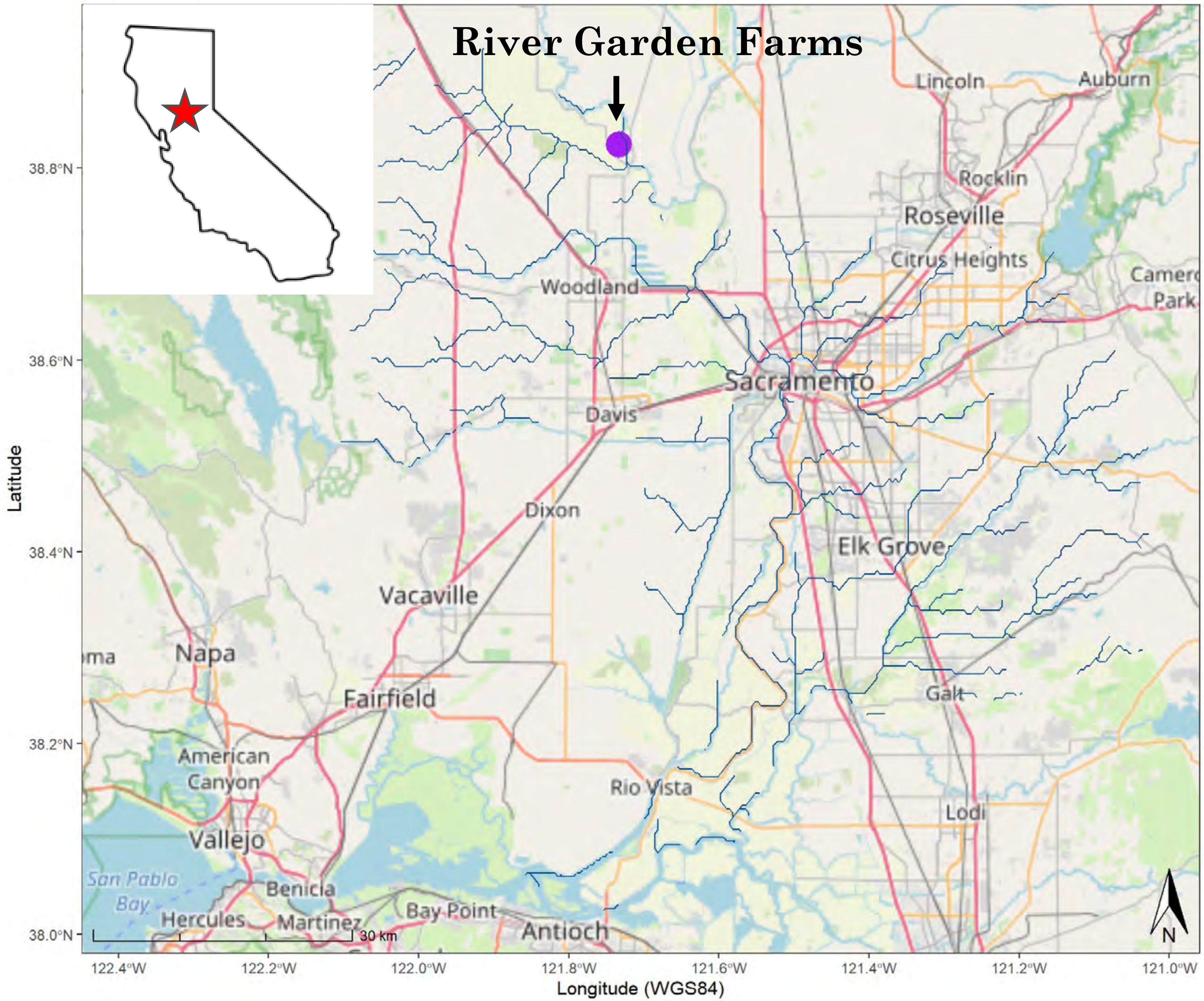

Rice Field
River
3/11/19 MNT 3A
ACC 3/11/19
Photo By: Jak Wonderly


Jan 31 – Week 0 – planted in rice field
100 mm
March 12 – Week 6 – released from rice field
100 mm
Katz et al. 2017
100 mm
April 13 – Week 10 – 13 miles downstream

Question 1: Which field treatments promote survival of juvenile salmon on agricultural floodplains?

Images by: California Rice Commission

Map of River Garden Farms



In-field Habitat Treatments

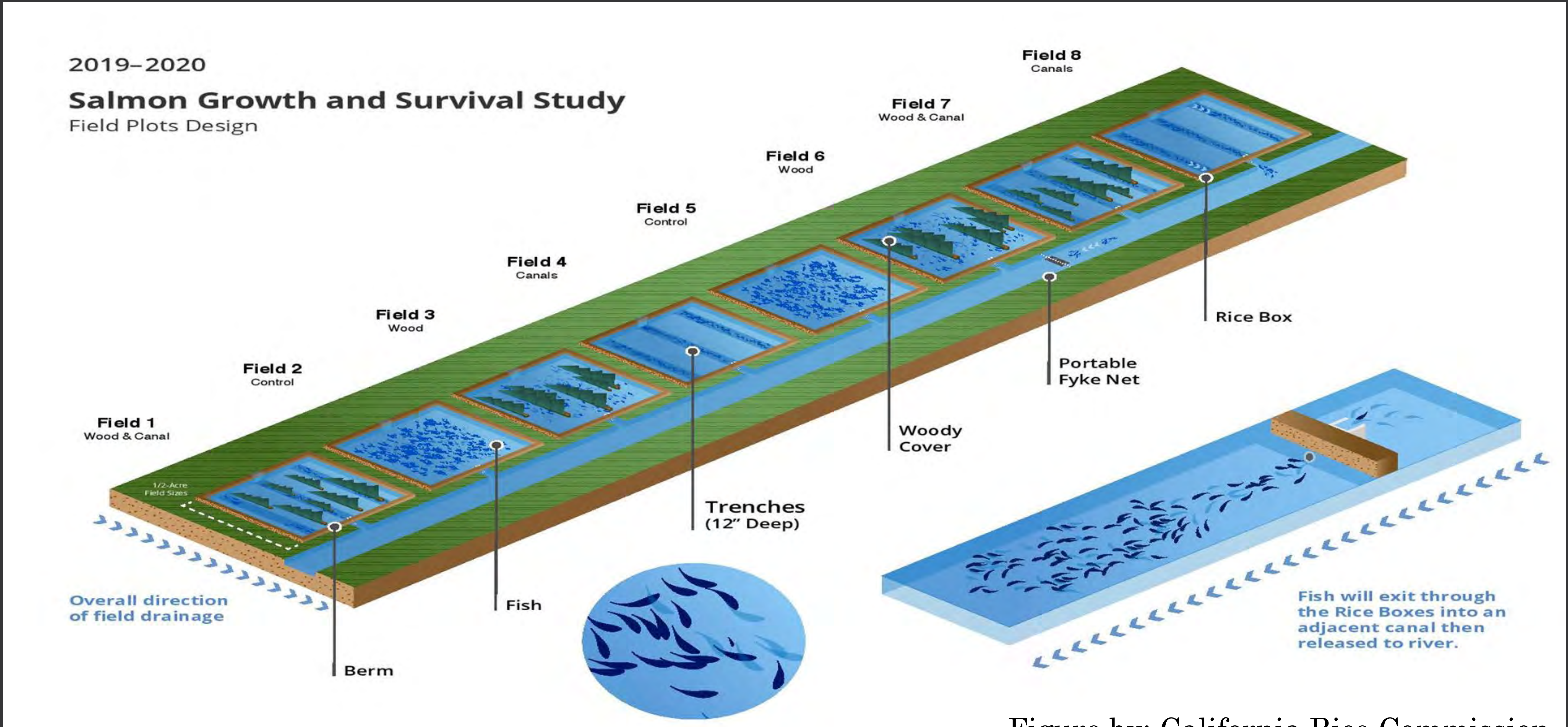
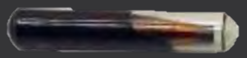


Figure by: California Rice Commission

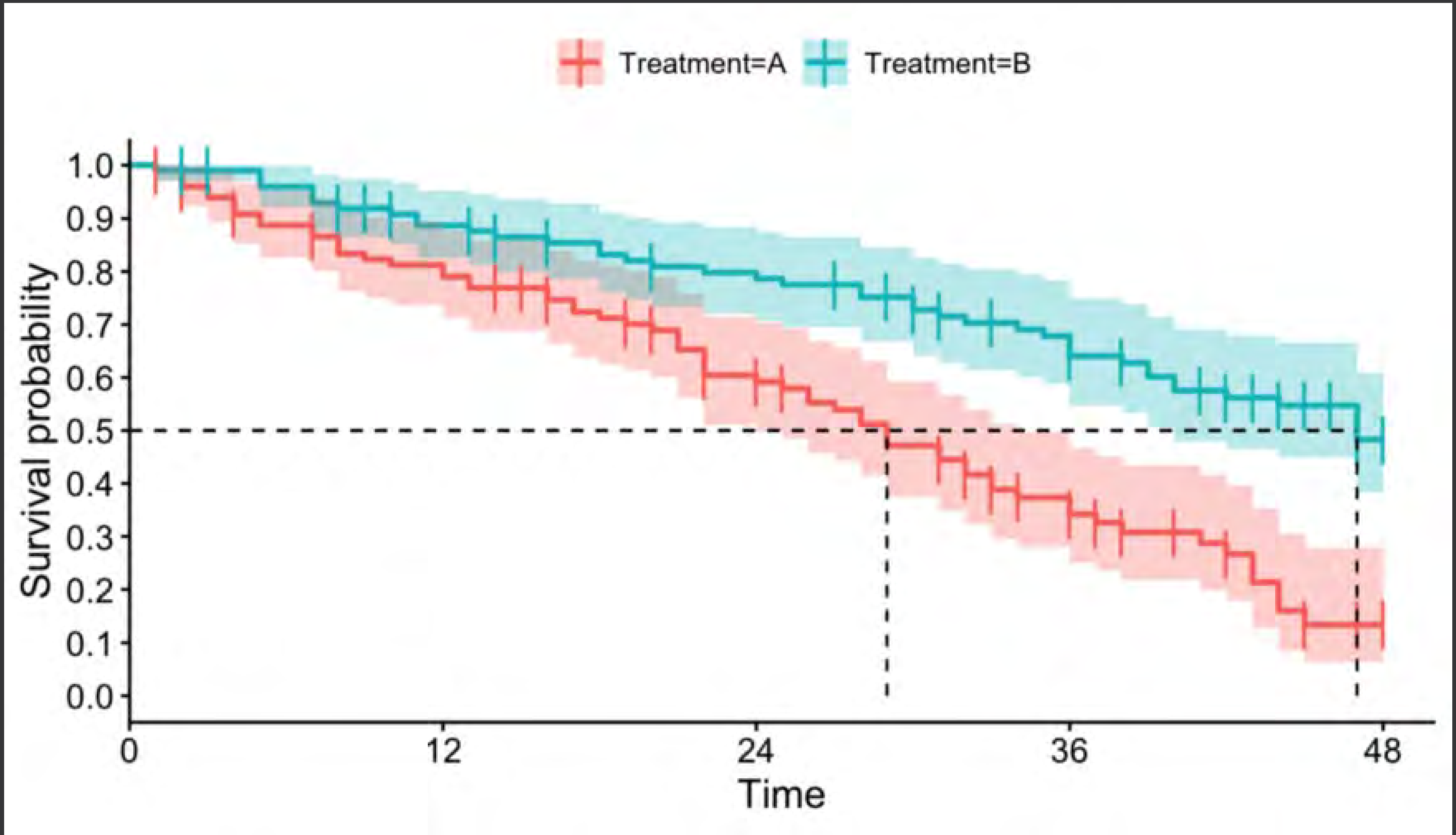

HONDA
TRITON Elite

- 1,000 fish were placed into each plot
- Fish were captured using a 25ft long beach seine
- All fish received an adipose fin clipping
- Fish over 50mm received a 10mm PIT tag

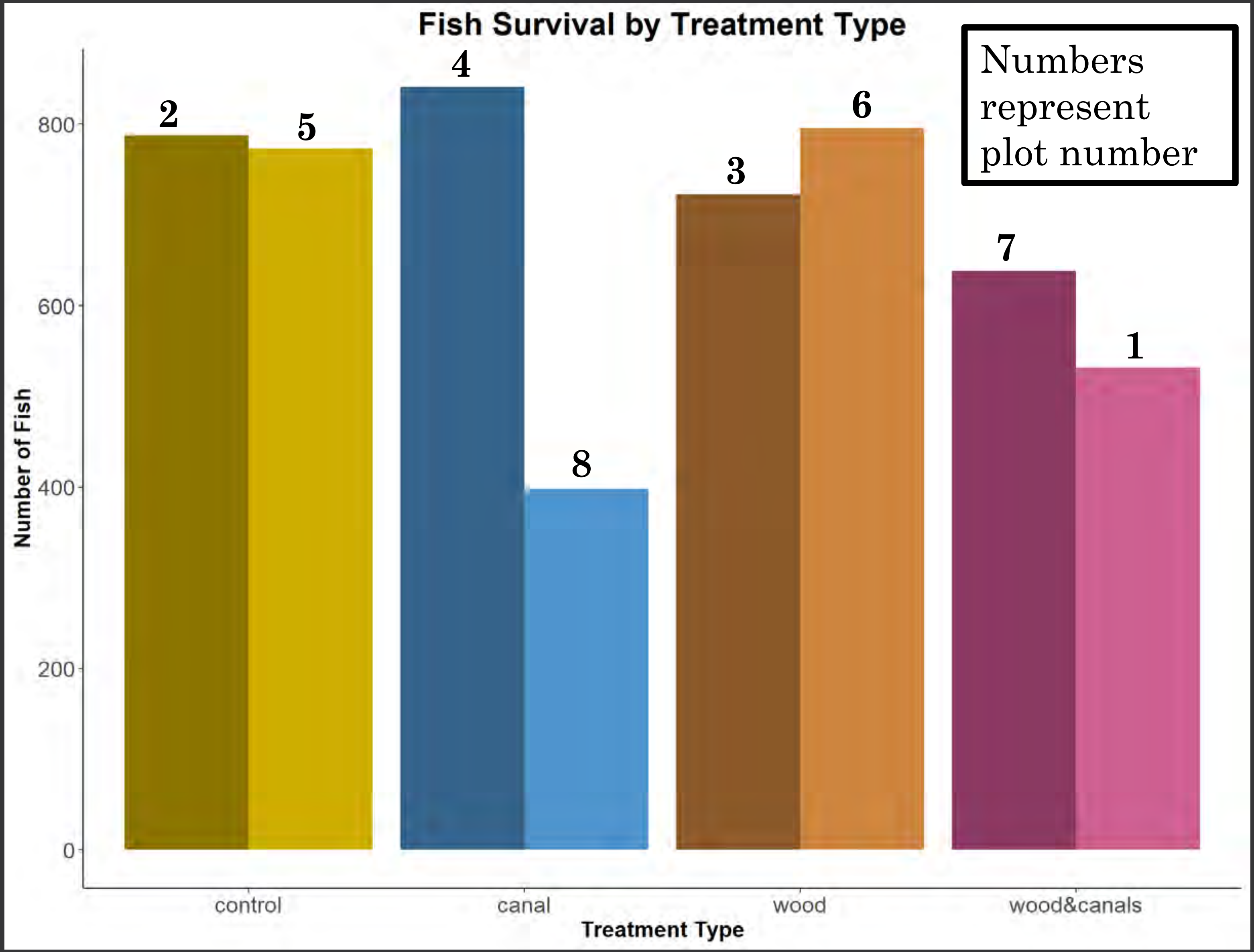


Planned Data Analysis:

Which field treatments promote in-field survival of juvenile salmon on agricultural floodplains?



Was there a difference in survival between East and West Side Fields?



In-field Habitat Treatments

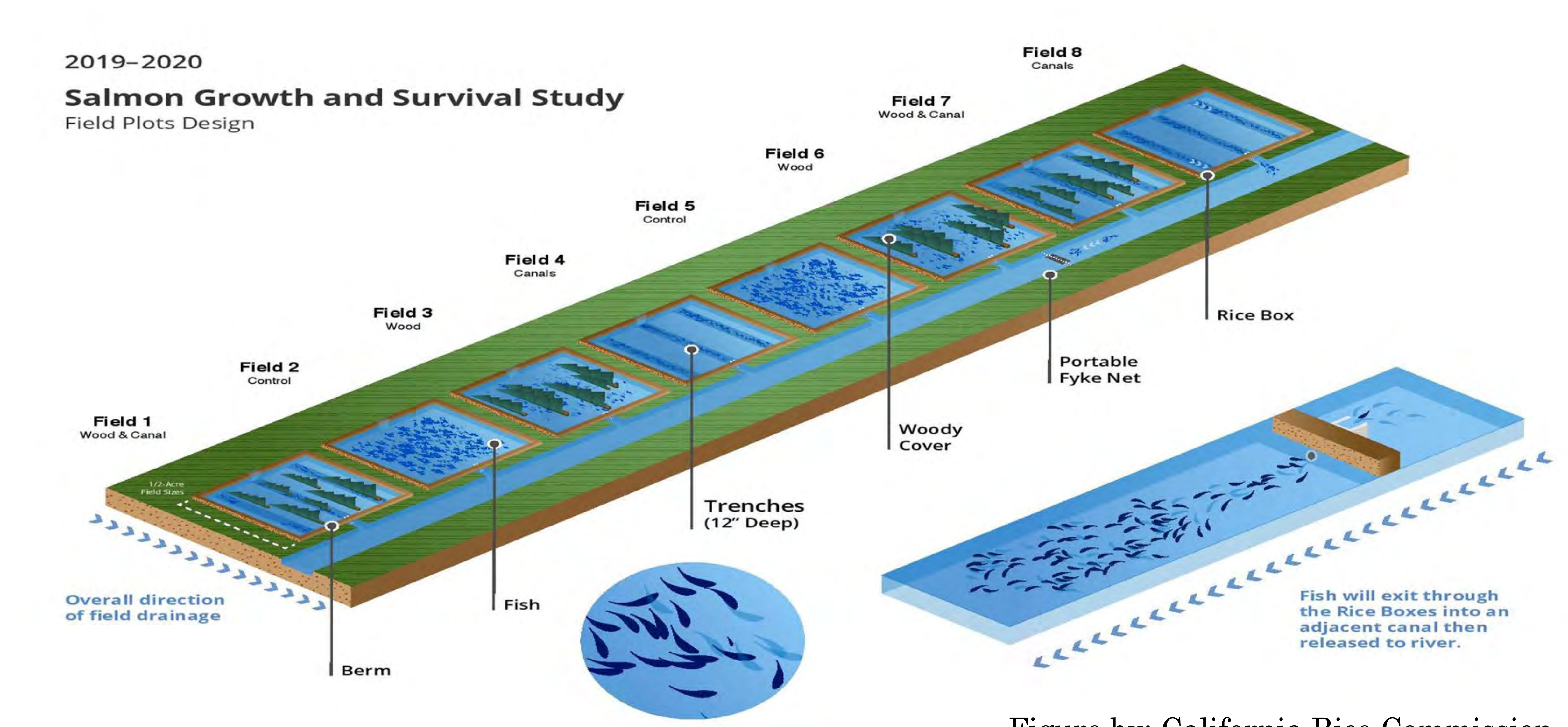
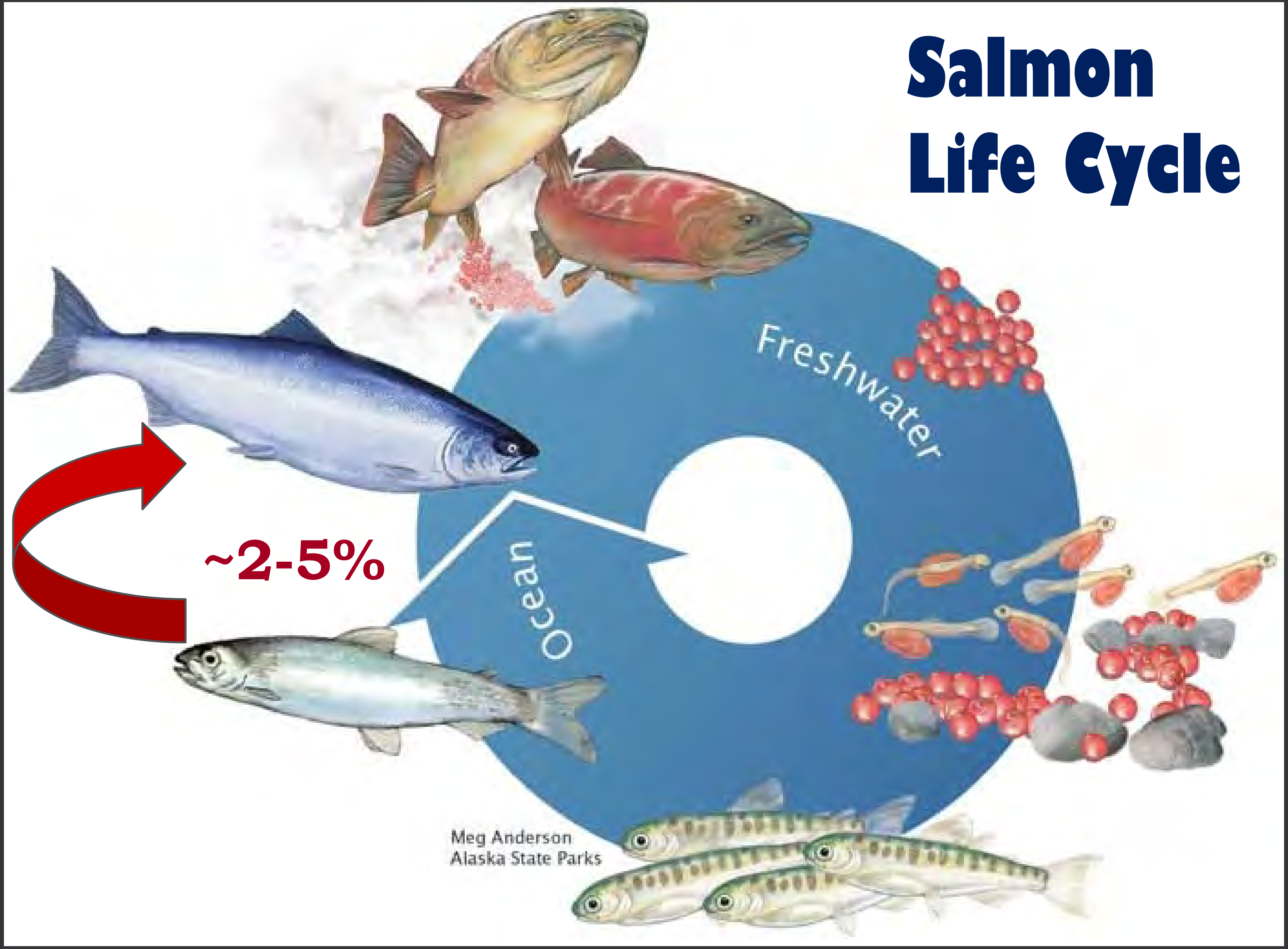


Figure by: California Rice Commission

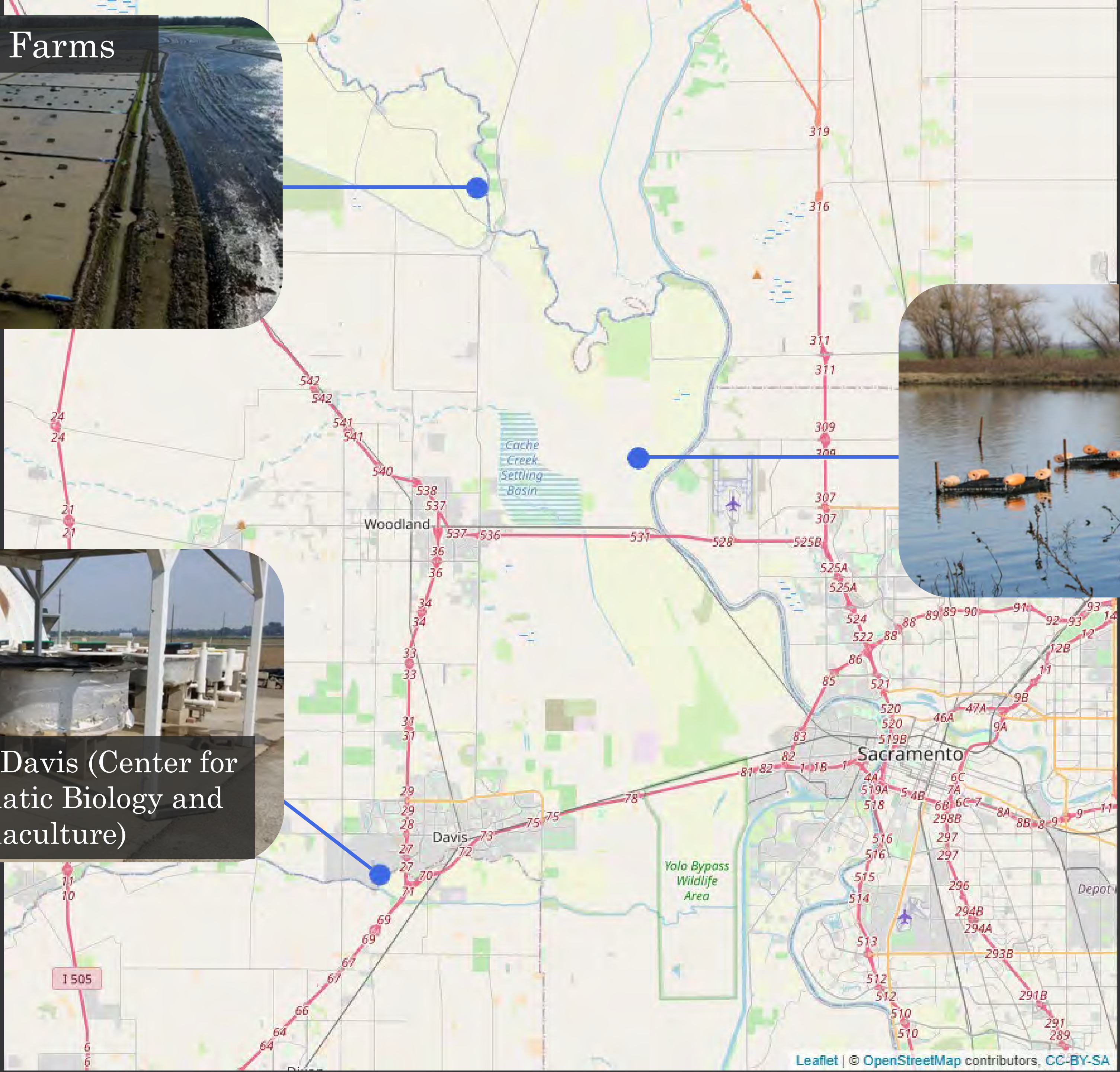
Question 2: What is the out-migration survival for juvenile salmon across different rearing groups?


Salmon
Life Cycle
Freshwater
Ocean
~2-5%
Meg Anderson
Alaska State Parks


River Garden Farms


Knaggs Ranch


UC Davis (Center for Aquatic Biology and Aquaculture)


Woodland
Cache Creek Settling Basin
Davis
Sacramento
Yolo Bypass Wildlife Area
Leaflet | © OpenStreetMap contributors, CC-BY-SA

Rearing Groups

Field Treatments

- Knaggs
- River Garden Farms

Control Treatments

- Control Group

Rearing Groups

Field Treatments

Knaggs

River Garden Farms

Rice/Lab*

Control Treatments

Control Group #1 (Coleman)

Control Group #2 (Nimbus)**

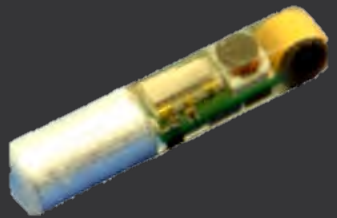
- *Rice fish brought back to UC Davis for further rearing.
- ** A second control group was created because there were not enough fish to have a comparable sample

Field-Setup

- River Garden Farms Density: 17 fish/cage
- Knaggs Ranch: 25 fish/cage
- Control groups reared at UC Davis

Using Acoustic Telemetry to Assess Survival

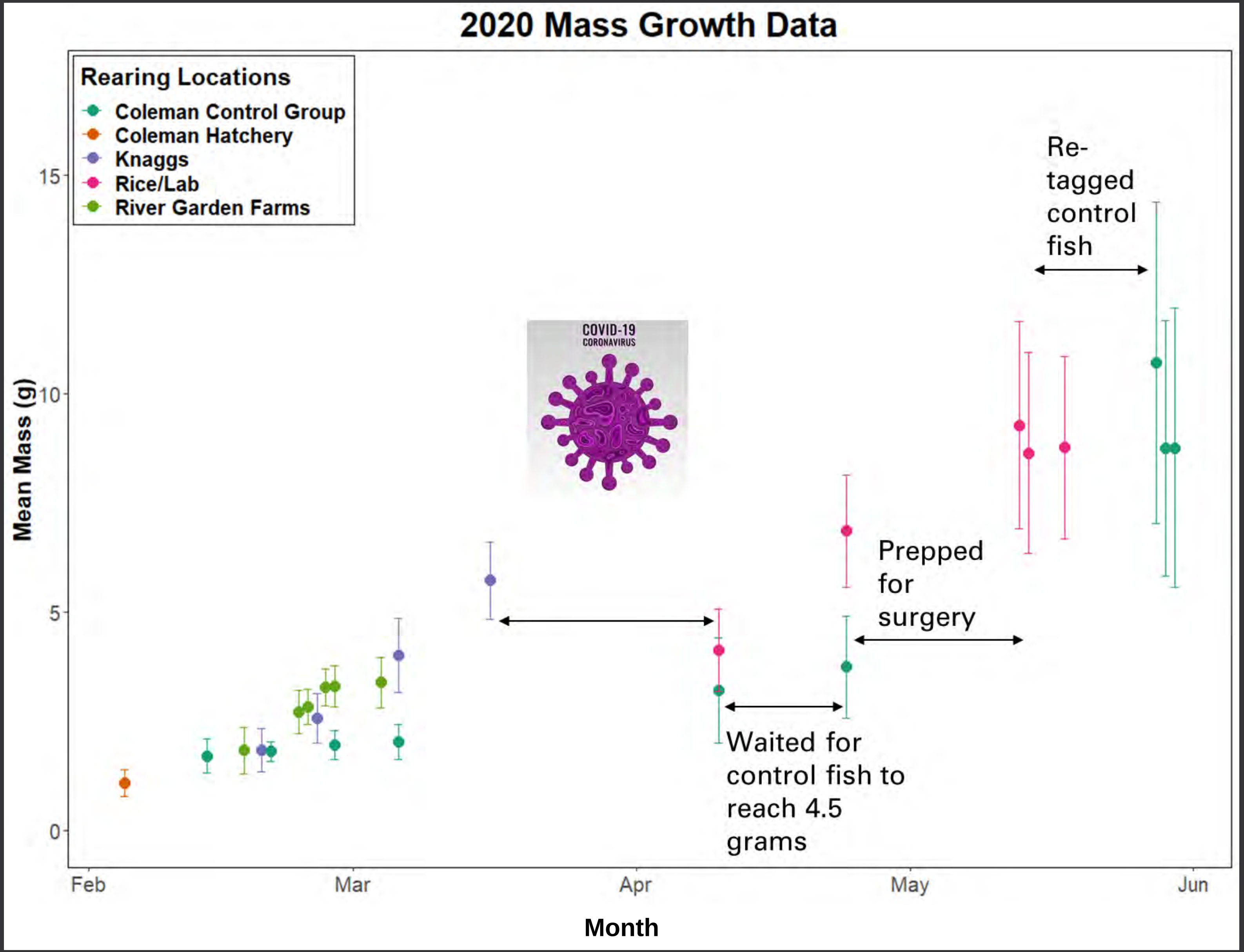
- Mark-recapture method that has high detection efficiency
- Not affected by salinity
- Stationary units and be deployed across large spatial areas



ATS SS400 Tag

Photo by Dr. Gabriel Singer

Fish Growth Data and Release



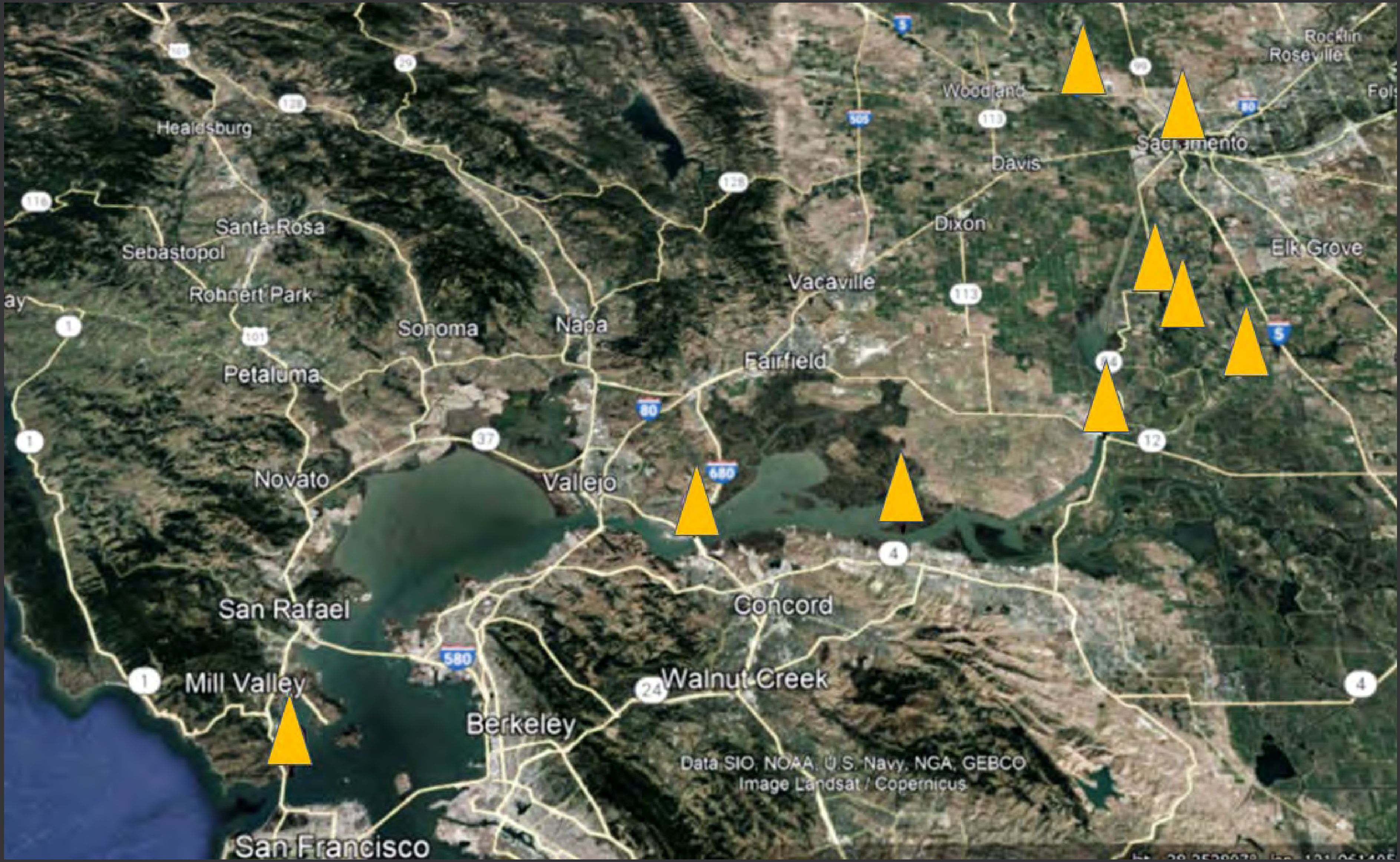
March Release:

Knaggs: 295
River Garden: 49

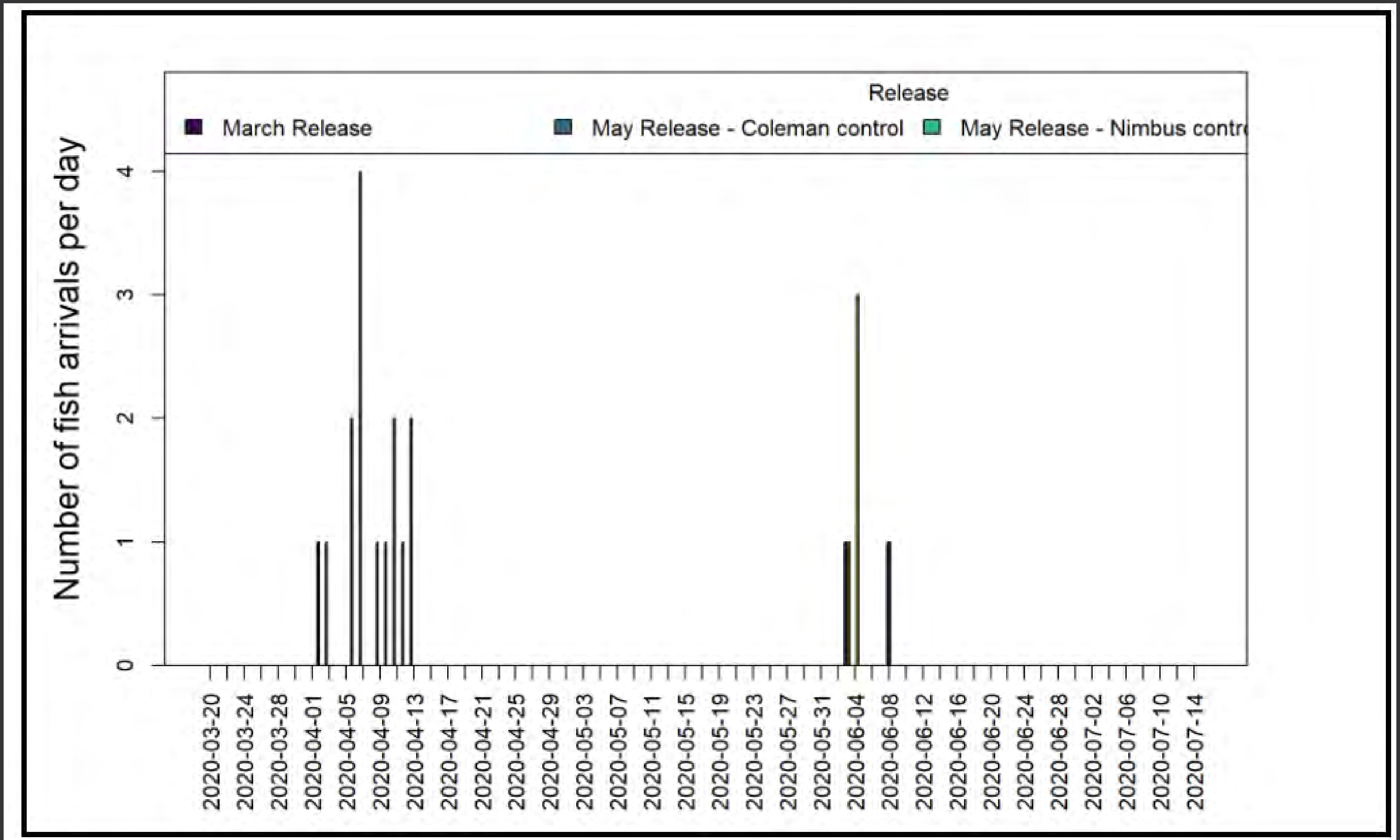
May Release:

Rice/Lab: 300
Control Group # 1: 109
Control Group # 2: 213

Acoustic Array Setup



Real Time Data



Detections at Benicia Bridge

Estimated survival

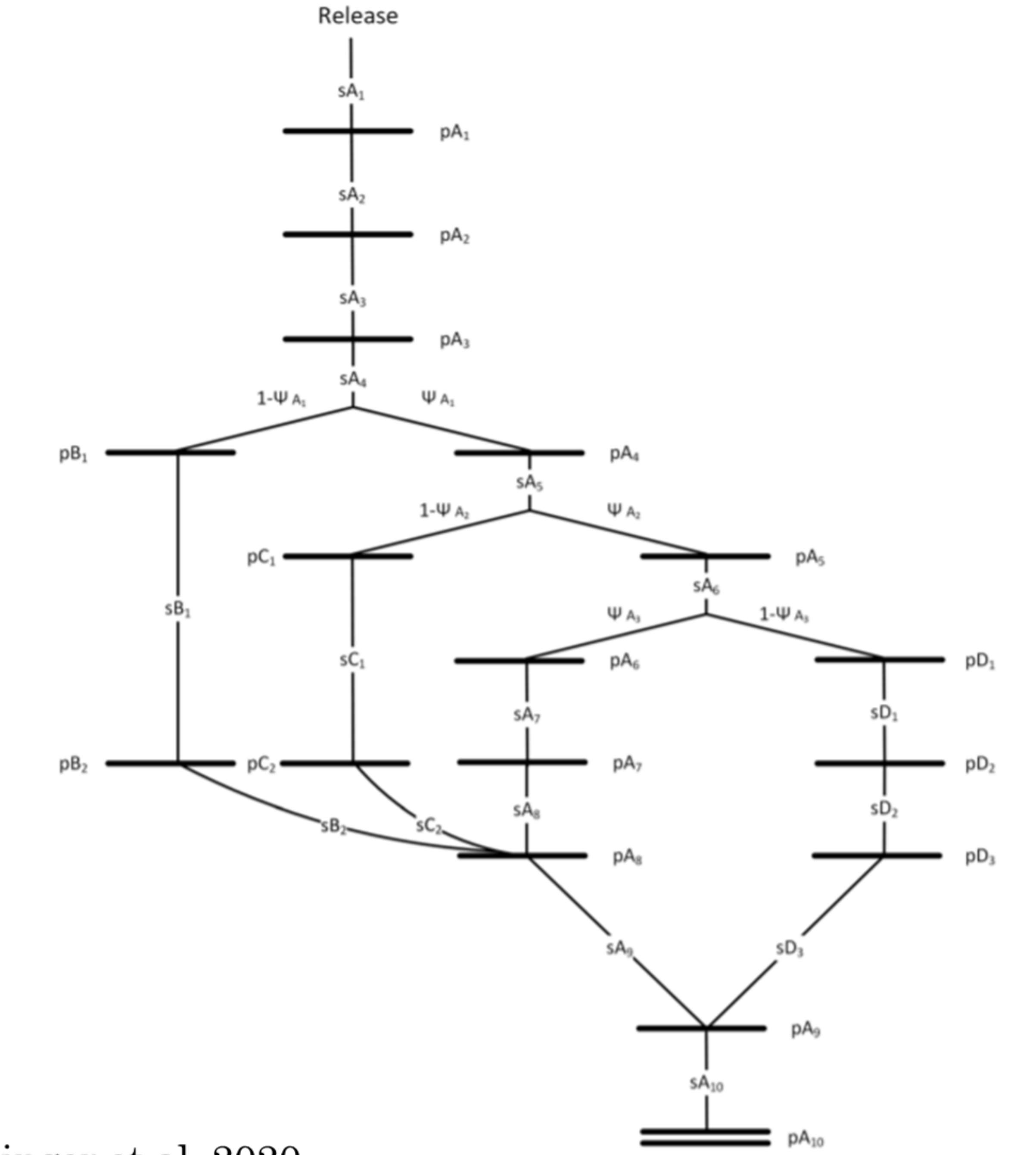
- March Release 4.4%
- Rice/Lab Fish: 1.4%
- Control Group 1 (Coleman): 2.1%
- Control Group 2
- (Nimbus): 0.5%

More info: https://calfishtrack.github.io/real-time/pageUCD_Rice_2020.html

Data Analy… ation survival ac… ps?

- Multi-state mark rec… analysis, an extensio… Cormack Jolly Seber… (Cormack 1964, Jolly 1…

…ecific survival …obability



Singer et al. 2020

R

…2)

Lessons Learned

Special Thanks

California Department of Fish and Wildlife
California Rice Commission
California Trout
Knaggs Ranch
National Oceanic Atmospheric Administration
Natural Resources Conservation Service
Oregon Department of Fish & Wildlife
River Garden Farms
The Nature Conservancy
UC Davis Center for Aquatic Biology & Aquaculture
UC Davis Center for Watershed Sciences
US Fish & Wildlife Service
Yolo Basin Foundation

To the dedicated field technicians who made this project possible:

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Wilson Xiong
Amanda Agosta
Heather Bell
Adrian Loera
Hailey Gleason
Emily Jacinto
Alexander Skinner

HOW DO BEAVER DAM ANALOGUES (BDAS) CHANGE STREAM FOOD WEBS: WHAT STABLE ISOTOPES CAN TEACH US ABOUT FOOD WEBS IN BDAS

Brandi Goss – Master's Student, UC Davis

Lanman et al. (2013), CFG Report

"The Shasta beaver, once relatively common in many of the streams of northern California, now is found only in scattered places within its former range. Most of the present colonies are remnants of what was once a flourishing native population" (Tappe, 1942).

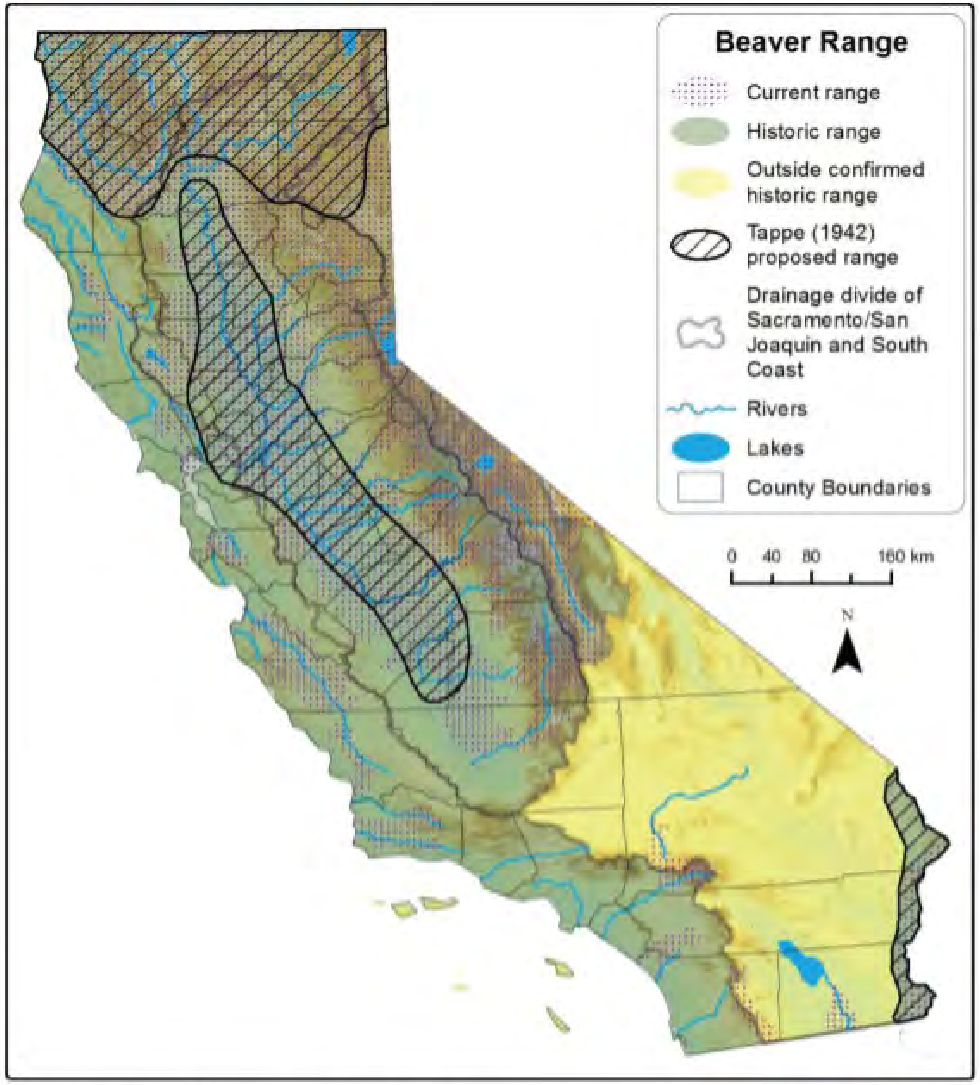


FIGURE 4.—Updated historical range map and current distribution of Castor *canadensis* in California. The current distribution was derived by combining ranges from CDFG (2005) and Asarian (2013) and conversion to 5th-field hydrologic units (watersheds) — except along the Mexican border where original CDFG polygons were retained — and removing Noyo River population in Mendocino County shown in

Beaver Benefits:

- More variety in hydrology 
- Pooling habitat can stabilize water temperature 
- Increased carbon storage
- Increased complexity & impacts on regional ecology 
- Improve ecosystem services
- Potentially particularly good for restoring impacted rivers

SONCC (Southern Oregon/Northern California Coast Coho Salmon

State and Federally Threatened

Scott River tributaries like Sugar Creek a remaining stronghold for these fish

Pooling habitat = higher smolt production (Roni et al. 2006 and Bouwes et al. 2016)

Beaver historically influenced the Scott Valley ecosystem

Beaver populations significantly reduced by fur trapping – and still haven’t recovered

Beaver have significant benefits for stream organisms – including Coho salmon

Re-introductions can be hard, and are not always successful

Beaver Dam Analogues

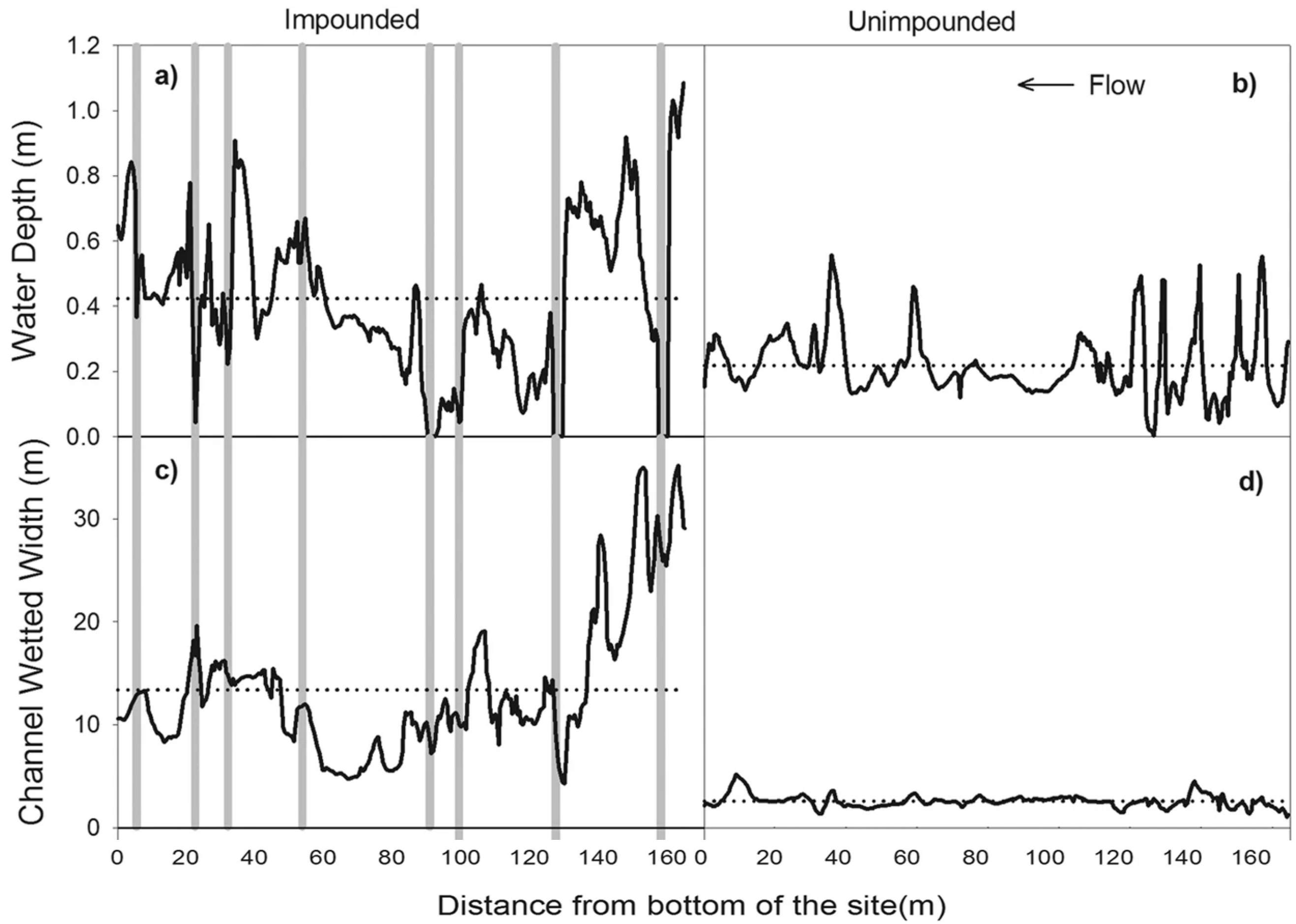
Traditional Stream Habitat vs. BDA

Beaver (and BDA?) Benefits:

- More variety in hydrology
- Pooling habitat can stabilize water temperature
- Increased complexity & impacts on regional ecology

Beaver (and BDA?) Benefits:

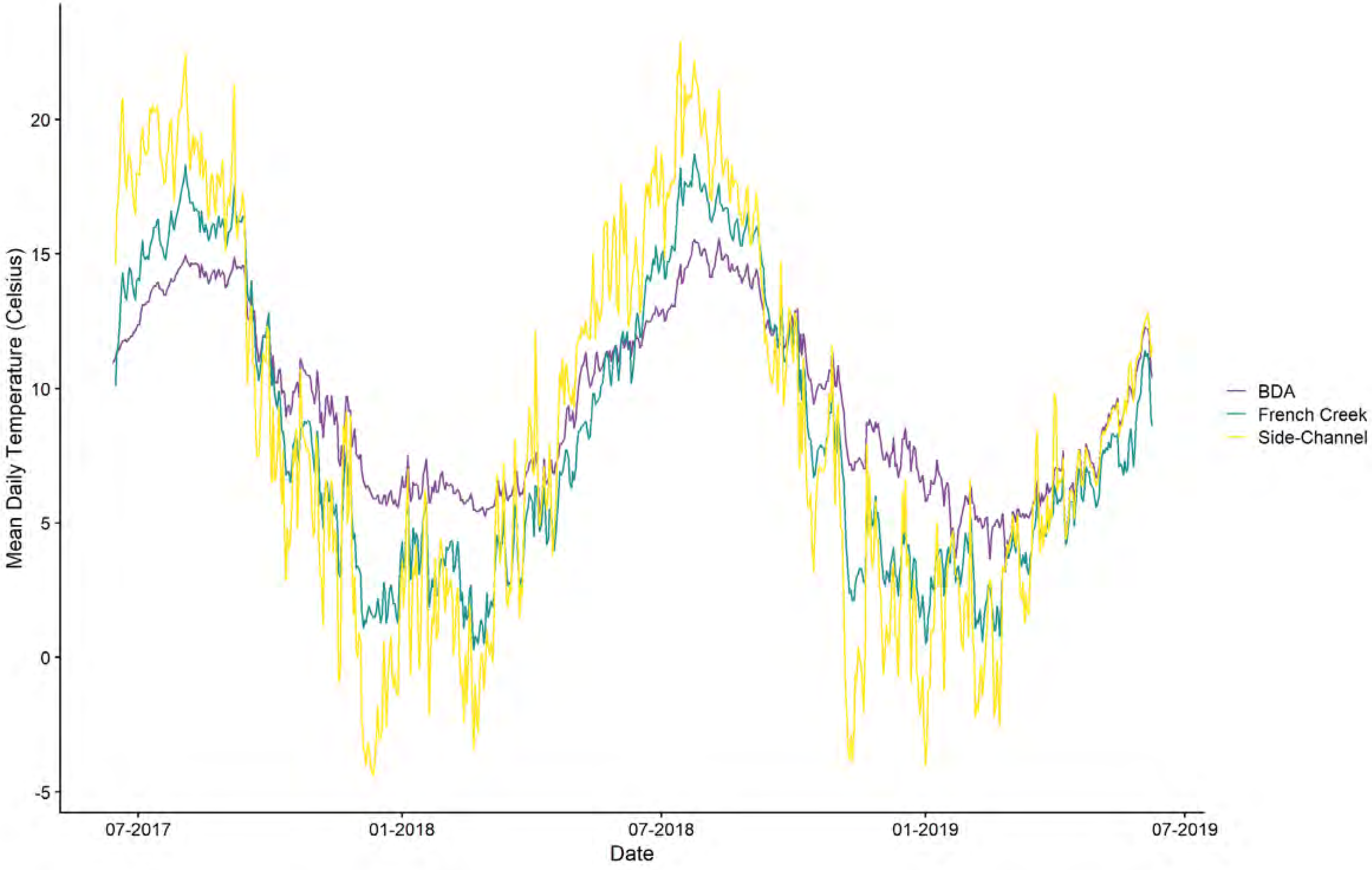
- More variety in hydrology



Bouwes et al. (2016)

Beaver (and BDA?) Benefits:

- Pooling habitat can stabilize water temperature



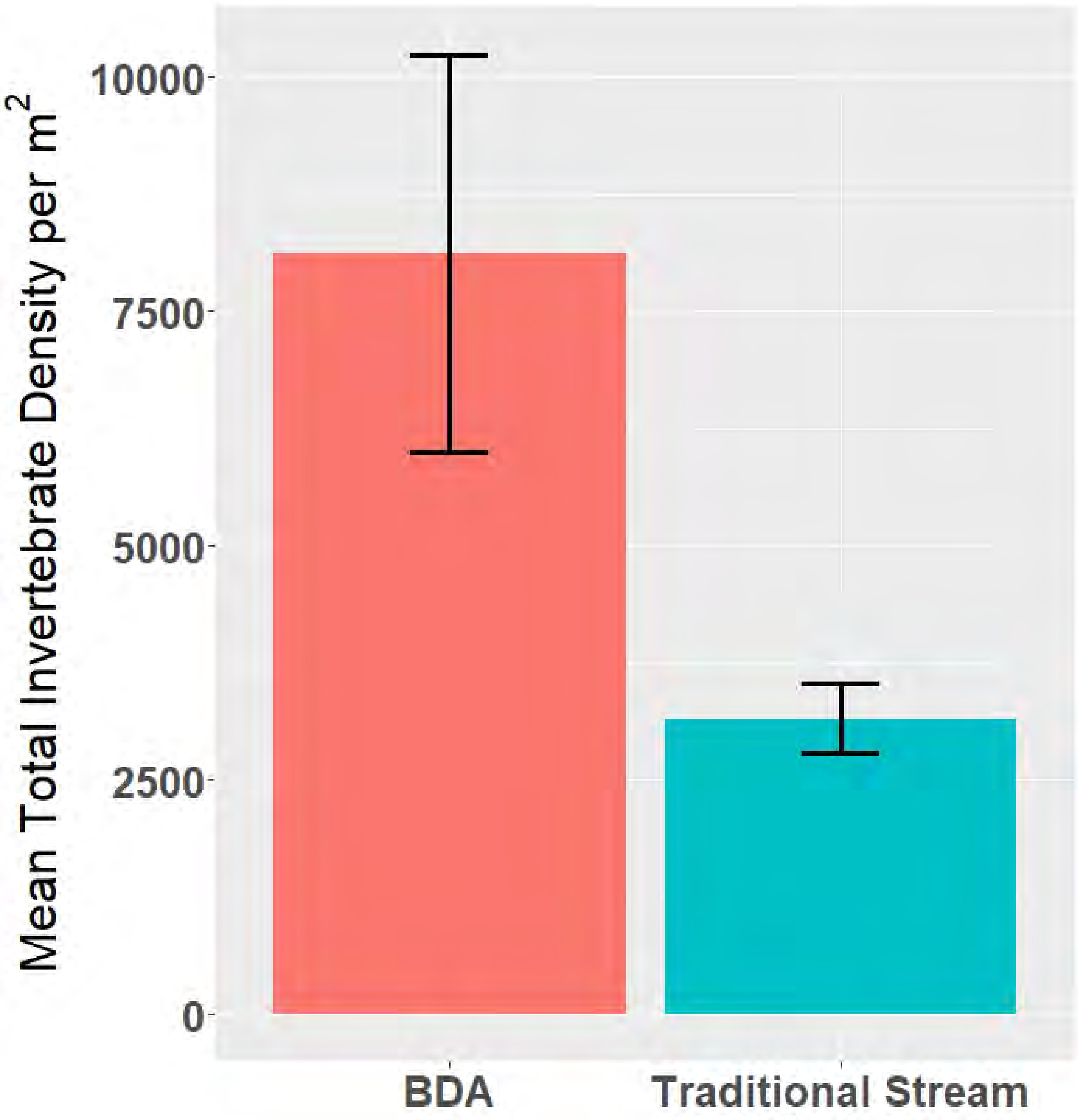
Corline et al. (2022)

Beaver (and BDA?) Benefits:

- Increased complexity & impacts on regional ecology 

Key Question: Food Webs

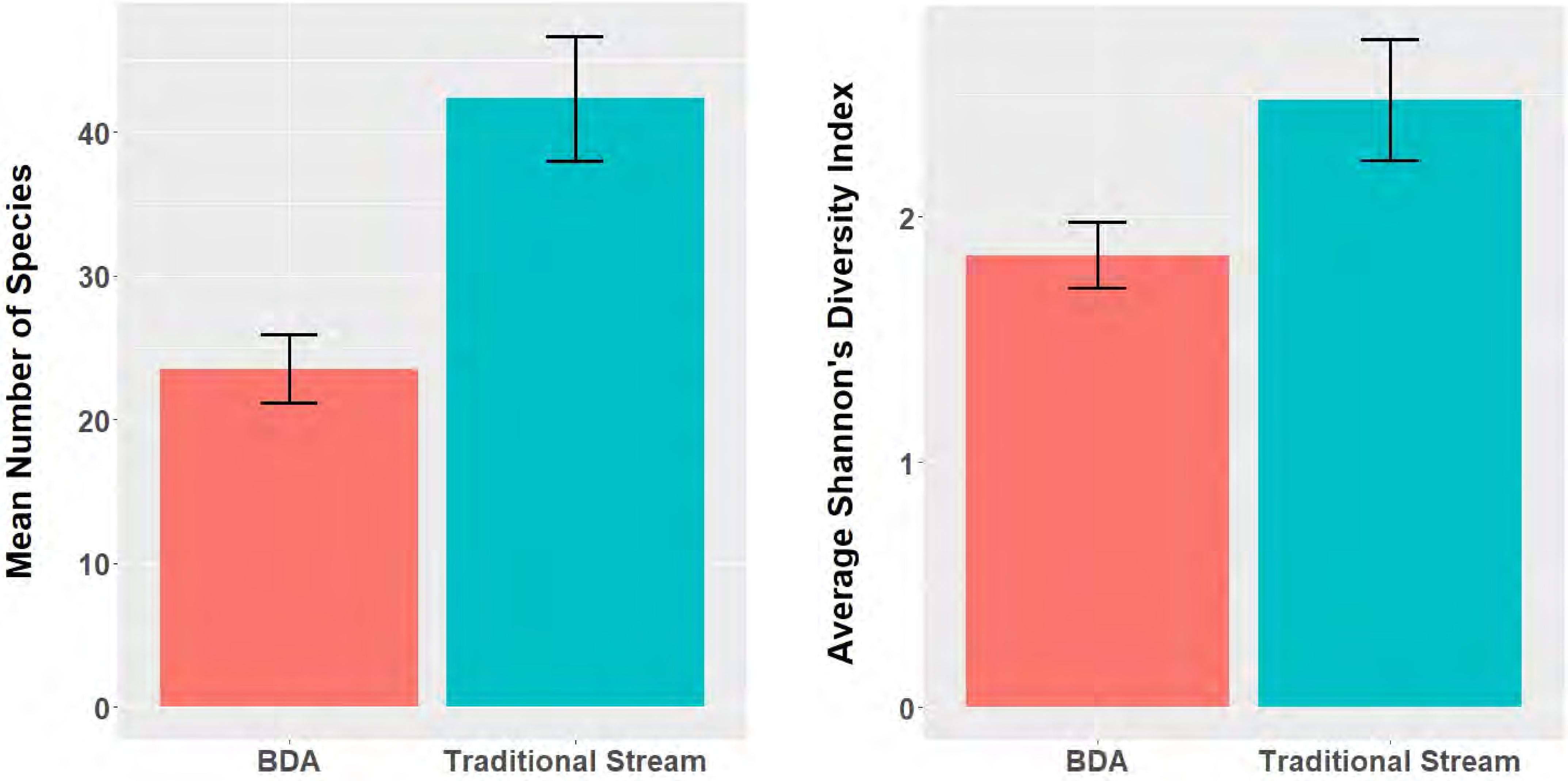
- Why are food webs important for Coho?
  - Increased food availability has been found to improve growth and survival of juvenile Coho (Lusardi et al. 2020)
  - Disturbance & Continuity!
- Do we have any evidence that BDAs impact food webs already?
  - Regional macroinvertebrate diversity increases with BDAs (Corline et al. 2022)
  - Macroinvertebrate density higher in BDAs (Corline et al. 2022)
  - My samples indicate this as well…

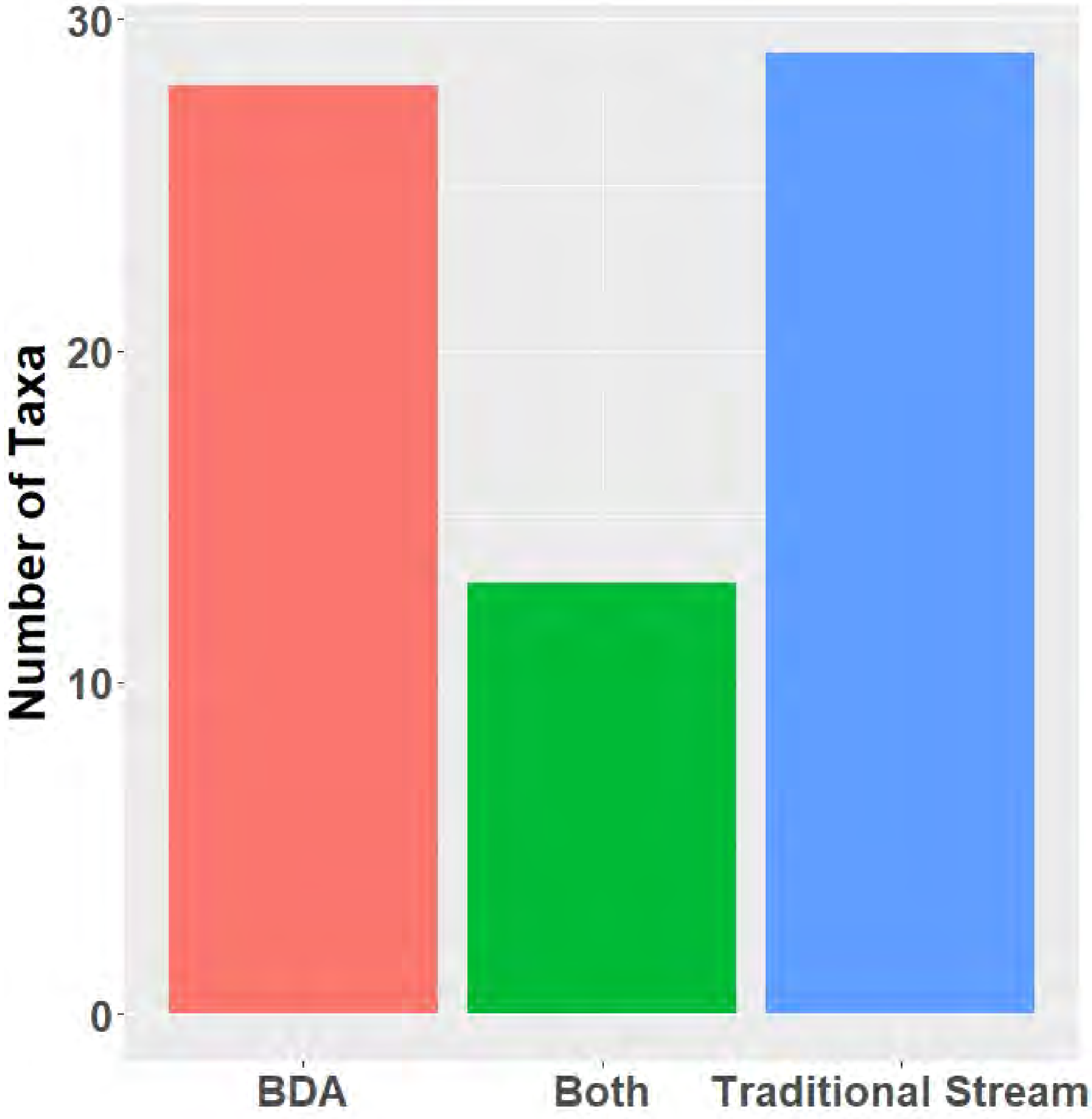


Higher macroinvertebrate density in BDAs

DENSITY BY SITE

SPECIES RICHNESS & SHANNON'S DIVERSITY





NUMBER UNIQUE TAXA

Many taxa unique to each habitat, and few that are found in both habitats.

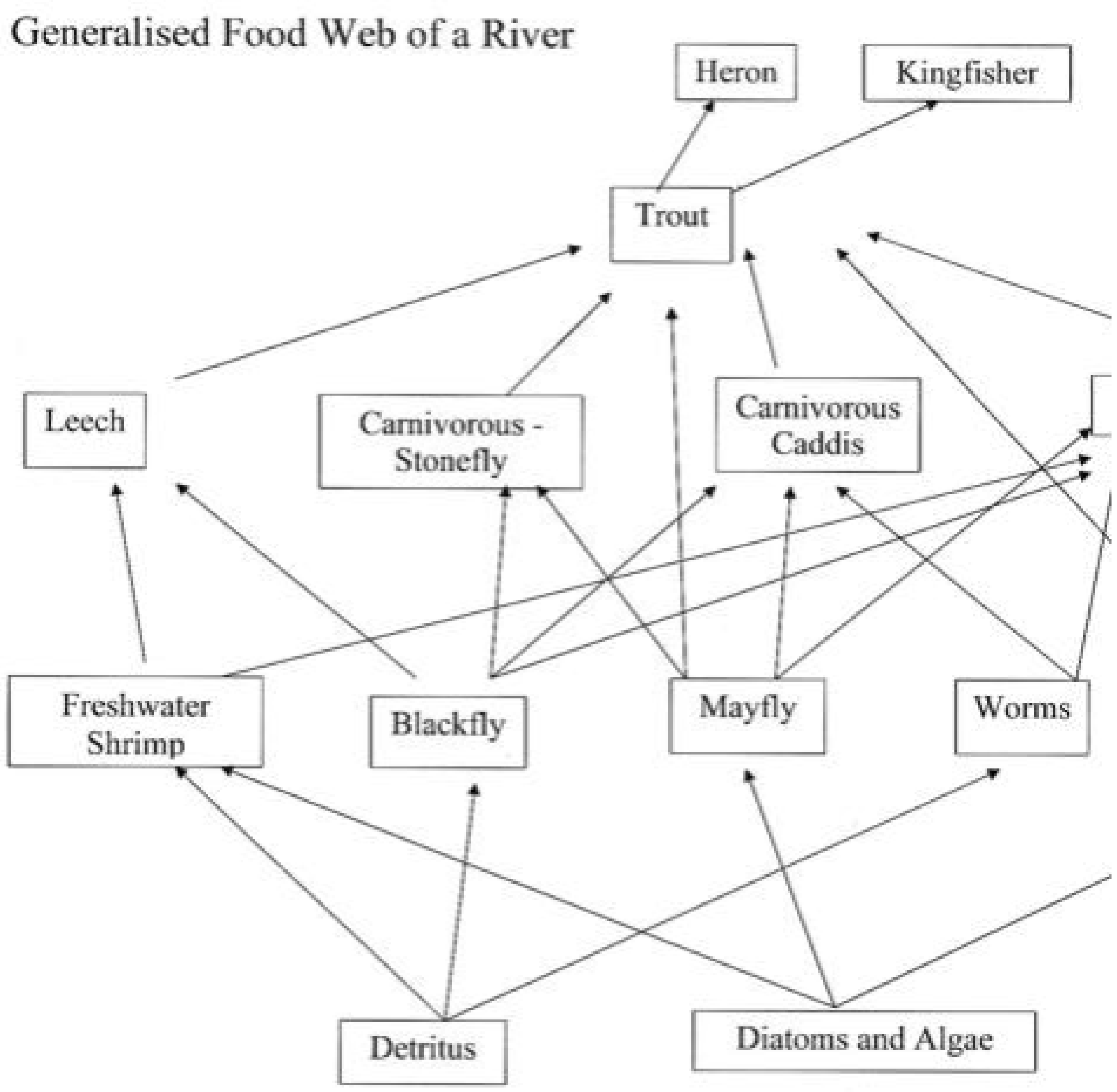
What Are Stable Isotopes?

- Naturally occurring and derived from tissue of organism
- Commonly used to provide an understanding of trophic or feeding interactions within an ecosystem

- Carbon signature = ratio of the heavy to light forms of an element (isotopes)
    - Different types of plants treat 12C and 13C differently, so this signature helps us understand basal resource use
- Nitrogen signature = ratio of heavy to light isotopes
    - Increases as we move up the food web, so this signature helps us understand trophic position and consumer feeding patterns

Why Use Stable Isotopes?

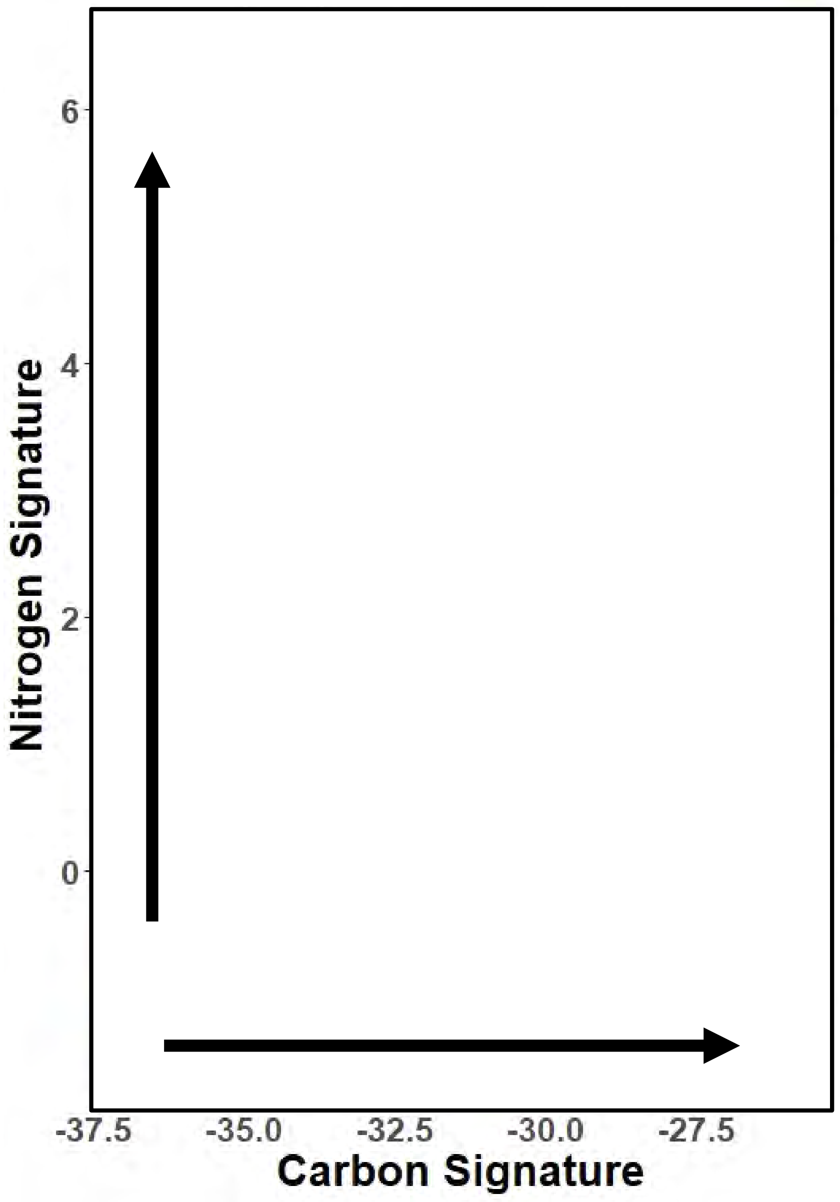
- Accuracy
- Primary Producers to Coho
- Time integrated information
- Little experimental design or manipulation is required and relatively inexpensive



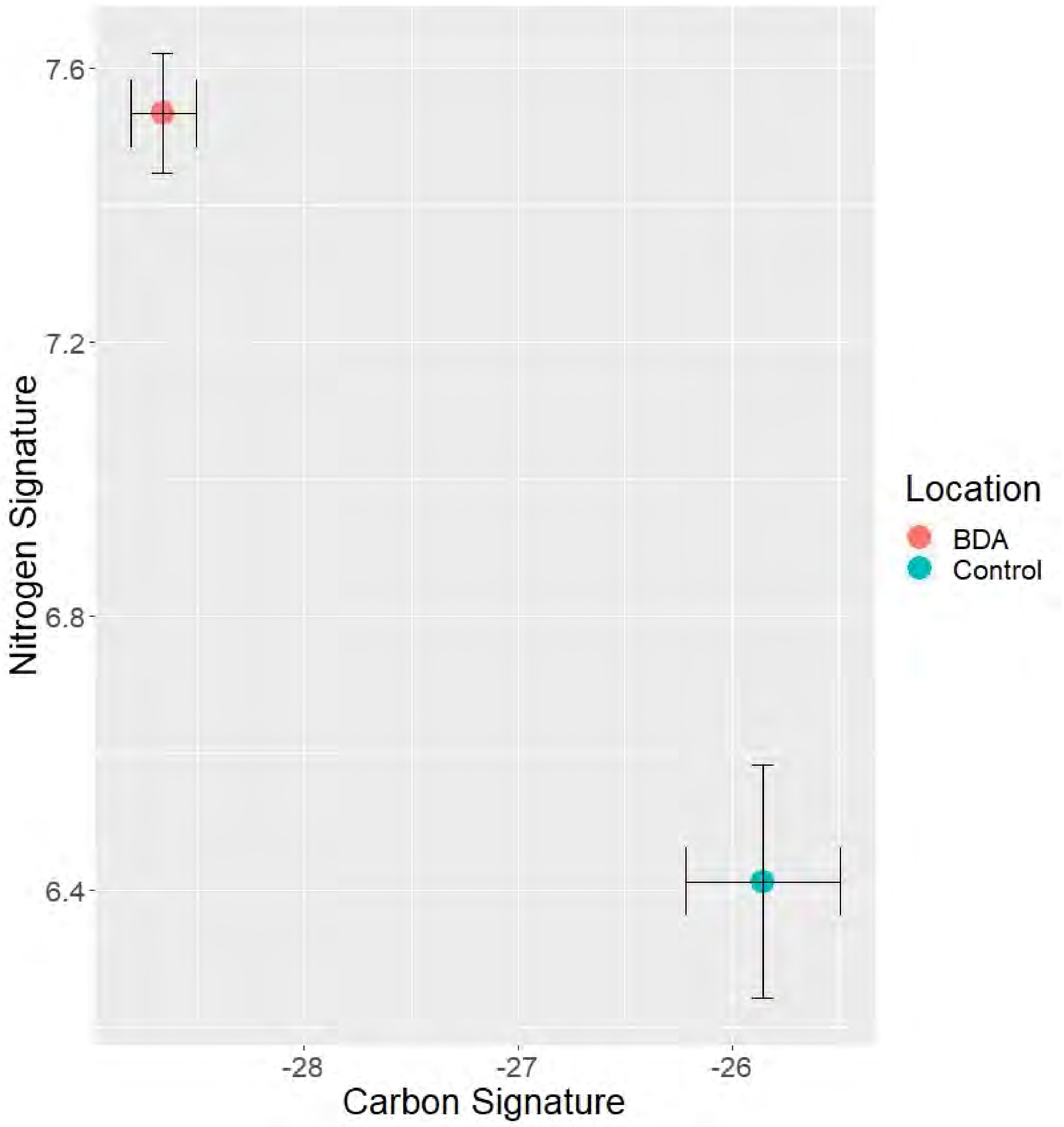


Isotope Samples Collected

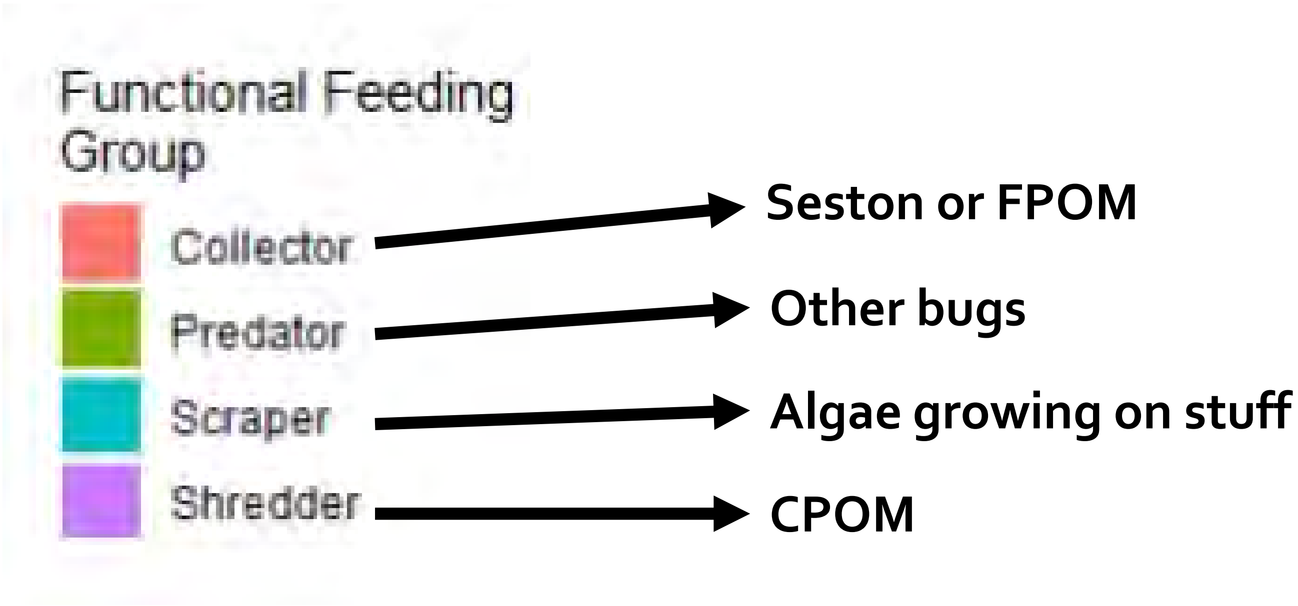
- Coarse Particulate Organic Matter (CPOM)
- Fine Particulate Organic Matter (FPOM)
- Primary Producers (moss, stringy algae, rooted plants)
- Aquatic Insects!
- Coho Fin Clips

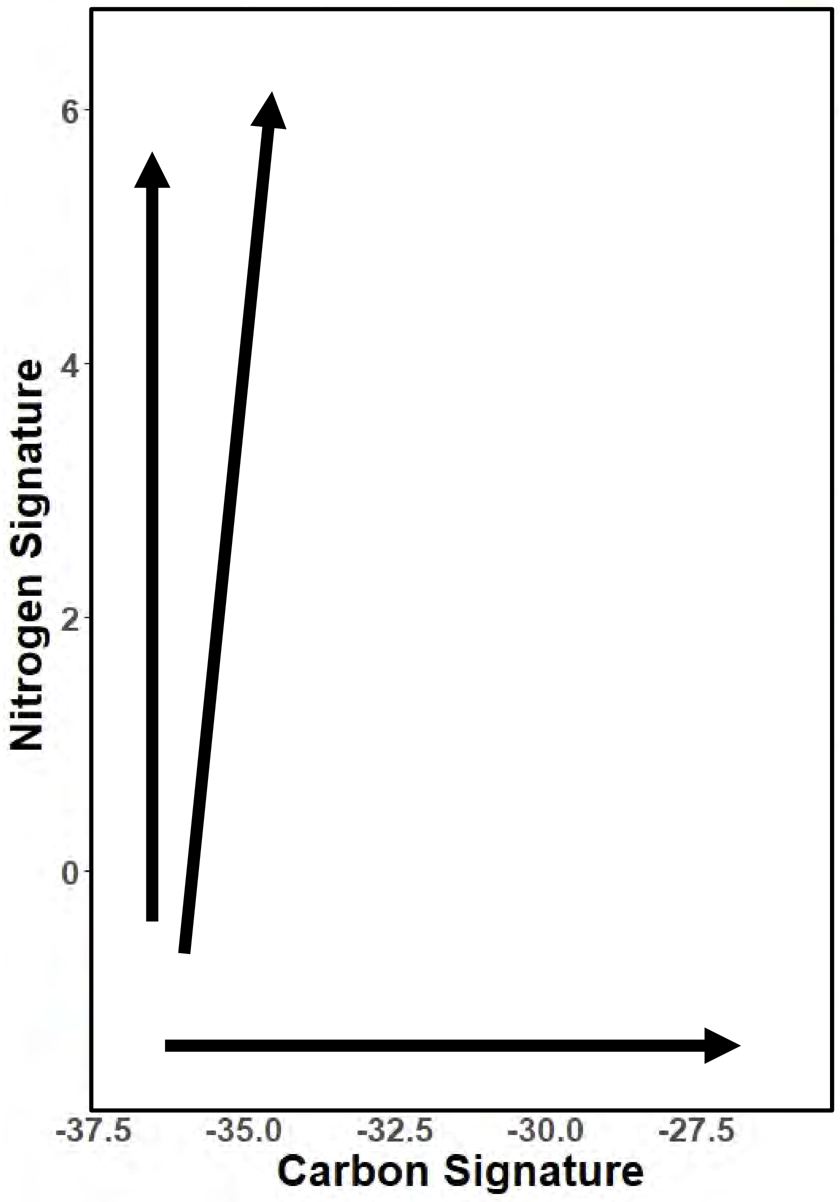

6
4
2
0
Nitrogen Signature
-37.5
-35.0
-32.5
-30.0
-27.5
Carbon Signature

THE ISOTOPES – FIN CLIPS

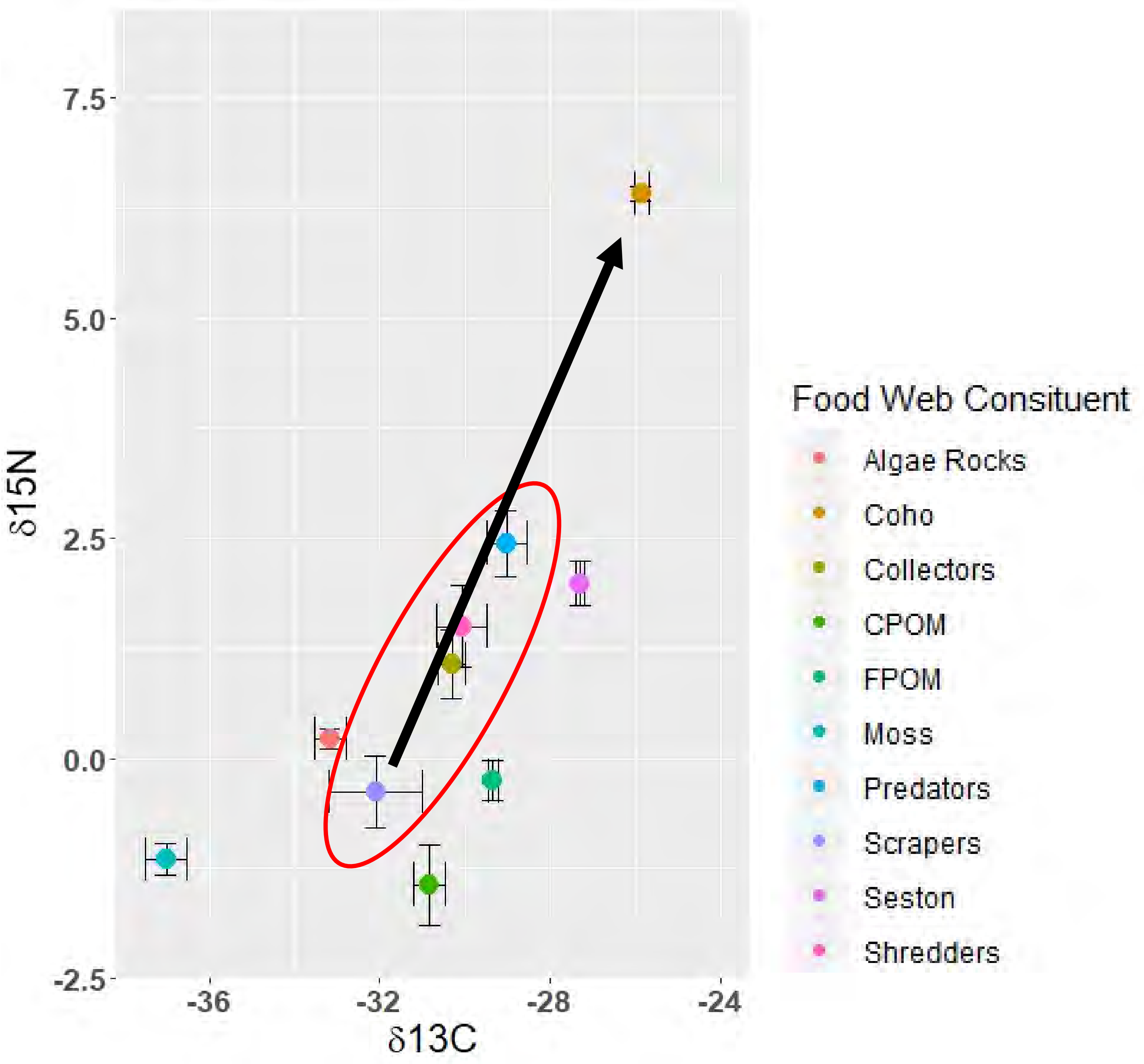


A Functional Feeding Group Approach

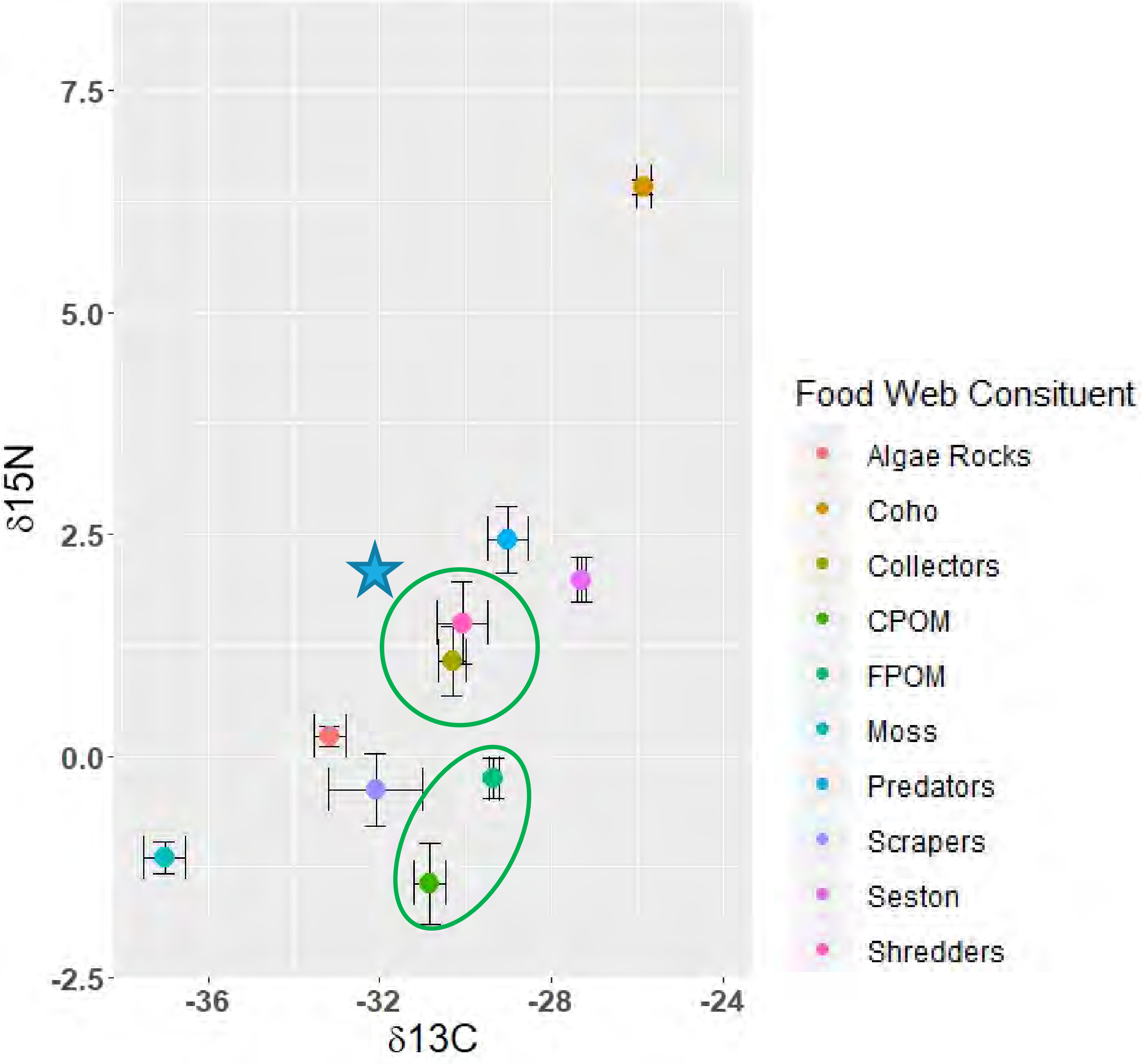



Nitrogen Signature
6
4
2
0
-37.5
-35.0
-32.5
-30.0
-27.5
Carbon Signature

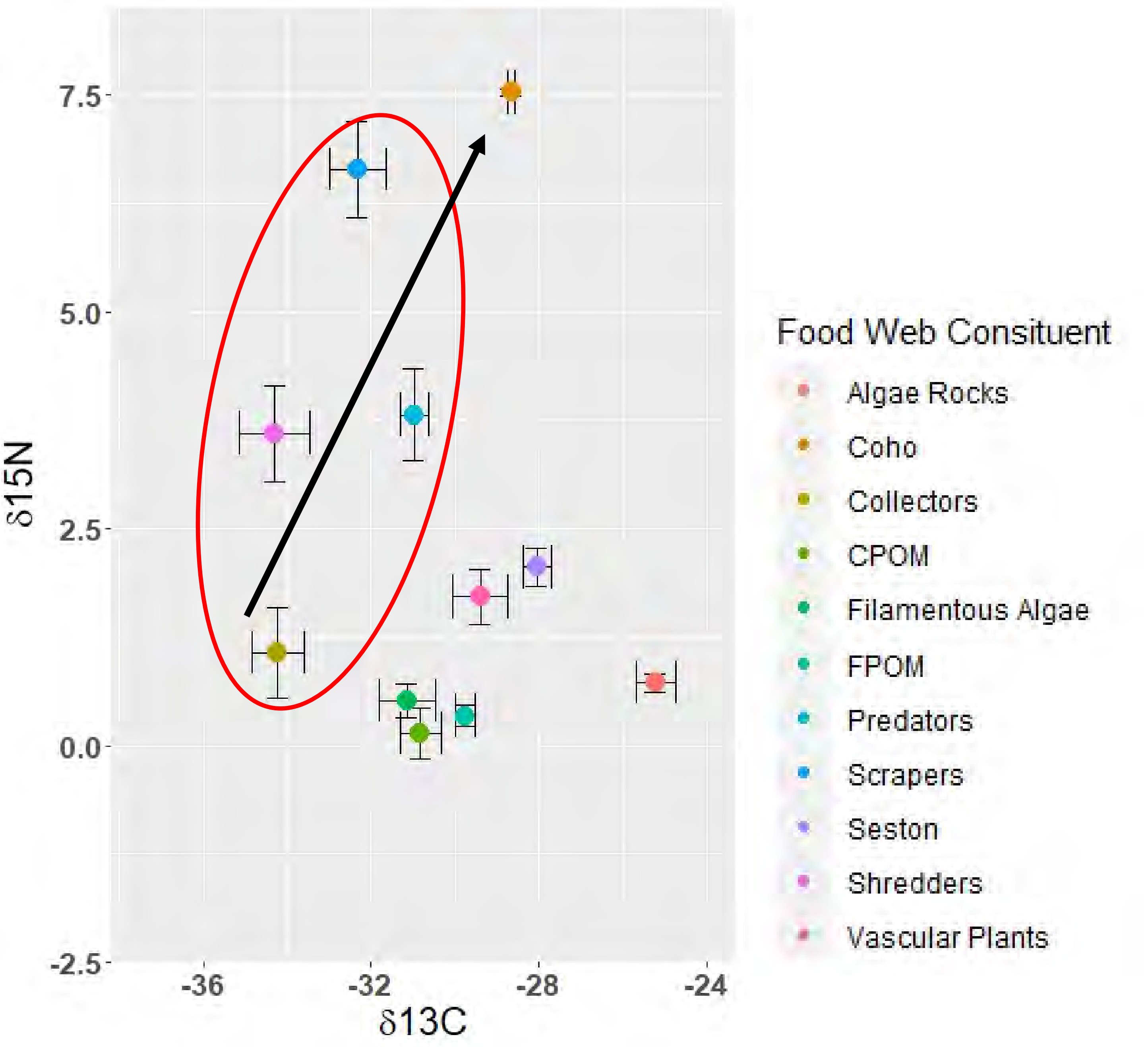
The Isotopes - Traditional Stream Habitat



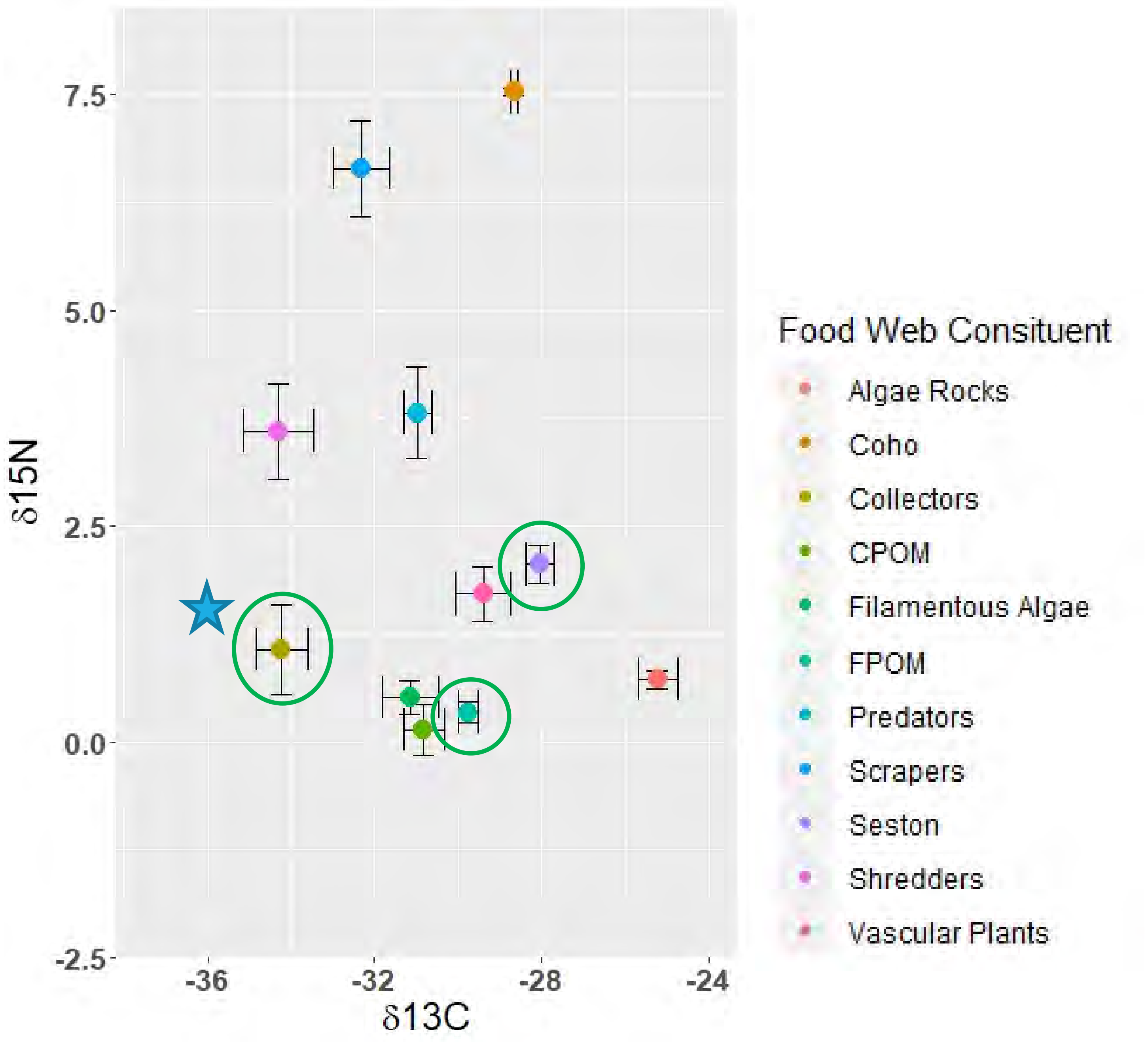
The Isotopes - Traditional Stream Habitat



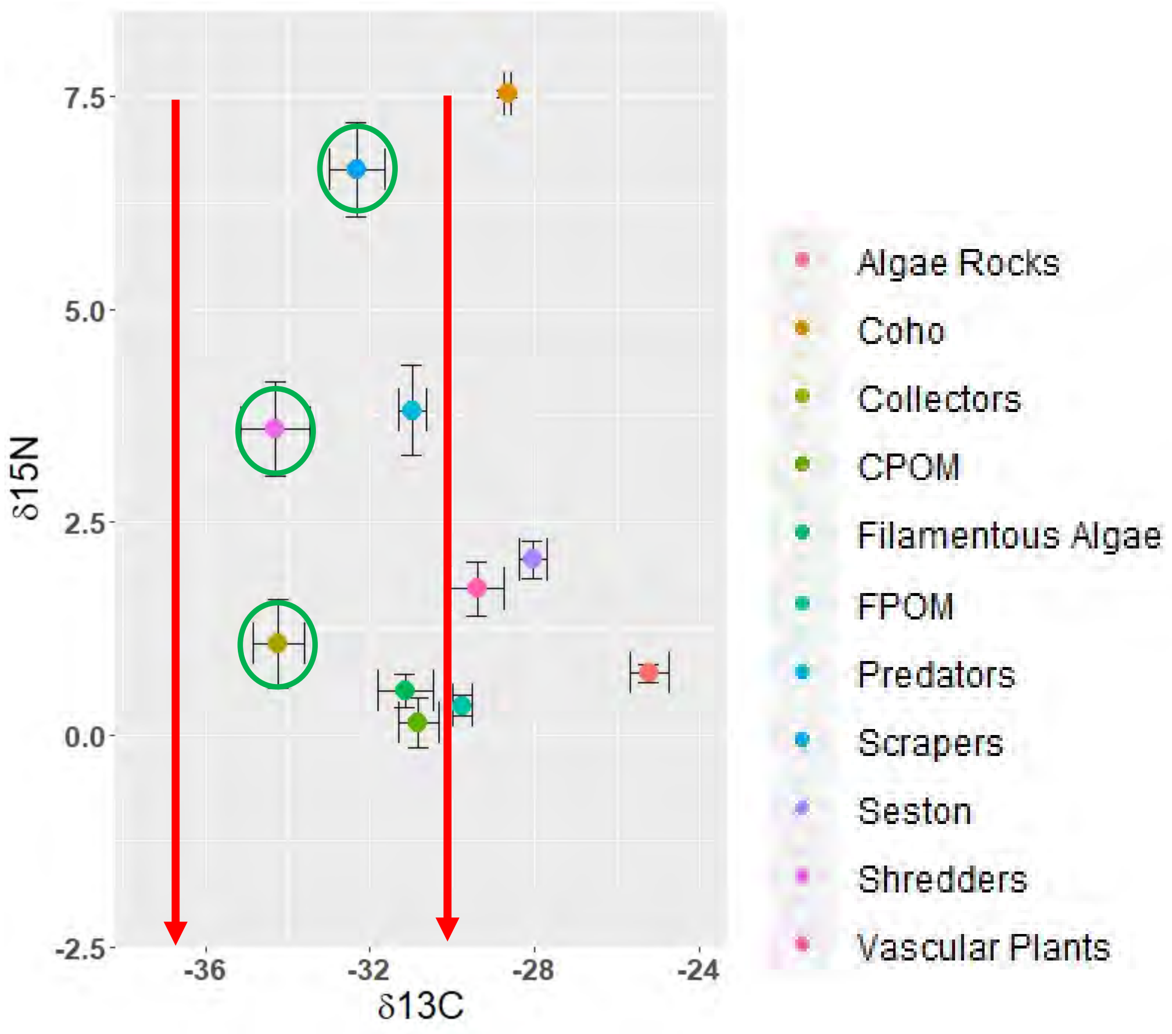
The Isotopes - BDA

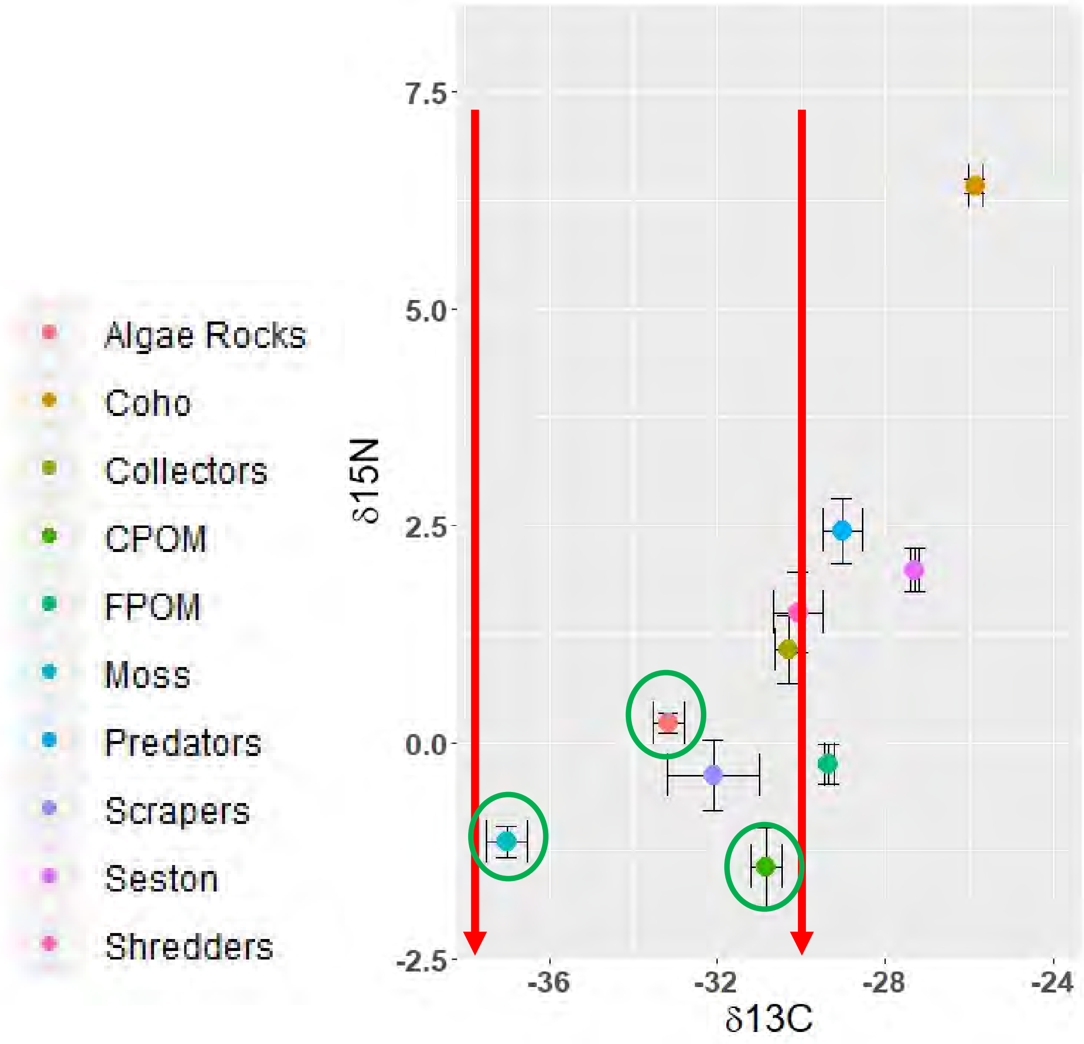


The Isotopes - BDA



The Isotopes – Putting It All Together





Conclusions

- BDAs are a rich source of food and add to the regional bug diversity of streams where they are found
- Fish DO have different isotopic signatures, but why?
    - Increased nitrogen cycling in BDAs?
    - BDA productivity + subsidies from upstream?

Next Steps

- Begin building a model using MixSIAR to reconstruct Coho trophic pathways by estimating diet contributions using our 15N and 13C isotope data
    - Incorporate a subsidy element with support from the framework developed by Dr. Ethan Baruch et al. (2021)?
- Samples collected summer 2021 – comparison of feeding pathways with a much drier year

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- Dr. Robert A. Lusardi, Advisor, UC Davis
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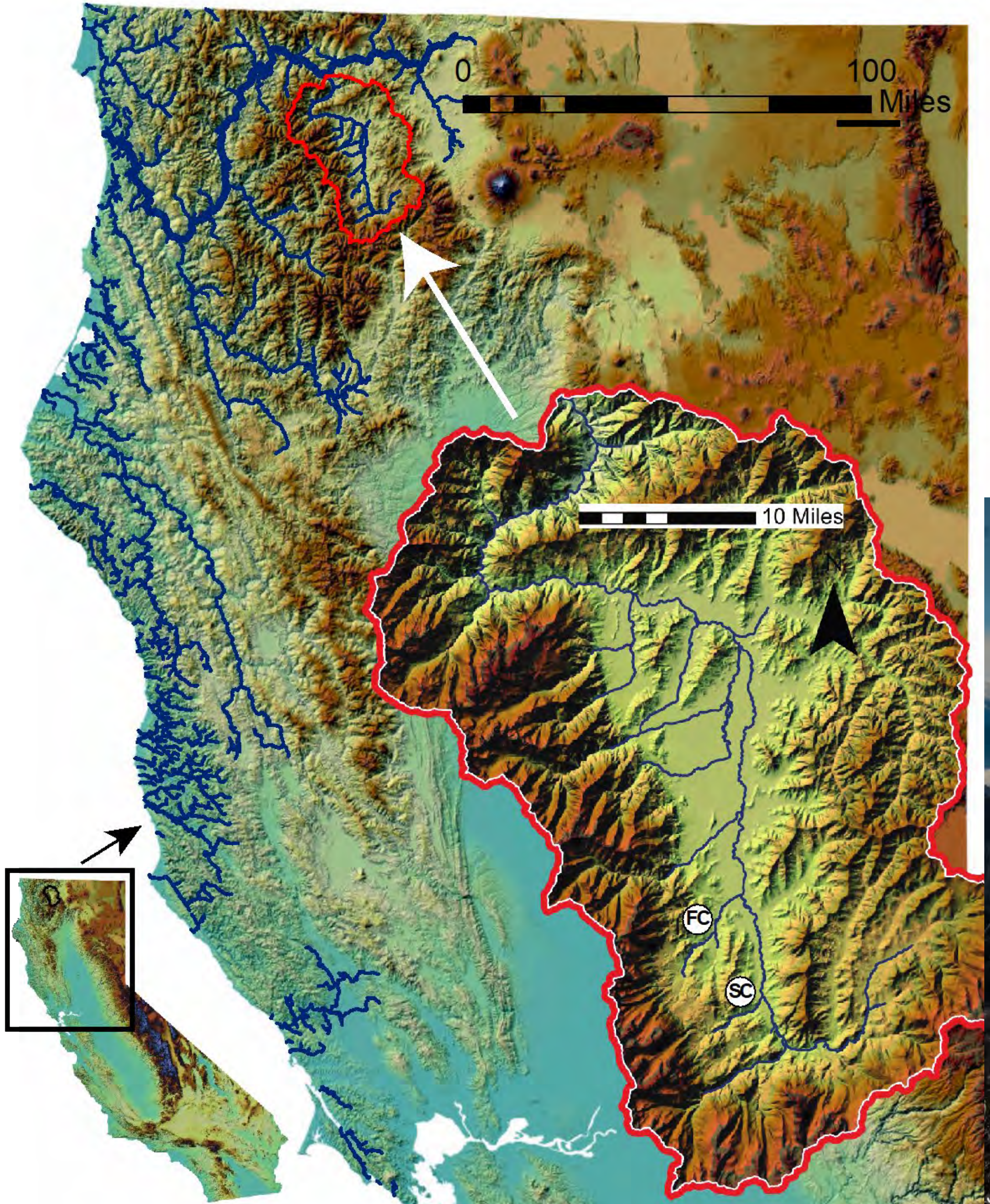
- Madeline Frey, Past Freshwater Ecology Lab Member
- Erich Yokel, Scott River Watershed Council
- Scott River Watershed Council


UCDAVIS
UNIVERSITY OF CALIFORNIA

SCOTT RIVER
WATERSHED COUNCIL

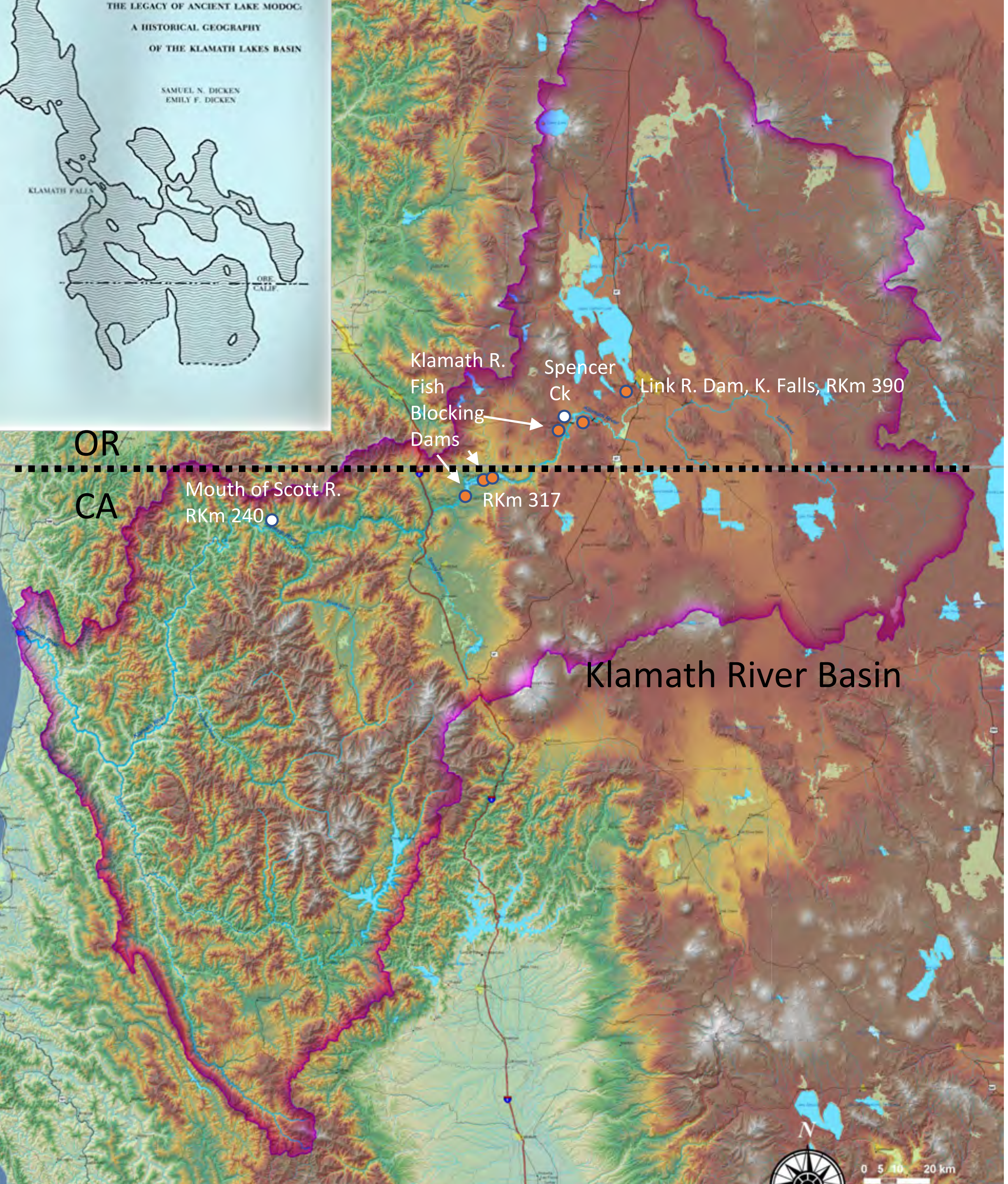




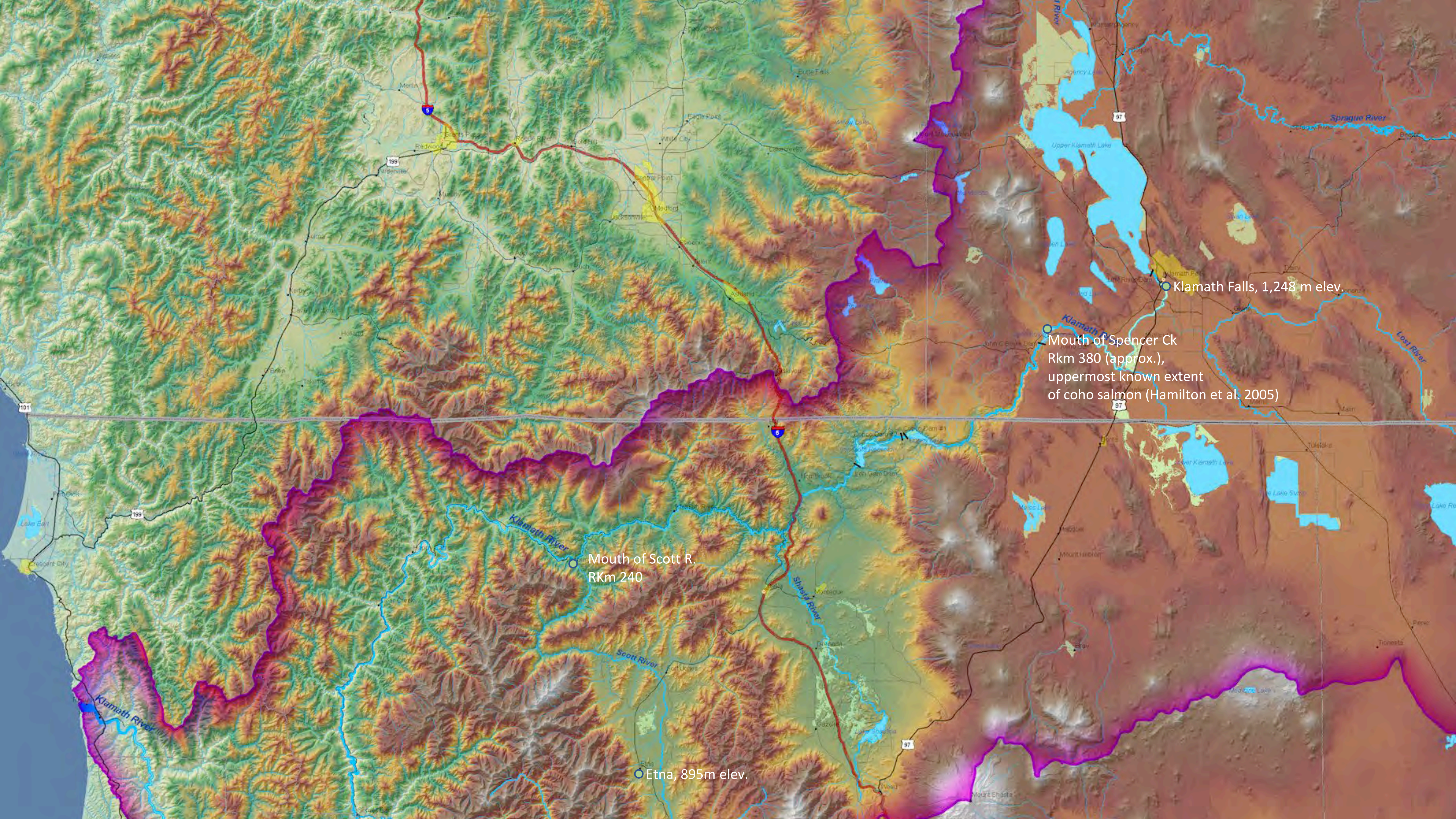
Past, Present and Future Coho Habitat Restoration in the Scott River, tributary to the Klamath River

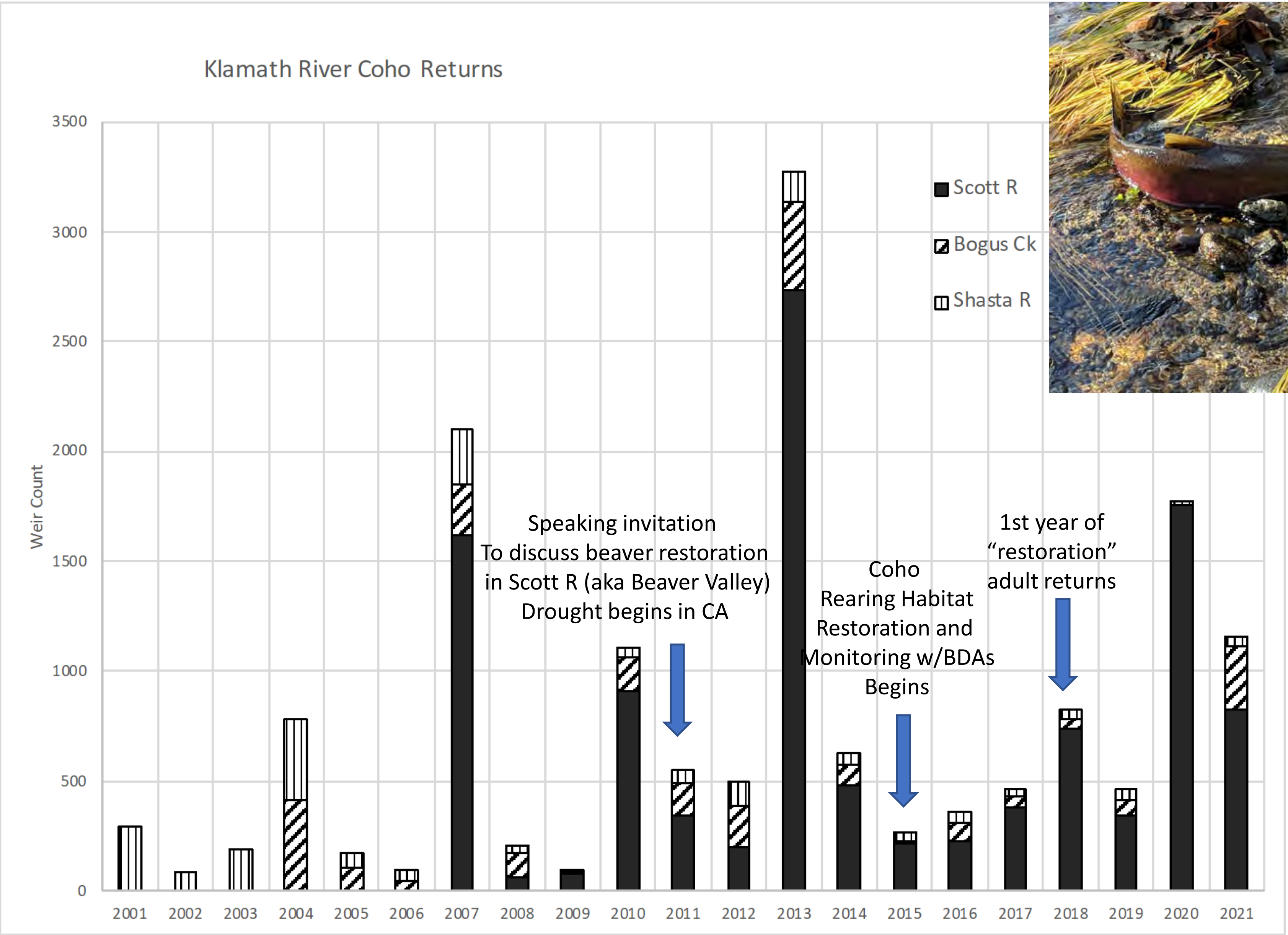
Michael Pollock[1] , Erich Yokel[2] ,Charnna Gilmore[2] , Betsy Stapleton[2] ,

1 NOAA NWFSC Watershed Program, Seattle, Washington
2 Scott River Watershed Council, Etna, California



Basin	Area mi2 (km2)
Klamath Basin	15,751 (40,790)
Sprague / Williamson	3,069 (7,950)
Lost	3,009 (7,790)
Sprague	1,565 (4,053)
Russian	1,485 (3,846)
Scott	813 (2,110)
Shasta	795 (2,060)
Elwha	318 (824)
U. Klamath Lake	96 (250)
L. Klamath and Tule Lks (historic)	195 (510)
Lake Modoc (prehistoric)	1,100 (2,800)


Klamath Falls, 1,248 m elev.
Mouth of Spencer Ck
Rkm 380 (approx.),
uppermost known extent
of coho salmon (Hamilton et al. 2005)
Mouth of Scott R.
RKm 240
Etna, 895m elev.
Klamath River
Scott River
Shasta River
Sprague River
Lost River



Pilot Studies

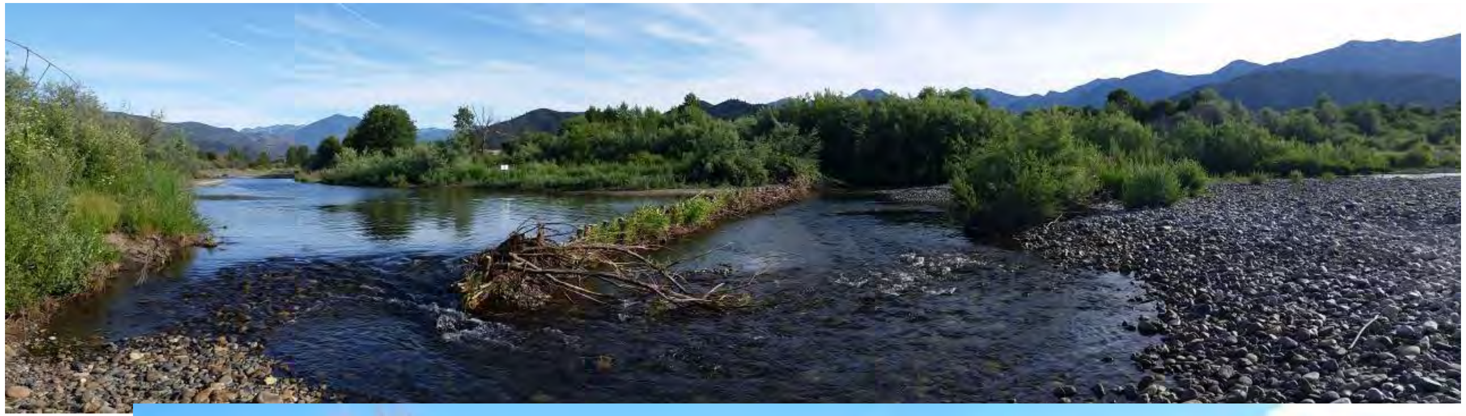
Expansion

Regulatory Negotiations

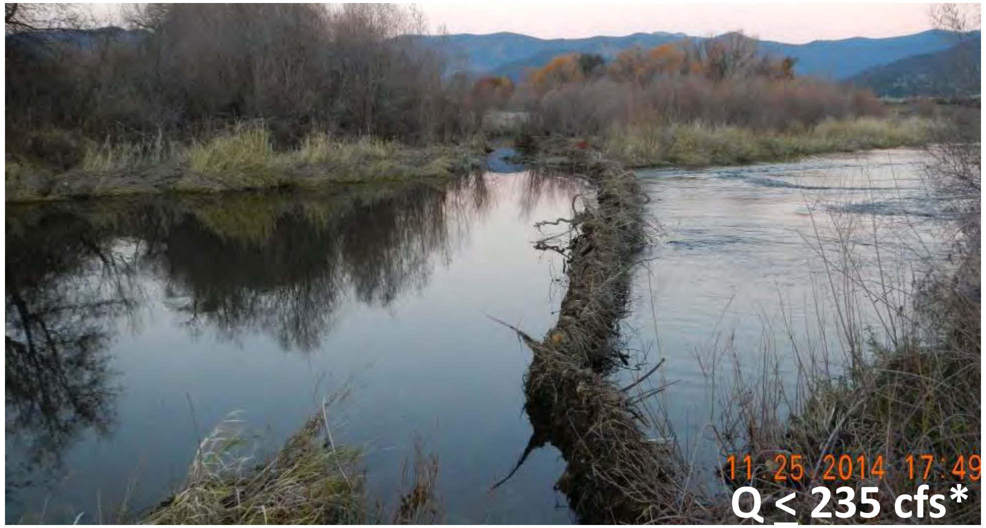
Collaboration with USFWS et al.; Grant Writing and Institutional Capacity Building

Beaver Dam Analogues

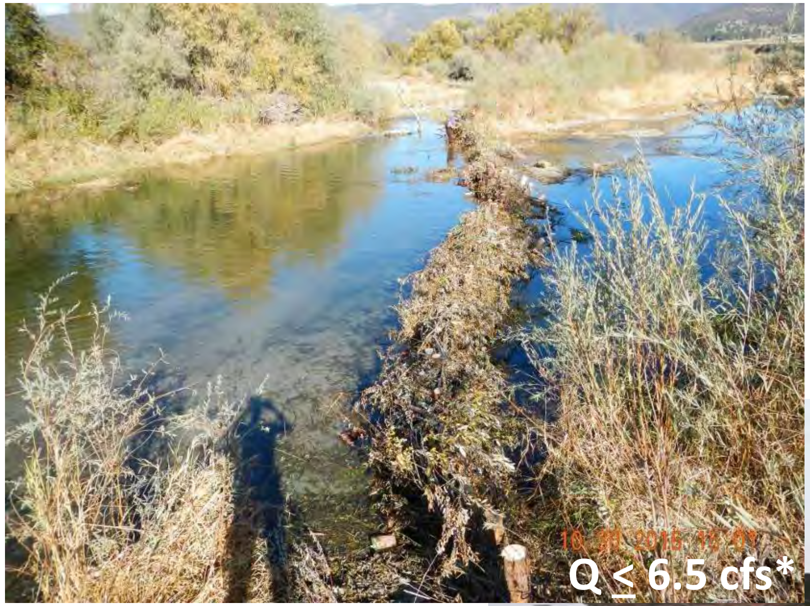
BDA Evolution & Maintenance

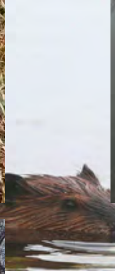


BDA Evolution and Maintenance

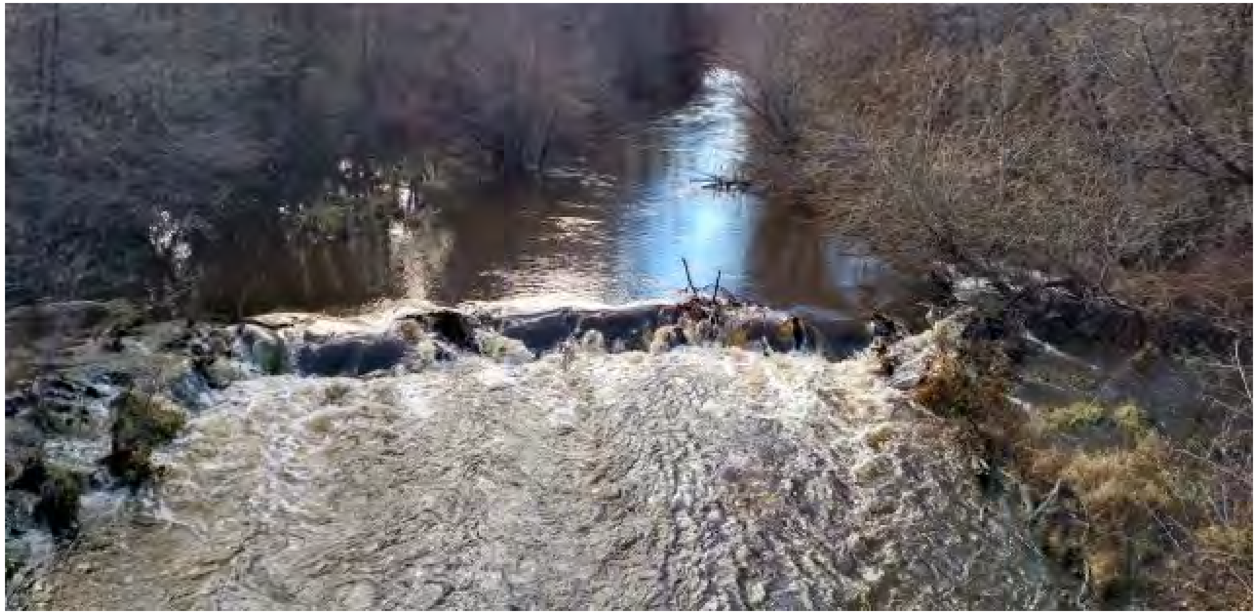


BDA Evolution and Maintenance





Beaver Dam Fish Passageways



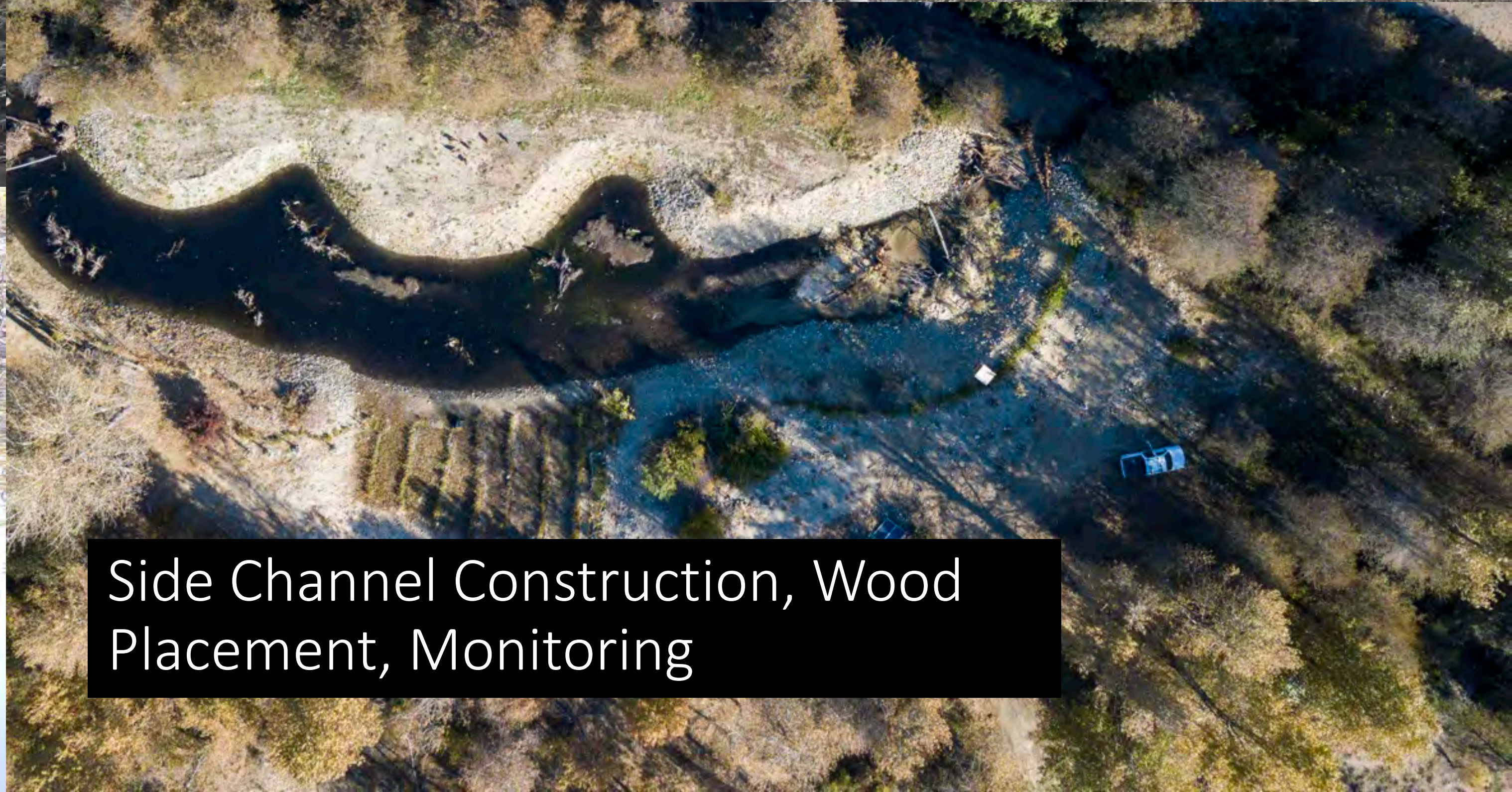
Sugar Creek-Beaver Dam Analogue Pond 1 Pre-Treatment v. Post Treatment

French Creek mainstem in winter (above)

French Creek side channel in winter (below)

Large Wood Placement

Stage Zero Stream Construction



Side Channel Construction, Wood Placement, Monitoring

Prescribed Burning

Sugar Creek Coho Habitat Restoration Project Using Beaver Dam Analogues

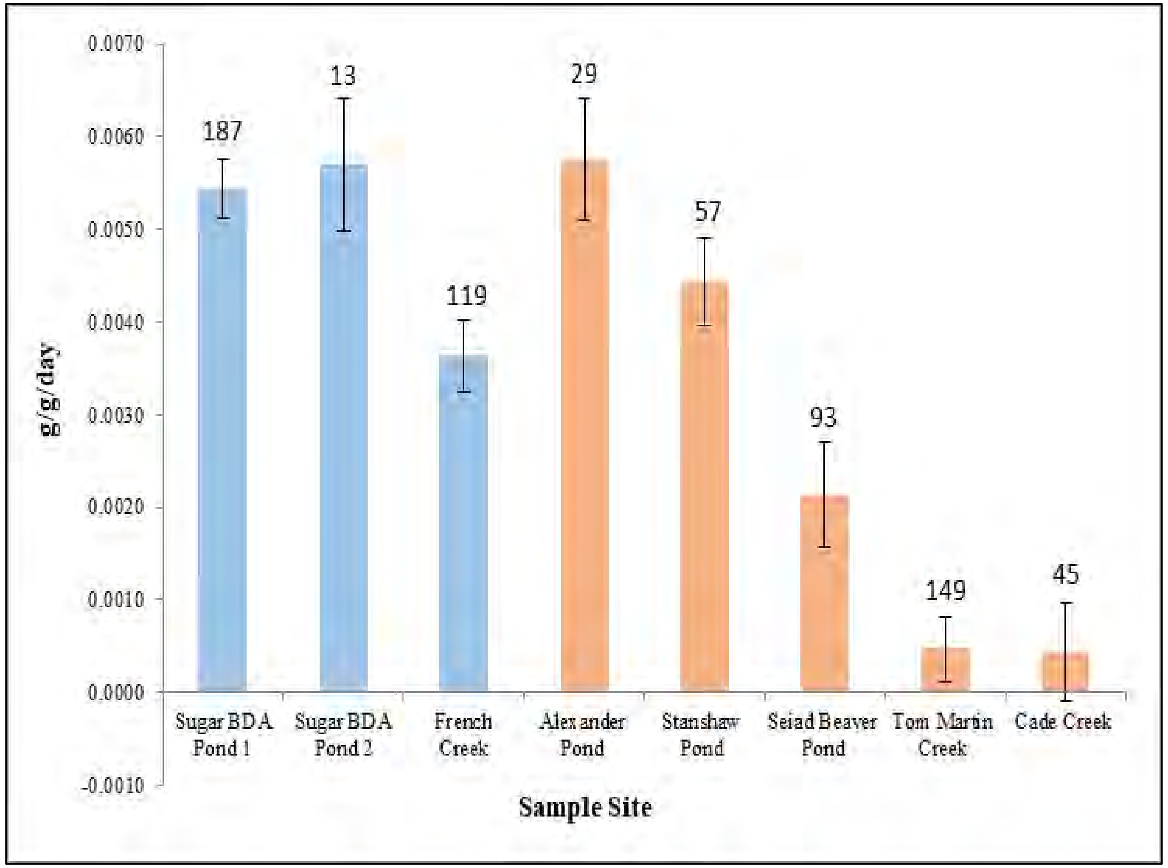
Late summer (2016) parr capacity estimate = 6,327
Overwinter survival 2016-17 est. = 88%
Coho outmigrant population in Spring 2017, est = 5,568
Historical Smolt-to-Adult Return Rates 1-13%, average = 5%
(source CDFW)

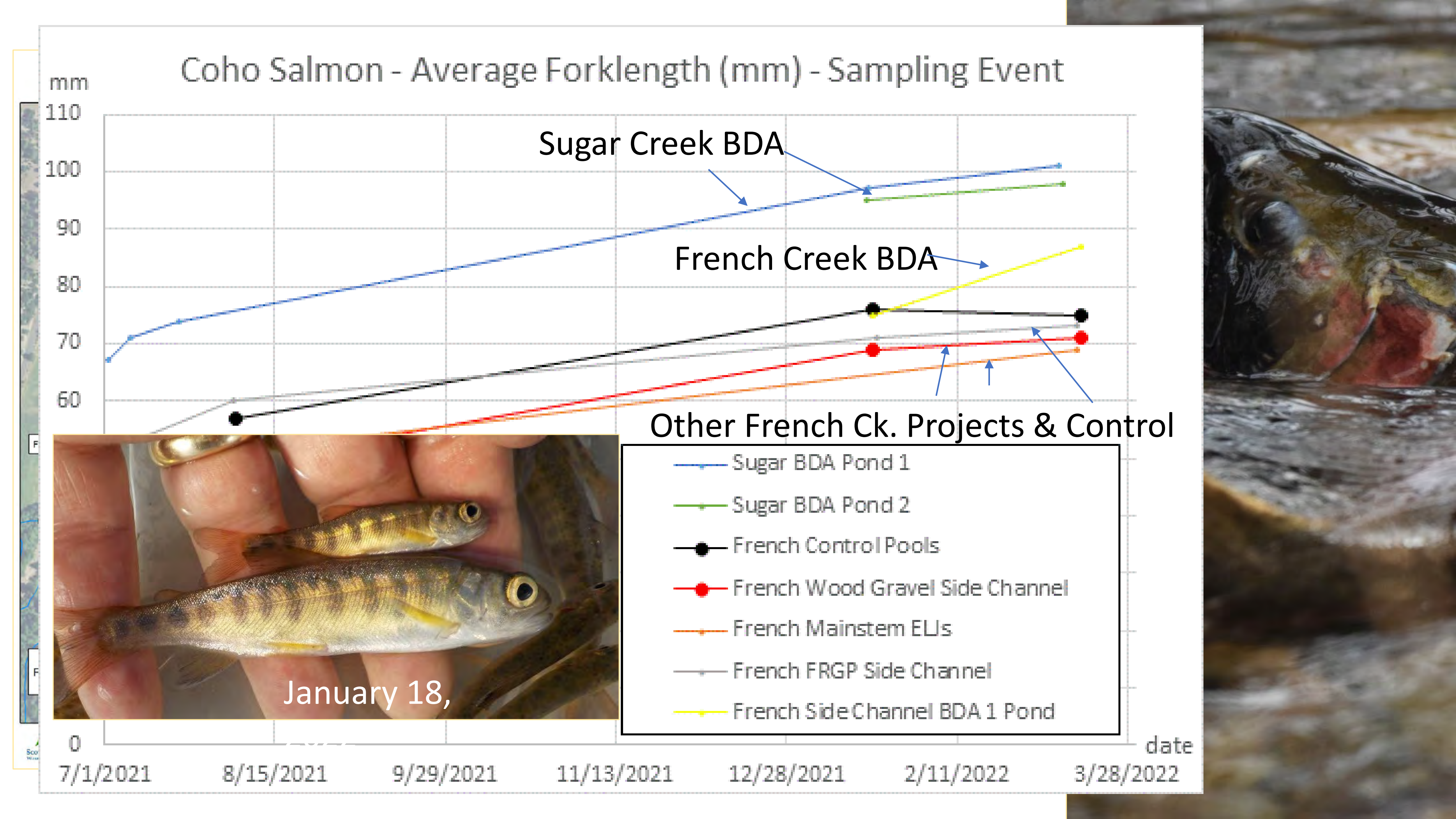
Late summer habitat capacity and population estimates

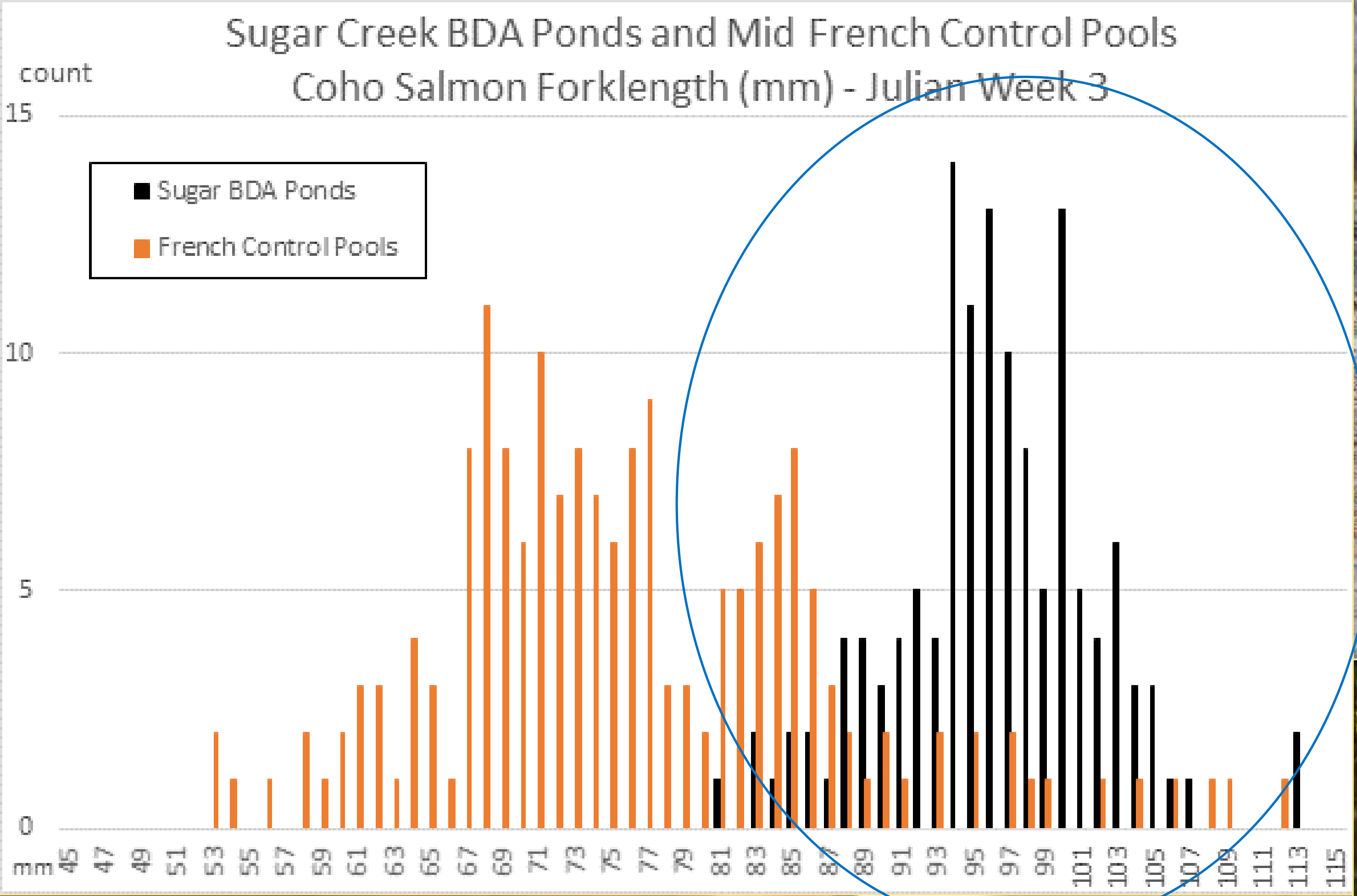
Habitat	Area(m2)	Sm-Ttl	Sm/m2	% all thab	% PP	Pop Est.
BDAP1	2260.9	1731.7	0.8	13-7$	16-3$	346
BDAP2	3162.1	2946.6	0.9	23-5$	35-5$	3591
SCB-Marsh	645.4	735.4	1.1	6-0$	00-5$	896
SCA	353.1	165.0	0.5	2-8$	1-5$	201
OCP	2049.0	748.4	1.3	11-3$	00-7$	912
Total BDAPs	6068.4	**5413.7**	0.9	55-4$	74-5$	**4834**
Total-All	8470.5	**6327.1**	0.7		0/ / -/ $	**5947**
Pre-project	708.0	**322.0**	0.5	0/ / -/ $	0/ / -/ $	/)

*Bad drought year, treatment reach dried up

Growth rate of juvenile coho salmon at restoration site (Sugar Ck) and control site (French Ck) in relative to growth rates in other ponds and tributaries in the Klamath River basin.

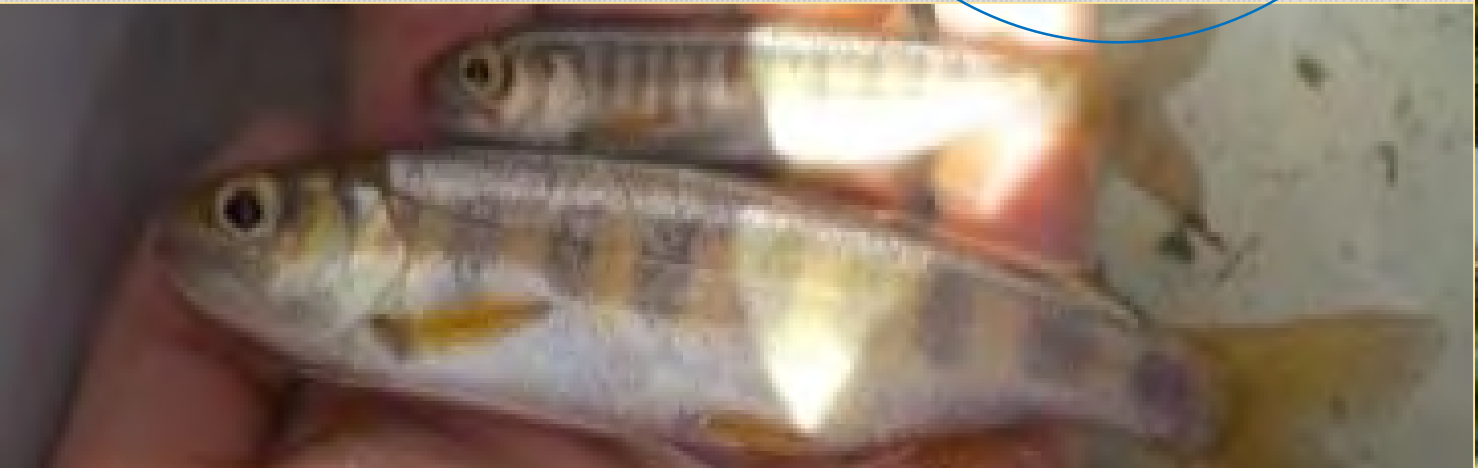



Coho Salmon - Average Forklength (mm) - Sampling Event
mm
110
100
90
80
70
60
0
7/1/2021
8/15/2021
9/29/2021
11/13/2021
12/28/2021
2/11/2022
3/28/2022
date
Sugar Creek BDA
French Creek BDA
Other French Ck. Projects & Control
Sugar BDA Pond 1
Sugar BDA Pond 2
French Control Pools
French Wood Gravel Side Channel
French Mainstem ELJs
French FRGP Side Channel
French Side Channel BDA 1 Pond
January 18,

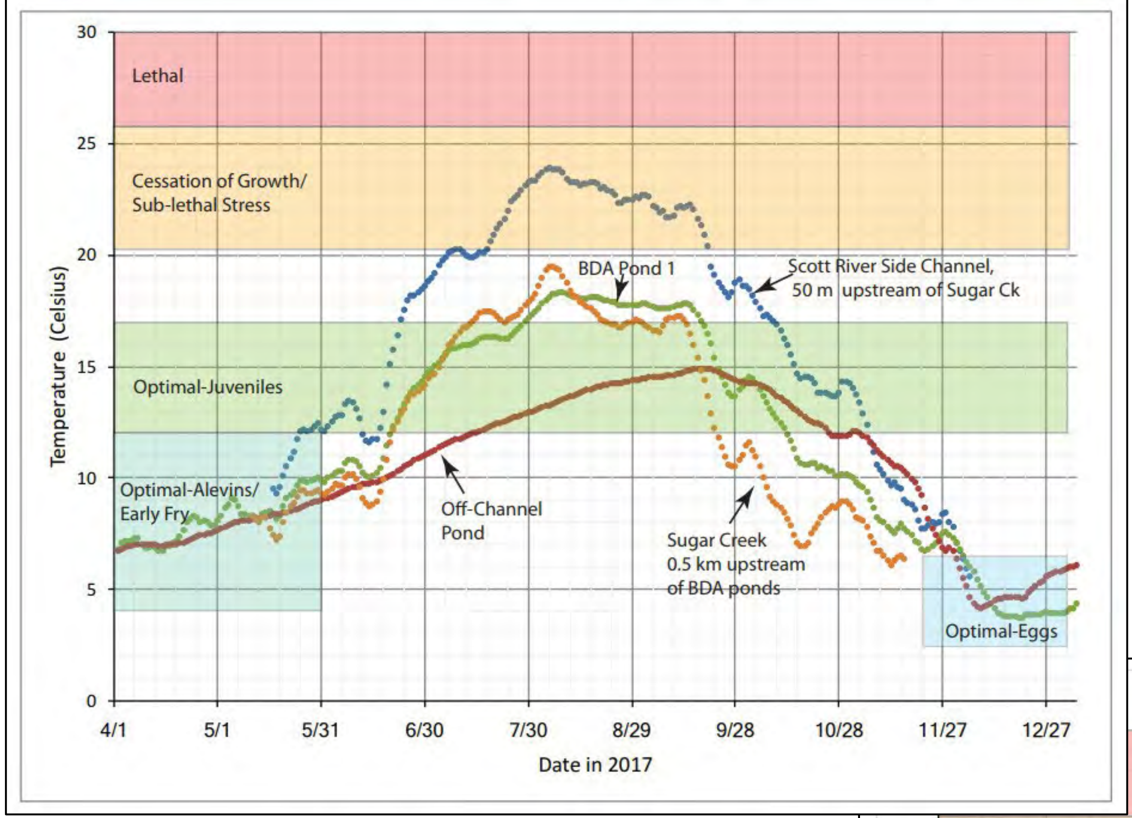


Sugar Creek BDA Ponds and Mid French Control Pools
Coho Salmon Forklength (mm) - Julian Week 3
count
15
10
5
0
Sugar BDA Ponds
French Control Pools
mm
45
47
49
51
53
55
57
59
61
63
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
97
99
101
103
105
107
109
111
113
115

2020 01 13



07 30 2020

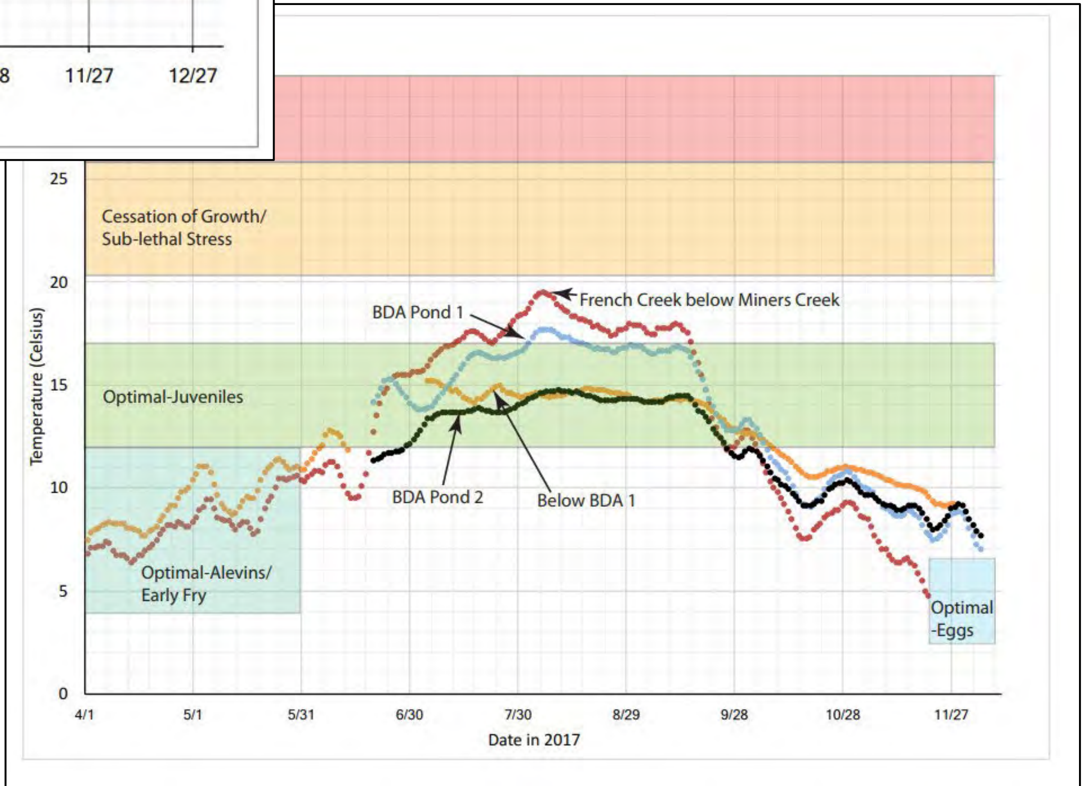


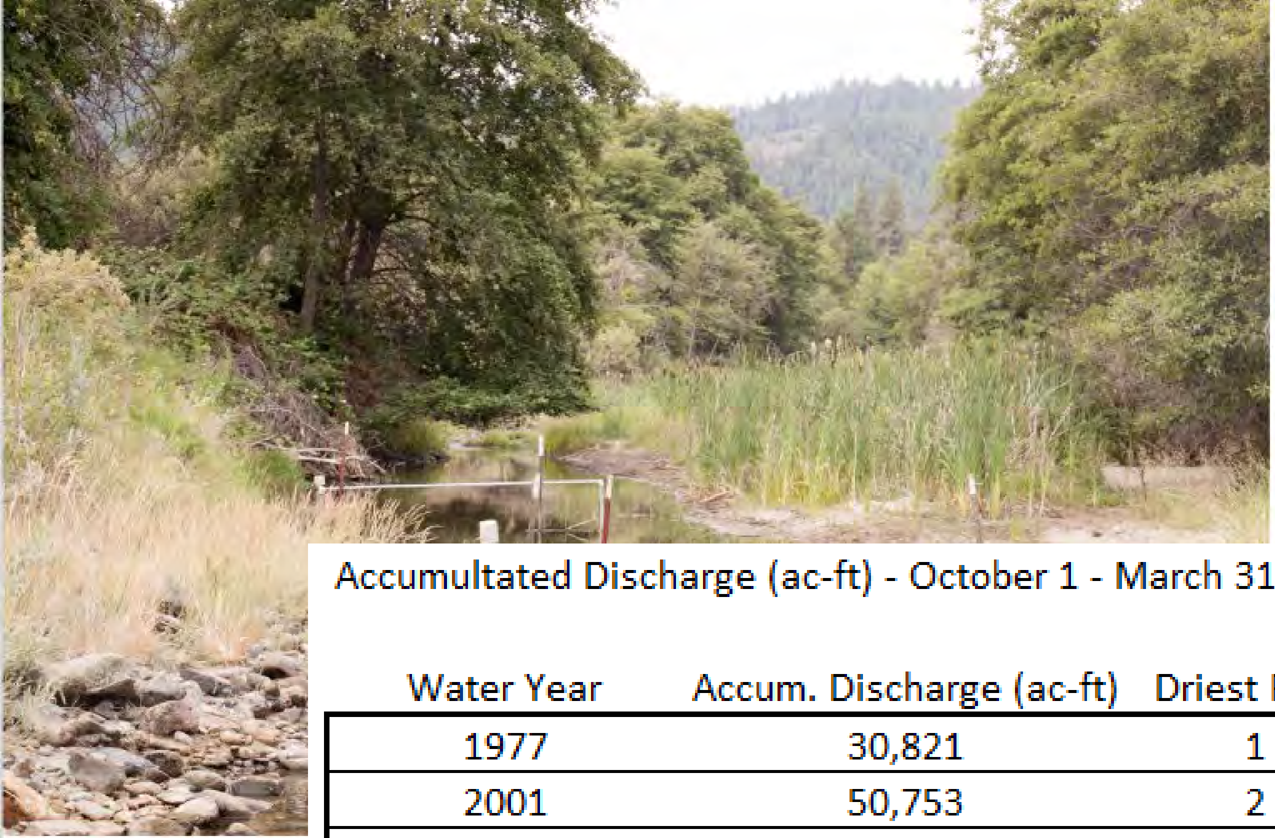
Moving weekly maximum temperature (MWMT) (°C). Thermal optimum and stressful ranges for coho salmon life stages based on Richter and Kolmes (2005).

Surface Water Temperatures, April-December, 2017

Sugar Creek (above)

French Creek (right)





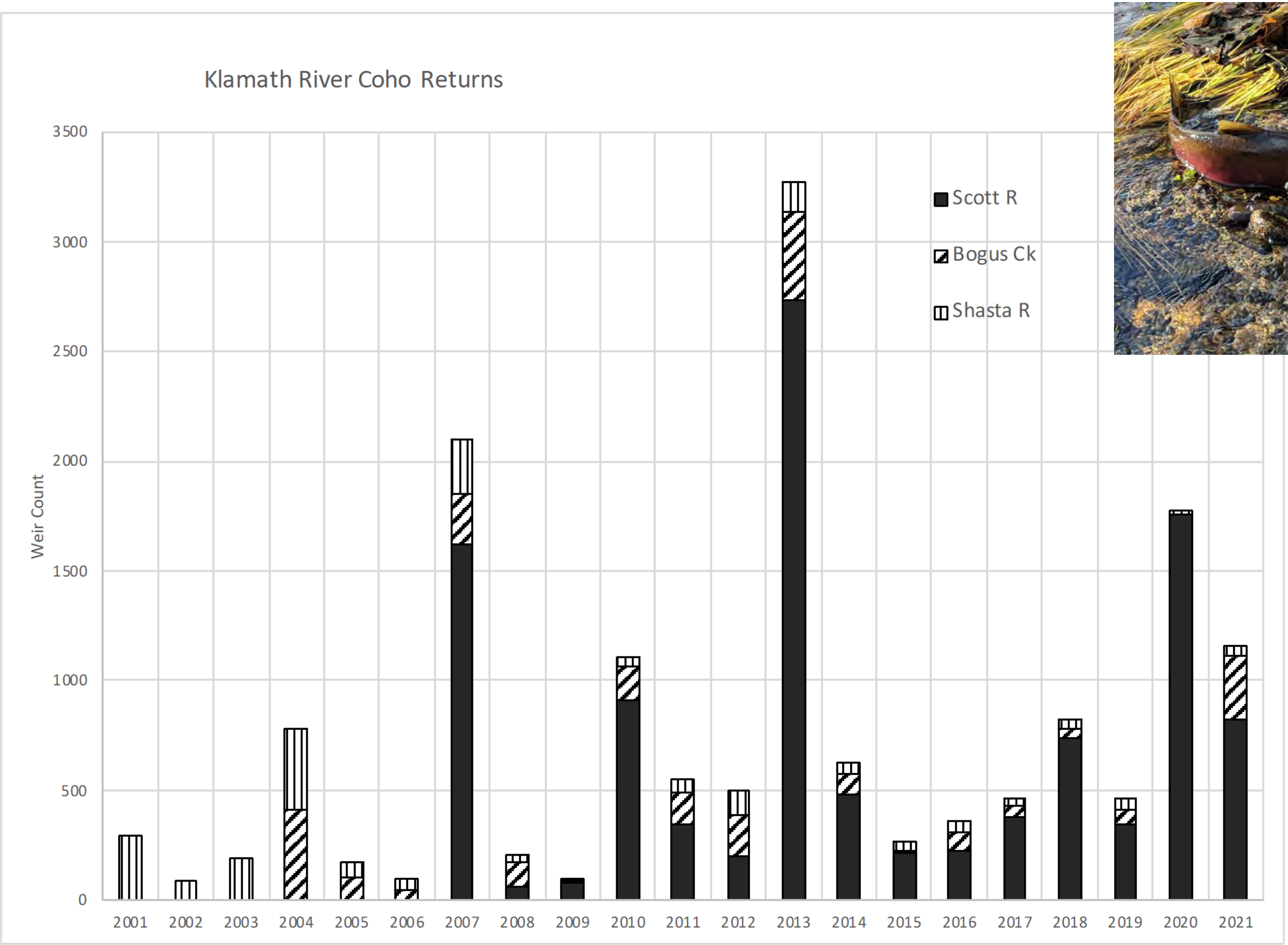
July 24, 2014

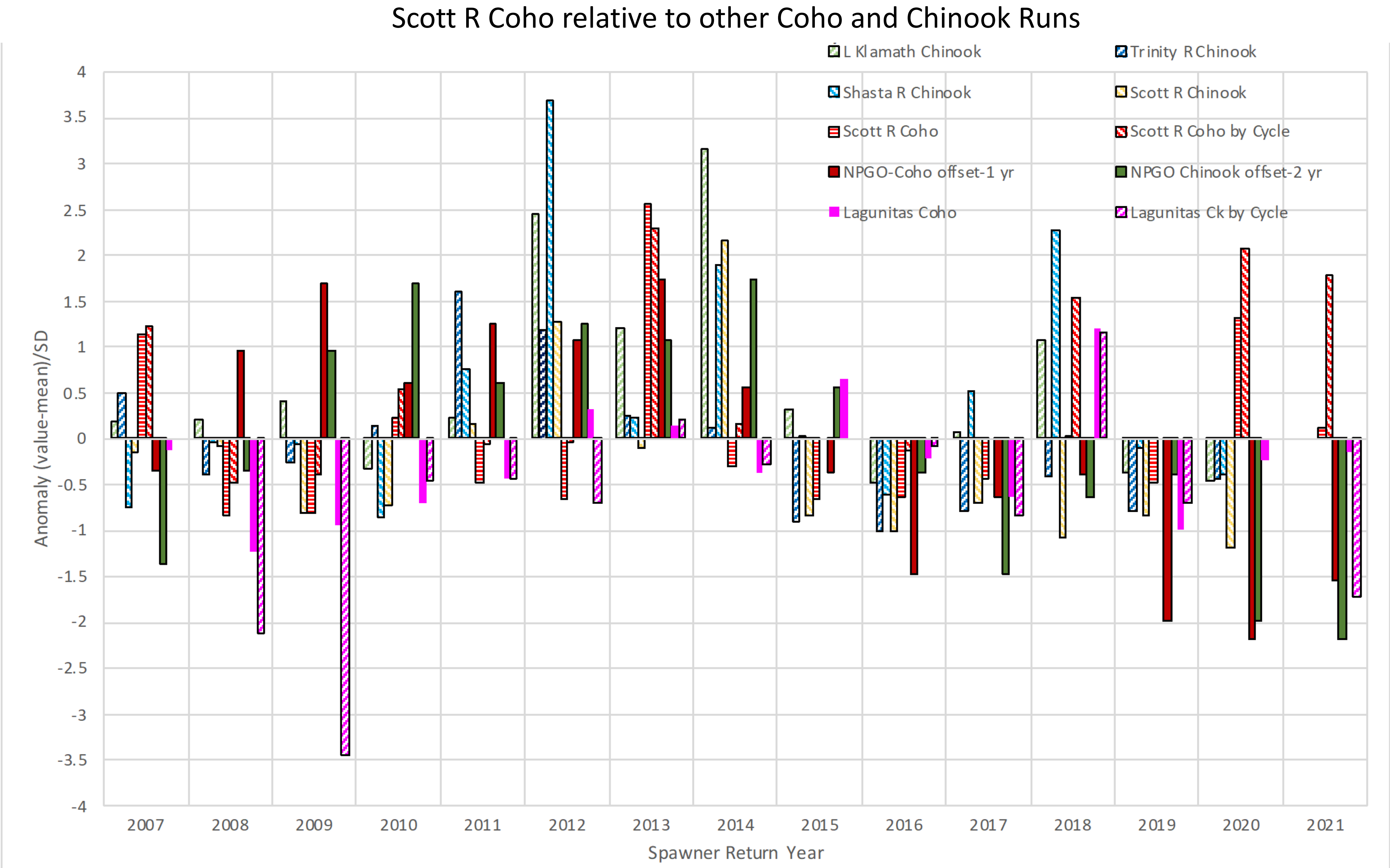
Accumultated Discharge (ac-ft) - October 1 - March 31

Water Year	Accum. Discharge (ac-ft)	Driest Rank
1977	30,821	1
2001	50,753	2
1991	52,981	3
2021	60,524	4
2020	63,115	5
1992	66,029	6
1994	66,323	7
1955	67,918	8
1944	72,172	9
2009	86,263	10
2014	91,510	11
Average (80 years)	254,525	

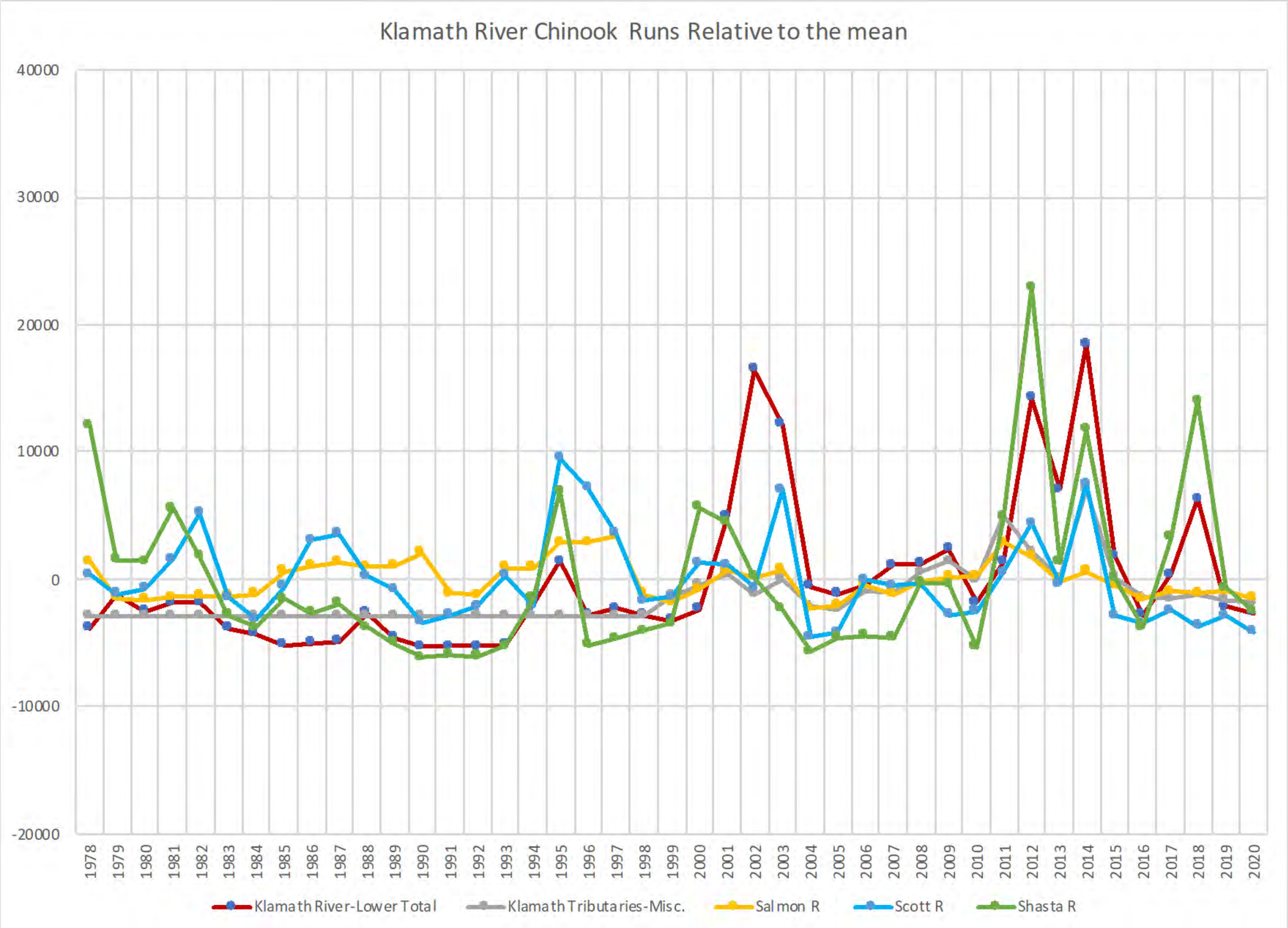
July 23, 2020

August 24, 2020

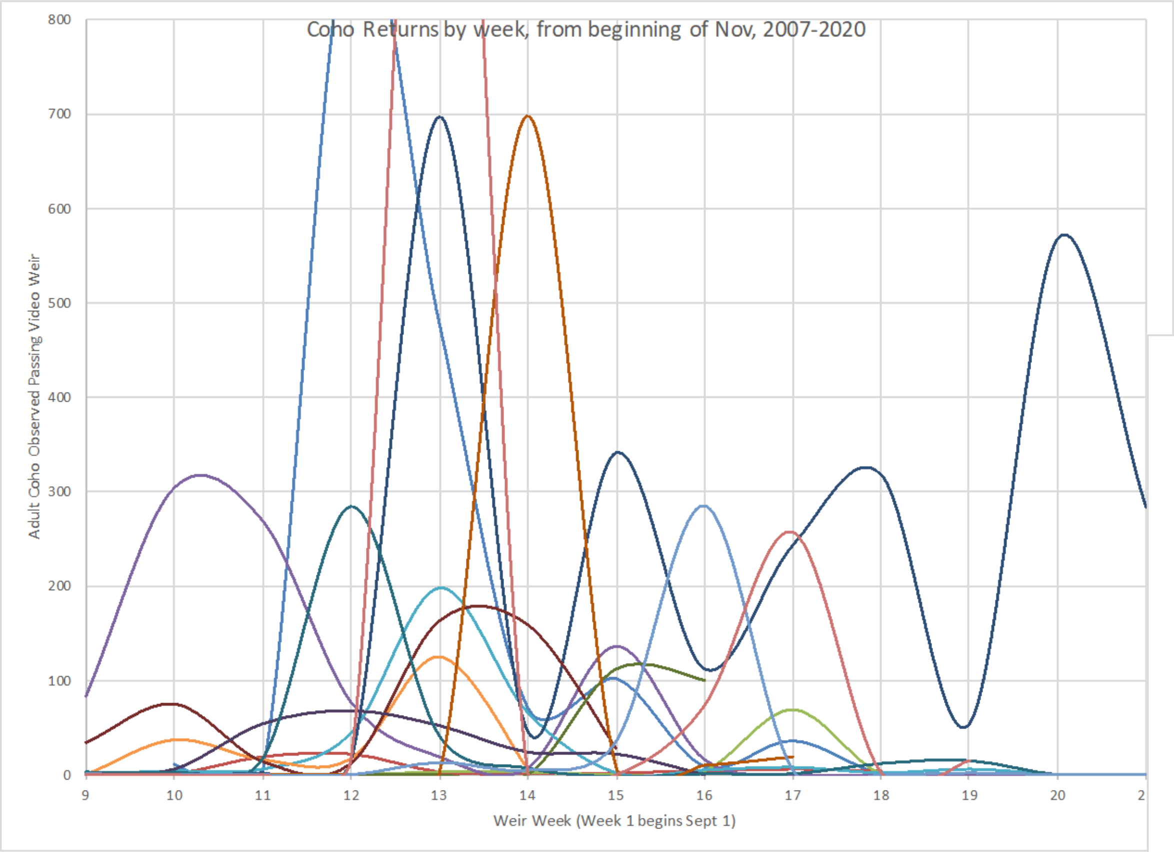

Klamath River Coho Returns
Weir Count
3500
3000
2500
2000
1500
1000
500
0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Scott R
Bogus Ck
Shasta R

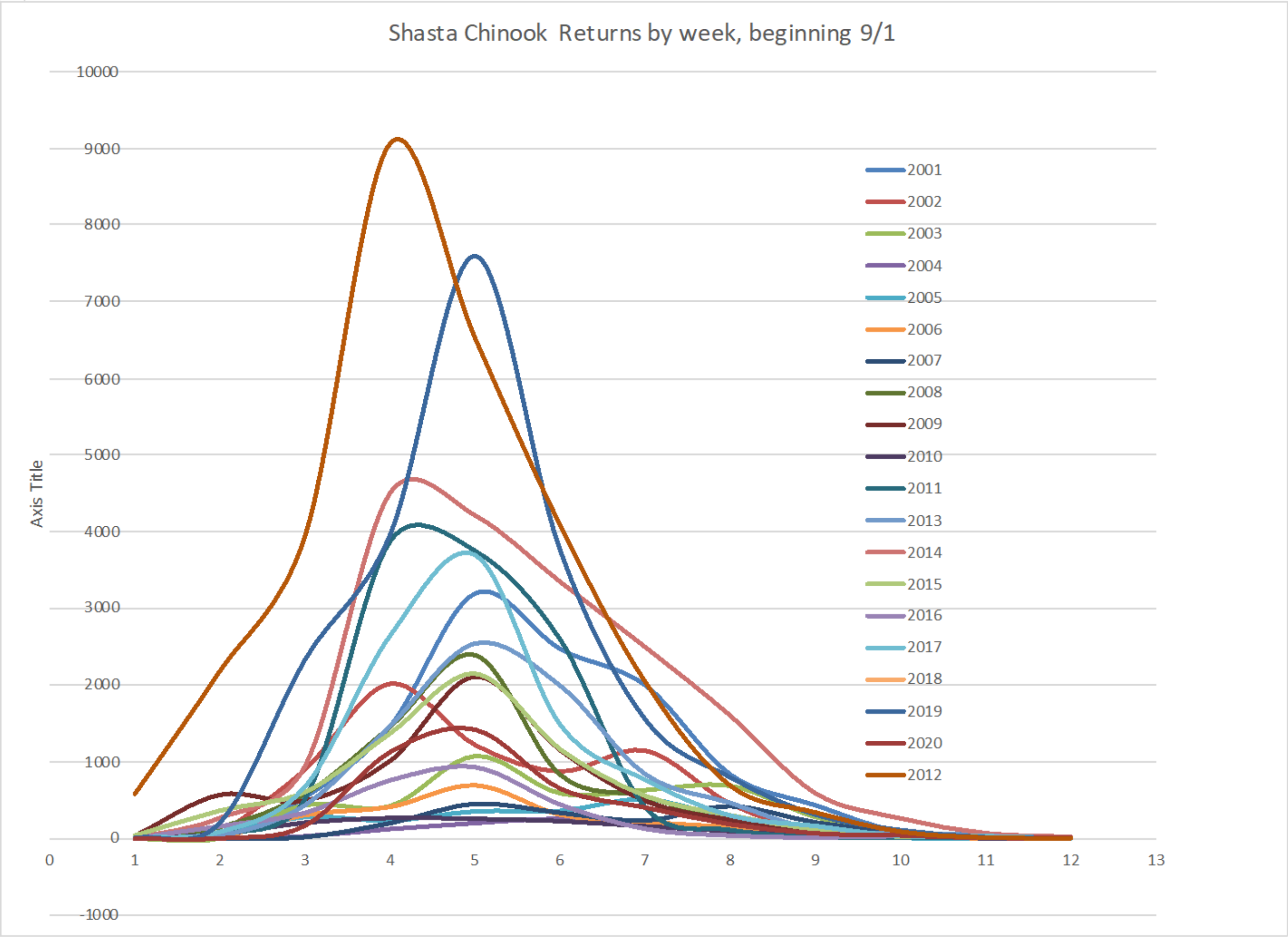

Scott R Coho relative to other Coho and Chinook Runs
L Klamath Chinook
Trinity R Chinook
Shasta R Chinook
Scott R Chinook
Scott R Coho
Scott R Coho by Cycle
NPGO-Coho offset-1 yr
NPGO Chinook offset-2 yr
Lagunitas Coho
Lagunitas Ck by Cycle
Anomaly (value-mean)/SD
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Spawner Return Year

Timing of Klamath River Chinook Runs



Variability of Run Timing Coho v. Chinook



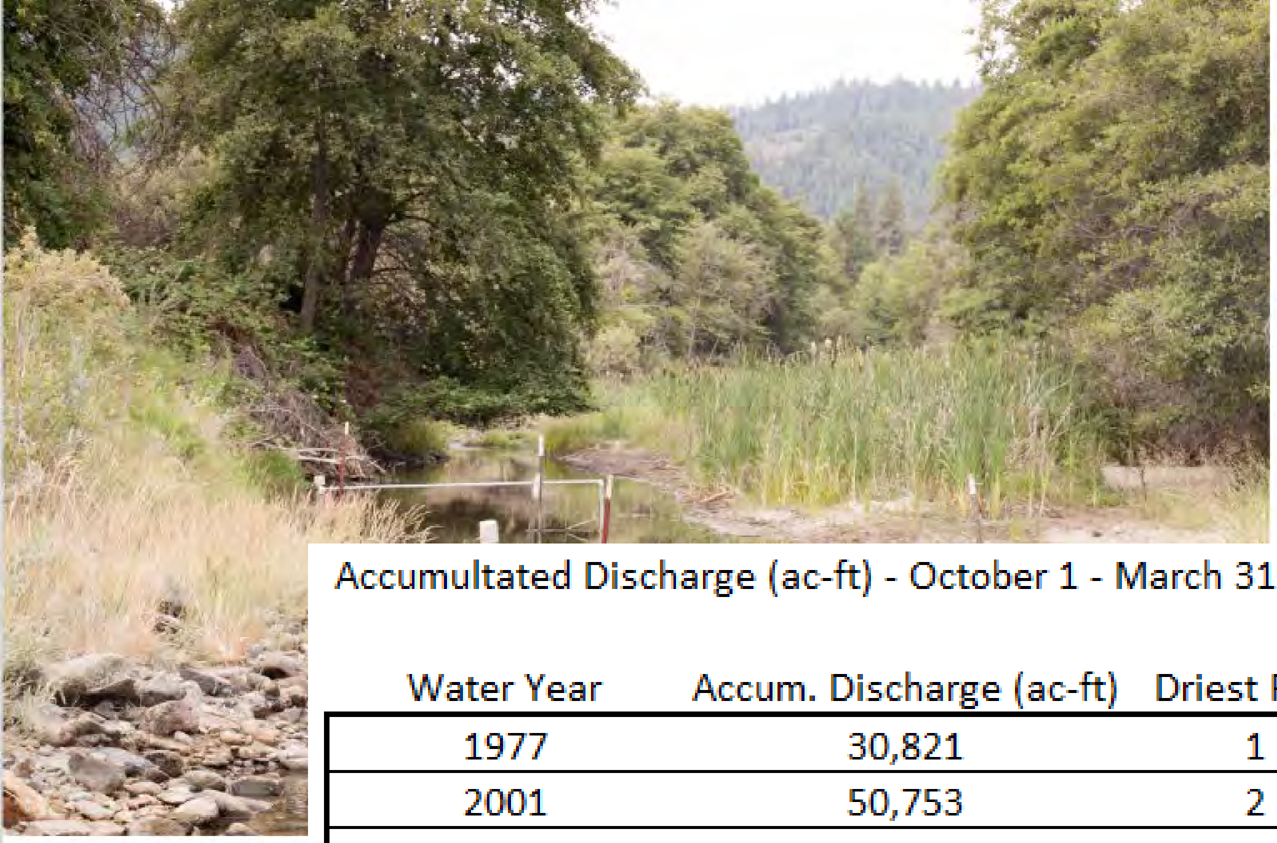


Ocean Condition "Stoplight" Indicators

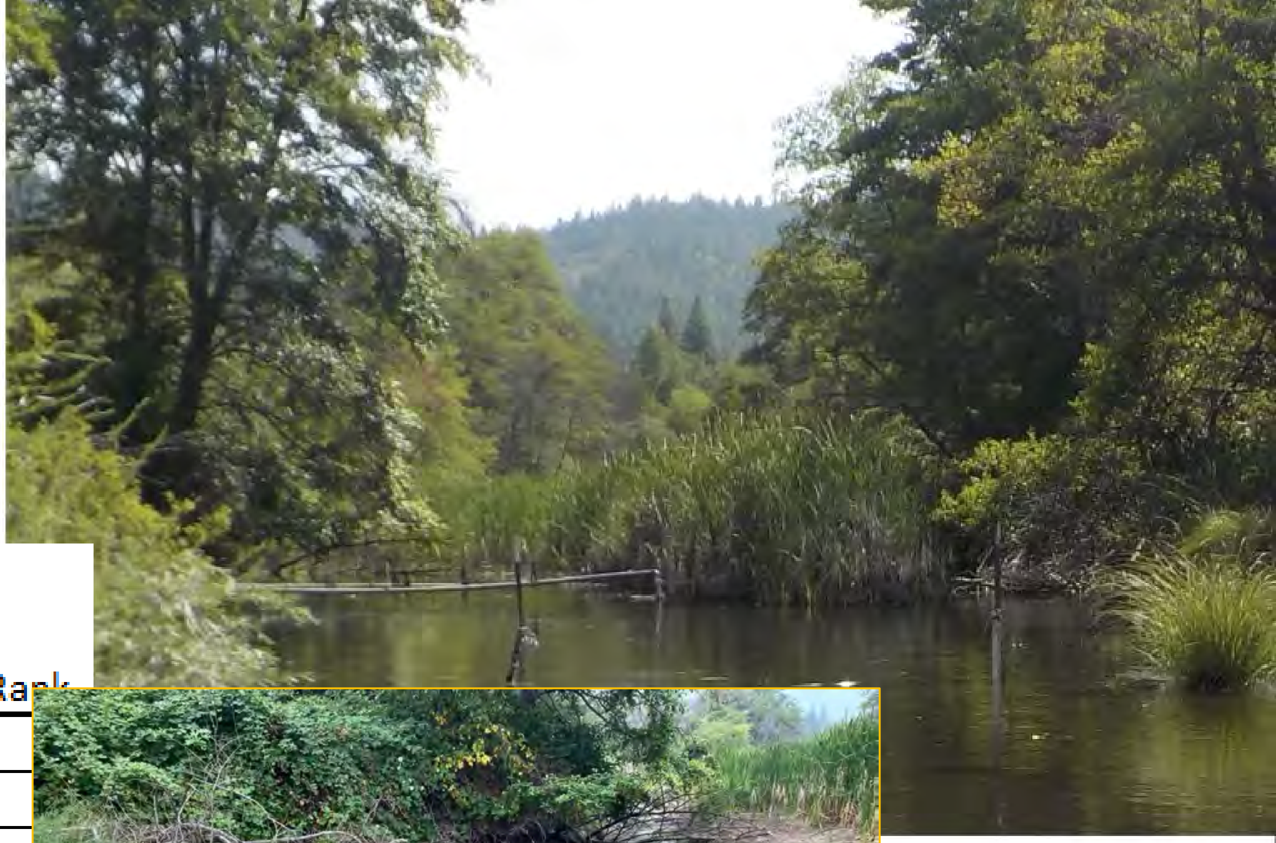
Ecosystem Indicators	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
PDO (Sum Dec-March)	21	7	3	15	8	23	14	19	16	11	5	1	18	4	2	9	12	24	22	20	13	17	10	6
PDO (Sum May-Sept)	12	5	7	6	13	19	18	20	14	16	2	11	8	4	1	9	22	24	23	17	15	21	10	3
ONI (Average Jan-June)	23	1	1	8	15	17	16	19	9	13	3	12	20	5	7	9	11	21	24	14	6	22	18	4
SST NDBC buoys (°C; May-Sept)	19	7	9	5	6	13	24	14	2	16	1	12	3	8	10	18	22	21	20	15	17	23	11	4
Upper 20 m T (°C; Nov-Mar)	23	13	10	12	7	17	18	15	14	6	1	11	20	5	4	9	3	24	22	21	16	19	2	8
Upper 20 m T (°C; May-Sept)	16	11	13	4	1	3	24	20	9	10	2	6	17	8	7	18	22	19	14	12	15	23	21	5
Deep temperature (°C; May-Sept)	23	7	9	5	1	11	13	17	12	6	2	8	15	10	4	16	22	21	14	19	20	18	24	3
Deep salinity (May-Sept)	23	4	12	5	6	19	20	13	8	2	3	17	21	15	16	14	24	18	10	9	7	11	22	1
Copepod richness anom. (no. species; May-Sept)	22	2	1	9	8	17	16	21	18	12	10	11	20	5	7	3	13	23	24	19	15	14	6	4
N. copepod biomass anom. (mg C m^{-3}; May-Sept)	22	17	13	14	6	19	16	23	18	15	9	12	11	3	5	7	8	20	24	21	10	4	2	1
S. copepod biomass anom. (mg C m^{-3}; May-Sept)	24	2	6	5	3	16	18	23	15	12	1	8	19	11	9	7	13	21	22	20	14	17	10	4
Biological transition (day of year)	21	13	8	3	11	17	14	22	16	4	1	2	19	5	12	6	6	23	23	20	15	17	8	10
Nearshore Ichthyoplankton Log(mg C 1,000 m^{-3}; Jan-Mar)	19	3	13	7	1	23	24	17	10	19	3	15	2	9	5	12	21	16	17	14	11	22	8	6
Nearshore & offshore Ichthyoplankton community index (PCO axis 1 scores; Jan-Mar)	11	6	5	8	10	13	18	22	2	15	3	12	16	4	1	7	9	20	23	24	19	21	17	14
Chinook salmon juvenile catches Log(no. km^{-1}; June)	21	3	7	19	6	10	17	23	14	12	1	8	5	15	2	4	9	16	20	24	18	13	22	11
Coho salmon juvenile catches Log(no. km^{-1}; June)	22	11	19	5	7	6	21	23	17	2	4	8	9	18	13	1	10	16	15	24	3	14	20	12
Mean of ranks	20.1	7.0	8.5	8.1	6.8	15.2	18.2	19.4	12.1	10.7	3.2	9.6	13.9	8.1	6.6	9.3	14.2	20.4	19.8	18.3	13.4	17.3	13.2	6.0
Rank of the mean rank	23	5	8	7	4	17	19	21	12	11	1	10	15	6	3	9	16	24	22	20	14	18	13	2

Ocean Condition Indicators v. Klamath R Indicator Salmon Returns

Brood Year			2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Shasta Chinook			####	6820	4195	978	2129	2184	2036	6362	6275	1348	####	####	8023	####	6745	2889	9905	####	6004	4088	6908
Rank			5	9	14	21	18	17	19	11	12	20	4	1	7	3	10	16	6	2	13	15	8
Rank of the mean rank			8	7	4	17	19	21	12	11	1	10	15	6	3	9	16	24	22	20	14	18	13
Brood Year			2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Scott Coho									1622	62	81	911	344	201	2731	485	212	227	382	737	346	1754	823
Rank									3	15	14	4	10	13	1	7	12	11	8	6	9	2	5
Coho Catch Rank									4	14	12	11	10	3	8	15	9	5	6	1	13	7	2



July 24, 2014



July 23, 2020

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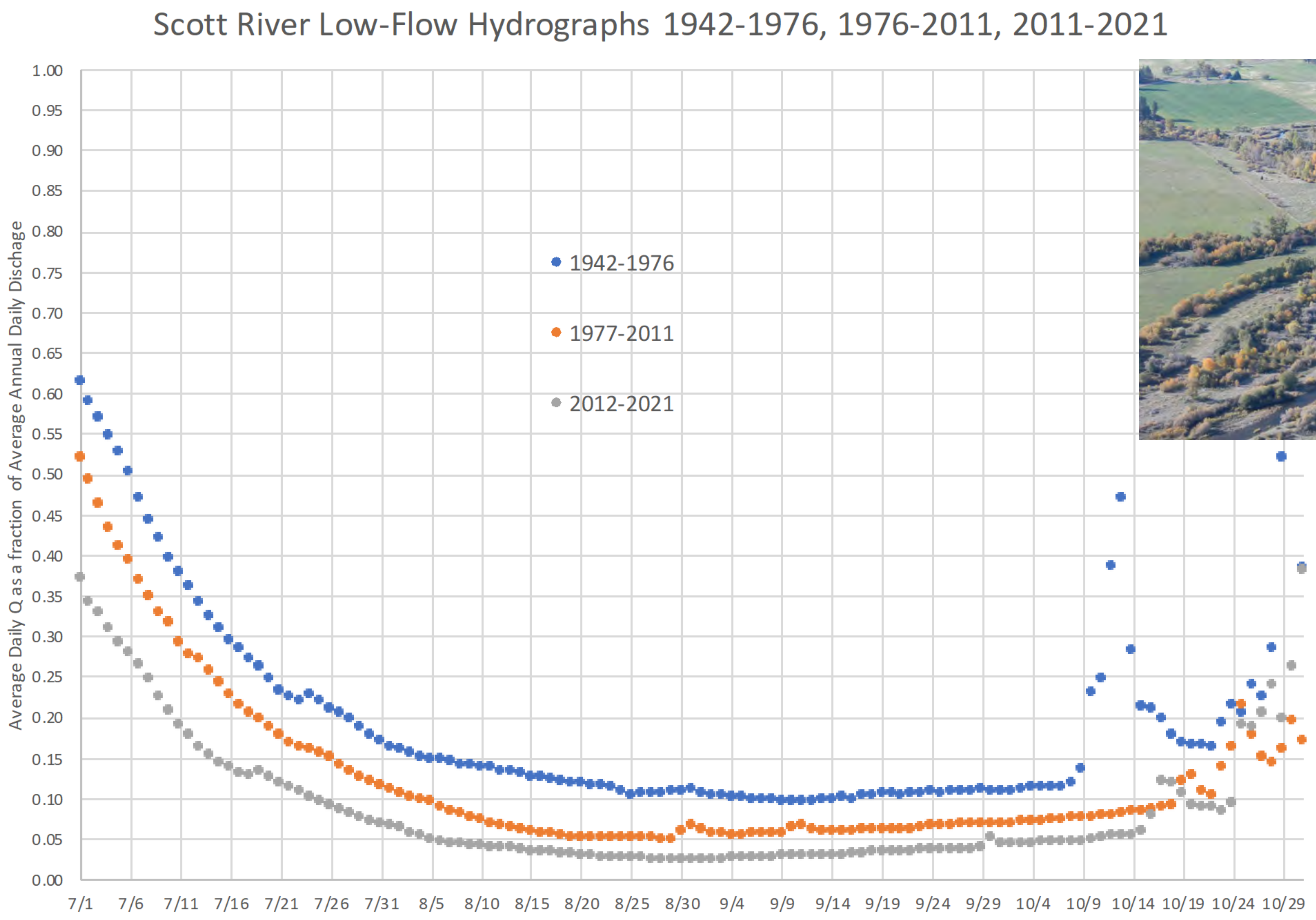
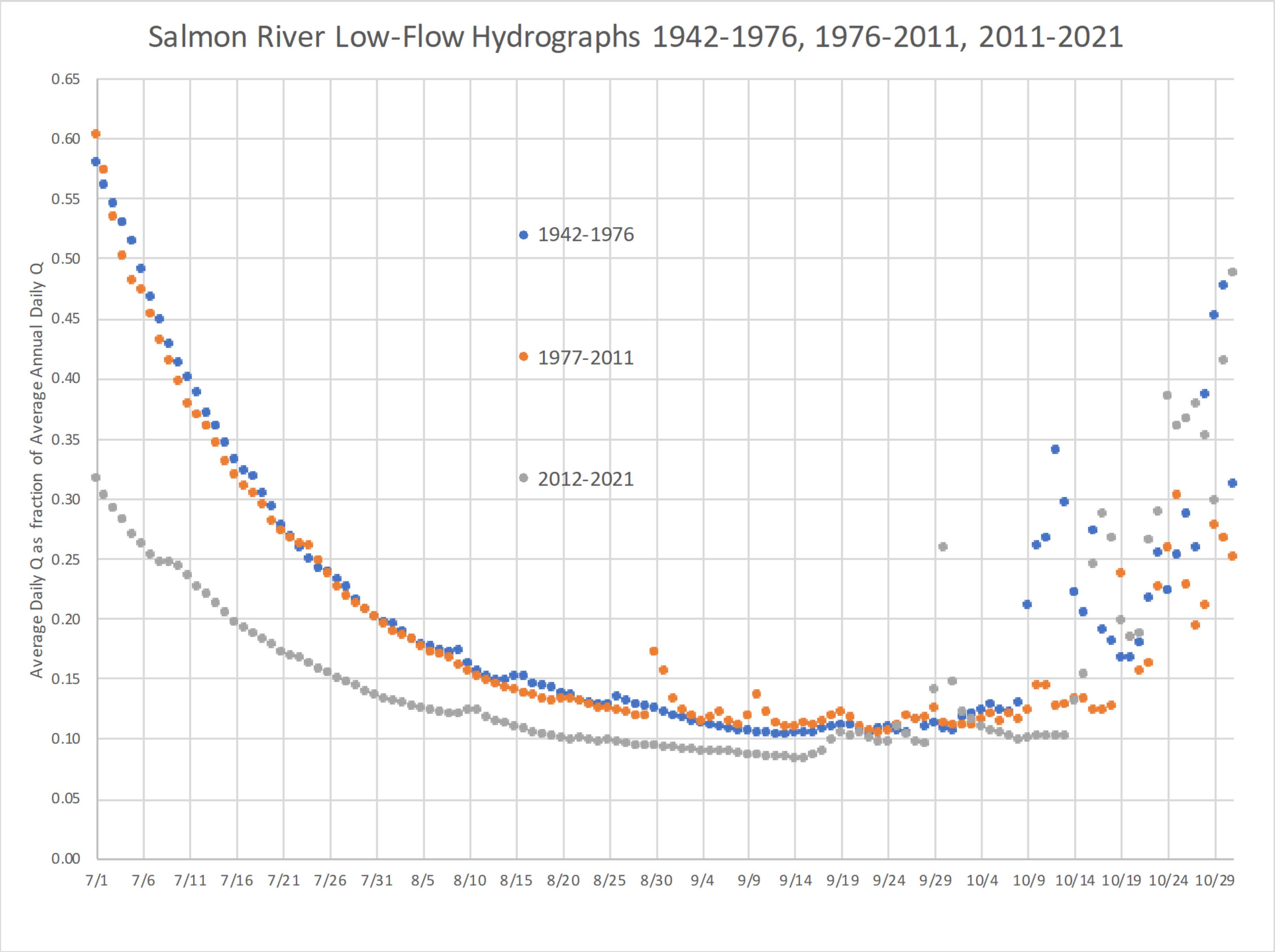
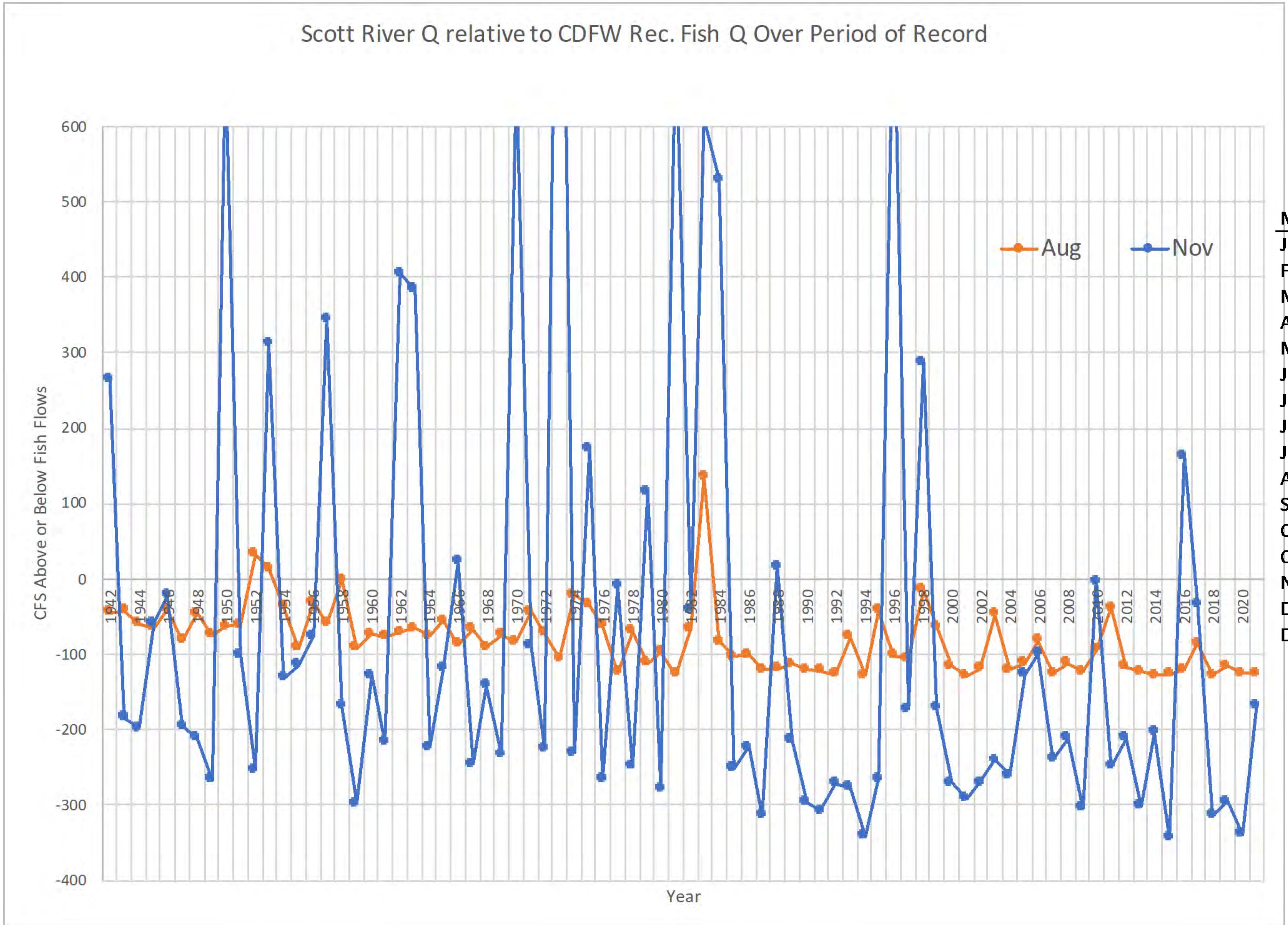


Scott River Low-Flow Hydrographs 1942-1976, 1976-2011, 2011-2021
Average Daily Q as a fraction of Average Annual Daily Dischage
1942-1976
1977-2011
2012-2021

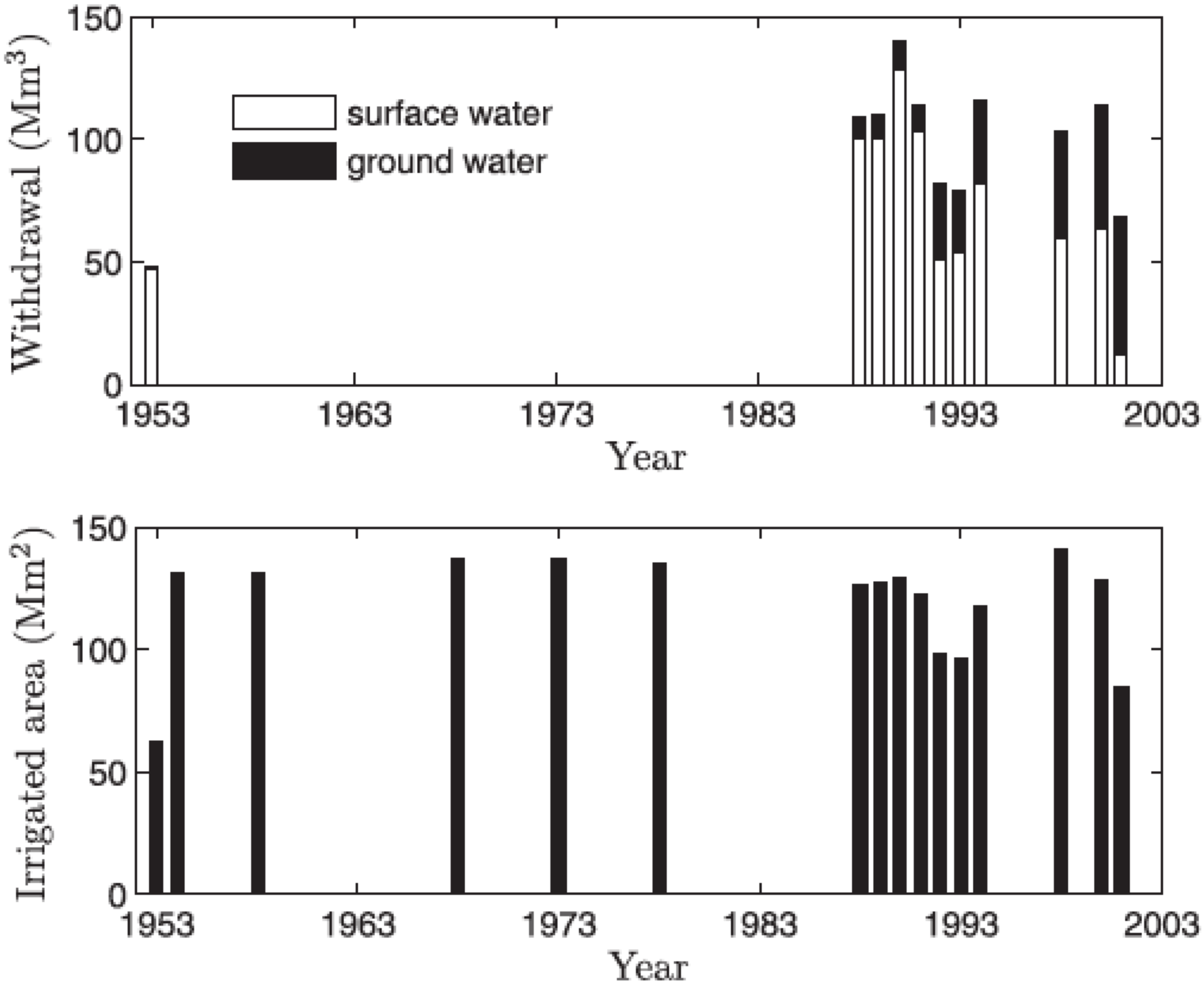
11.03.2014 15:07


Salmon River Low-Flow Hydrographs 1942-1976, 1976-2011, 2011-2021
Average Daily Q as fraction of Average Annual Daily Q
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
7/1
7/6
7/11
7/16
7/21
7/26
7/31
8/5
8/10
8/15
8/20
8/25
8/30
9/4
9/9
9/14
9/19
9/24
9/29
10/4
10/9
10/14
10/19
10/24
10/29
1942-1976
1977-2011
2012-2021



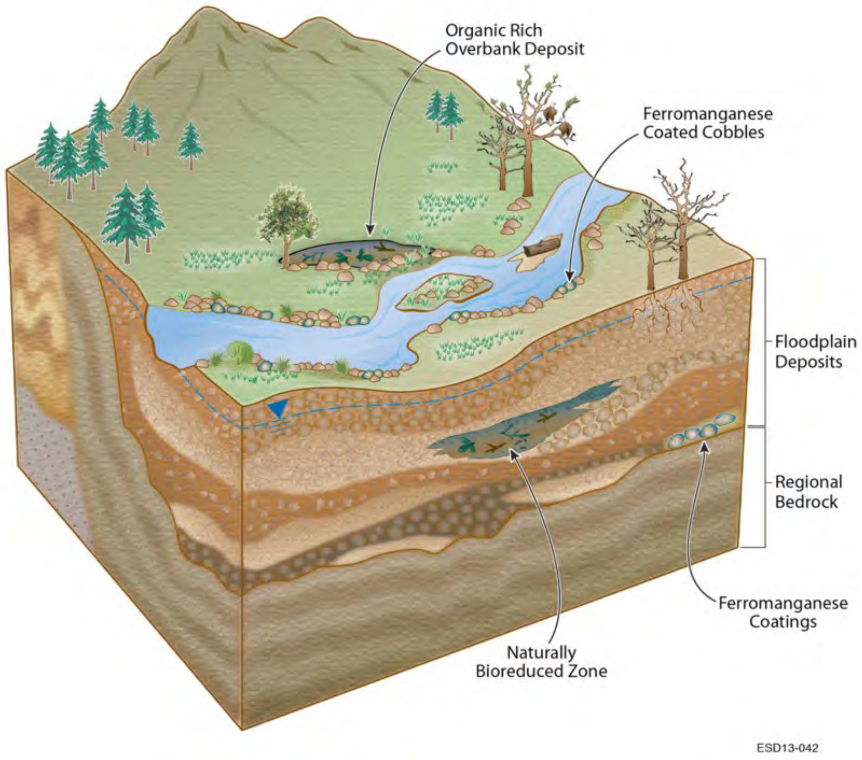
Month	SRD min Flow	CDFW min Flow
January	200	362
February	200	362
March	200	362
April	150	134
May	150	165
June, 1st half	150	165
June, 2nd half	100	165
July, 1st half	60	165
July, 2nd half	40	134
August	30	134
September	30	134
October, 1st half	40	134
October, 2nd half	40	351
Noember	200	351
December, 1st half	200	351
December, 2nd half	200	362

Scott R. water withdrawals and irrigated land



Van Kirk and Naman 2008

Around the world, groundwater dams are being used to address
The interrelated problems of incision and alluvial groundwater lowering, particularly in arid regions



Q 45 (1), 51 - 61 (2011) http://www.jircas.affrc.go.jp

REVIEW
Sustainable Use of Groundwater with Underground Dams

Satoshi ISHIDA[1]*, Takeo TSUCHIHARA[1], Shuhei YOSHIMOTO[1] and Masayuki IMAIZUMI[2]
[1] Department of Rural Technologies, National Institute for Rural Engineering, National Agriculture and Food Research Organization (NARO) (Tsukuba, Ibaraki 305-8609, Japan)
[2] Department of Rural Environment, National Institute for Rural Engineering, NARO (Tsukuba, Ibaraki 305-8609, Japan)

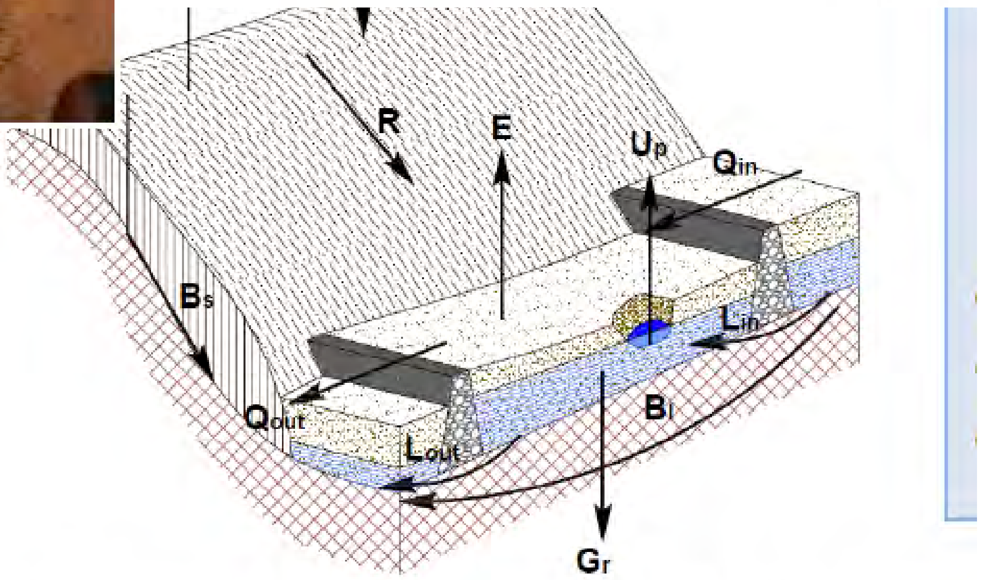


Figure 4: Water balance components (Borst & de Haas, 2006).

GREAT SEAL OF THE KARUK TRIBE

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

SISKIYOU RESOURCE CONSERVATION DISTRICT
RCD

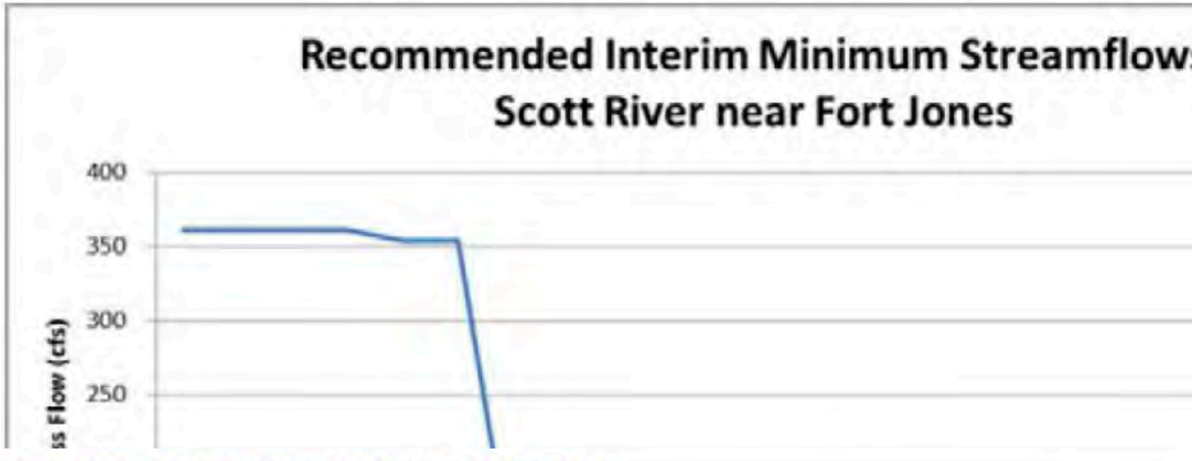
CALIFORNIA
DEPARTMENT OF FISH & WILDLIFE

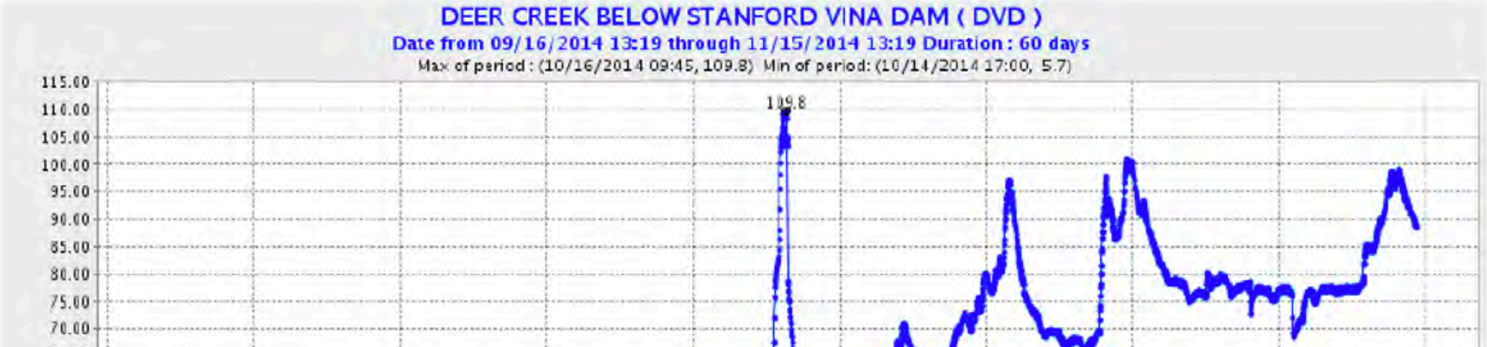
SCOTT RIVER RANCH LLC
ORGANIC GRASS FED & FINISHED BEEF
OREGON TILTH
Oregon Tilth Certified Organic

Scott River Watershed Council

USGS

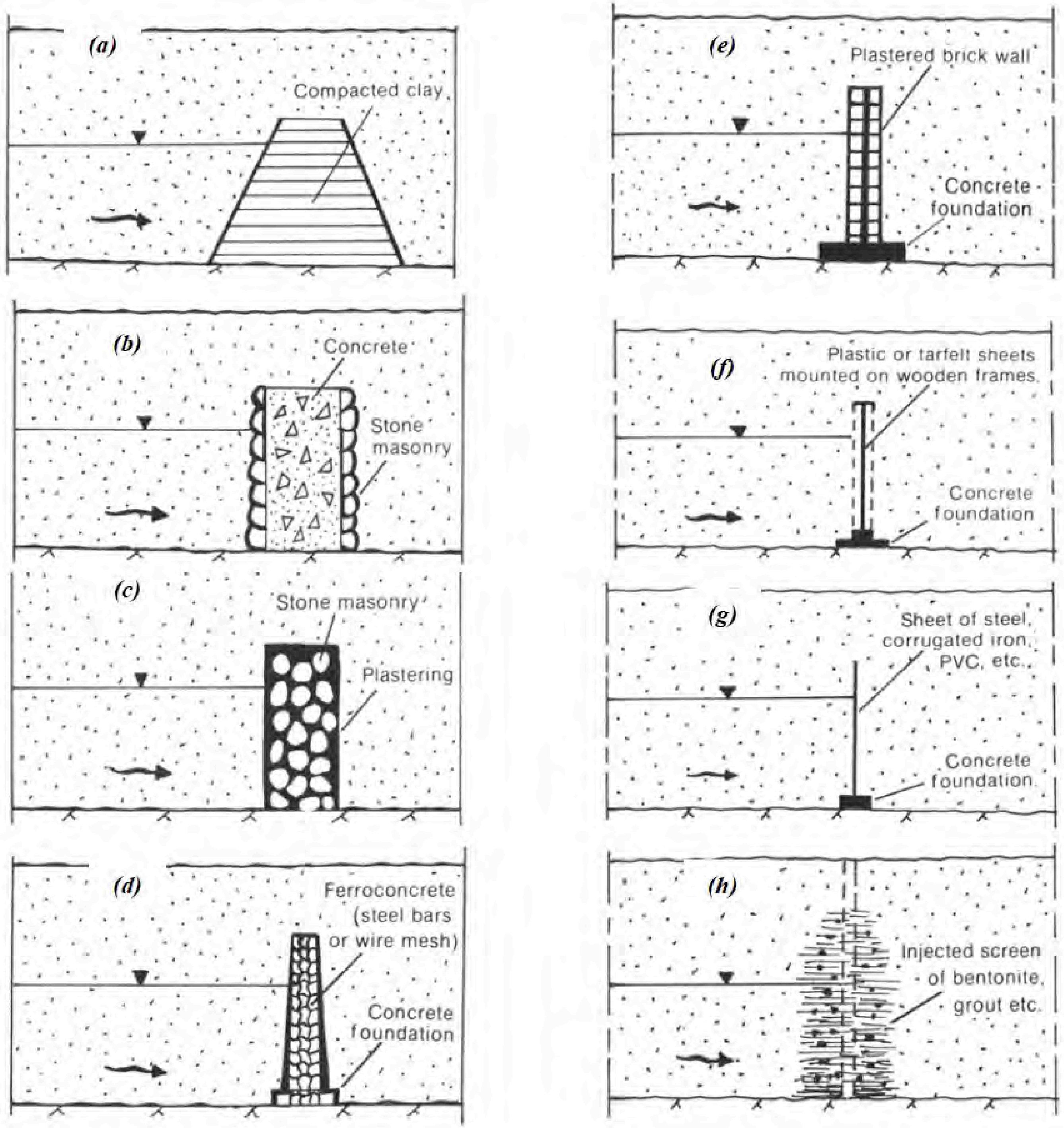
Thank You!


Recommended Interim Minimum Streamflow
Scott River near Fort Jones
400
350
300
250


DEER CREEK BELOW STANFORD VINA DAM (DVD)
Date from 09/16/2014 13:19 through 11/15/2014 13:19 Duration : 60 days
Max of period : (10/16/2014 09:45, 109.8) Min of period: (10/14/2014 17:00, 5.7)
115.00
110.00
105.00
100.00
95.00
90.00
85.00
80.00
75.00
70.00
109.8

Types of Groundwater Dams-Subsurface

(Hanson and Nilsson 1986, Nilsson 1988)



High-Tech Groundwater Dams

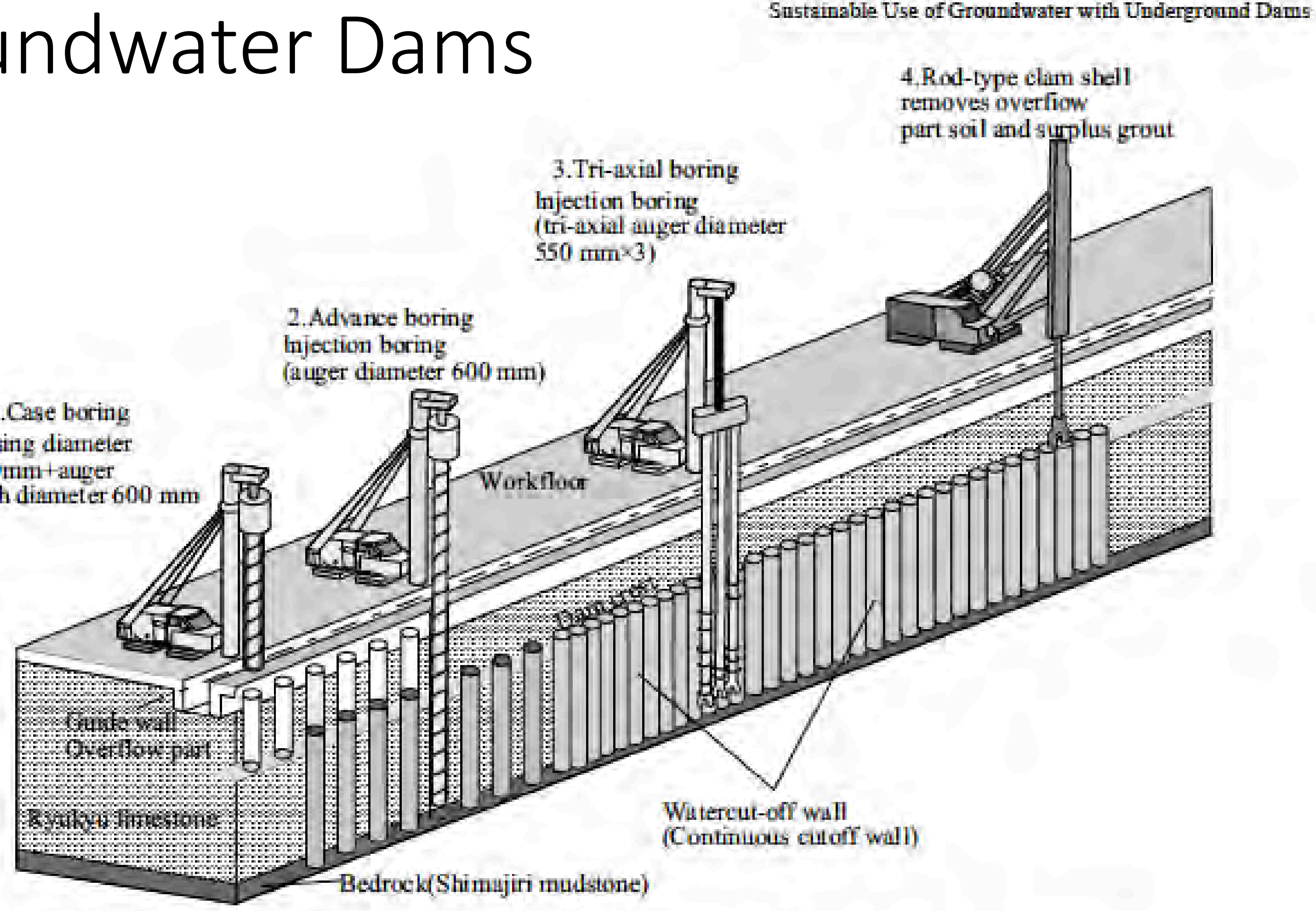
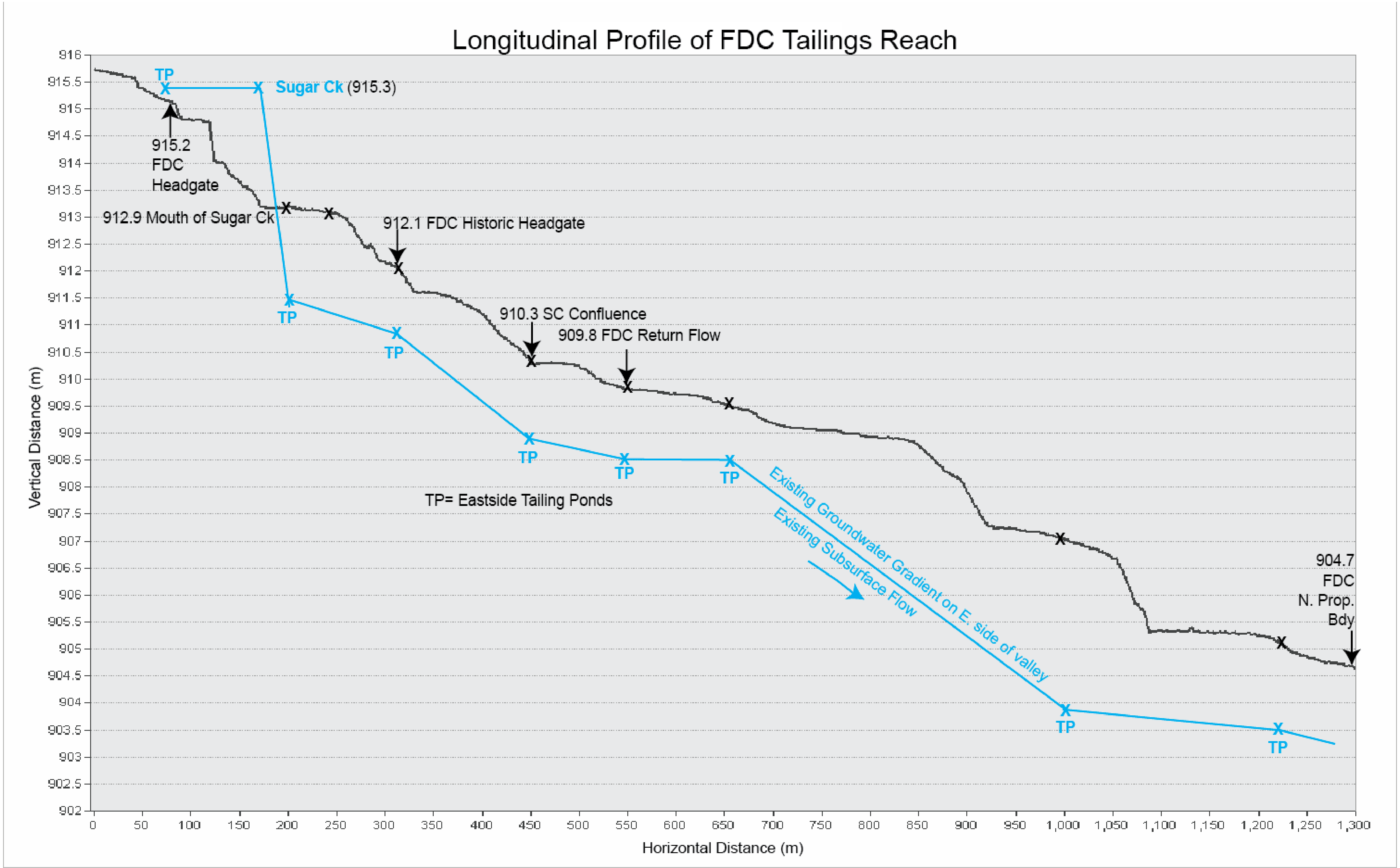


Fig. 3. Conceptual diagram of the mix-in-place construction method (Ishida et.al. 2003 retouched)

Scott River Dredge Tailings Reach



2018-Aug
Gravel Mining
Ponds
No Flowing Water
(for > 2 mi. downstream)
Diversion Return Flow
Critical Rifle
Sugar Ck Water
Boulder Weirs
FDC Diversion
No Standing Water



Longitudinal Profile of FDC Tailings Reach
Vertical Distance (m)
Horizontal Distance (m)
Sugar Ck (915.3)
915.2 FDC Headgate
912.9 Mouth of Sugar Ck
912.1 FDC Historic Headgate
910.3 SC Confluence
909.8 FDC Return Flow
TP= Eastside Tailing Ponds
Existing Groundwater Gradient on E. side of valley
Existing Subsurface Flow
904.7 FDC N. Prop. Bdy
TP


11.03.2014 15:07