Shelter in the Slow Lane: Off Channel Ponds and Beaver Influenced Habitats

A Conference Session at the 34th Annual Salmonid Restoration Conference held in Fortuna, CA from April 6-9, 2016.

Session Overview

- Session Coordinator:
  - Eli Asarian, Riverbend Sciences

Off-channel wetlands, ponds, and side channels provide slow water habitat where juvenile salmonids can find refuge during high winter flows. These refugia are particularly important to coho salmon. These slow water habitats can also offer rich invertebrate food resources, which in combination with reduced metabolic demand can result in high fish growth rates. Channelization, diking, and filling have caused widespread loss of such habitats. Restoring these critically important habitats is a currently a major focus of fisheries restoration, with techniques including reconnection of existing (but disconnected) ponds/wetlands, excavation of new ponds, and construction of channel-spanning structures such as large wood and beaver-dam analogs. Natural forces contributing to formation, maintenance, and complexity of slow water habitats include large wood, beavers, and channel migration. In addition to building dams, beavers can also promote cover and habitat complexity by digging tunnels into streambanks and bringing wood into the water including in side channels and backwaters. This session will feature presentations focusing on the lessons learned from experiences creating off-channel ponds/wetlands but will also include research on the ecology of slow water habitats.

Presentations

(Slide 4) Fast Life In The Slow Lane - Or How Flooding Facilitates The Floodplain Fatty Feeding Frenzy
Jacob Katz, Ph.D., California Trout

Slowing Down Fast Traffic: Adapting a Levee System Built For Speed to Provide a Bit of Comfort (and a Fatty Feeding Frenzy)
Eric Ginney, Environmental Science Associates (ESA)
*presentation not included

(Slide 66) Creating Off-Channel Coho Rearing Habitat in the Middle Klamath River Sub-basin: A Status Review of Constructed Projects (2010-2015)
Will Harling, Mid Klamath Watershed Council

(Slide 127) The Influence of Habitat Characteristics on Juvenile Coho Salmon Abundance and Growth in Constructed Off-Channel Habitats in the Middle Klamath River Sub-basin
Michelle Krall, Humboldt State University

(Slide 160) Physical and Biological Monitoring of Beaver Dam Analogs in the Scott River Watershed
Erich Yokel, Scott River Watershed Council

(Slide 202) The Role Beavers Have in Creating Salmonid Rearing Habitats in Coastal California Streams Lacking Perennial Beaver Dams
Marisa Parish, Humboldt State University and Smith River Alliance, and Justin Garwood, California Department of Fish and Wildlife

Fins, Feathers, Farms and Flood Control

Managing Floodplain Productivity for Multiple Benefits

Jacob Katz – California Trout

C. Jeffres

CALIFORNIA TROUT

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Managing floodplains for multiple uses:

- Flood protection
- Agriculture
- Aquifer recharge
- Critical habitat for:
  Native fish and wildlife
- Food web production

Inland Sea

K, STREET, FROM THE LEVEE.

INUNDATION OF THE STATE CAPITOL,

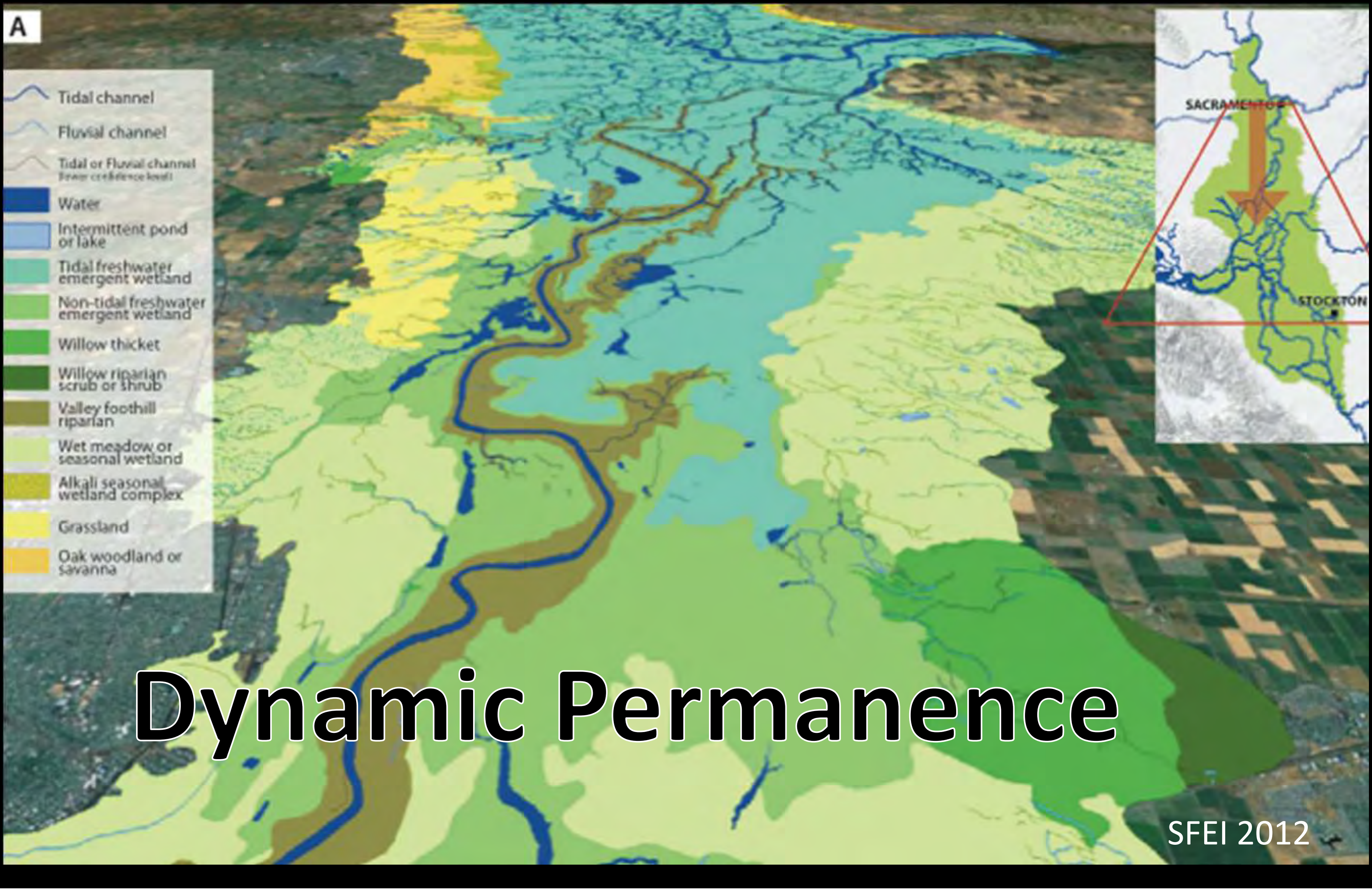
City of Sacramento, 1862.

Published by A ROSENFIELD; San Francisco

Flood of 1862

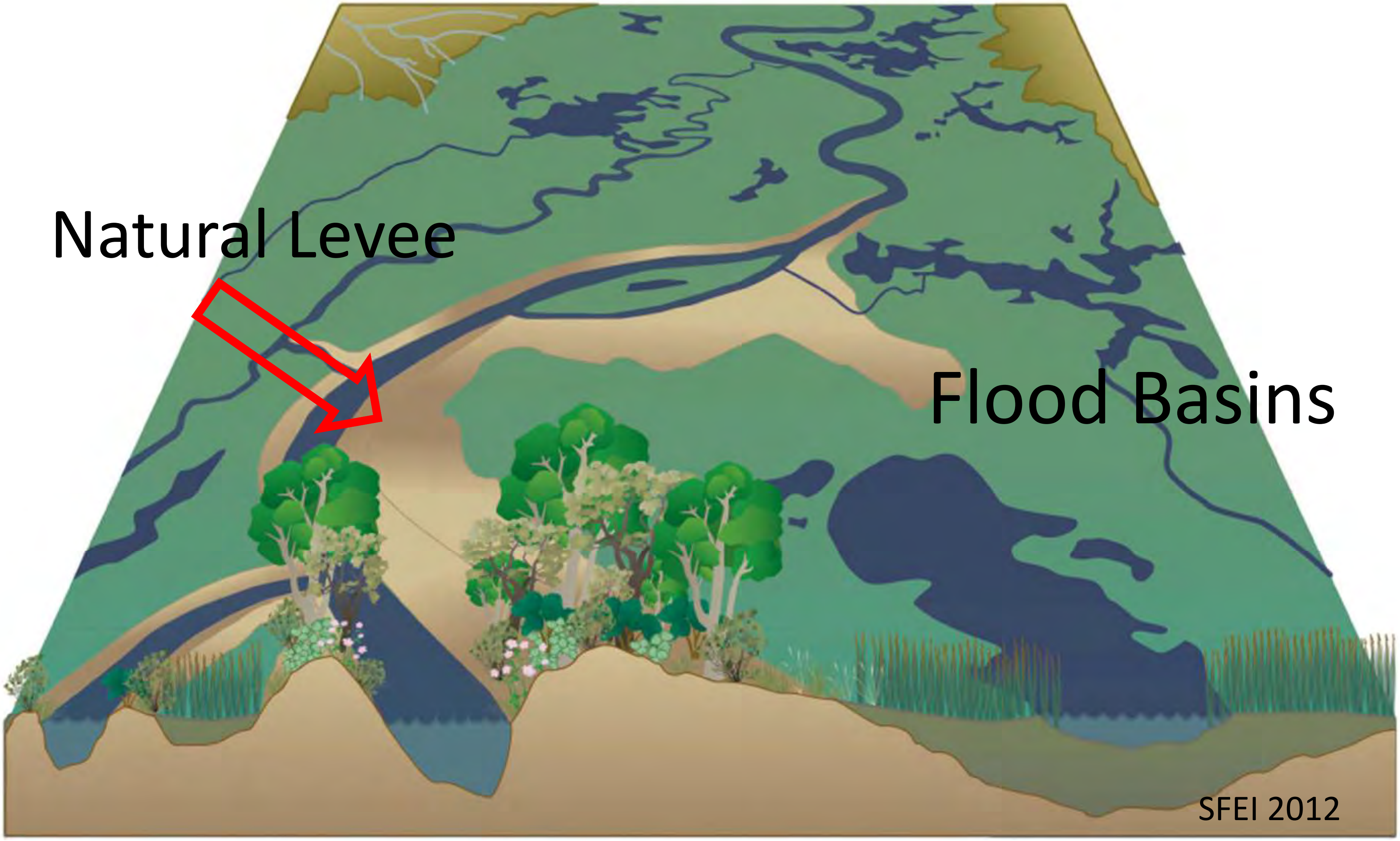
J street

A Shifting Mosaic of Wetland Habitat Types



Dynamic Permanence

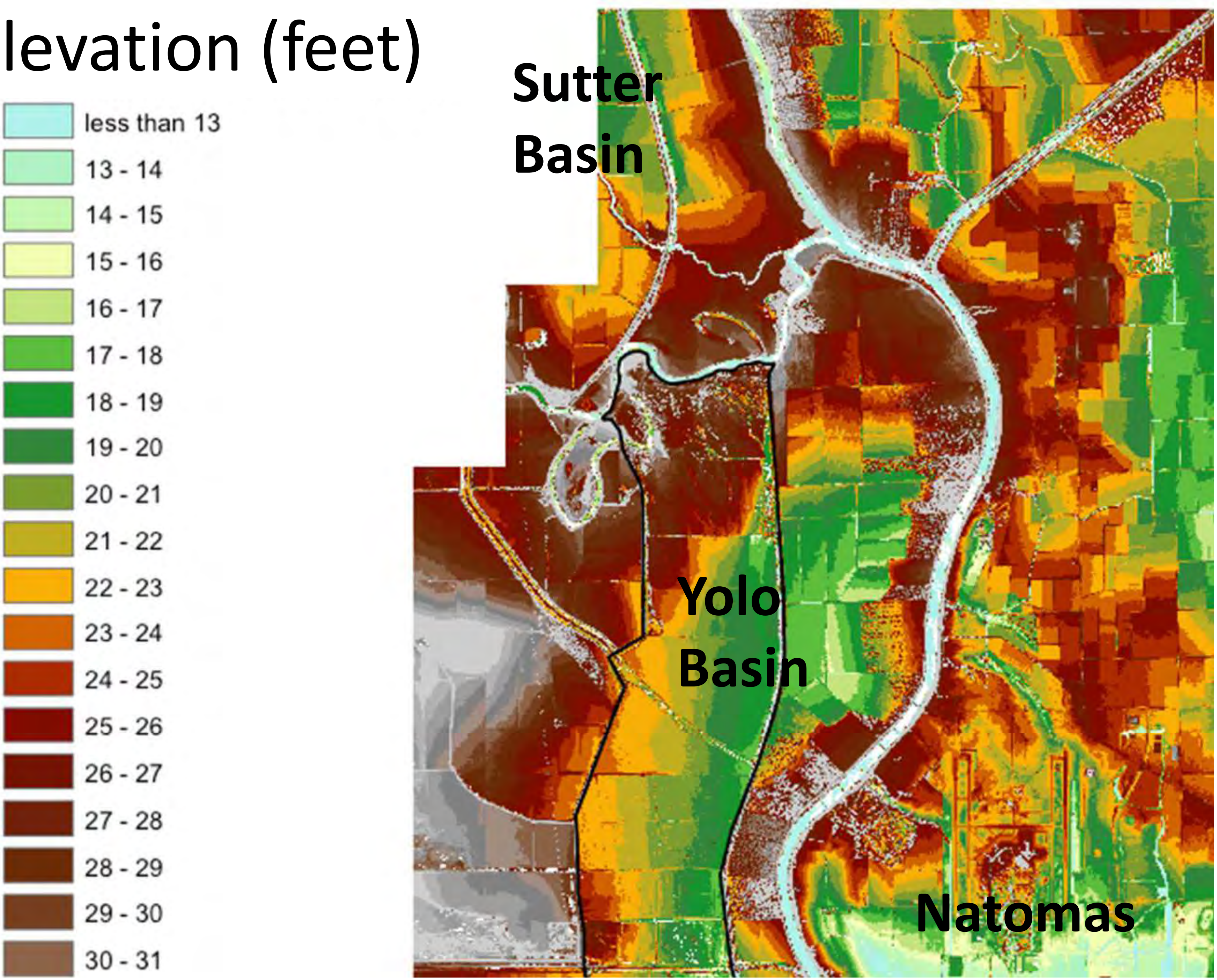
SFEI 2012



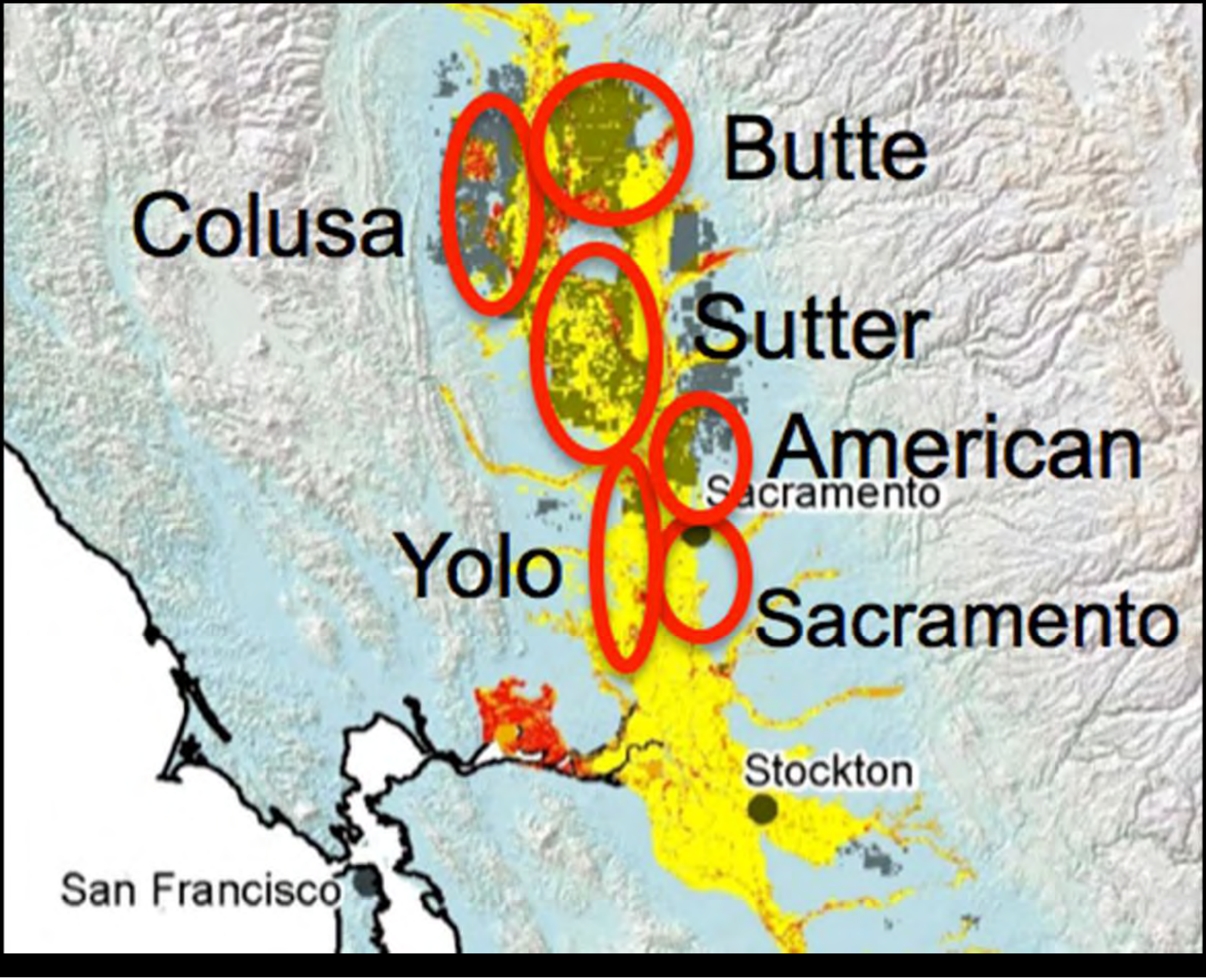
SFEI 2012

Fluvial Processes

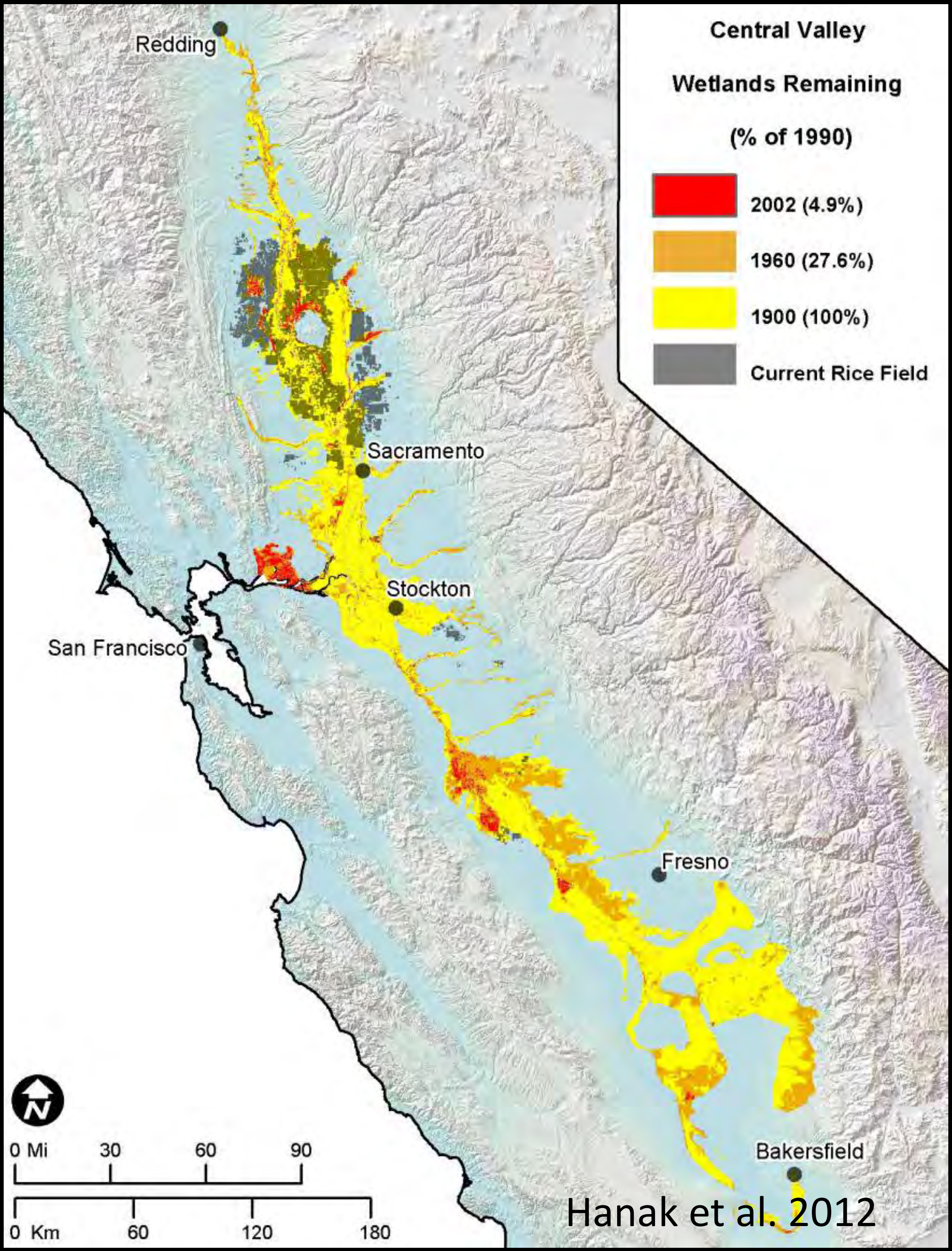
Elevation (feet)



Sac Valley Flood Basins



13,000 miles of levees



Hanak et al. 2012

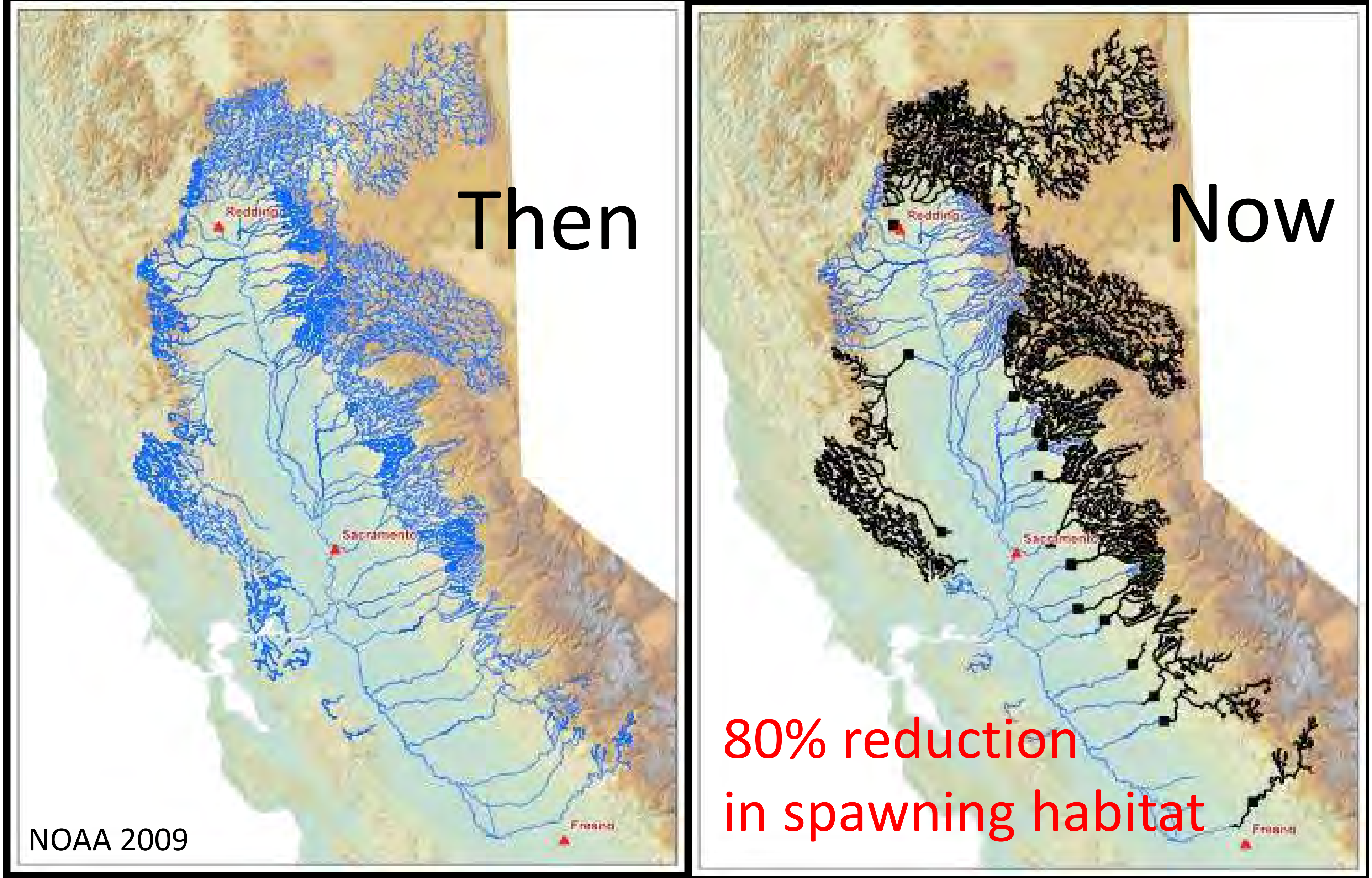
Central Valley Floodplain reduced by more than 95%

Rearing Habitat lost

Every major river in California dammed-

At least once

Central Valley Water Infrastructure – Dams



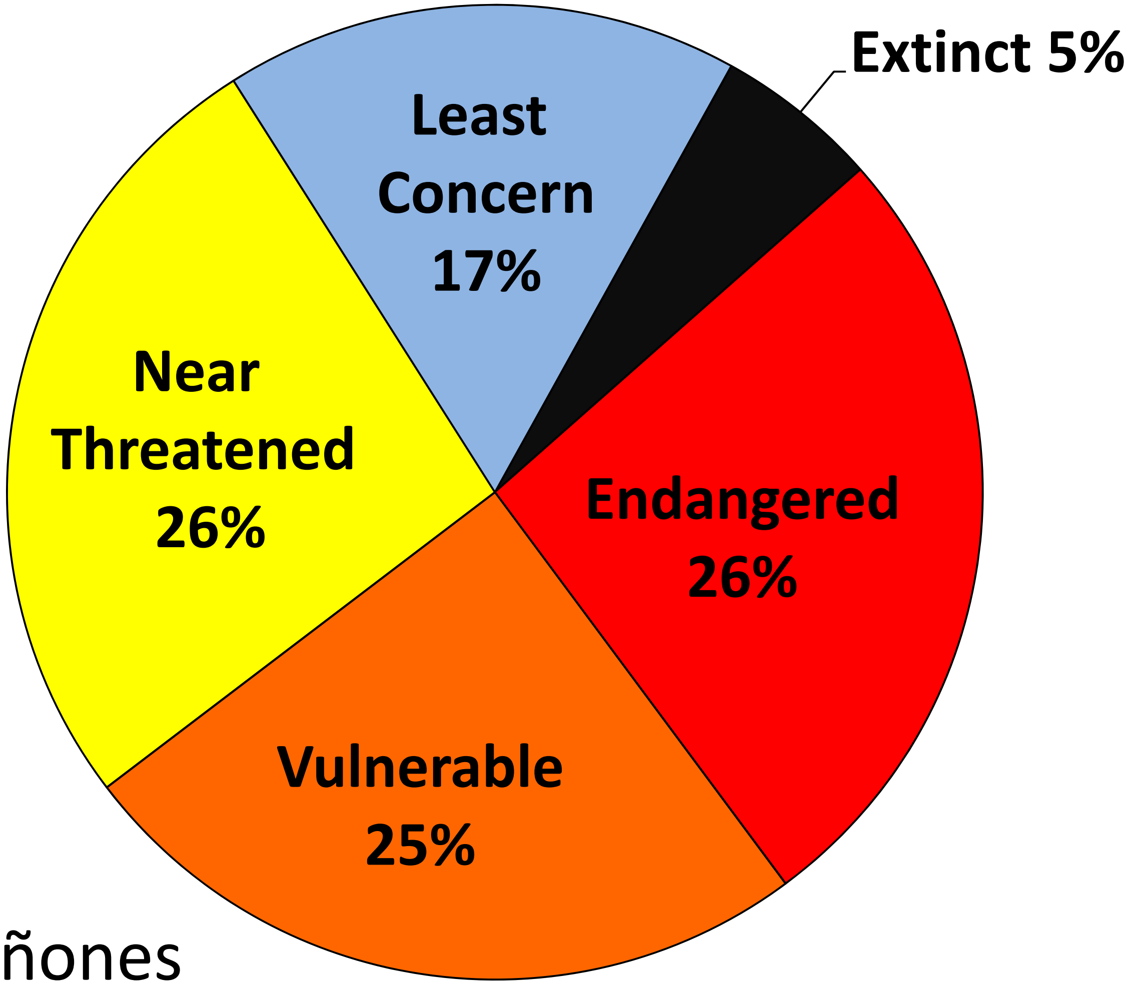
80% reduction in spawning habitat

NOAA 2009

CA NATIVE FISHES

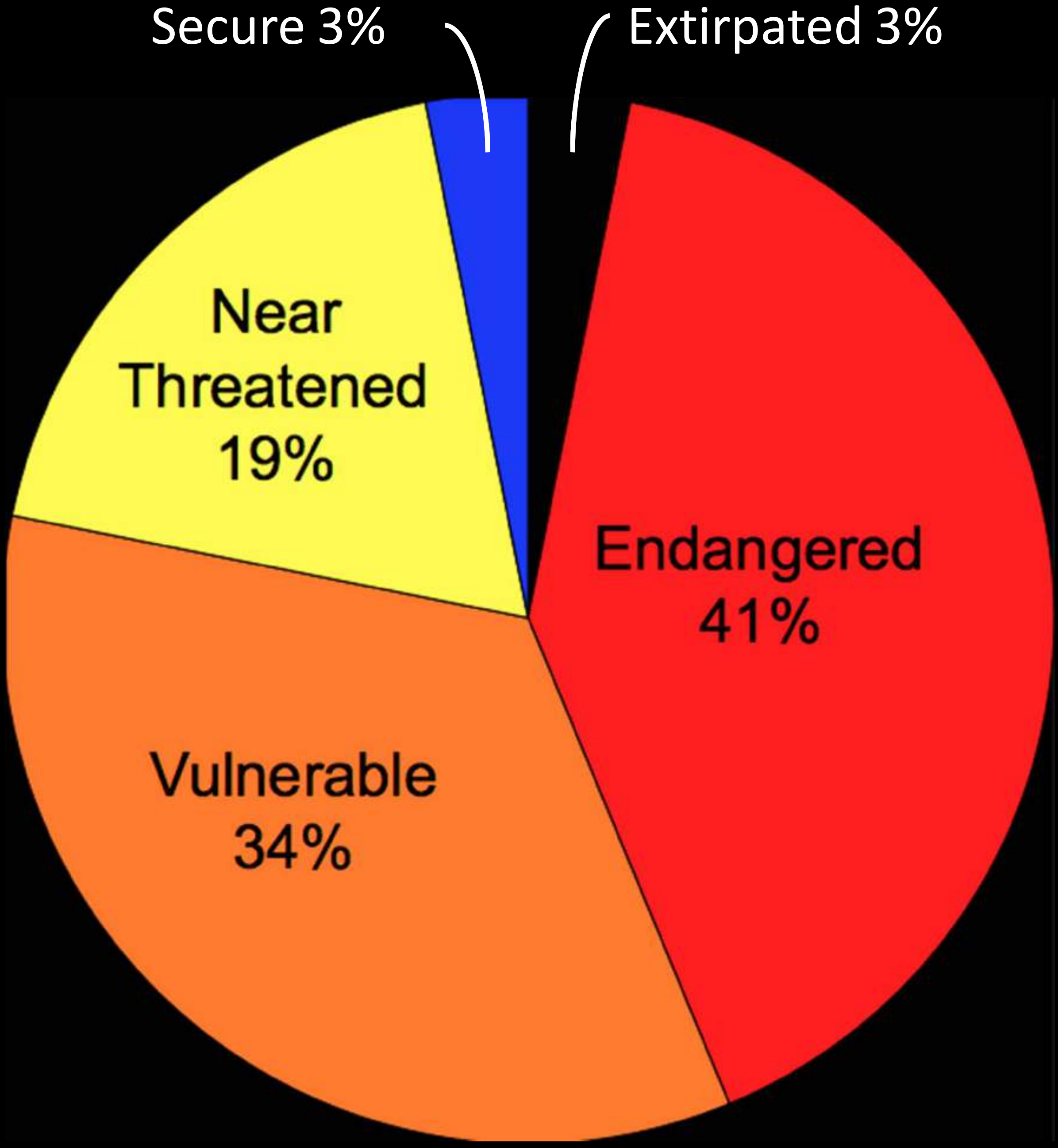
83%

Extinct or in decline



N=129

Moyle, Katz & Quiñones
Biological Conservation,
Vol 144, issue 10, Oct. 2011



Impending extinction of CA salmonids

Vast Majority (94%) of California native salmonids in sharp decline

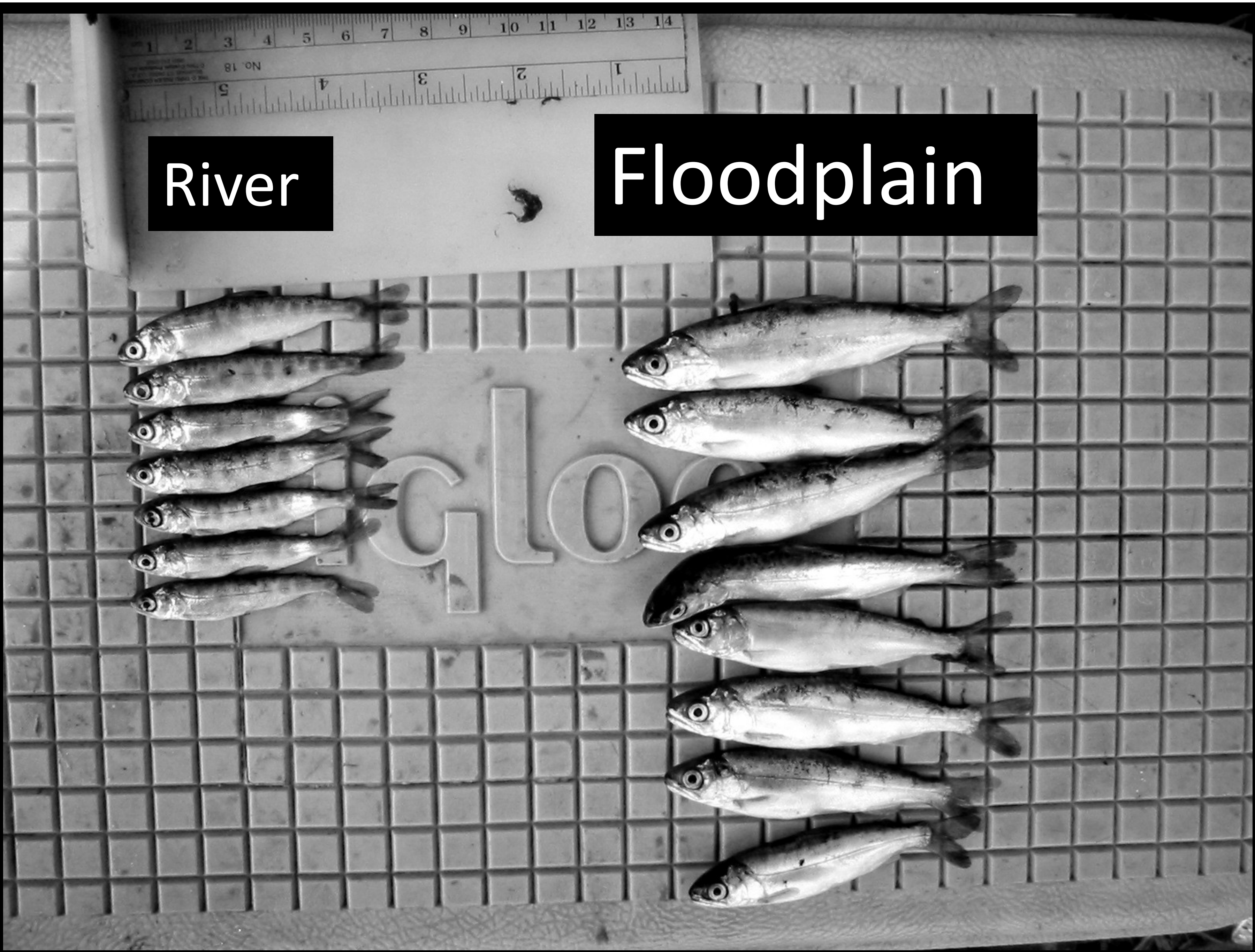
Katz et al. 2013
Env. Biology of Fishes 10

Central Valley Chinook

Of 4 runs
3 are endangered, the other is dominated by hatcheries

Cosumnes River 2008

No Dams = Floods with winter rain events = inundates floodplain



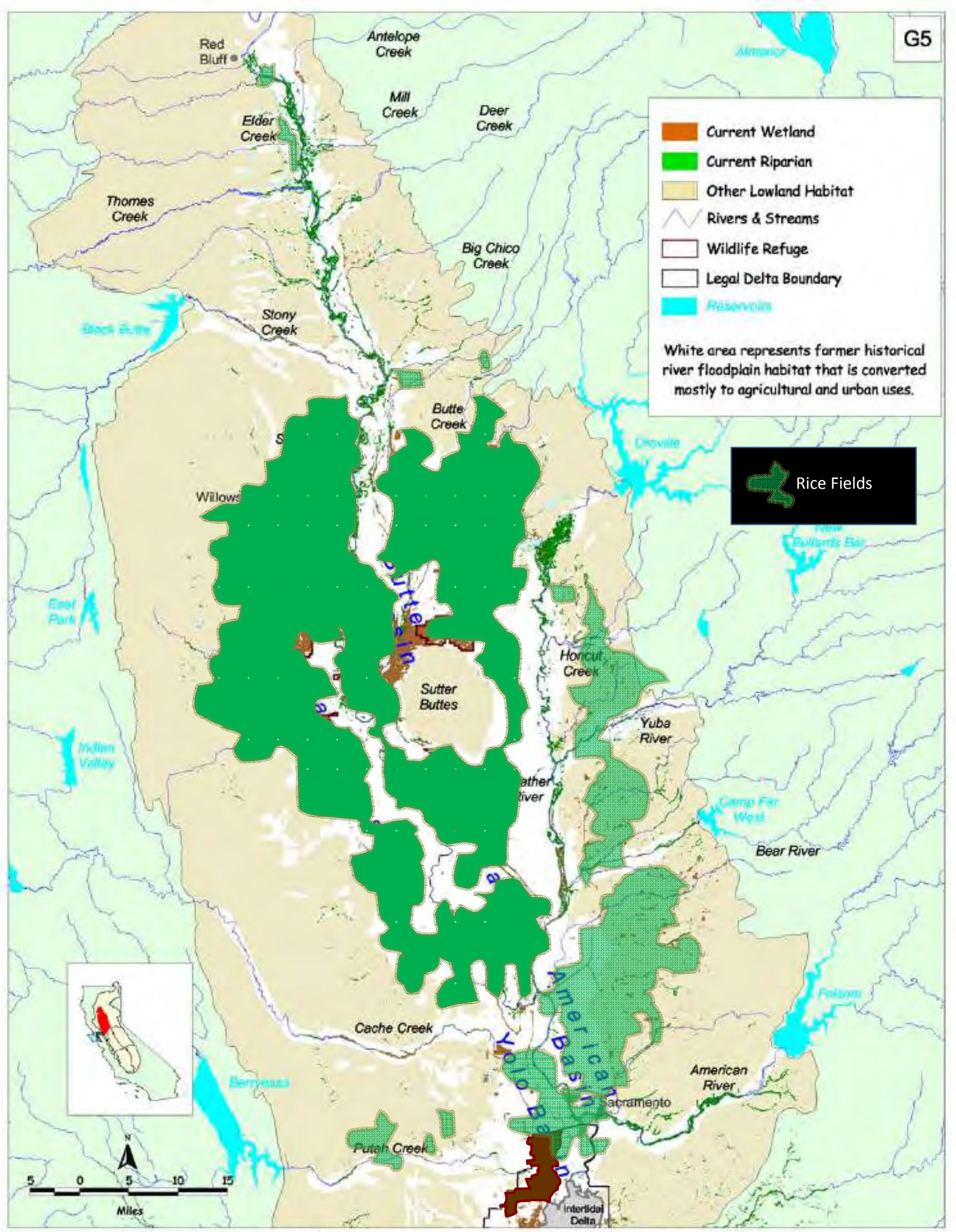
Jeffres et al. 2008

Historic:

Fall run Chinook evolved
 rearing on floodplains

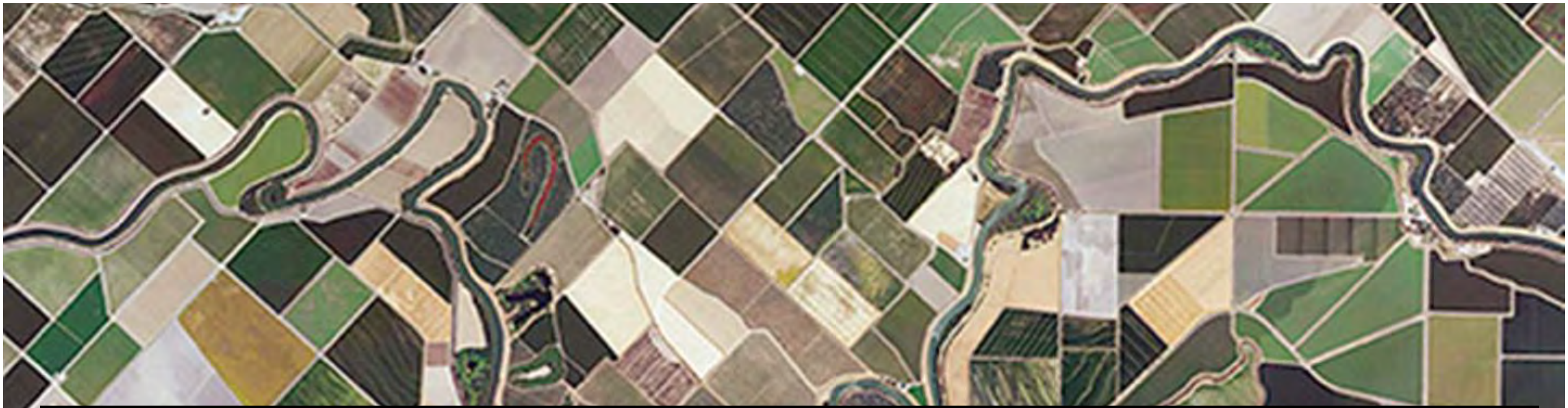
TODAY:

- 95% of floodplains lost
- drained and converted to rice.
- In California 550,000 acres of rice is farmed annually.
- Now, many of the rice fields are managed for migrating birds during winter months.



White area represents former historical river floodplain habitat that is converted mostly to agricultural and urban uses.

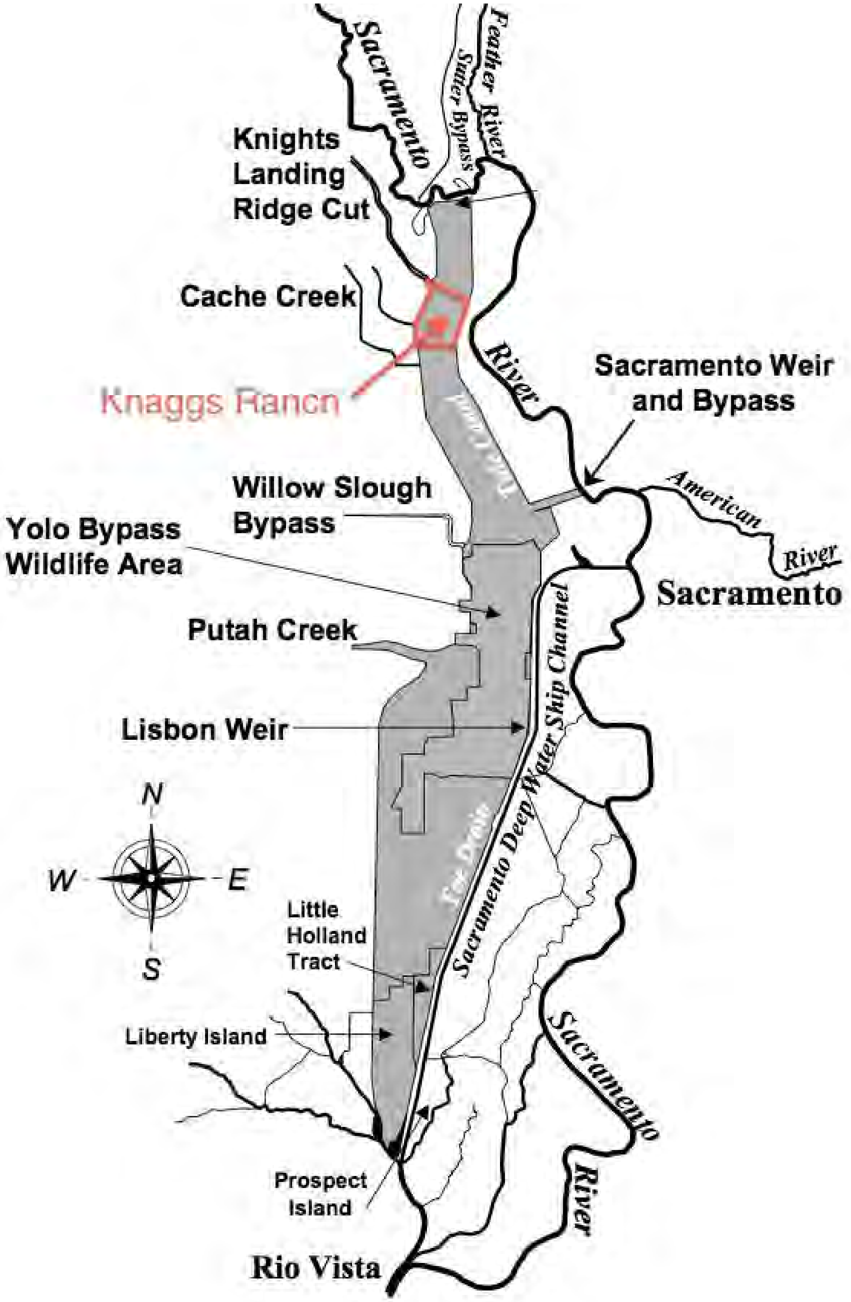
Sacramento Valley Current River Floodplain Ecosystem

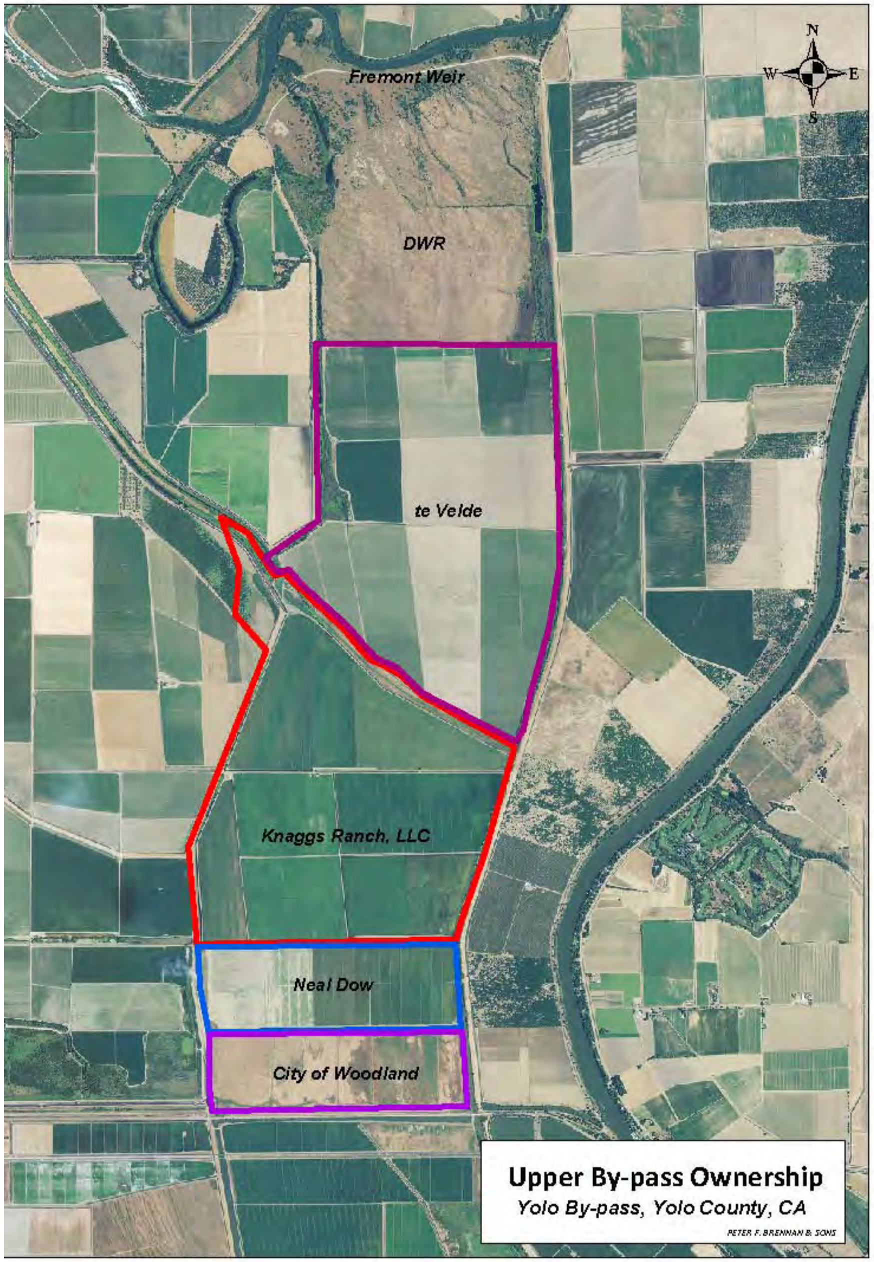


We are never going back

Mimicking natural floodplain processes in post-harvest floodplain rice fields

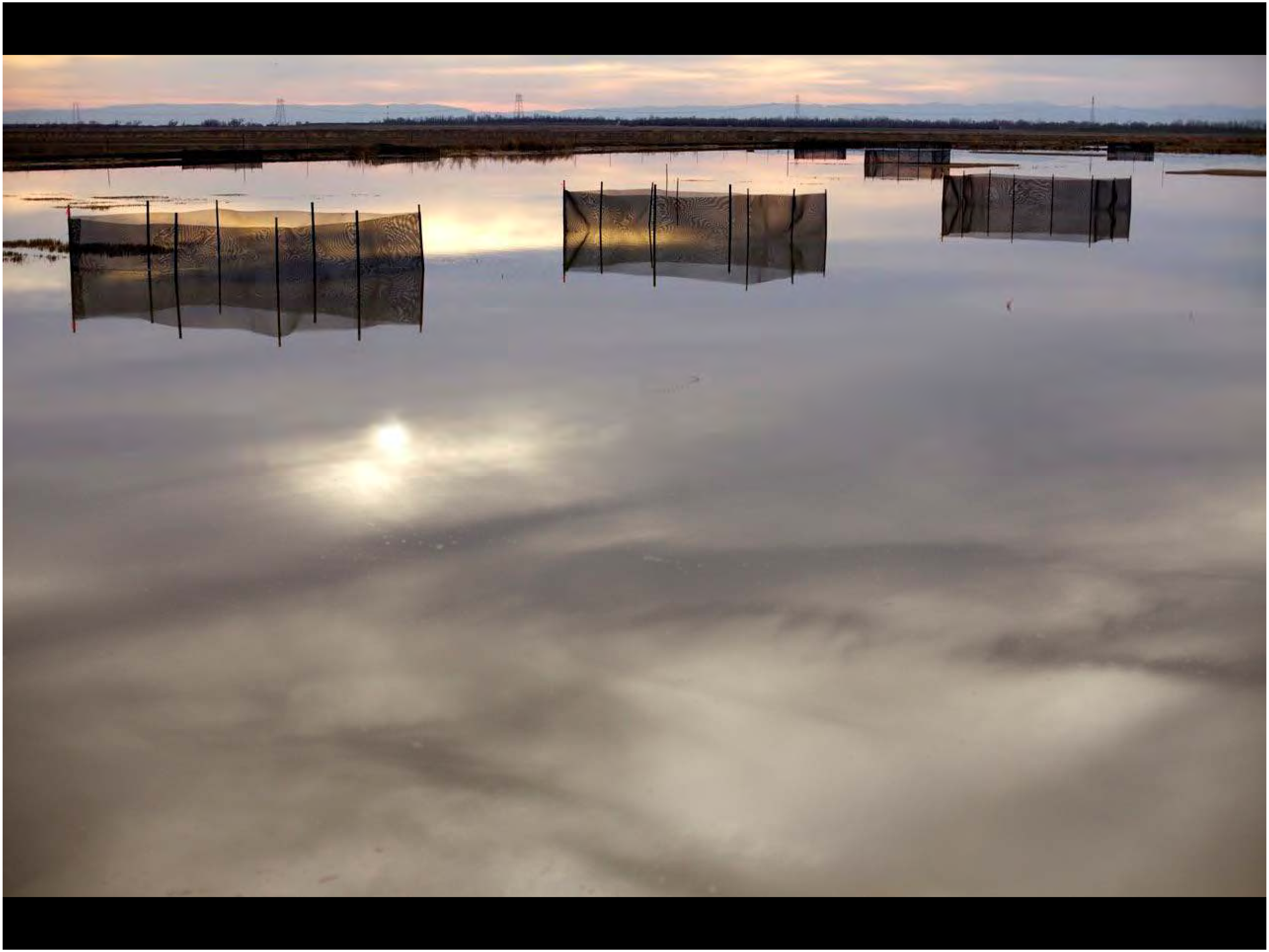
Knaggs Ranch on Yolo Bypass

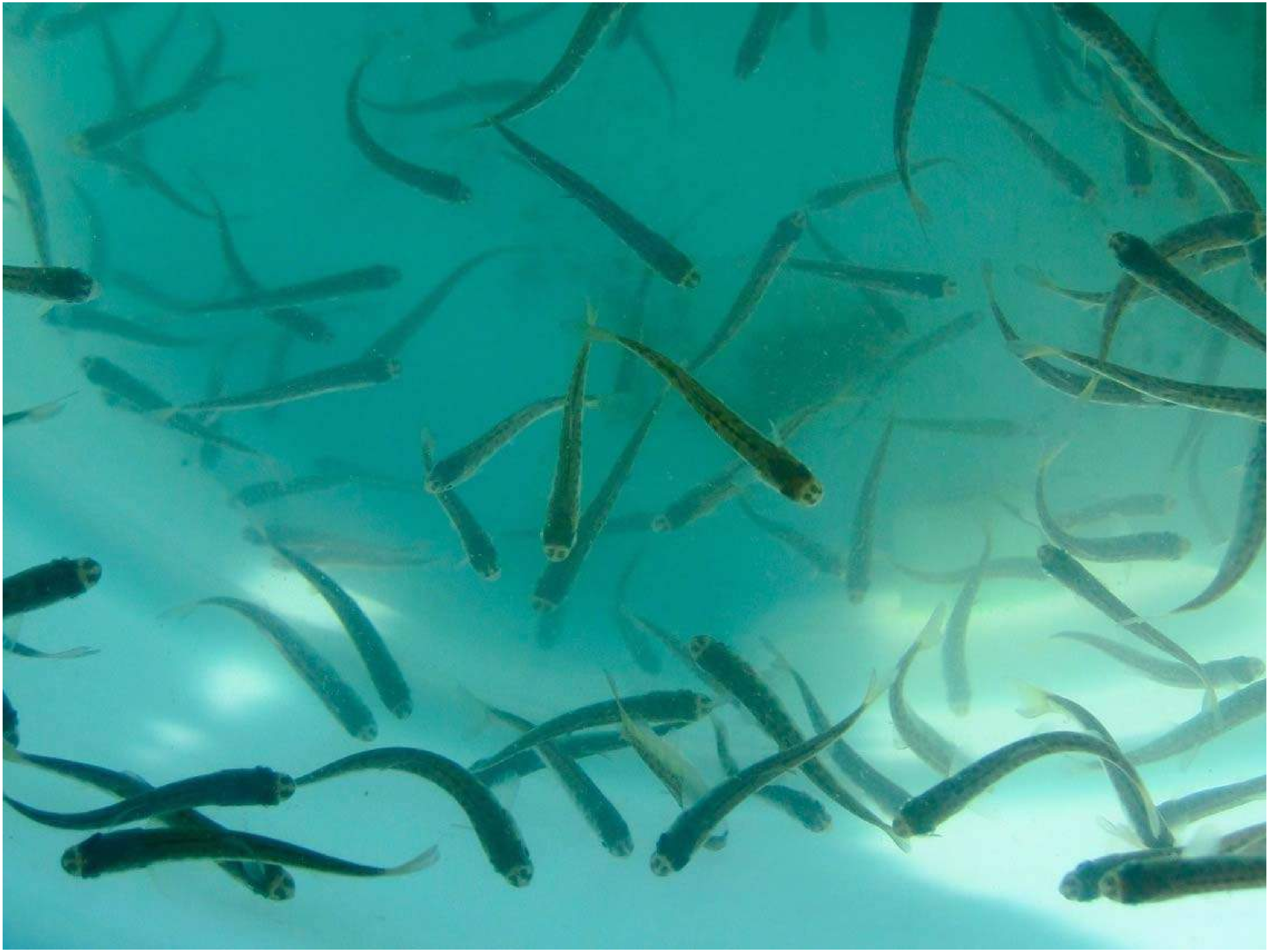




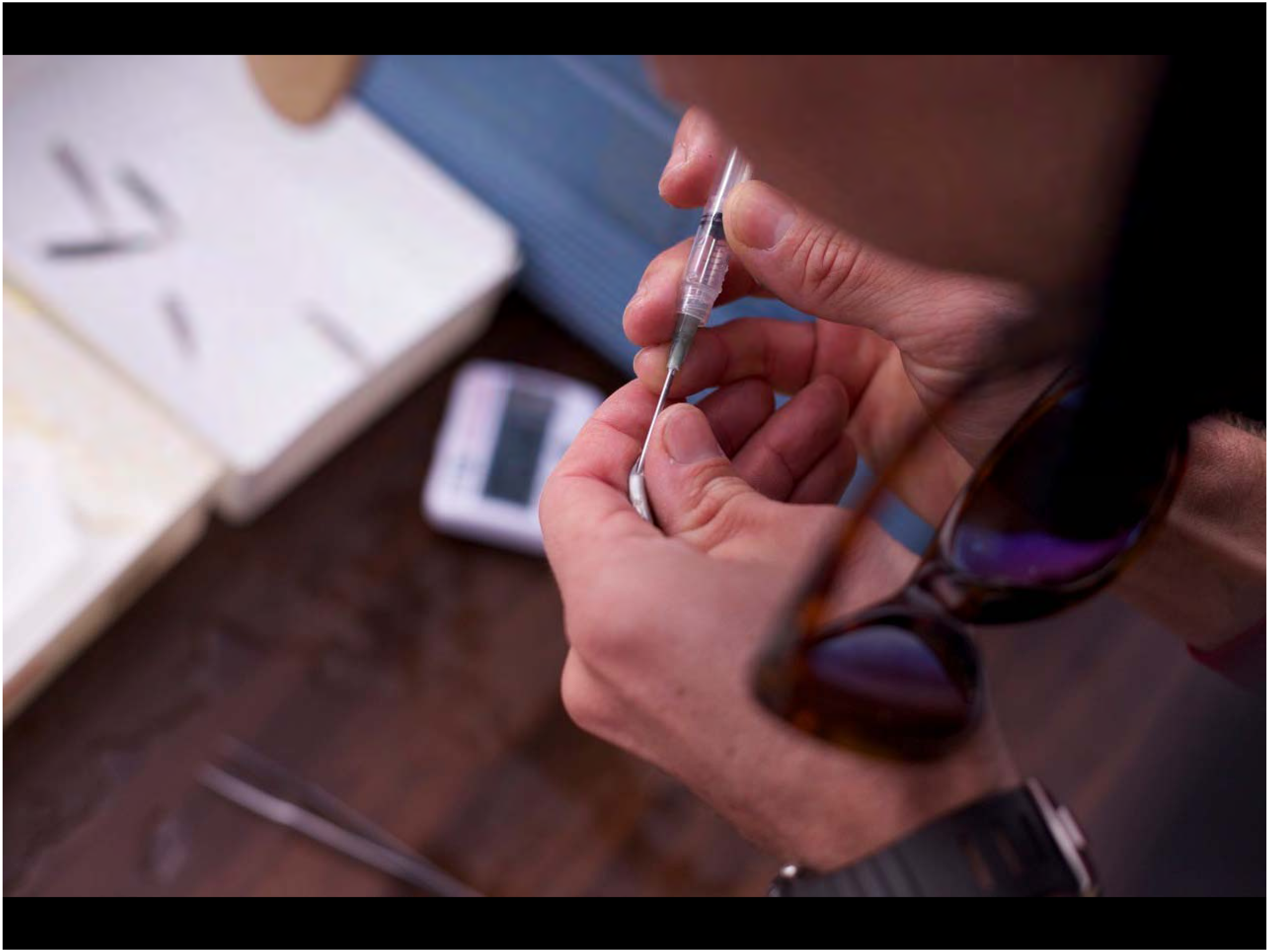
Post Rice Harvest - November

Carson Jeffres





Passive integrated transponder (PIT tags)

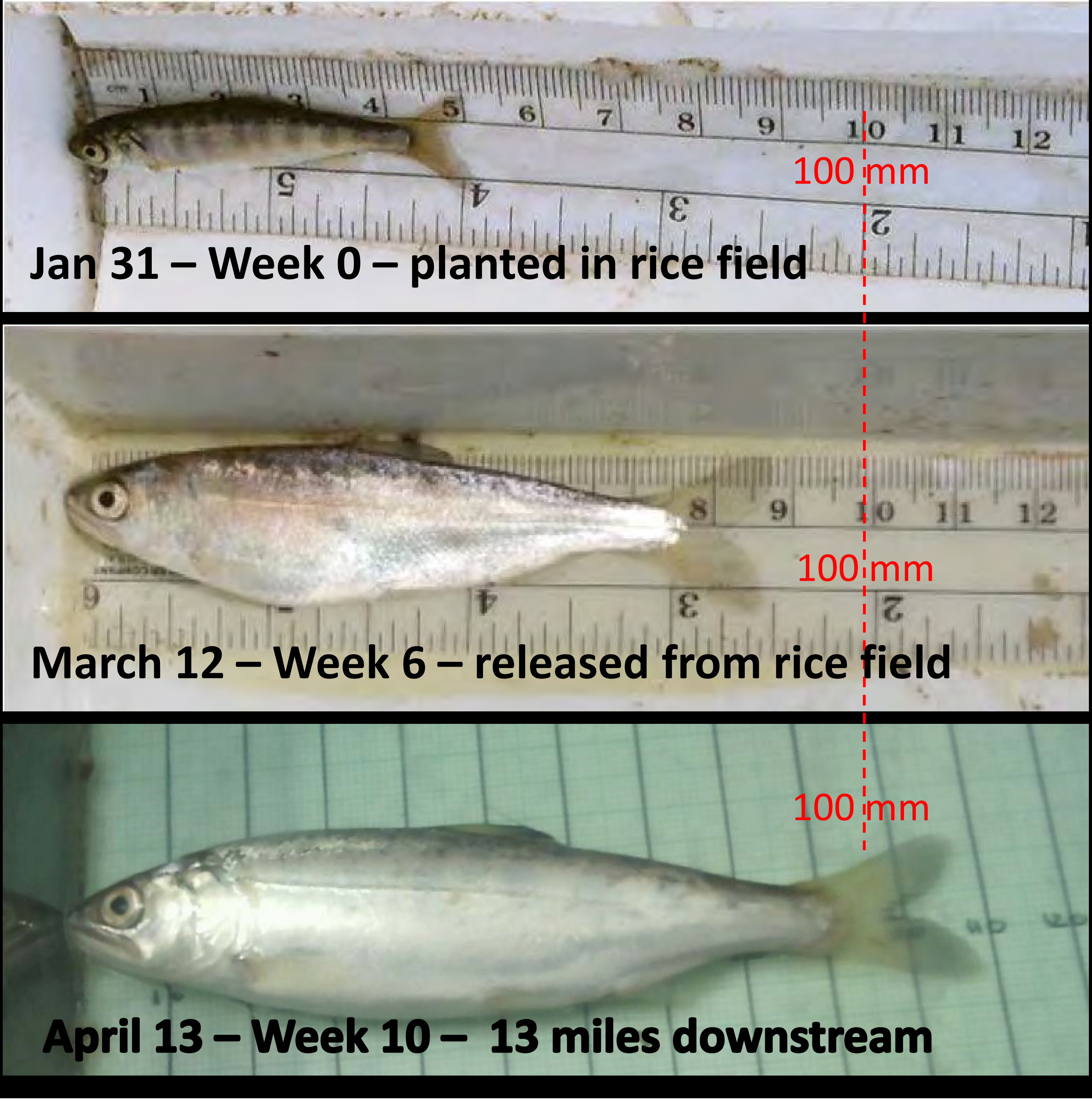


Fish measured every 2 weeks

After 6 weeks field drained

Fish measured and tags read

GROWTH



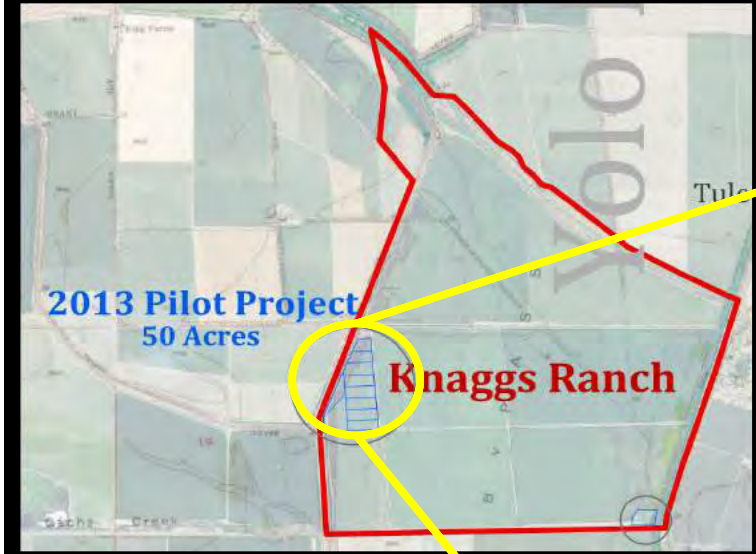
Jan 31 – Week 0 – planted in rice field

March 12 – Week 6 – released from rice field

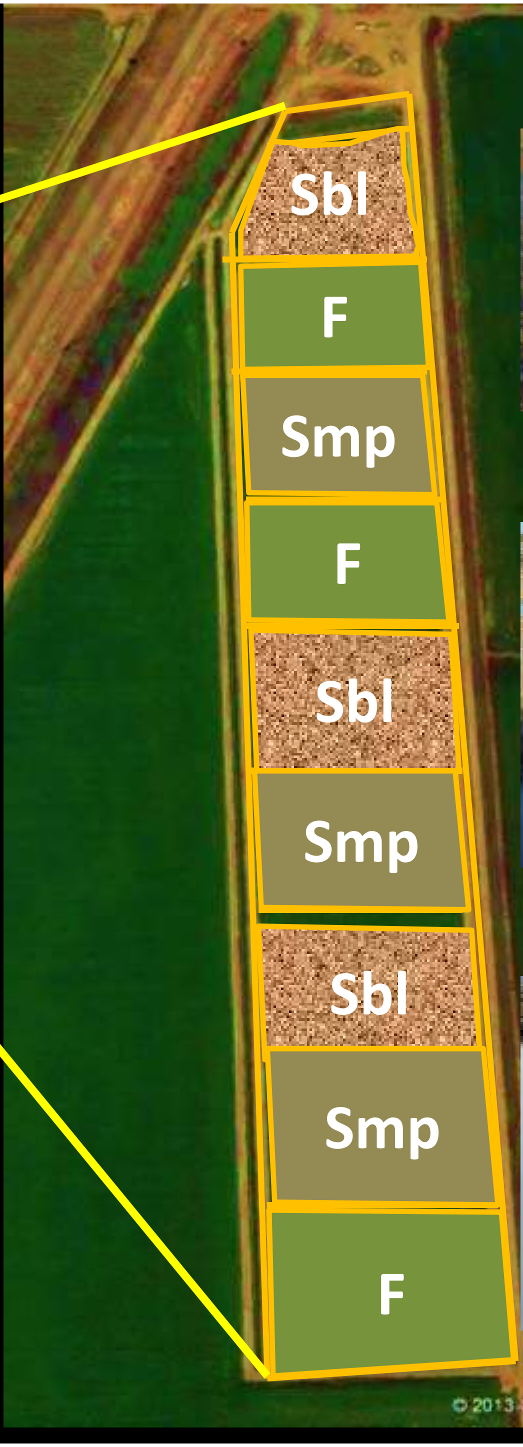
April 13 – Week 10 – 13 miles downstream

Nine 2-acre fields

2013: Farm Practices?



42,000 hatchery fish



Substrate type?

Fallow

Stubble

Stomped

Day 0 Day 38

2013

3/19

53 mm

1.5 g

4/27

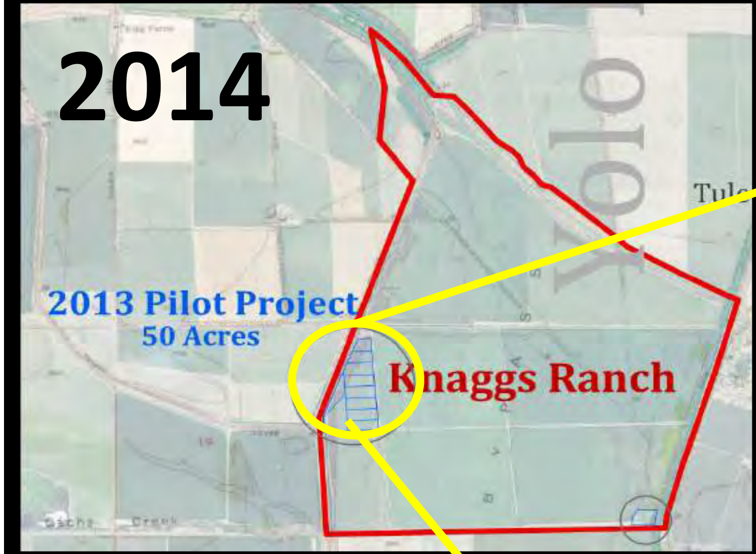
90 mm

9.4 g

0.94 mm/d

0.18 g/d

3 Ditch Depth Treatments



45,000 hatchery fish,
400 Feather River "wild" fish

All Fields Stomped

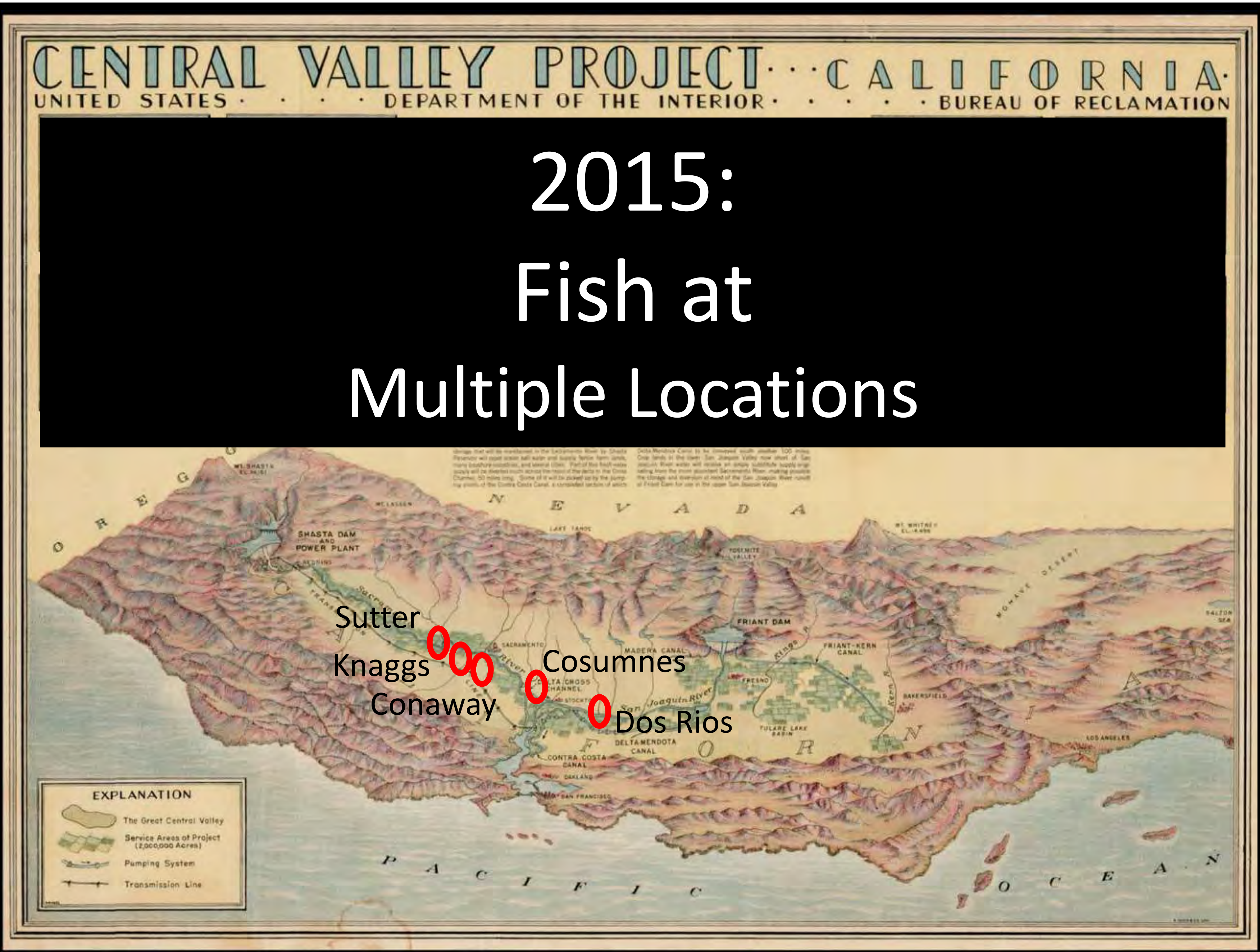
2014

Similar Growth
(1 mm/day)

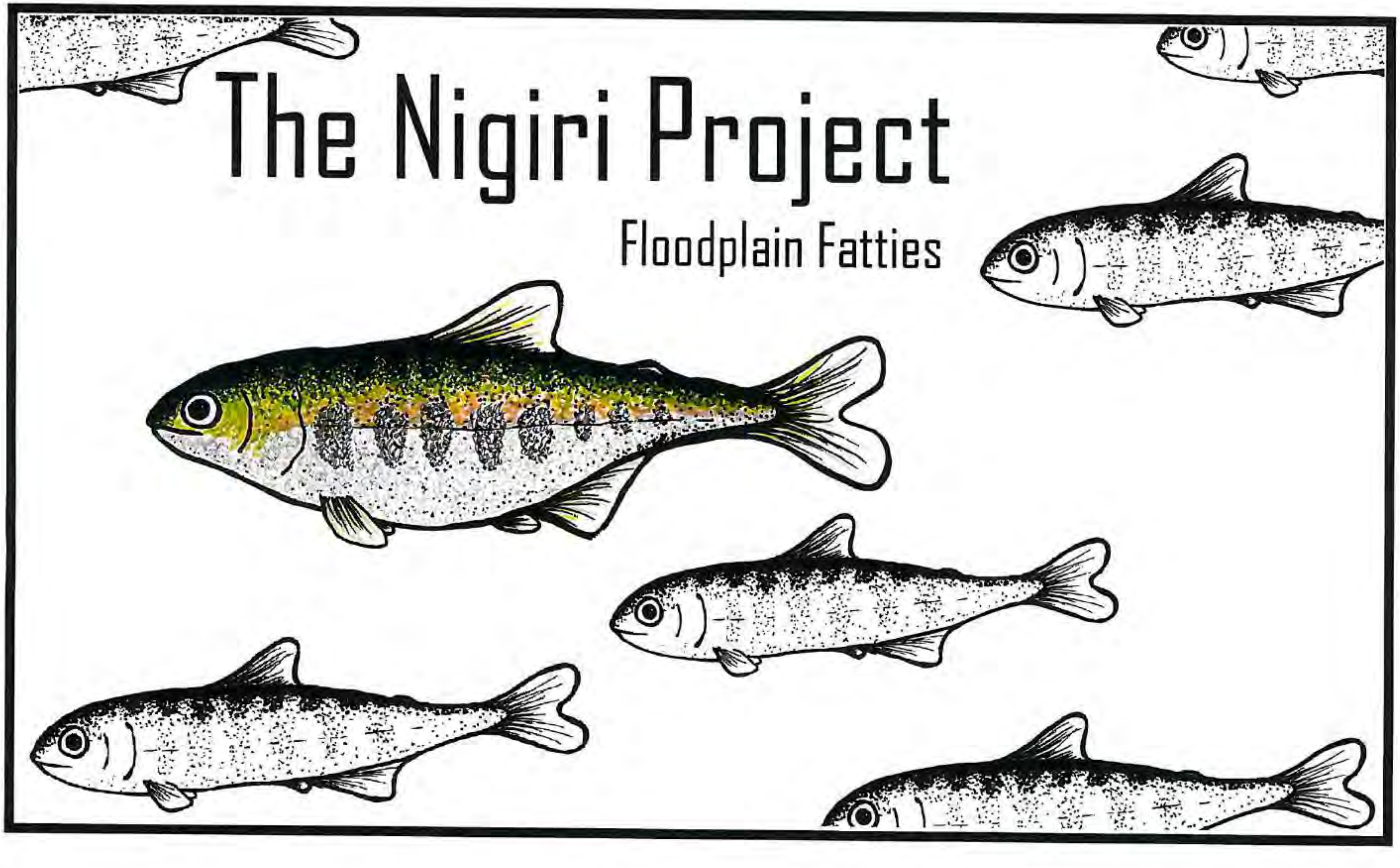
Better
Survival

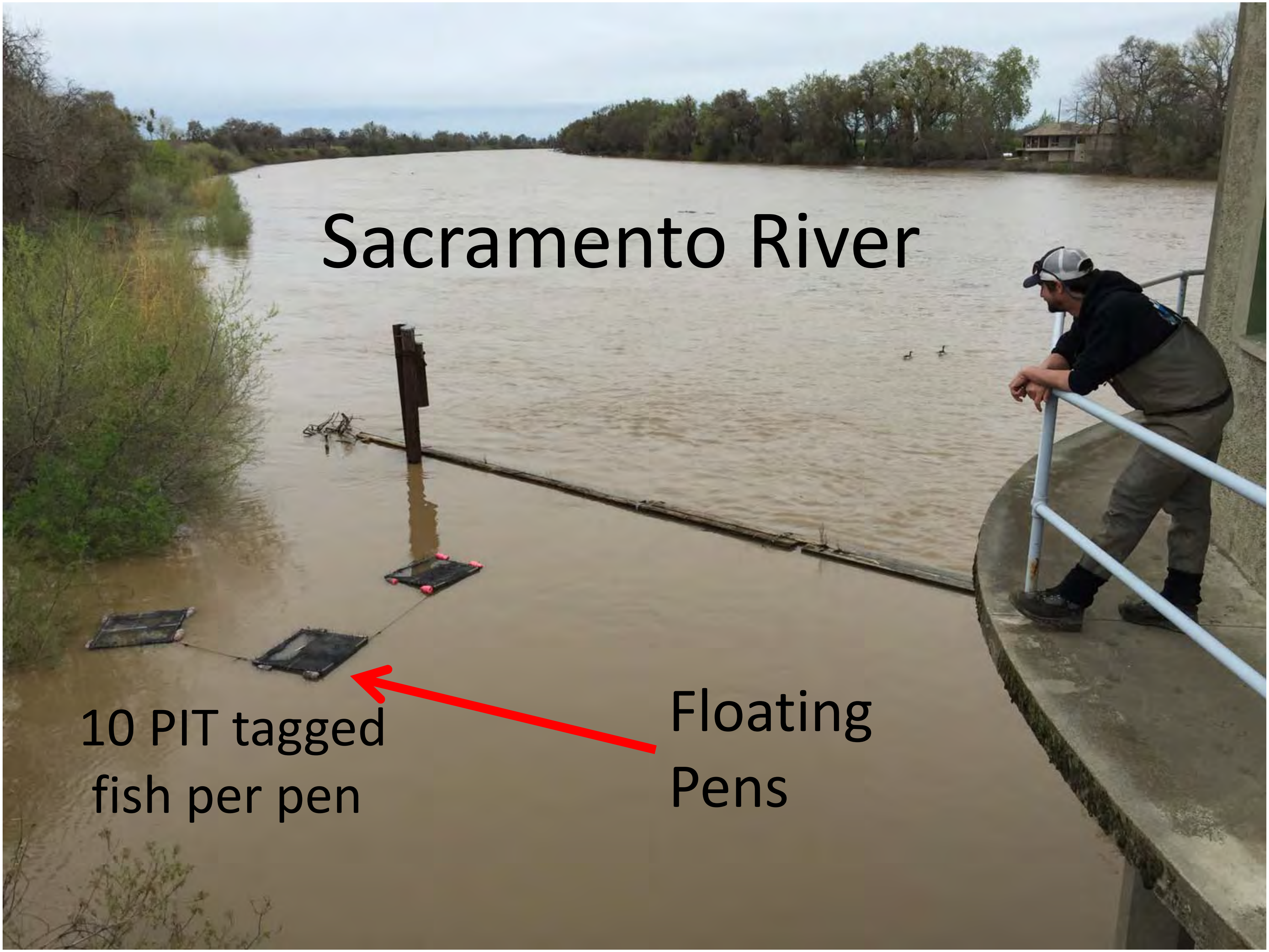
(Approx. 50%)

2015:
Fish at
Multiple Locations



Same Result

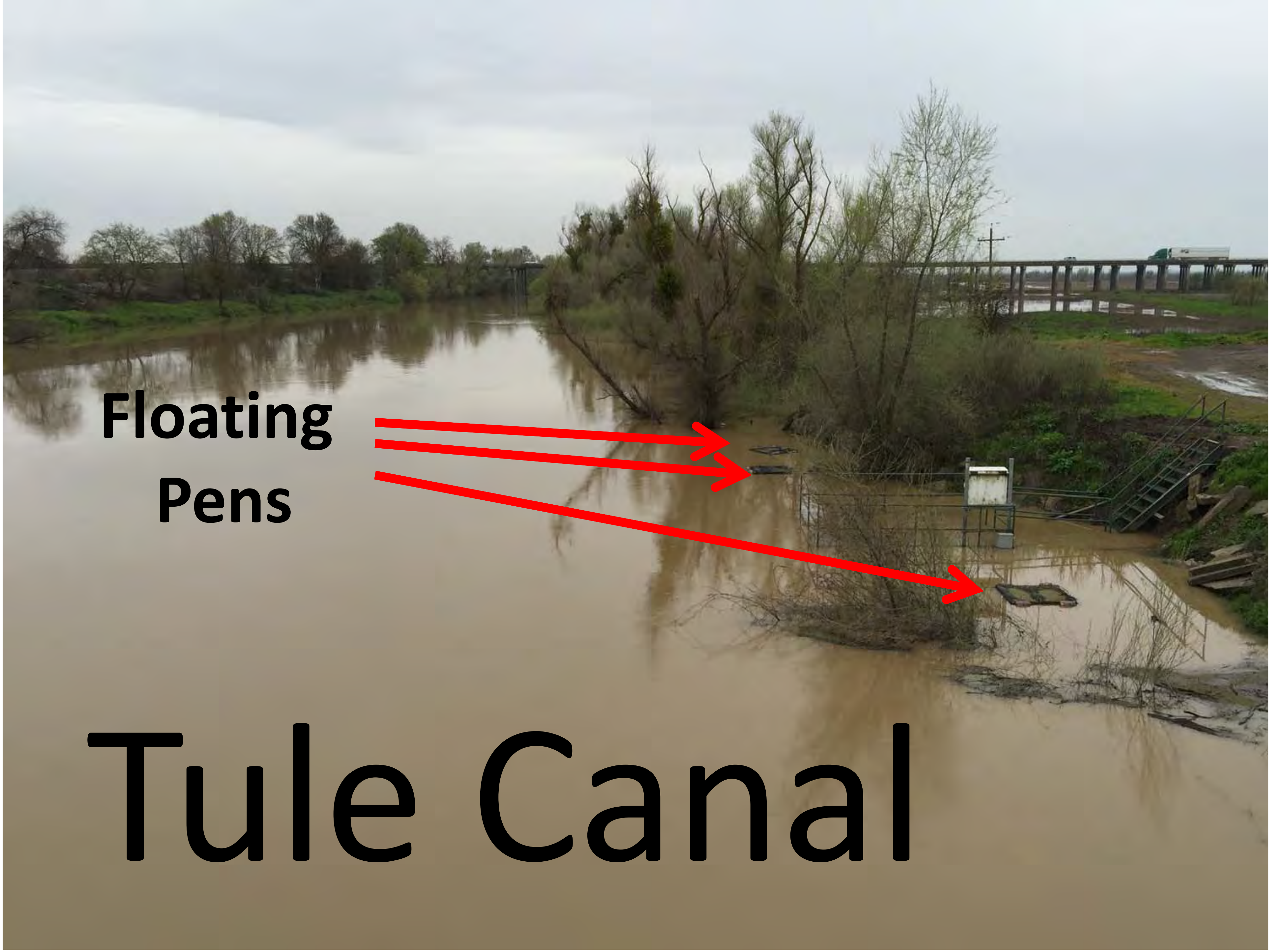




Sacramento River

10 PIT tagged fish per pen

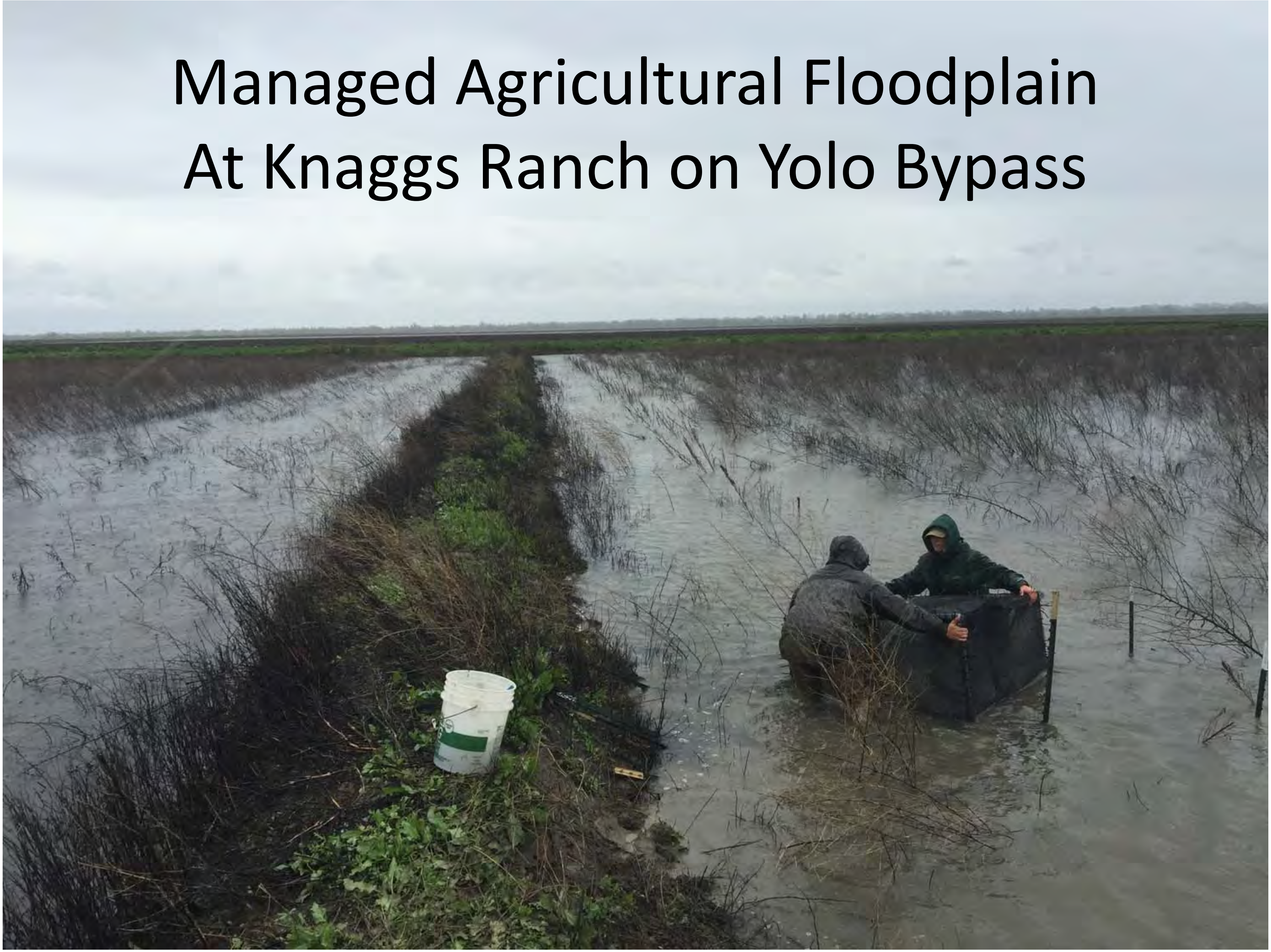
Floating Pens



Floating Pens

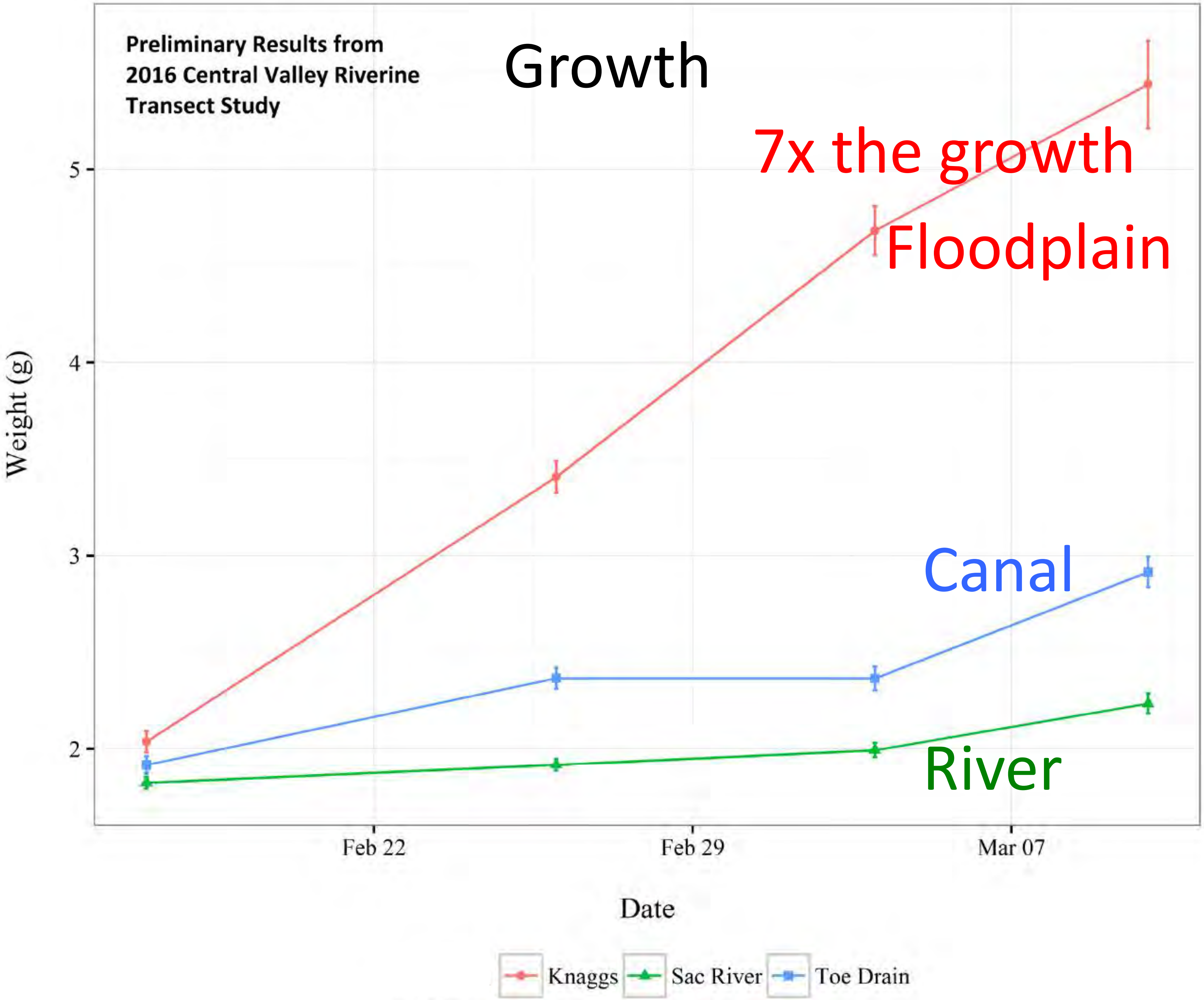
Tule Canal

Managed Agricultural Floodplain At Knaggs Ranch on Yolo Bypass



These fish were the same size 3 weeks ago

Growth



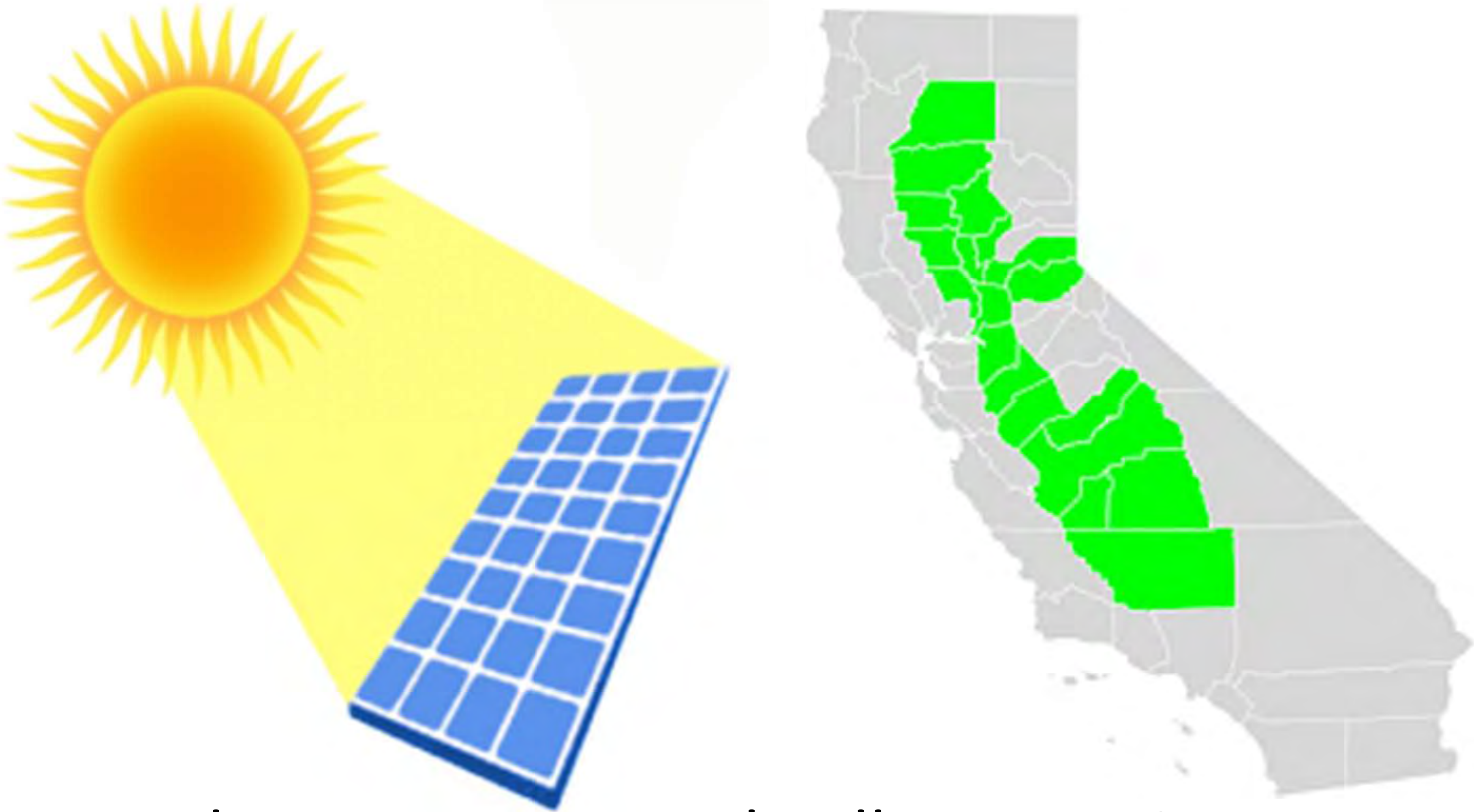
7x the growth

Floodplain

Canal

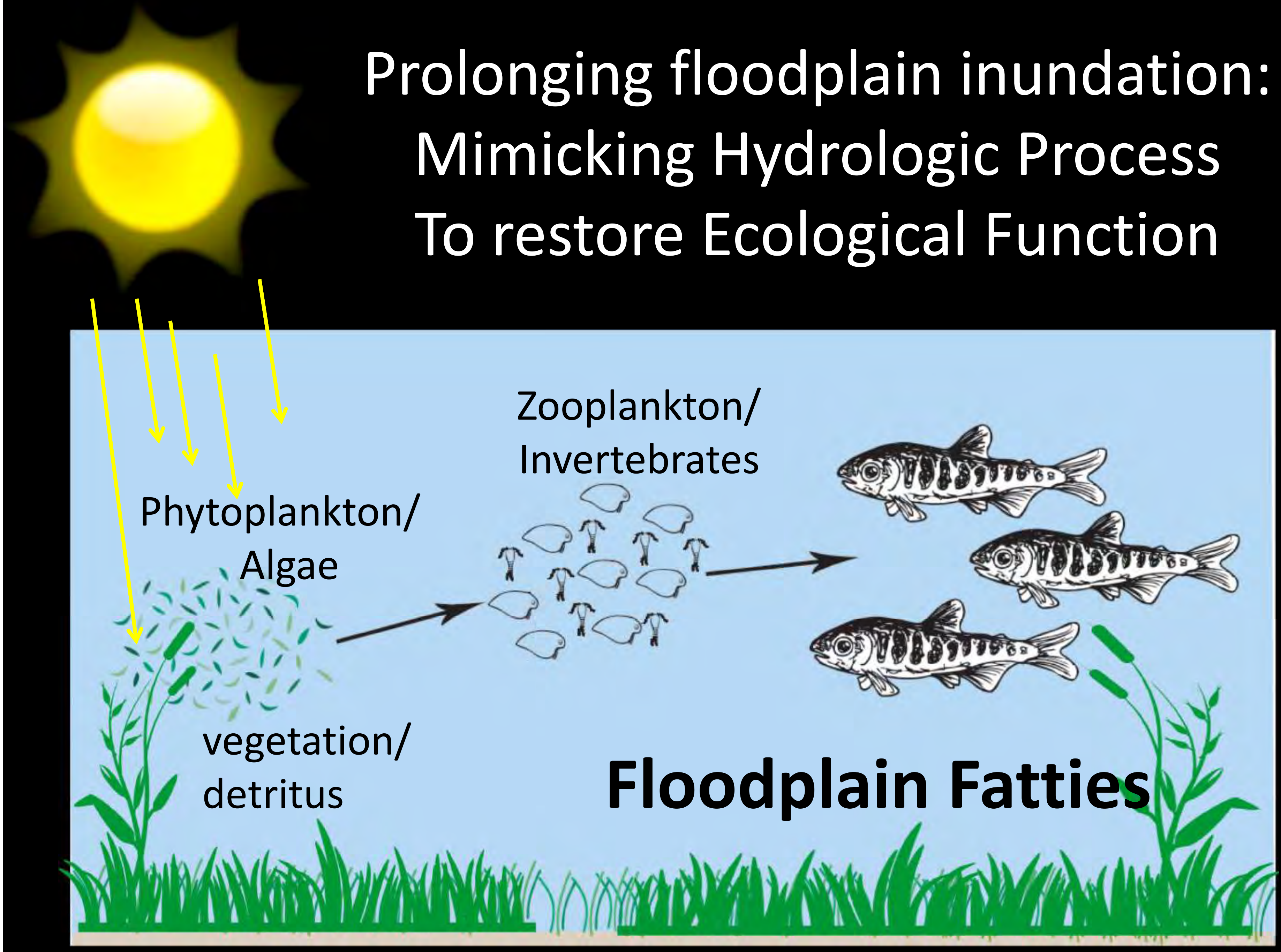
River

Floodplains are the solar collectors



That power Central Valley aquatic food webs

Prolonging floodplain inundation: Mimicking Hydrologic Process To restore Ecological Function



Phytoplankton/
Algae

Zooplankton/
Invertebrates

vegetation/
detritus

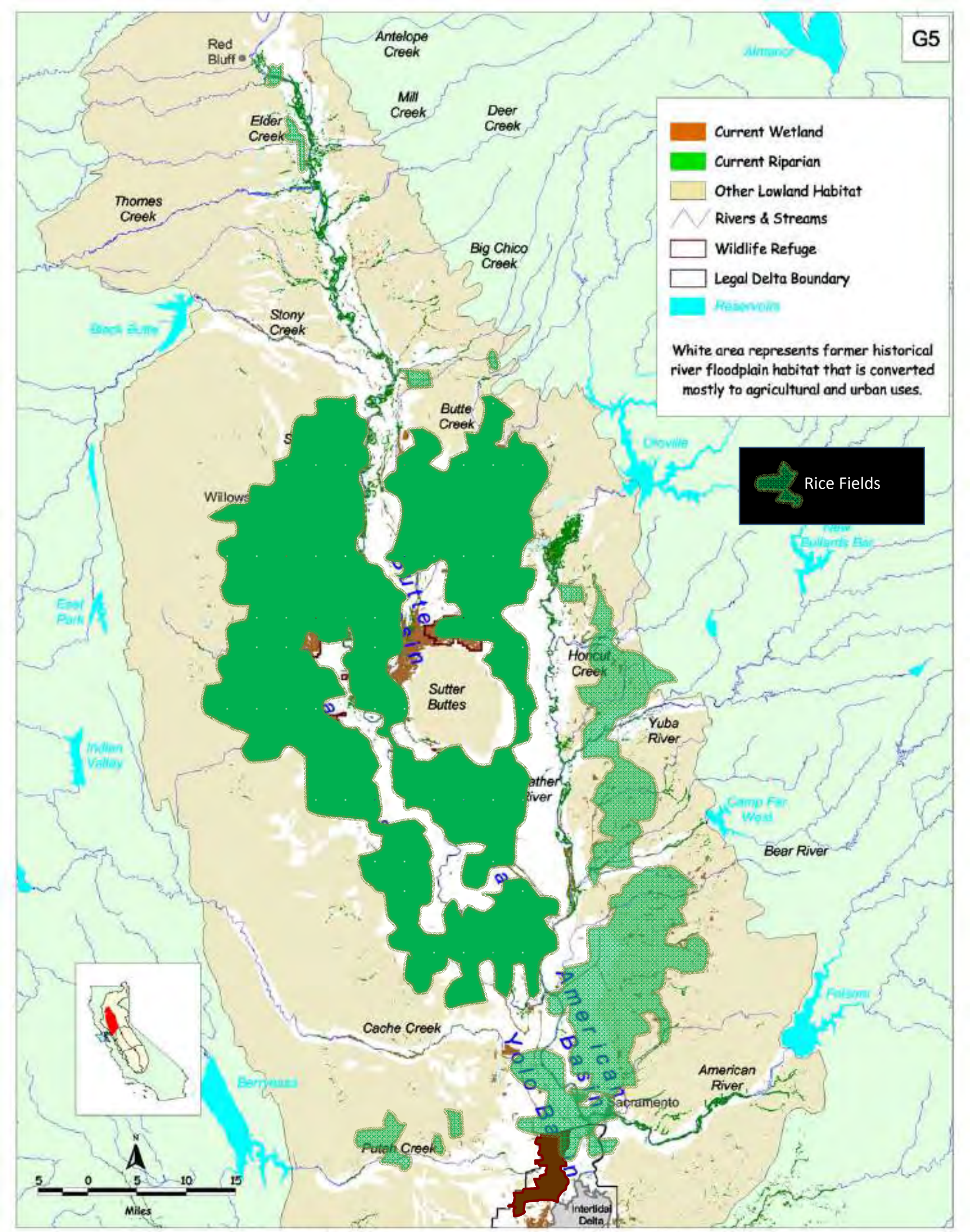
Floodplain Fatties

95%

of loss of floodplains

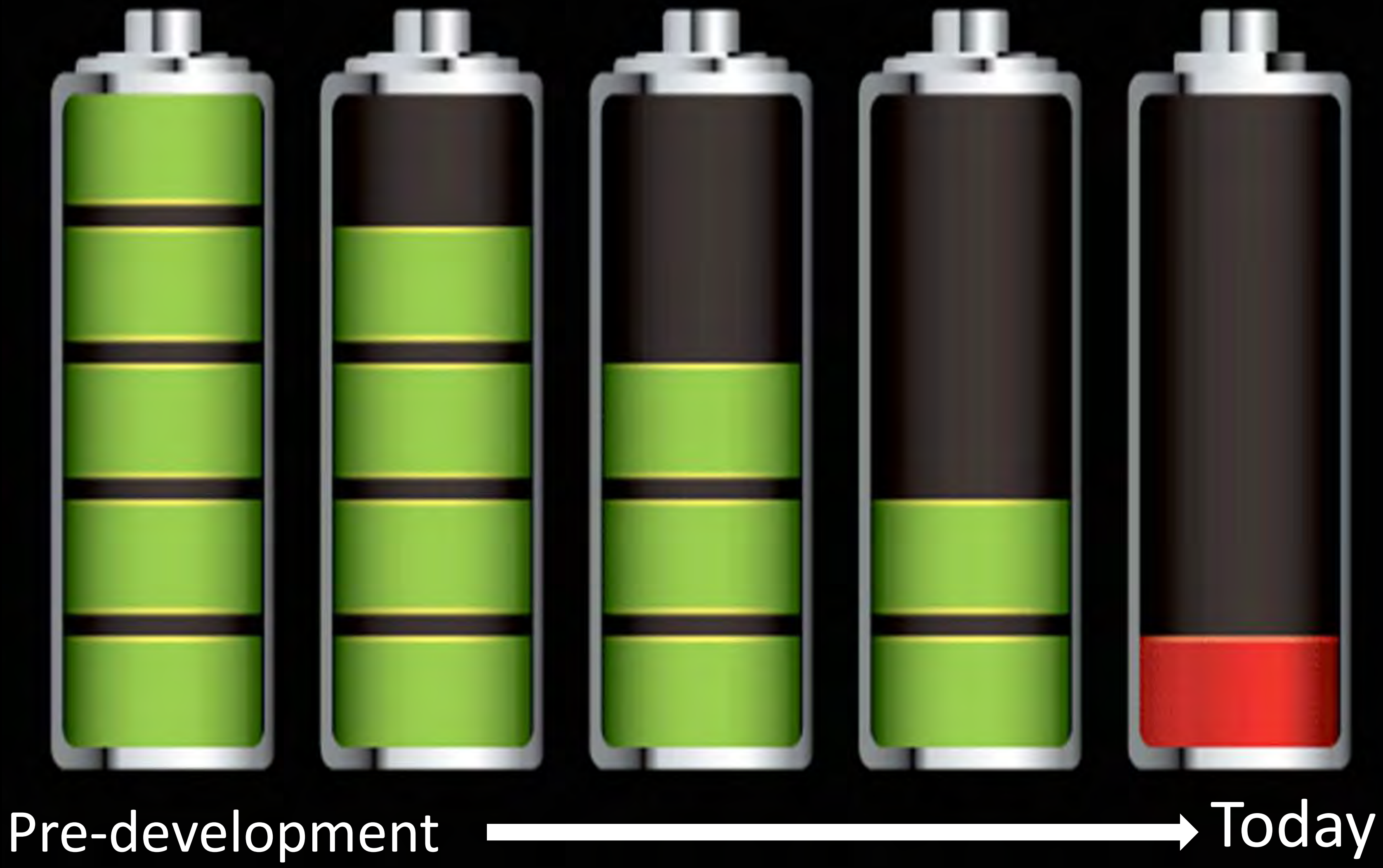
=

Running on fumes



Sacramento Valley Current River Floodplain Ecosystem

Extent of Seasonally Inundated Floodplain



Ecosystem Running Out of Power!

Slow it down!

Spread it out!

Grow them up!

Fish Gotta Eat Too!

Feb 2014

Smithsonian

Rice Can Help Save Salmon If Farms Are Allowed to Flood

The Nigiri Project aims to restore the beloved fish by cutting a notch in a California levee and letting some floodplains return to nature

Jacob Katz stands atop a long, narrow wall of rock and gravel, gazing east over an expanse of off-season rice fields a few miles west of Sacramento. The sky is winter gray and the levee clay is damp and sticky after a brief morning shower.

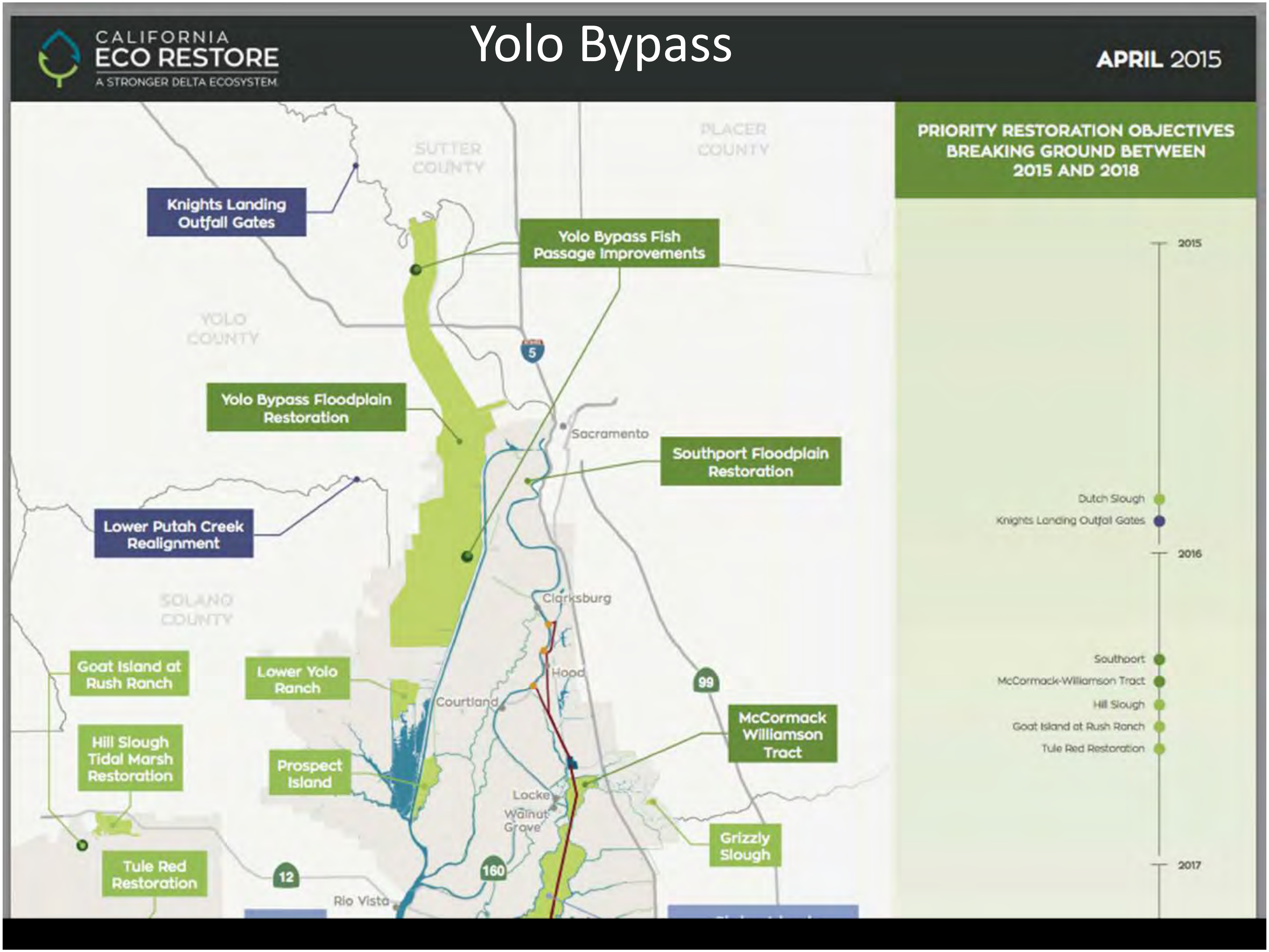
"When some people look out here, they see a field of mud," says Katz, a fishery biologist with the conservation group California Trout. "I see the potential for a biological solar panel that can power our entire river system."

CALIFORNIA TROUT

FISH · WATER · PEOPLE

By Alastair Bland
March 23, 2015

Yolo Bypass


CALIFORNIA ECO RESTORE
A STRONGER DELTA ECOSYSTEM
APRIL 2015
SUTTER COUNTY
PLACER COUNTY
YOLO COUNTY
SOLANO COUNTY
Knights Landing Outfall Gates
Yolo Bypass Fish Passage Improvements
Yolo Bypass Floodplain Restoration
Sacramento
Southport Floodplain Restoration
Lower Putah Creek Realignment
Clarksburg
Hood
Courtland
Goat Island at Rush Ranch
Lower Yolo Ranch
Hill Slough Tidal Marsh Restoration
Prospect Island
McCormack Williamson Tract
Locke
Walnut Grove
Grizzly Slough
Tule Red Restoration
Rio Vista
5
99
12
160
PRIORITY RESTORATION OBJECTIVES BREAKING GROUND BETWEEN 2015 AND 2018
2015
Dutch Slough
Knights Landing Outfall Gates
2016
Southport
McCormack-Williamson Tract
Hill Slough
Goat Island at Rush Ranch
Tule Red Restoration
2017

A Cooperative Partnership

California Trout

The California Department of Water Resources

The UC Davis Center for Watershed Science

Cal Marsh and Farm Ventures, LLC

Knaggs Ranch, LLC

The U.S. Bureau of Reclamation

NOAA – Southwest Fisheries

Center for Watershed Sciences
UC DAVIS

CALIFORNIA TROUT
KEEPER OF THE STREAMS

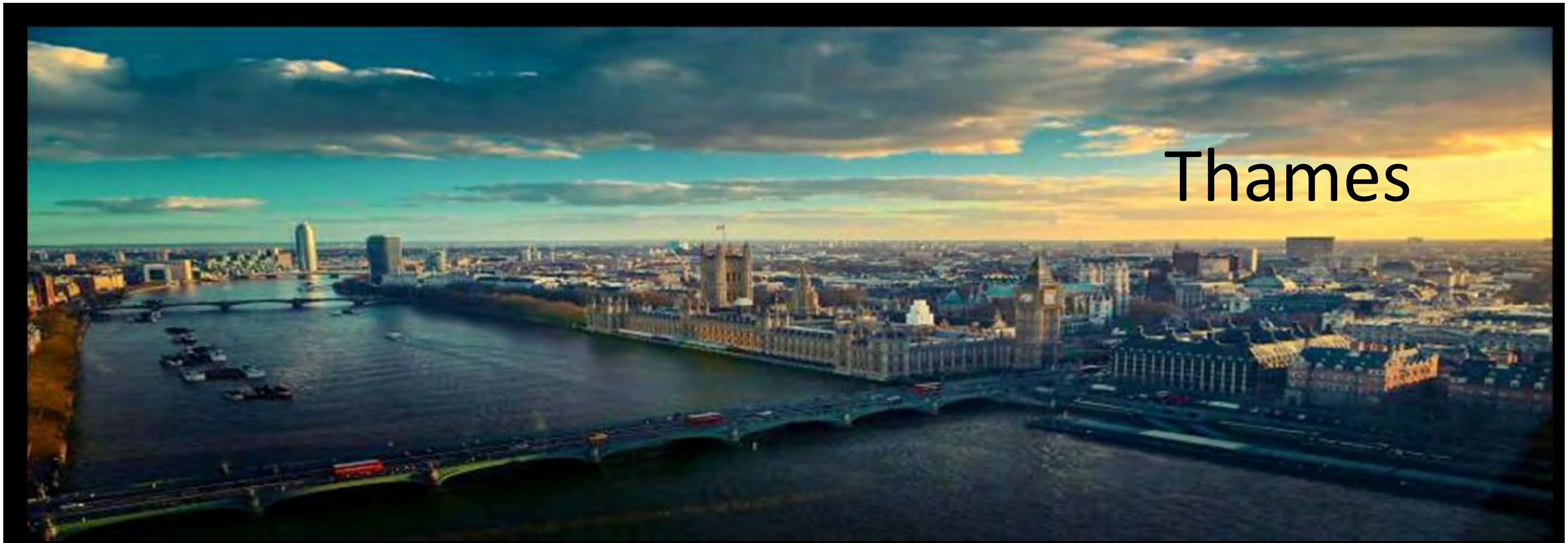
Cal Marsh & Farm Ventures, LLC

Questions?

Carson Jeffres

Process-Based Reconciliation

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

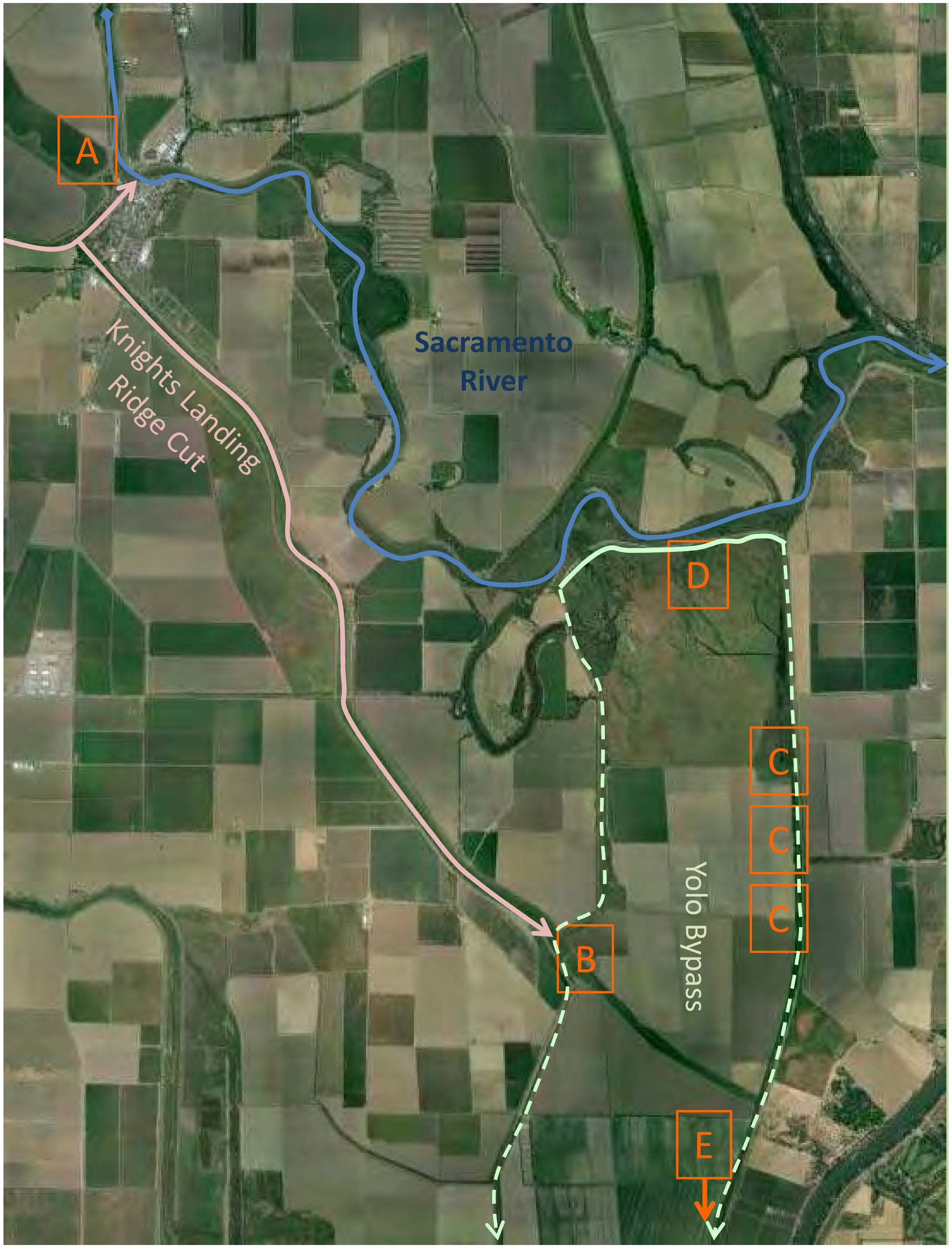

Thames


Mississippi


Seine


Thames

Danube



Near-Term **EcoRestore** & 2009 Biological Opinion Fish Passage Projects

- A Knights Landing Outfall Gates
- B Wallace Weir
- C Tule Ag. Crossings
- D Fish Ladder Modifications
- E Lisbon Weir

2009 BiOp

In advance of the Nov. 2015 completion of the voluntary Knights Landing Outfall Gates fish barrier, efforts are pivoting towards implementation of near-term fish passage projects per the 2009 BiOP. Wallace Weir will likely be pursued first (target groundbreaking in Summer 2016). Tule Ag. Crossings, Lisbon Weir, and Fremont Weir Fish Ladder modifications will be pursued simultaneously, with planned groundbreaking in 2017. Together, these efforts will effectively eliminate stranding in the Colusa Basin and significantly improve adult fish passage within the Bypass and across the Fremont Weir.

Time now to put the science into action and scale up

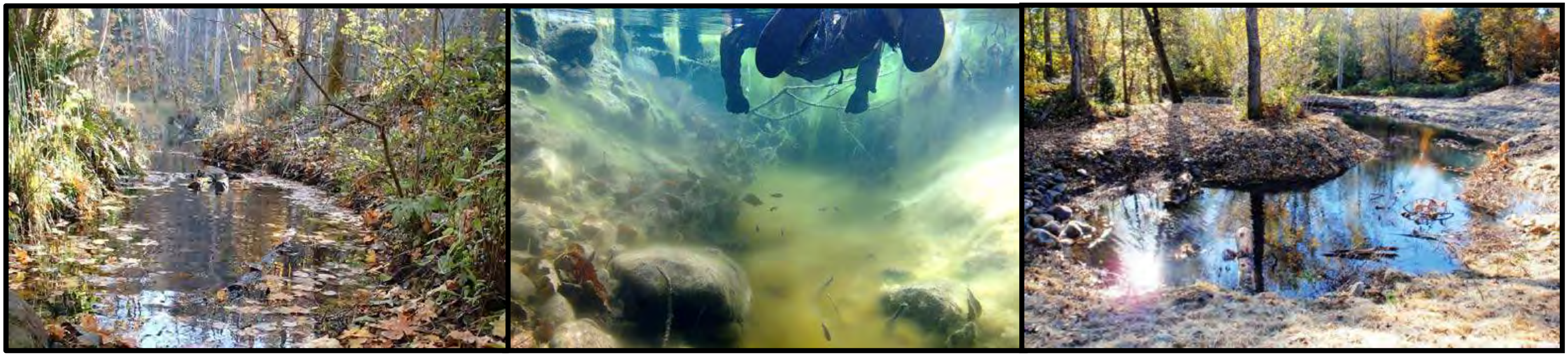
Use it to update obsolete water infrastructure built 100 years ago before anyone cared about fish

Working towards a mutually preferred alternative that creates greatest fish benefit, sustains ag and improves flood safety

Creating Off-Channel Coho Rearing Habitat in the Middle Klamath River Sub-basin

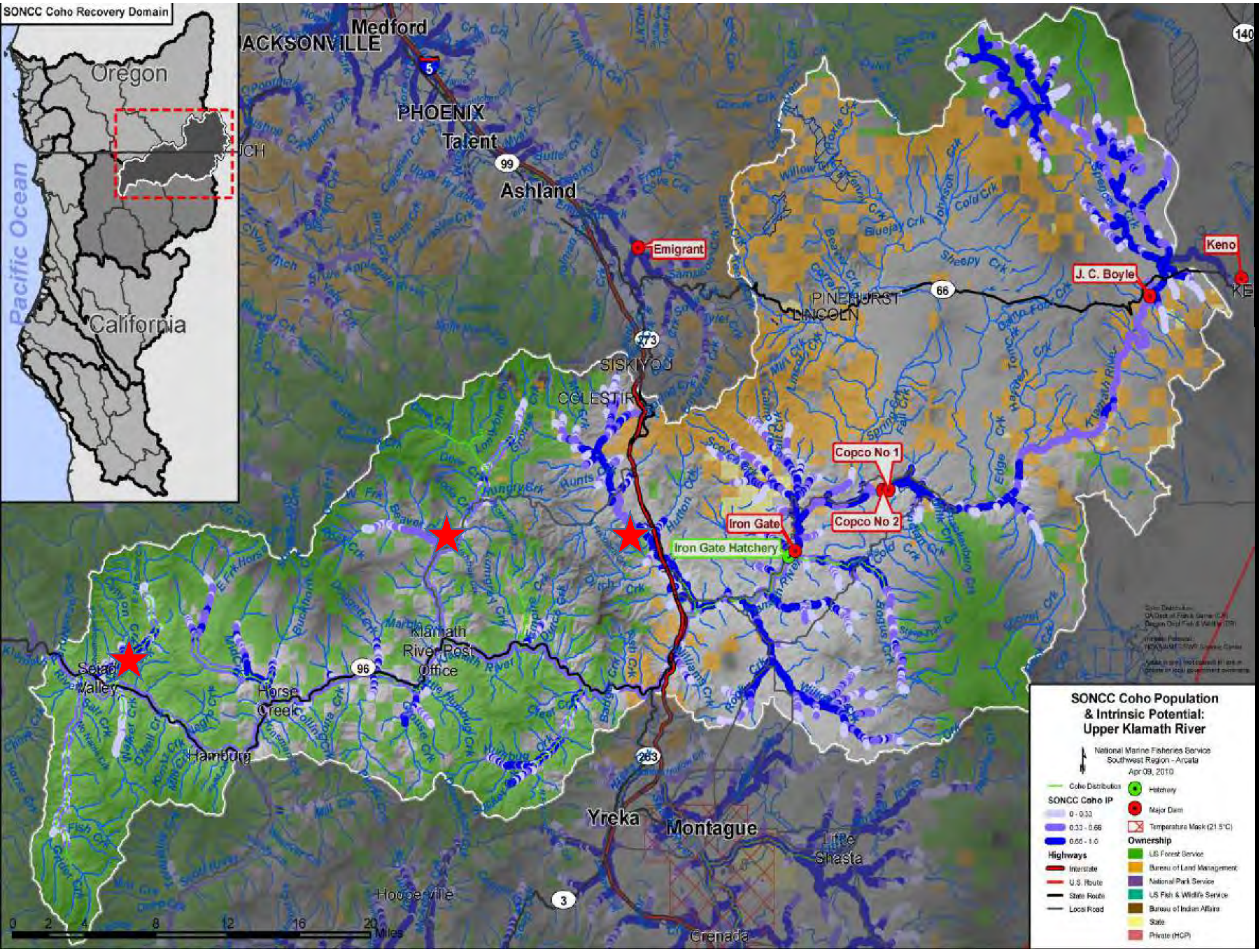
A Status Review of Constructed Projects (2010-2015)

Will Harling, Director, Mid Klamath Watershed Council



OUTLINE

- Intro to the Mid Klamath
- Overview of Off-Channel Habitats Constructed 2010-2015
  - Process for Selecting Project Sites
    - What Makes a Good Site?
    - Lessons learned the Hard Way
  - You Cannot Always Tell by Looking What is Happening
    - Adapting to the Unseen/Unknown
    - Listen to the Fish
- Recommendations for Future Off-Channel Habitat Projects

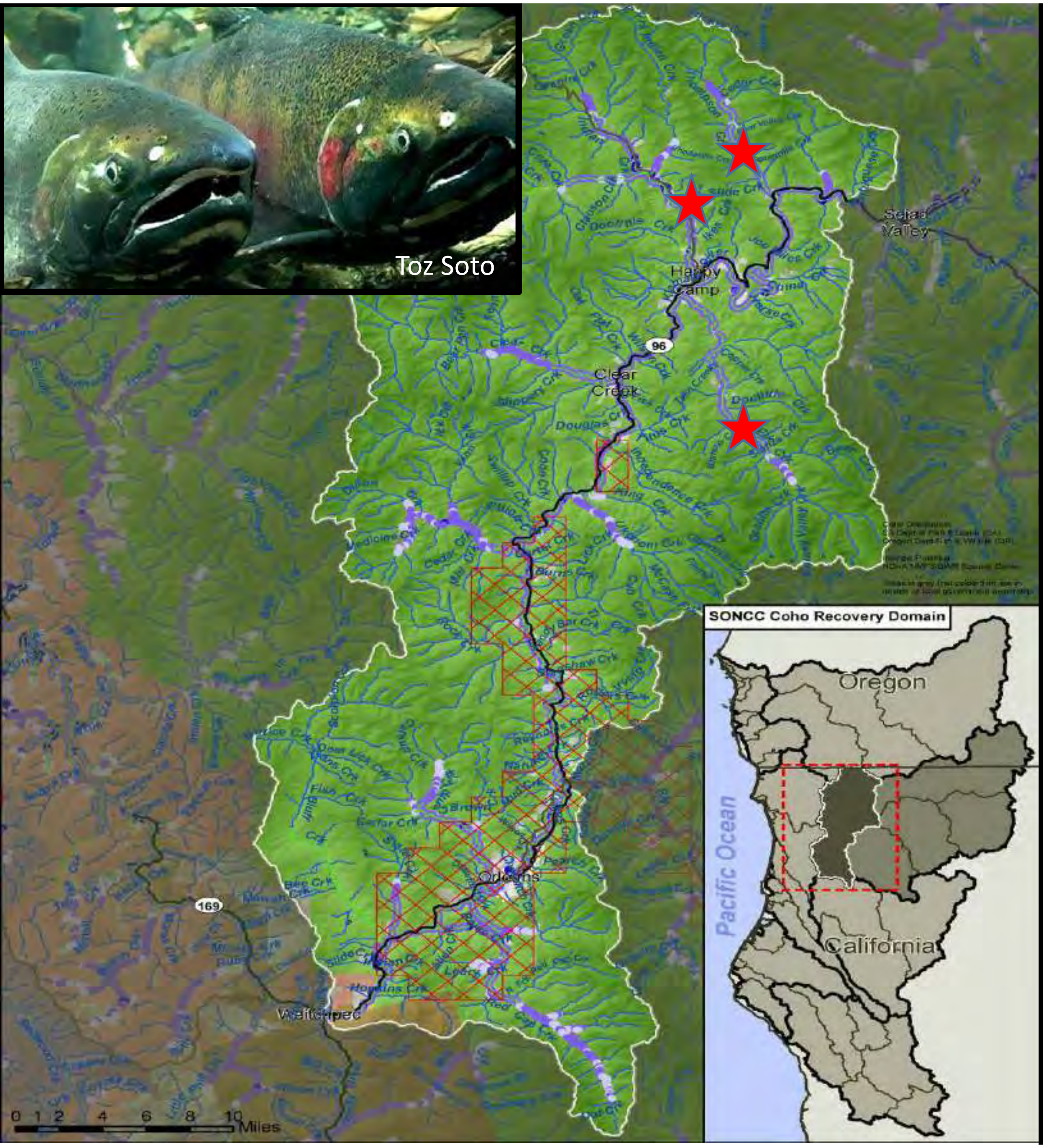


Beaver Creek, Riparian Road Corridor

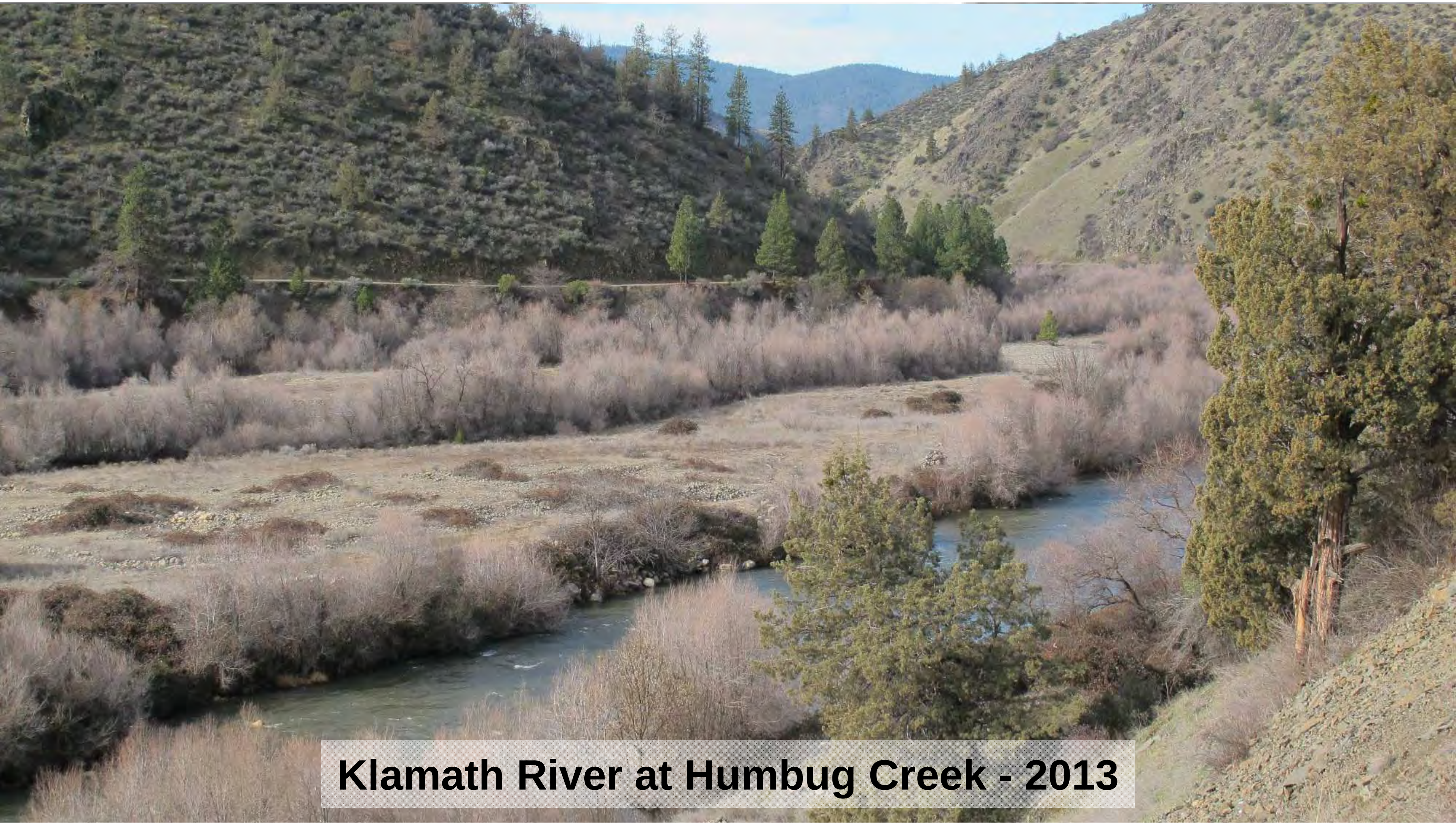
Mike Hentz

Cottonwood Creek, Mainstem Bridge Near Hilt

Mike Hentz


Toz Soto
Happy Camp
Clear Creek
Seiad Valley
Orleans
Weitchpec
96
169
SONCC Coho Recovery Domain
Oregon
California
Pacific Ocean
0 1 2 4 6 8 10 Miles


Slater Butte,
1987 Fire
Mike Hentz



Klamath River at Humbug Creek - 2013

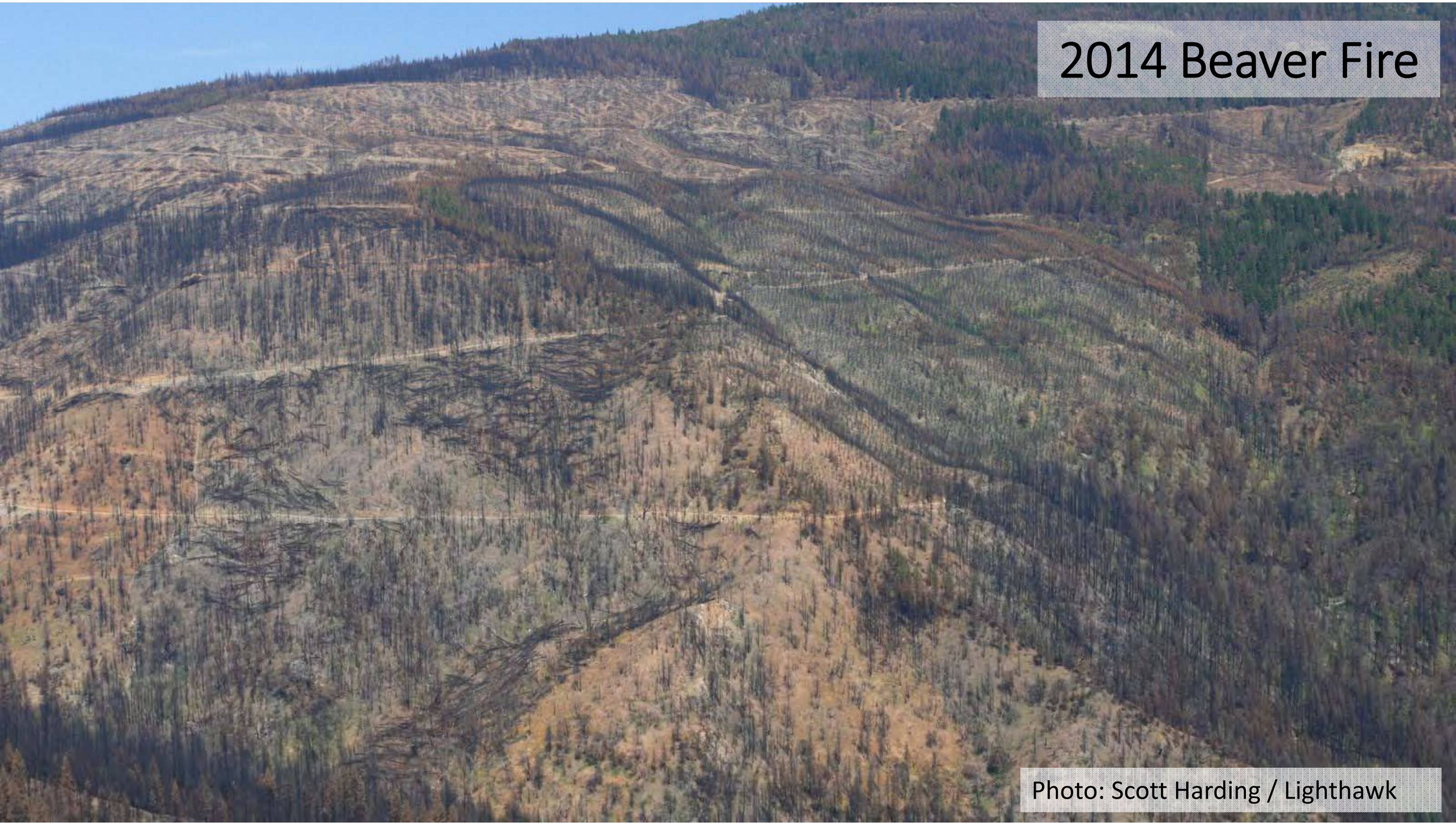
Seiad Creek at Hwy 96 Bridge
2006 Flood Event

Toz Soto

Mike Hentz

Elk Creek During the 2014 Happy Camp Complex Fire

2014 White Fire



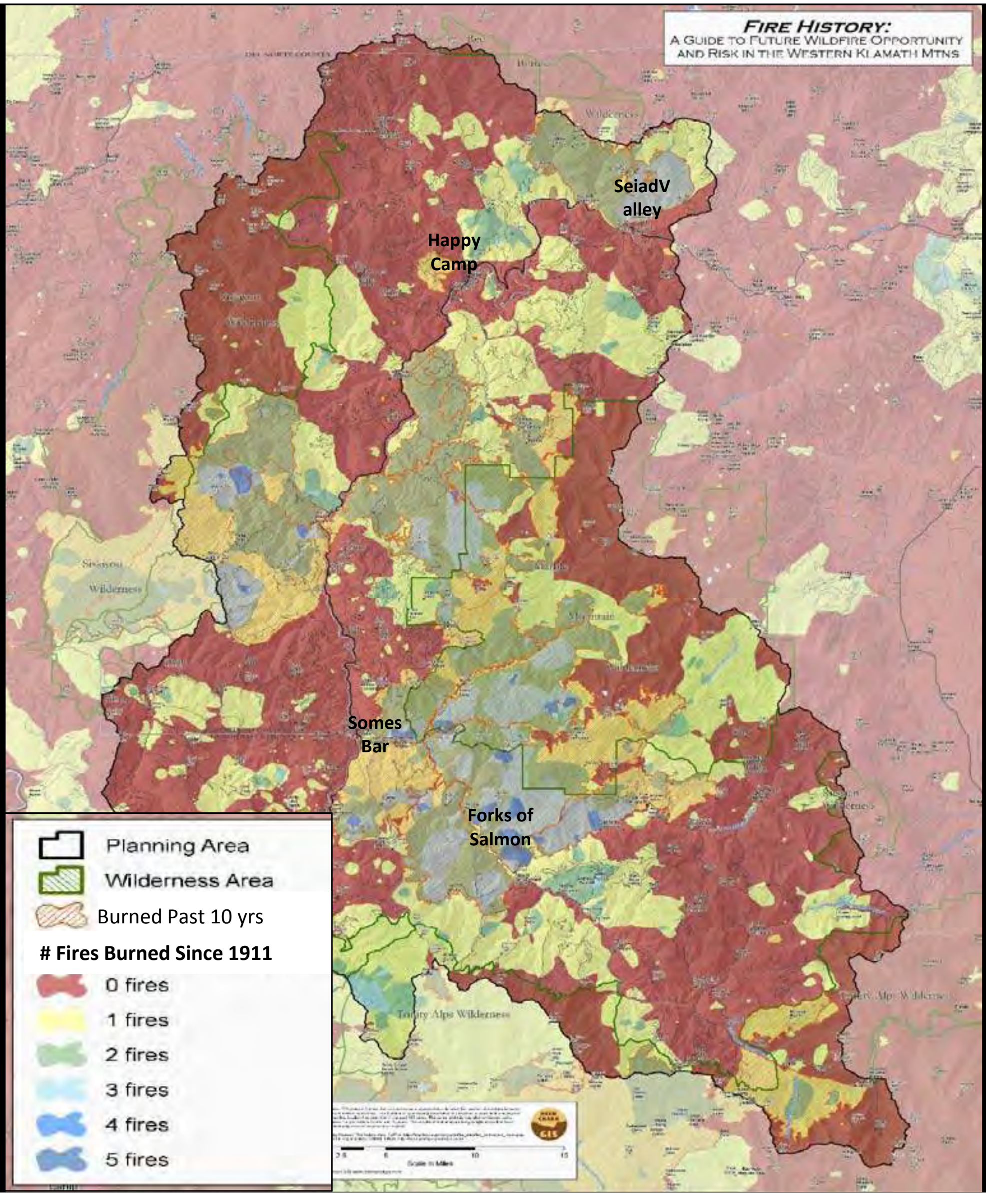
2014 Beaver Fire

Photo: Scott Harding / Lighthawk

Grider Creek at PCT Trailhead
After July 2015 T-Storm

Photo: Mark Motyka

July 2015



FIRE HISTORY:
A GUIDE TO FUTURE WILDFIRE OPPORTUNITY AND RISK IN THE WESTERN KLAMATH MTNS

David McLain

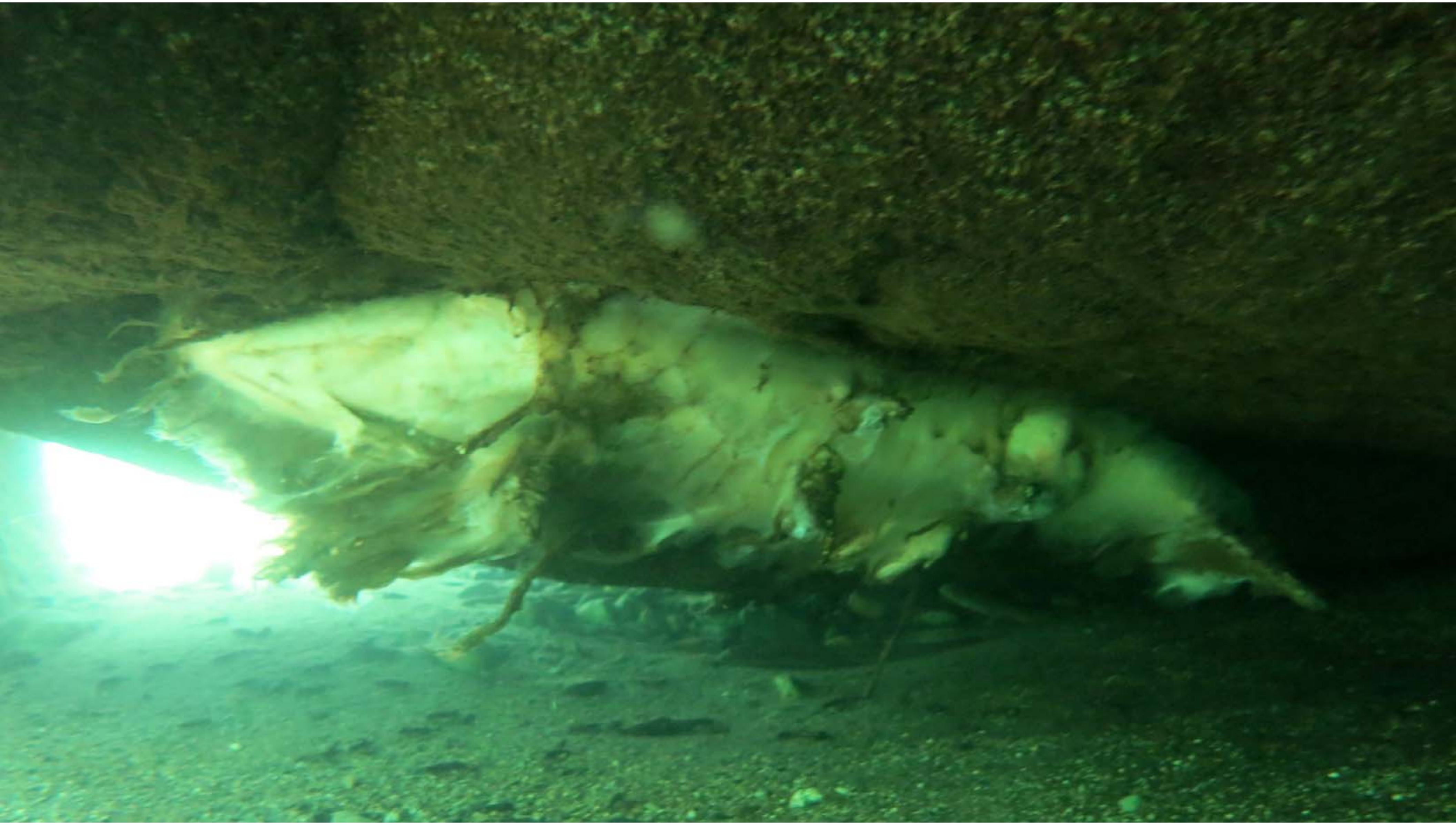
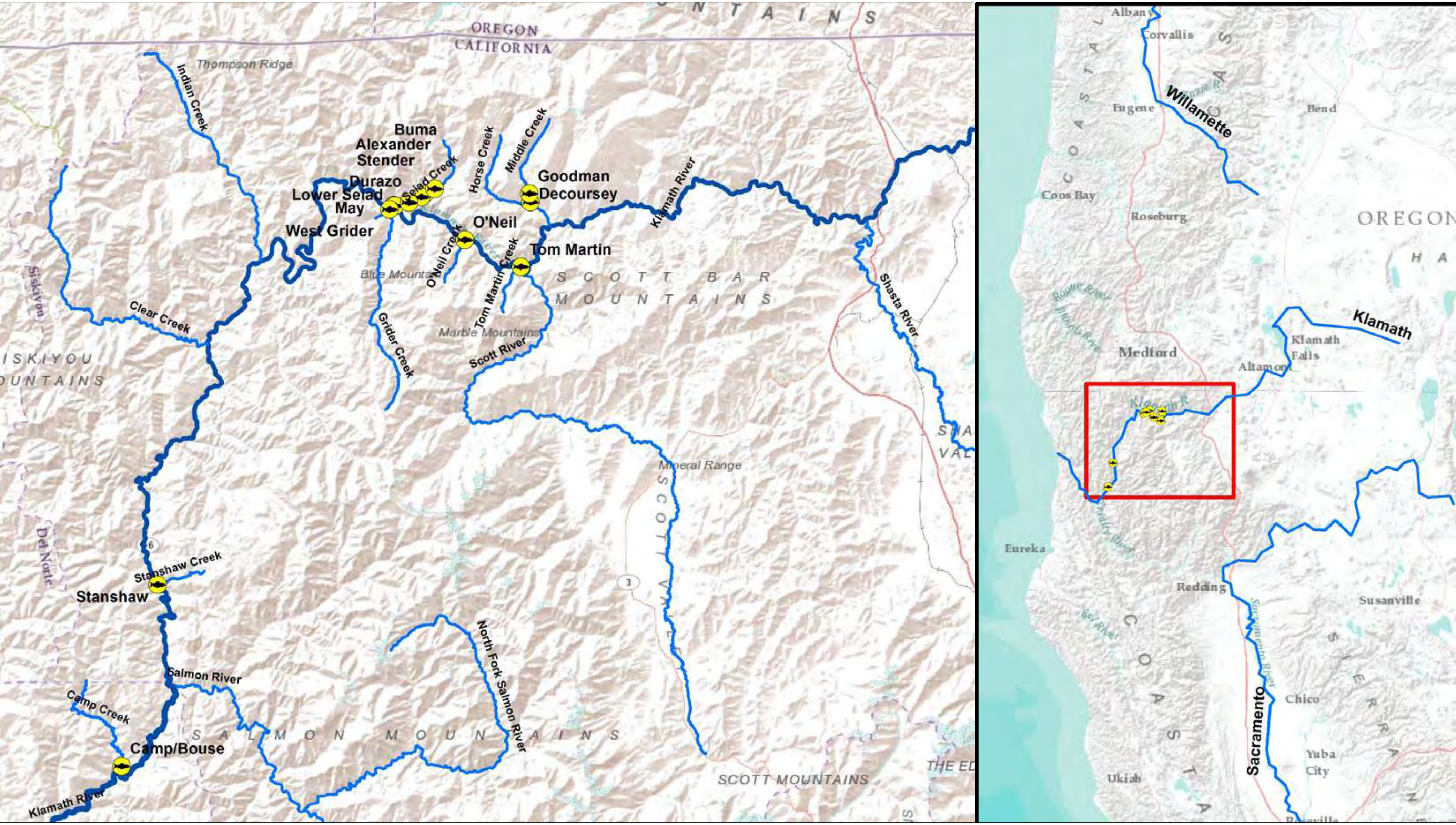


Photo: Mary Huffman (TNC)

Off-Channel Habitat Construction for Juvenile Coho Salmon

- 2010: Stender, Buma, Alexander Ponds – All on Seiad Creek
- 2011: Lower Seiad and West Grider Ponds
- 2012: May Pond on Seiad Creek
- 2013: Ponds on Tom Martin, O’Neil, Camp, and Stanshaw Creeks
- 2014: DeCoursey Pond (Middle Creek – trib to Horse Creek) and Durazo Ponds on Seiad Creek.
- 2015: Goodman Pond on Middle Creek.
- Primary objective is to rapidly increase coho winter rearing habitat, however summer use has been documented in all ponds.
- Extensive Monitoring: water quality (DO, temp), snorkel surveys, mark/recap popn estimates, maintaining habitat connectivity.
- Shari Anderson MS thesis (2014) on coho growth, density, and abundance in constructed habitats, as well as tributary and beaver influenced habitats. HSU grad student Michelle Krall about to publish MS thesis.
- Funding: USFWS Partners Program, NFWF/PacifiCorp, FishAmerica/NMFS, Caltrans/USFS and CDFW.


OREGON
CALIFORNIA
Thompson Ridge
Indian Creek
Buma
Alexander
Stender
Durazo
Lower Seiad
May
West Grider
Seiad Creek
Horse Creek
Middle Creek
Goodman
Decoursey
O'Neil
O'Neil Creek
Tom Martin
Tom Martin Creek
Klamath River
Blue Mountain
Grider Creek
Marble Mountains
Scott River
SCOTT BAR MOUNTAINS
Shasta River
Clear Creek
SISKIYOU MOUNTAINS
Siskiyou
Del Norte
Mineral Range
SCOTT VALLEY
Stanshaw Creek
Stanshaw
Salmon River
North Fork Salmon River
SALMON MOUNTAINS
Camp Creek
Camp/Bouse
Klamath River
SCOTT MOUNTAINS
THE ED
Albany
Corvallis
Eugene
Willamette
Bend
Coos Bay
Roseburg
OREGON
Medford
Klamath
Klamath Falls
Altamont
Klamath R.
Eureka
Redding
Susanville
Sacramento
Chico
Yuba City
Ukiah
Roseville

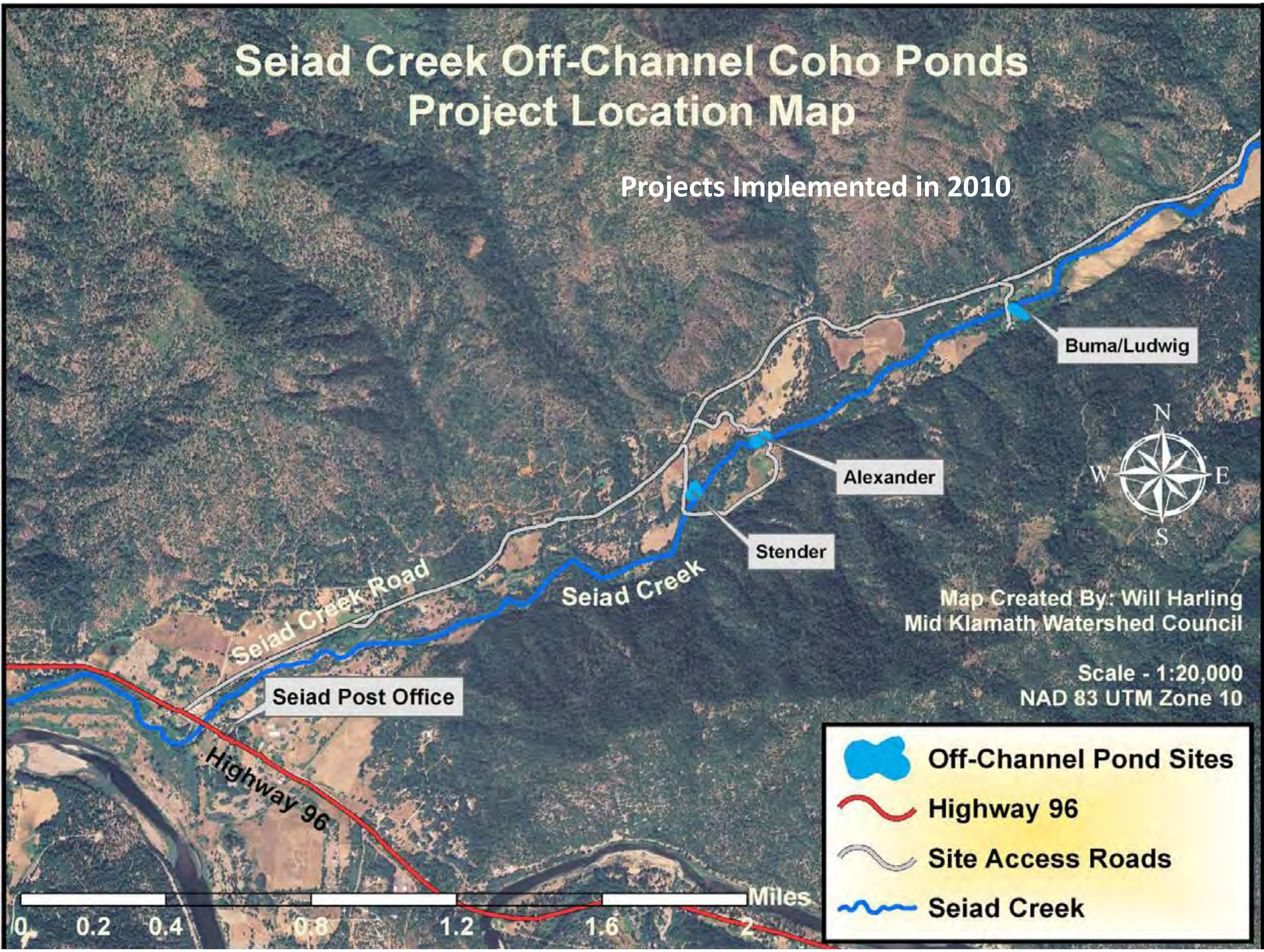


Klamath River Coho Ecology Study

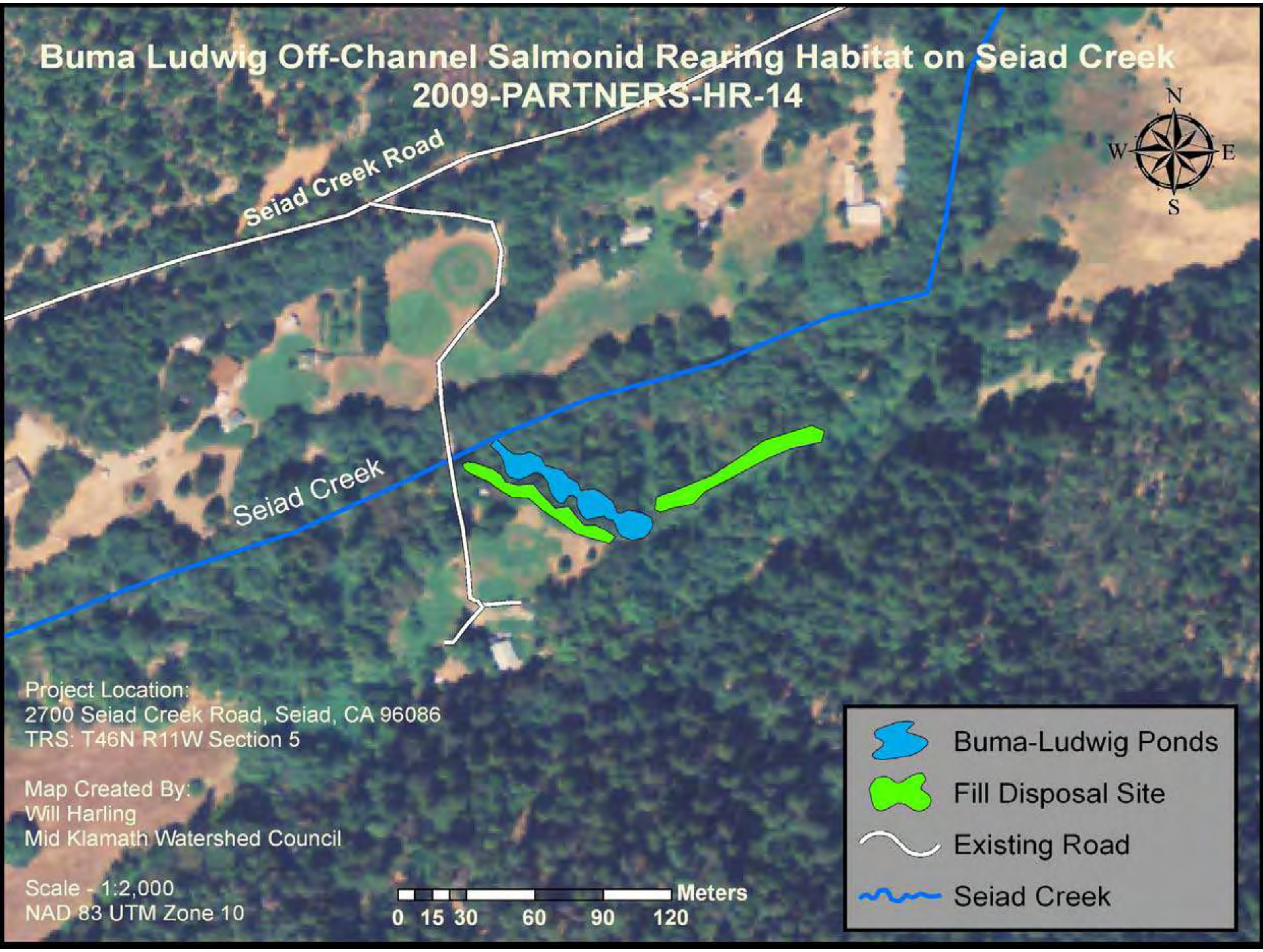
- Karuk Tribe, Yurok Tribe and partners have detailed coho life history patterns/movement in the Middle and Lower Klamath over the past decade +.
- These studies indicate winter rearing habitat is a major limiting factor to coho smolt production in many Klamath tributaries. (Soto et al 2008).
- This science is the basis for restoration actions occurring in the Klamath Basin from Iron Gate Dam to the mouth of the Klamath River.

“Overwinter survival of juvenile coho is approximately 2-6 times greater in off-channel habitats than within main channel habitats. This difference in survival rates is especially important in watersheds that have undergone significant changes due to land use.”

Larry Lestelle (2007)



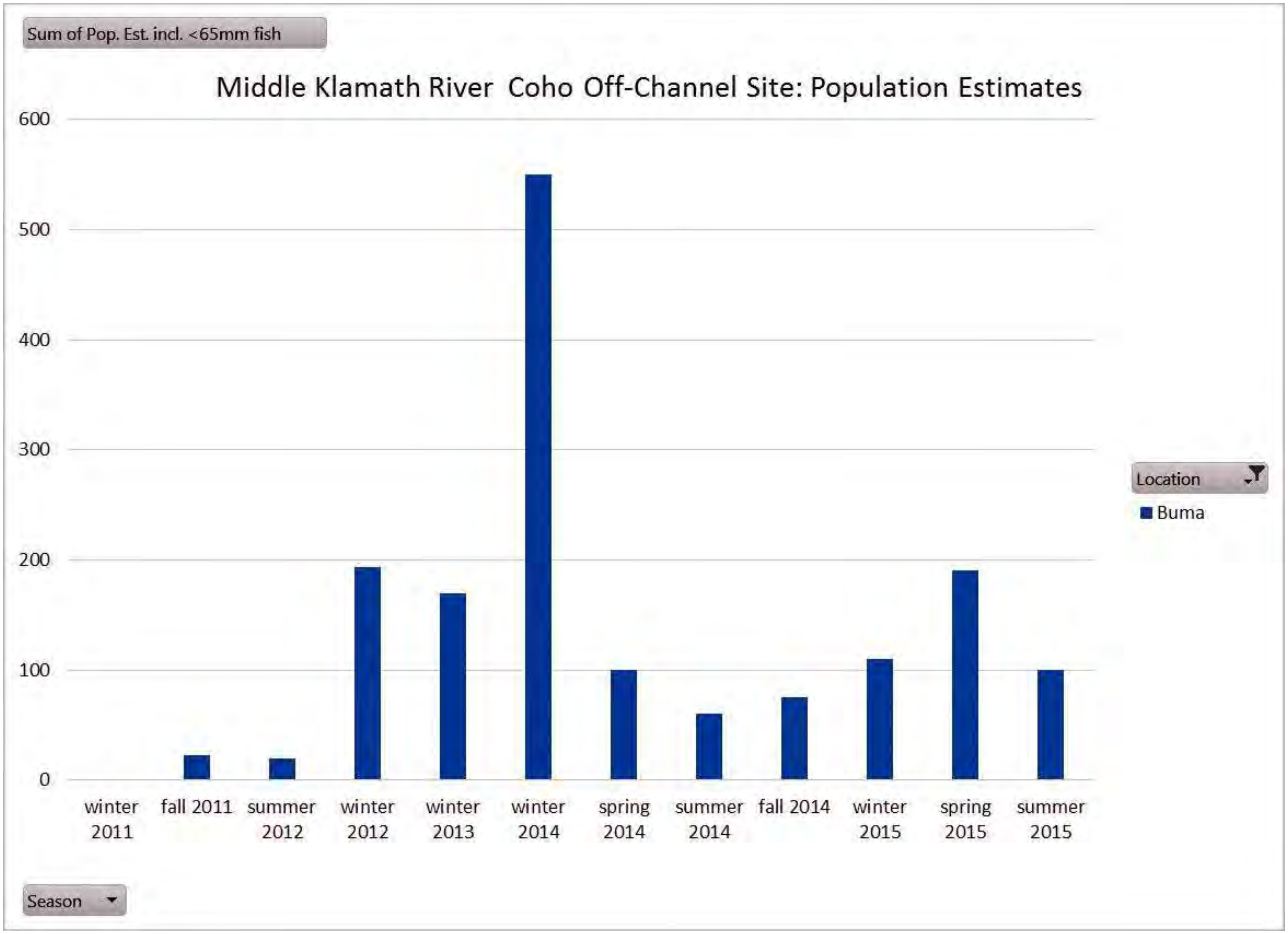
- Key coho stream in Mid Klamath.
- Heavily impacted by channelization (levees) to make room for ag/domestic use, and past mining.
- Willing landowners in a hostile landscape.
- Working in an altered landscape.
- Experimenting with site longevity based on connectivity during flood events.



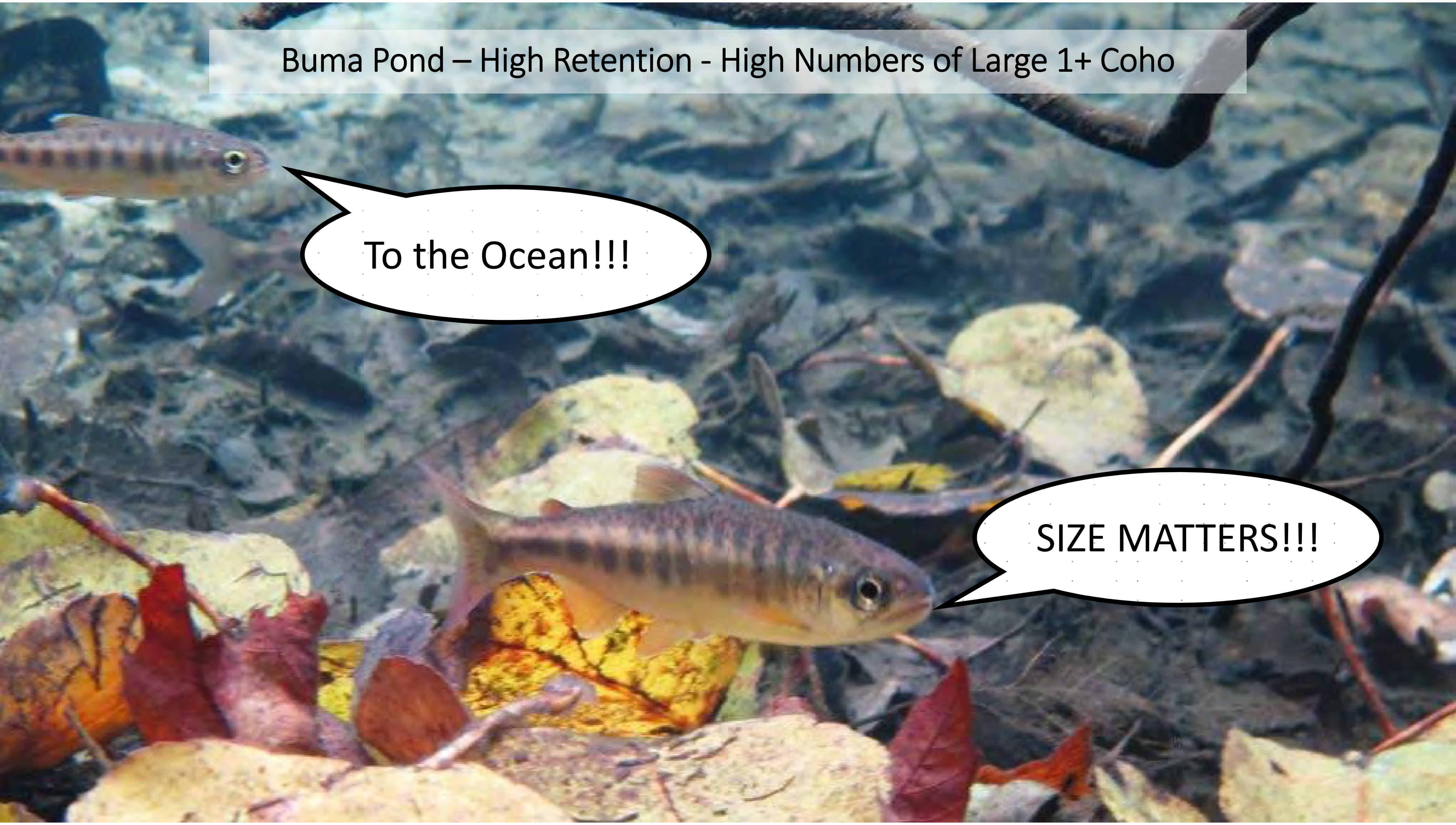
- Dug into side channel w through flow in 5-10 year flood event.
- Very low cost of construction (~$10,000).
- Beaded channel design.
- Early issues with connectivity. Entered Seiad Creek mid-riffle…

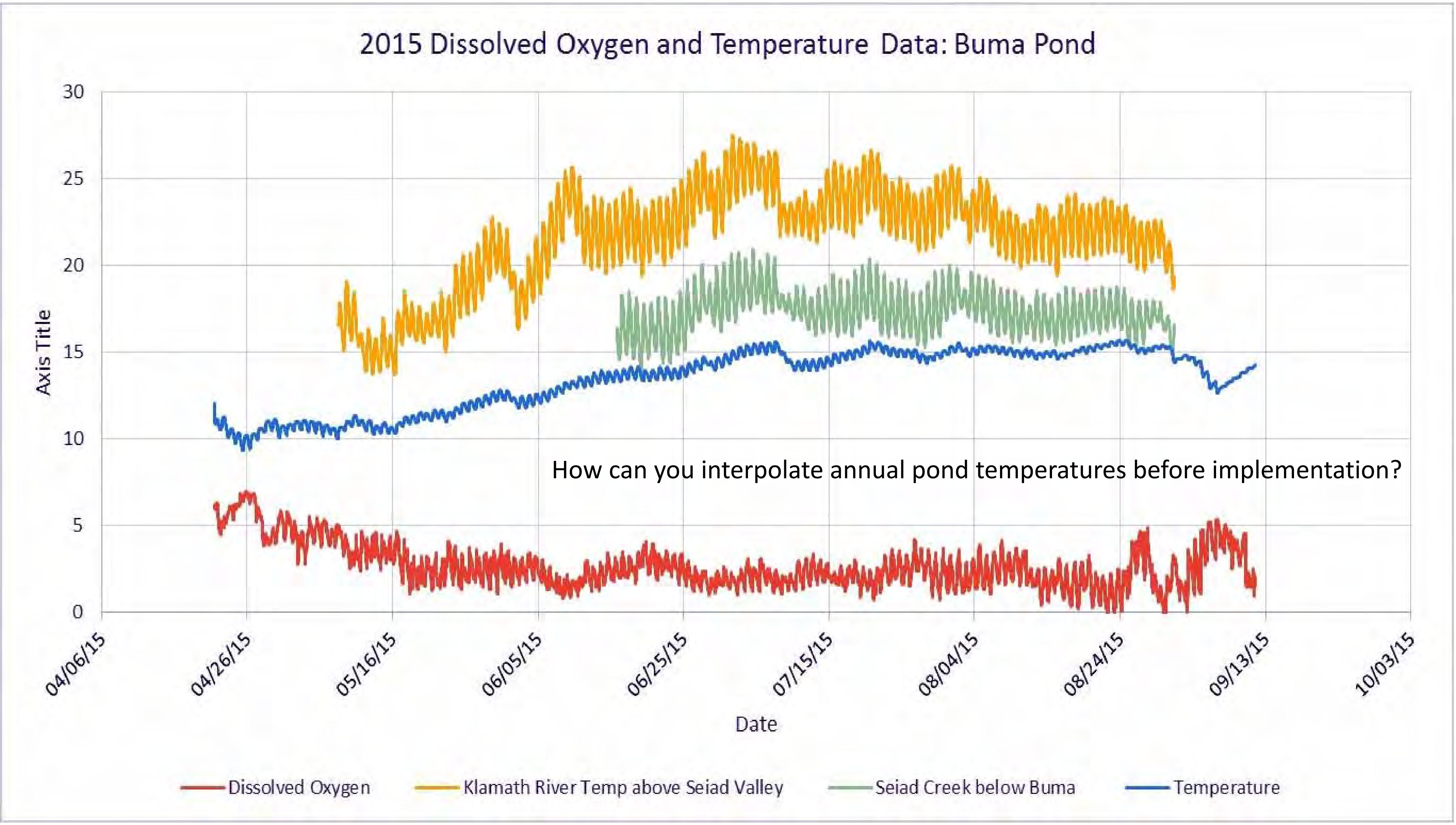
Buma Pond: After Construction 11-3-10


Off-channel habitat


Sum of Pop. Est. incl. <65mm fish
Middle Klamath River Coho Off-Channel Site: Population Estimates
600
500
400
300
200
100
0
winter 2011
fall 2011
summer 2012
winter 2012
winter 2013
winter 2014
spring 2014
summer 2014
fall 2014
winter 2015
spring 2015
summer 2015
Location
■ Buma
Season

Buma Pond – High Retention - High Numbers of Large 1+ Coho





How can you interpolate annual pond temperatures before implementation?

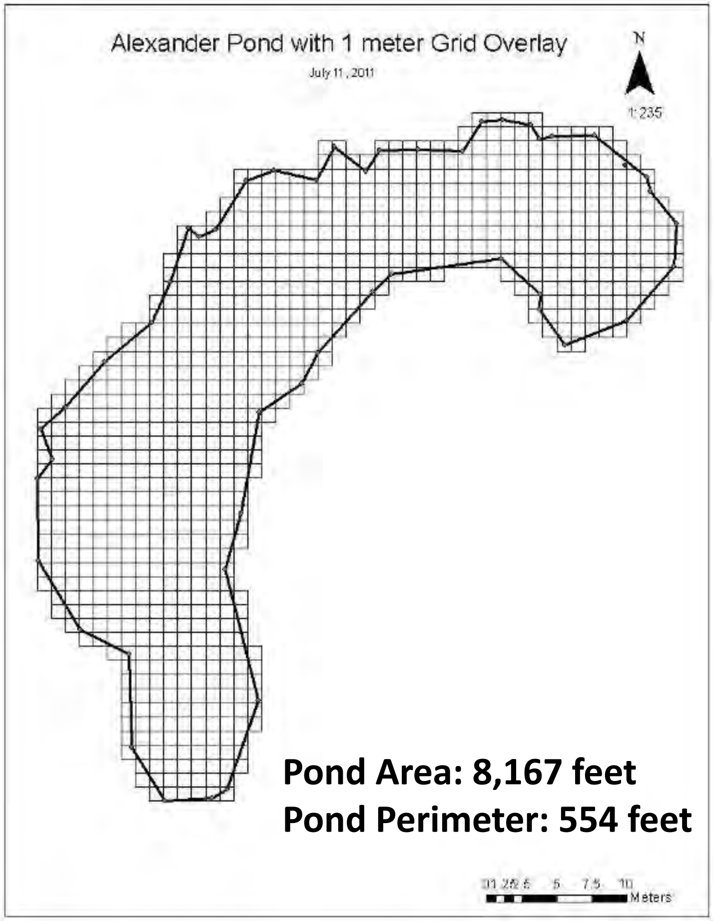
Alexander Pond

~ 2 mi. up Seiad Creek

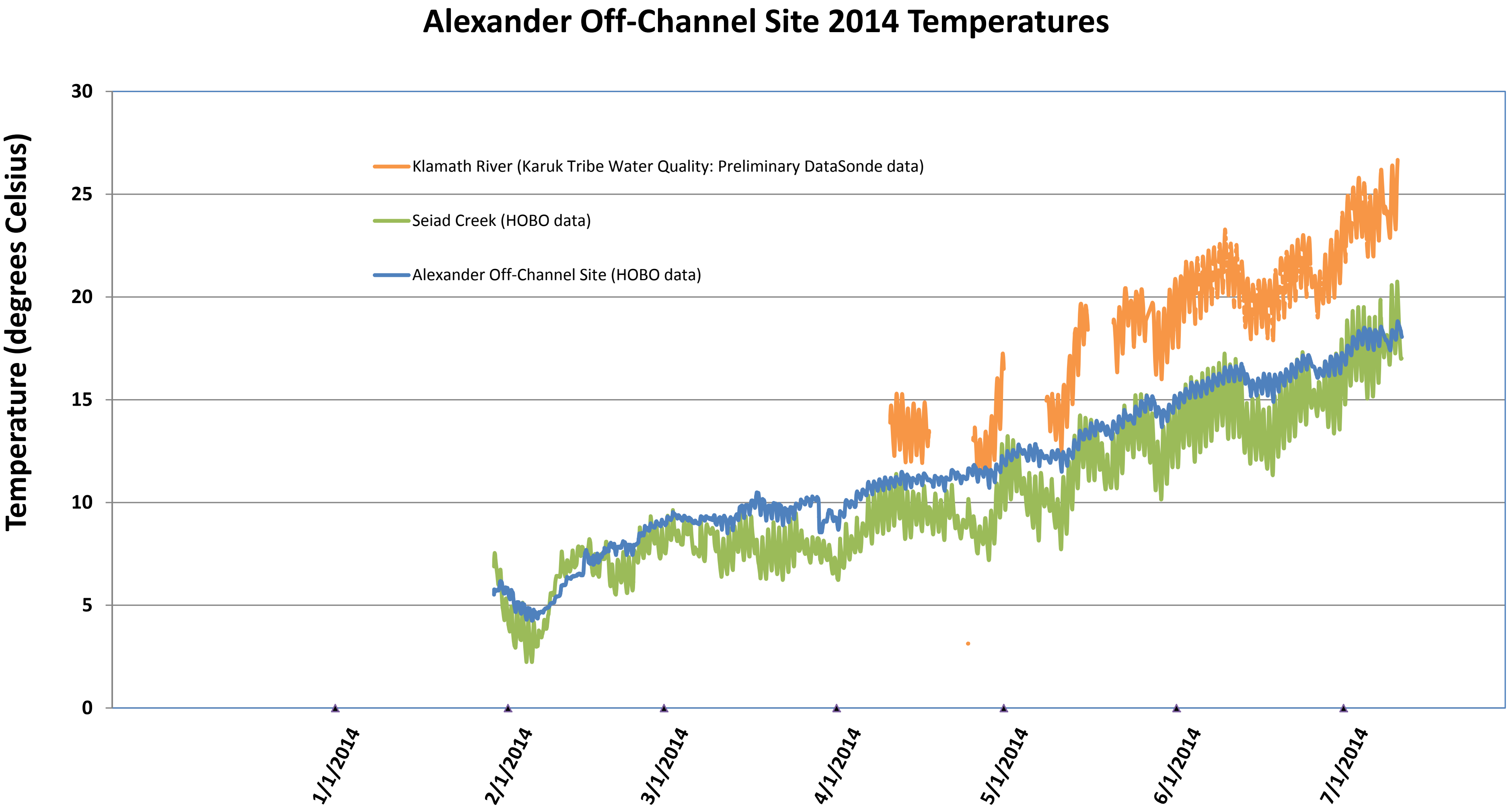
Before – November 2009

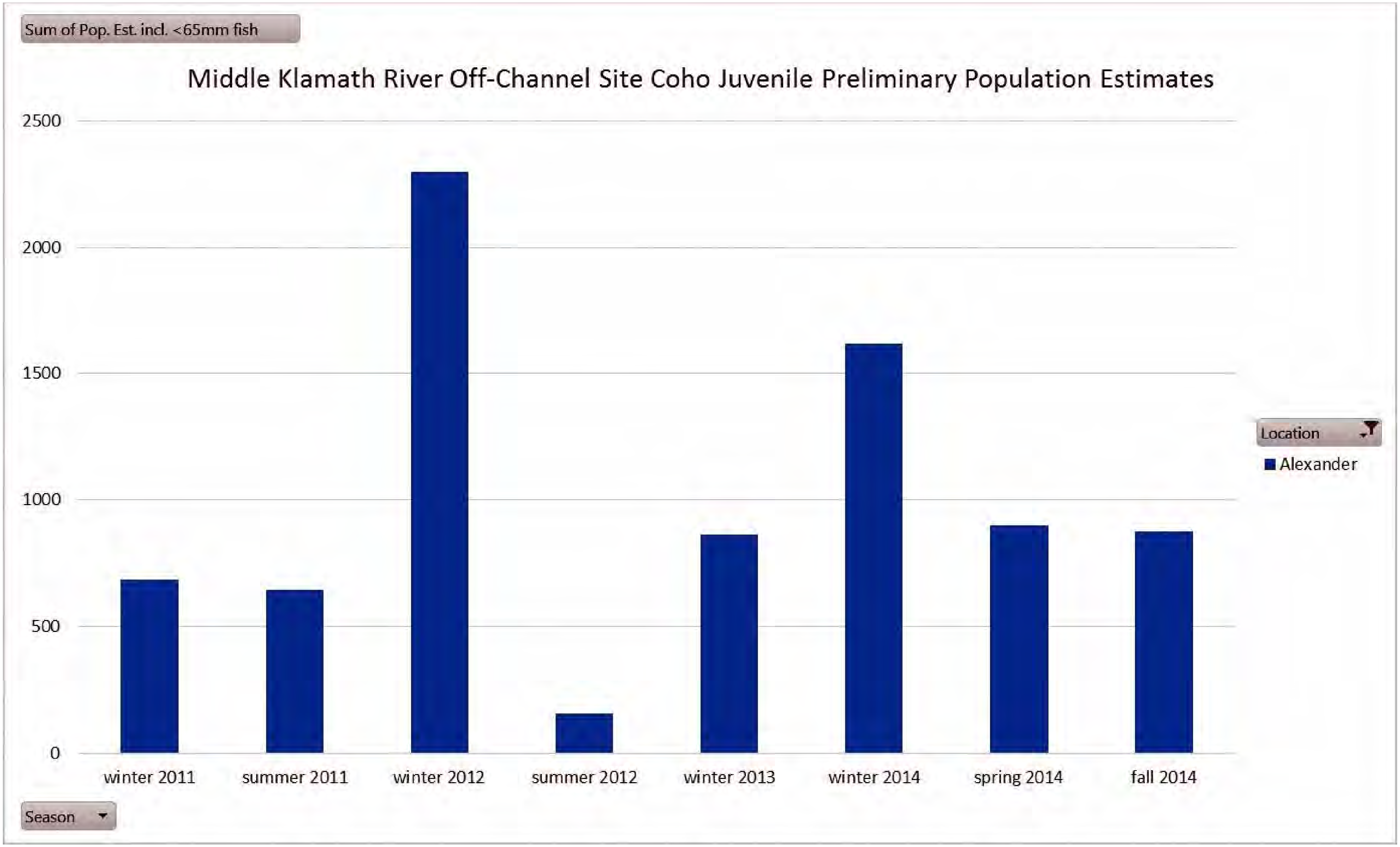
During – October 2010

After – February 2011



Pond Area: 8,167 feet
Pond Perimeter: 554 feet


Alexander Off-Channel Site 2014 Temperatures
Temperature (degrees Celsius)
30
25
20
15
10
5
0
Klamath River (Karuk Tribe Water Quality: Preliminary DataSonde data)
Seiad Creek (HOBO data)
Alexander Off-Channel Site (HOBO data)
1/1/2014
2/1/2014
3/1/2014
4/1/2014
5/1/2014
6/1/2014
7/1/2014


Sum of Pop. Est. incl. <65mm fish
Middle Klamath River Off-Channel Site Coho Juvenile Preliminary Population Estimates
2500
2000
1500
1000
500
0
winter 2011
summer 2011
winter 2012
summer 2012
winter 2013
winter 2014
spring 2014
fall 2014
Season
Location
Alexander

Alexander Pond - Why Do Coho Love It?

- Located just downstream of a key spawning reach on lower Canyon Creek.
- Eight feet deep at summer base flow.
- Suitable summer temperatures and dissolved oxygen levels.
- Complex wood structures
- High plankton levels may help to deter predation.
- Connection to Seiad Creek increases from two feet to nearly 20 feet during high flows. This may increase the ability for juvenile coho to find the site during high water events.

Stender Pond

2010-2015

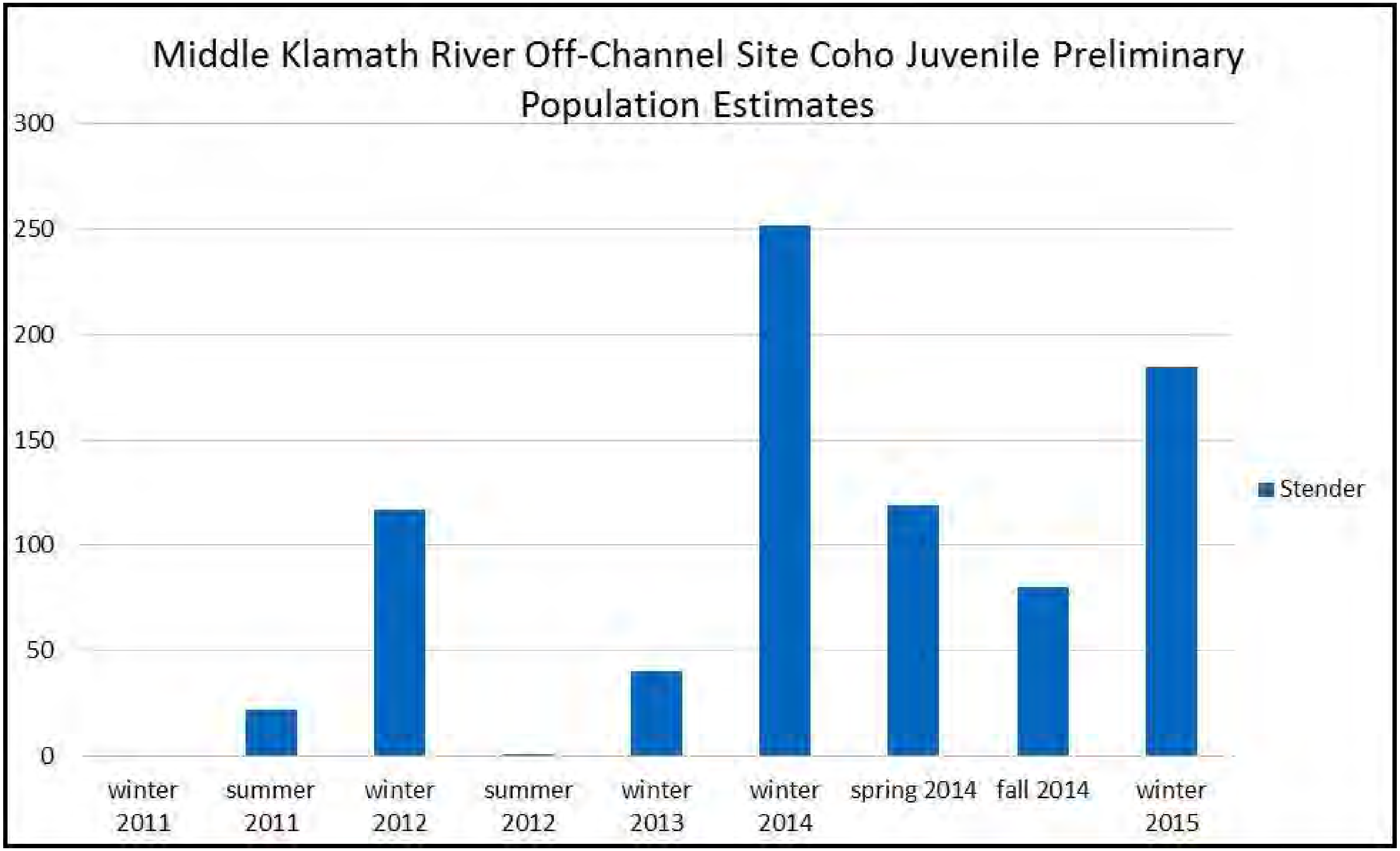

2010

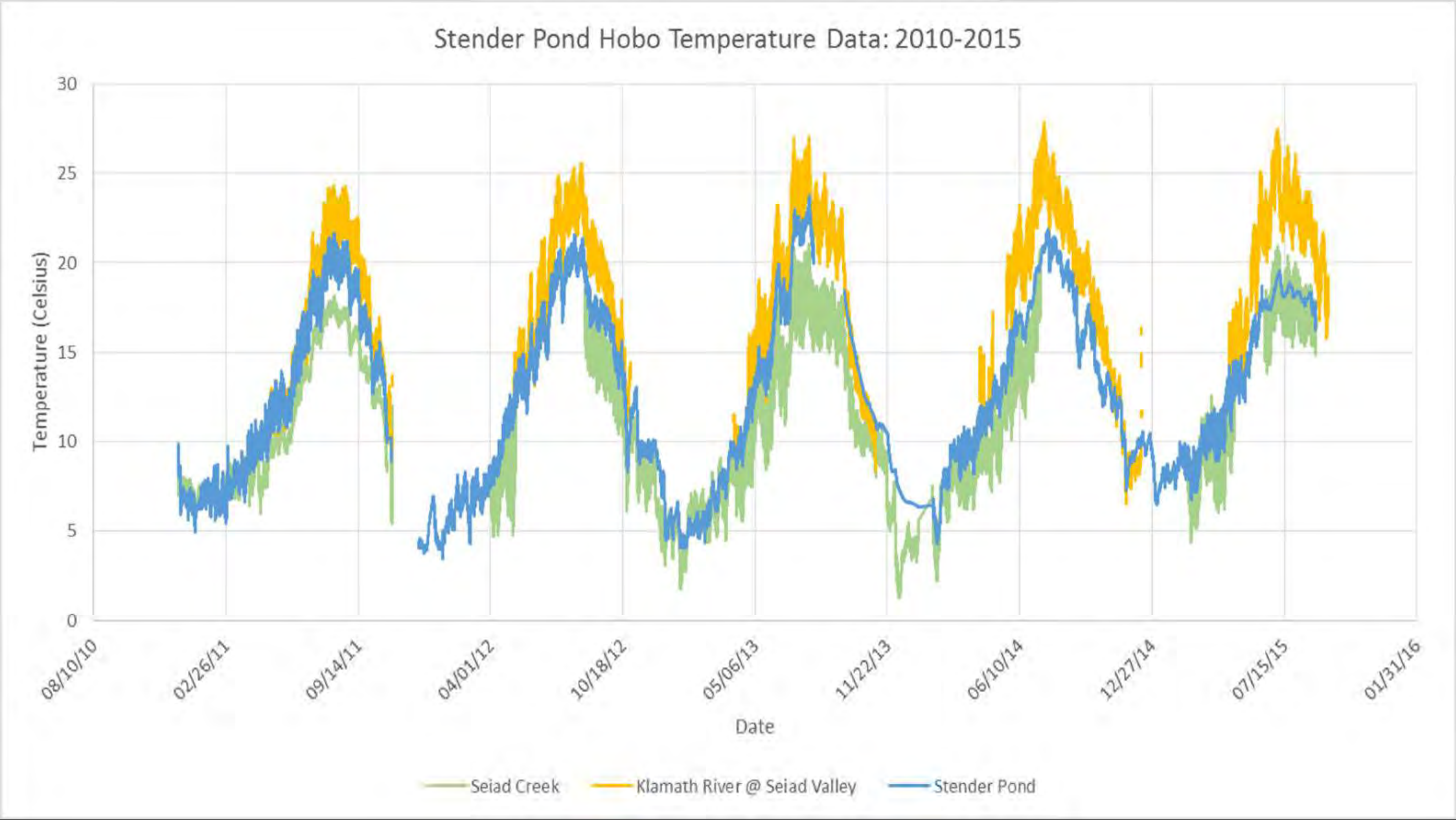

2011


2012


2015

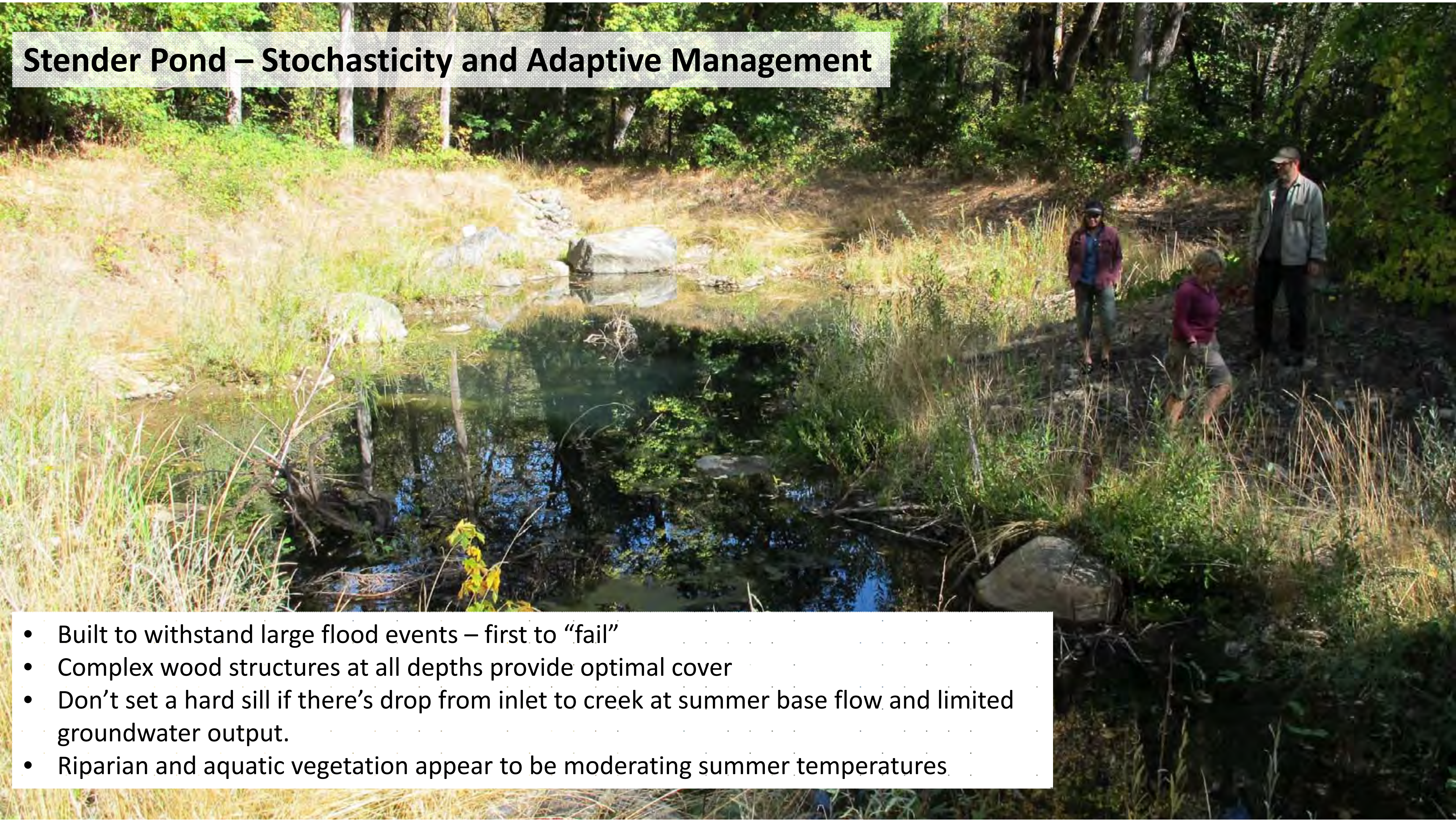
Summer 2012 – Debris Flow Into Stender Pond


Middle Klamath River Off-Channel Site Coho Juvenile Preliminary Population Estimates
300
250
200
150
100
50
0
winter 2011
summer 2011
winter 2012
summer 2012
winter 2013
winter 2014
spring 2014
fall 2014
winter 2015
Stender


Stender Pond Hobo Temperature Data: 2010-2015
Temperature (Celsius)
30
25
20
15
10
5
0
08/10/10
02/26/11
09/14/11
04/01/12
10/18/12
05/06/13
11/22/13
06/10/14
12/27/14
07/15/15
01/31/16
Date
Seiad Creek
Klamath River @ Seiad Valley
Stender Pond

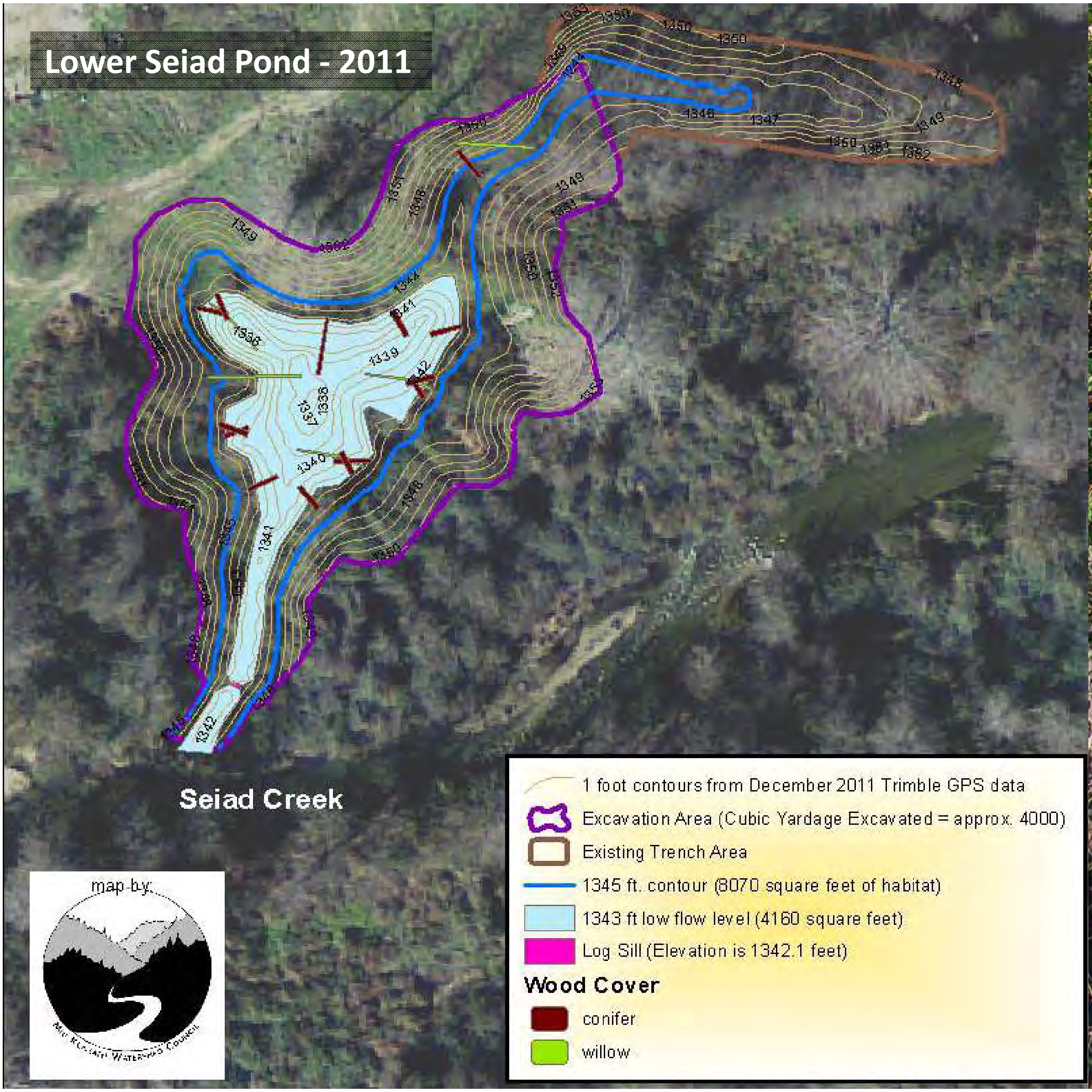

Off-channel habitat

Stender Pond – Stochasticity and Adaptive Management



- Built to withstand large flood events – first to "fail"
- Complex wood structures at all depths provide optimal cover
- Don't set a hard sill if there's drop from inlet to creek at summer base flow and limited groundwater output.
- Riparian and aquatic vegetation appear to be moderating summer temperatures

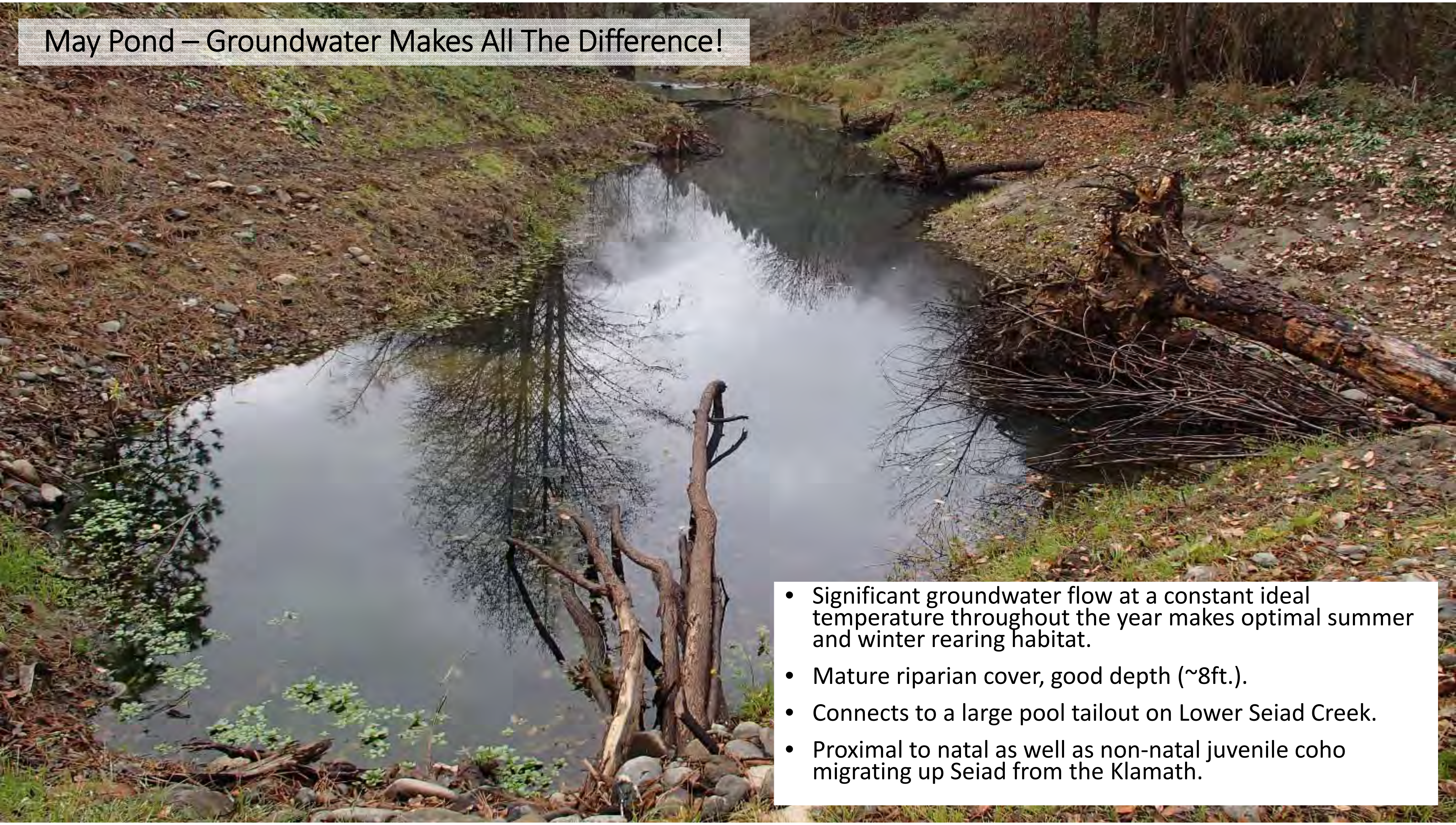
2012 May Off-Channel Coho Rearing Habitat Project on Seiad Creek


Lower Seiad Pond - 2011
Seiad Creek
1 foot contours from December 2011 Trimble GPS data
Excavation Area (Cubic Yardage Excavated = approx. 4000)
Existing Trench Area
1345 ft. contour (8070 square feet of habitat)
1343 ft low flow level (4160 square feet)
Log Sill (Elevation is 1342.1 feet)
Wood Cover
conifer
willow
map by:


Lower Seiad Pond Before

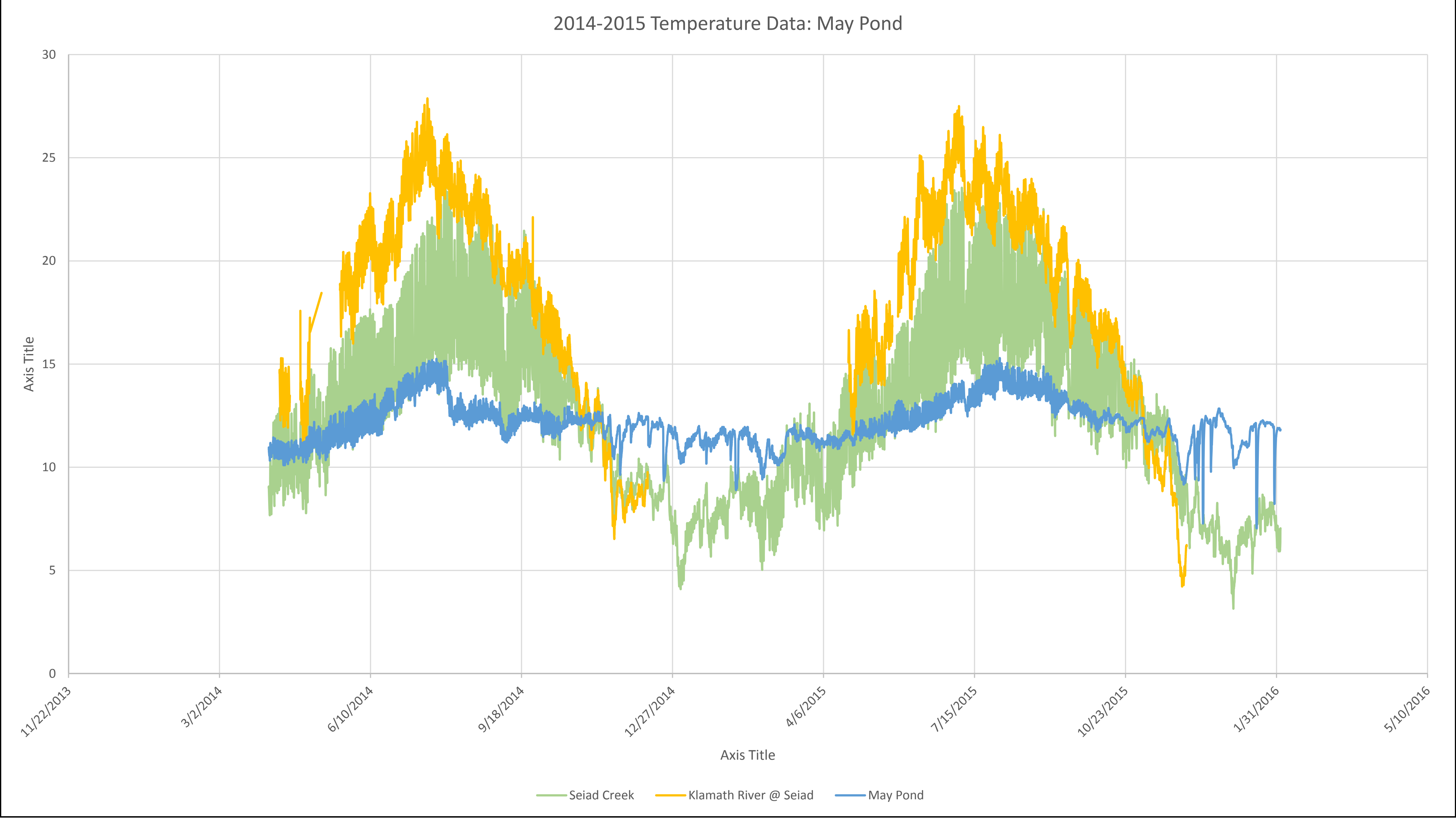

Lower Seiad Pond After

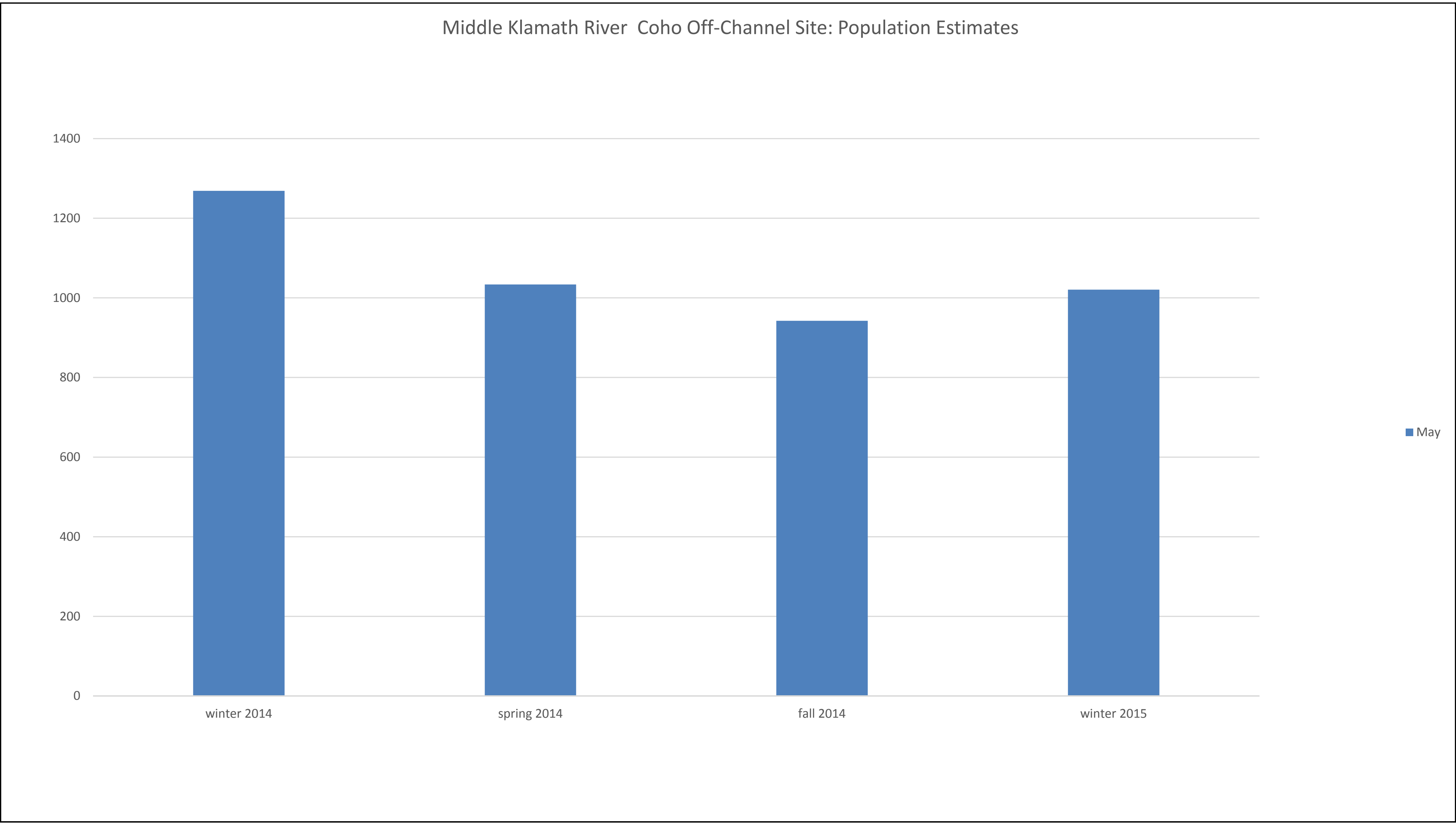
Lower Seiad and May Pond (Under Construction)

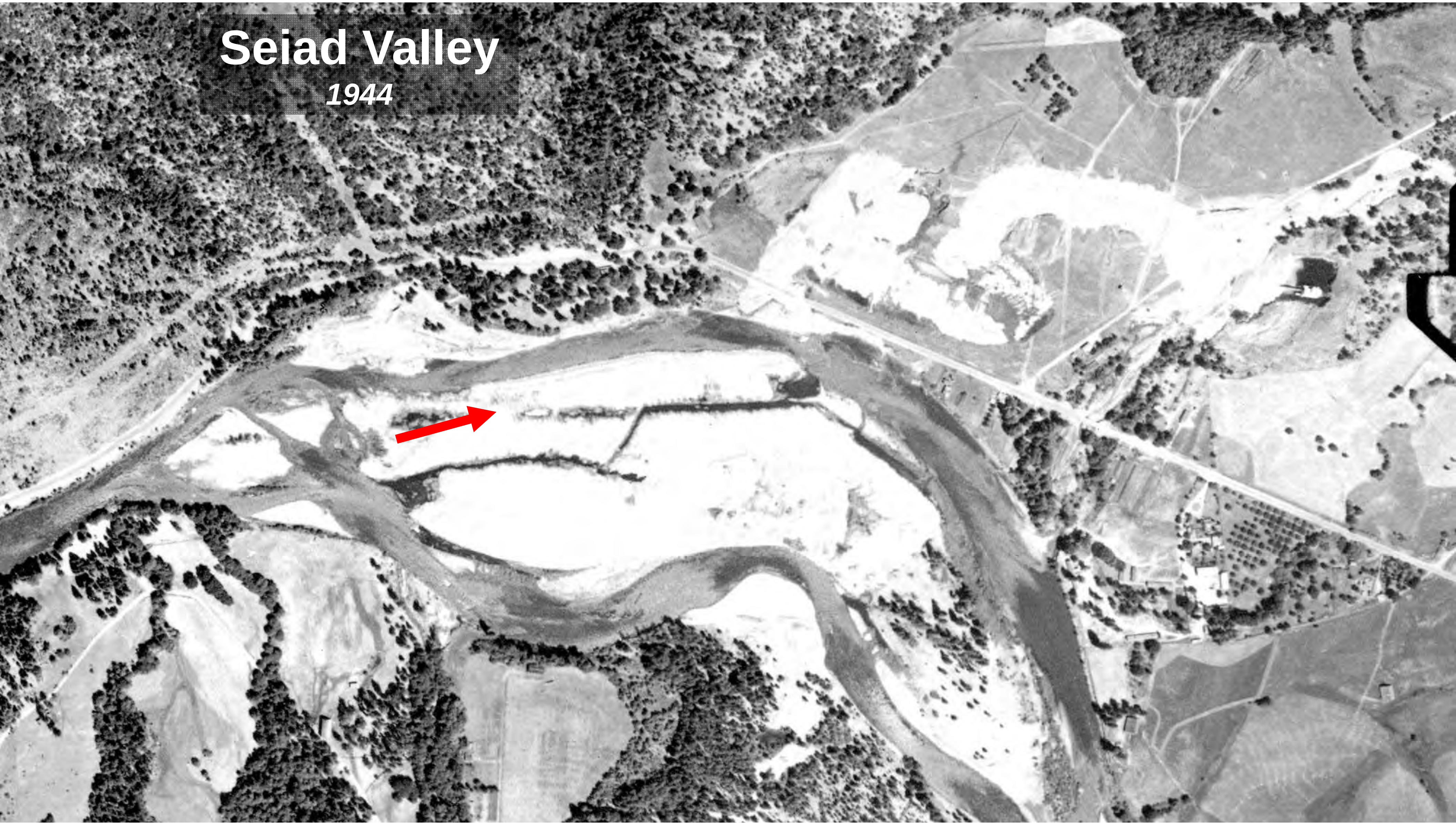


May Pond – Groundwater Makes All The Difference!

- Significant groundwater flow at a constant ideal temperature throughout the year makes optimal summer and winter rearing habitat.
- Mature riparian cover, good depth (~8ft.).
- Connects to a large pool tailout on Lower Seiad Creek.
- Proximal to natal as well as non-natal juvenile coho migrating up Seiad from the Klamath.


2014-2015 Temperature Data: May Pond
Axis Title
30
25
20
15
10
5
0
11/22/2013
3/2/2014
6/10/2014
9/18/2014
12/27/2014
4/6/2015
7/15/2015
10/23/2015
1/31/2016
5/10/2016
Axis Title
Seiad Creek
Klamath River @ Seiad
May Pond


Middle Klamath River Coho Off-Channel Site: Population Estimates
1400
1200
1000
800
600
400
200
0
winter 2014
spring 2014
fall 2014
winter 2015
May

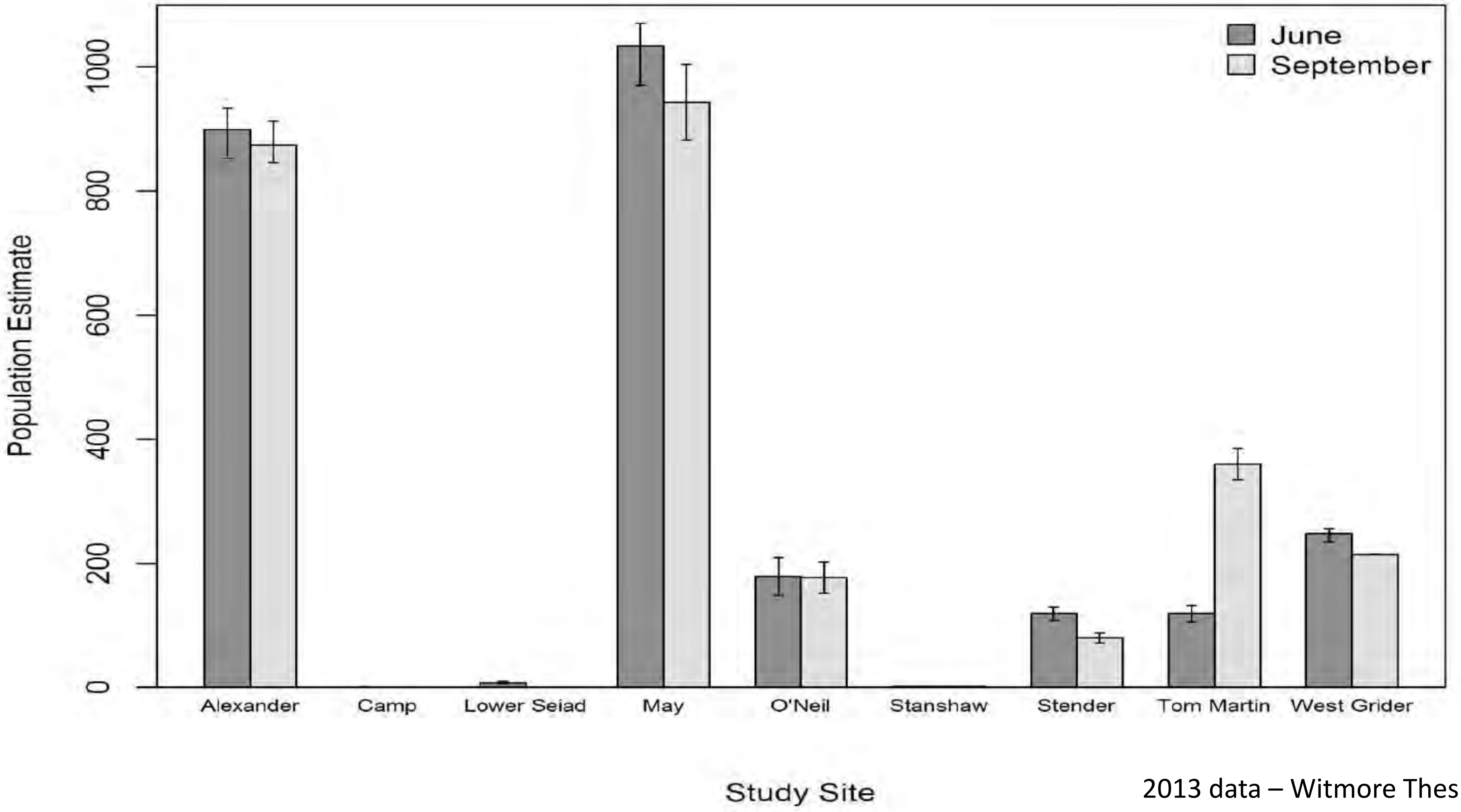


Seiad Valley

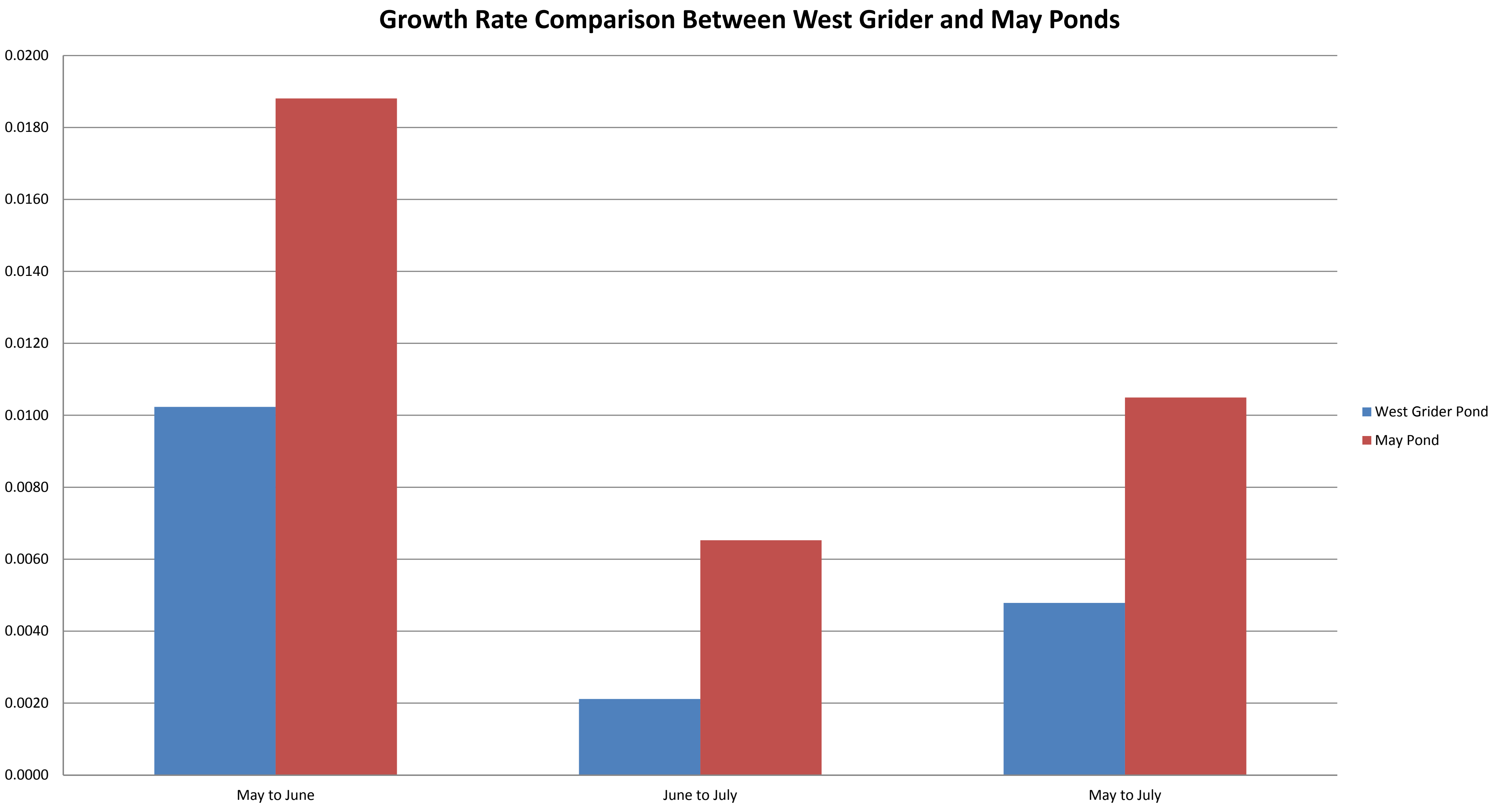
1944

Seiad Valley

1964 - Before Flood



2013 data – Witmore Thesis

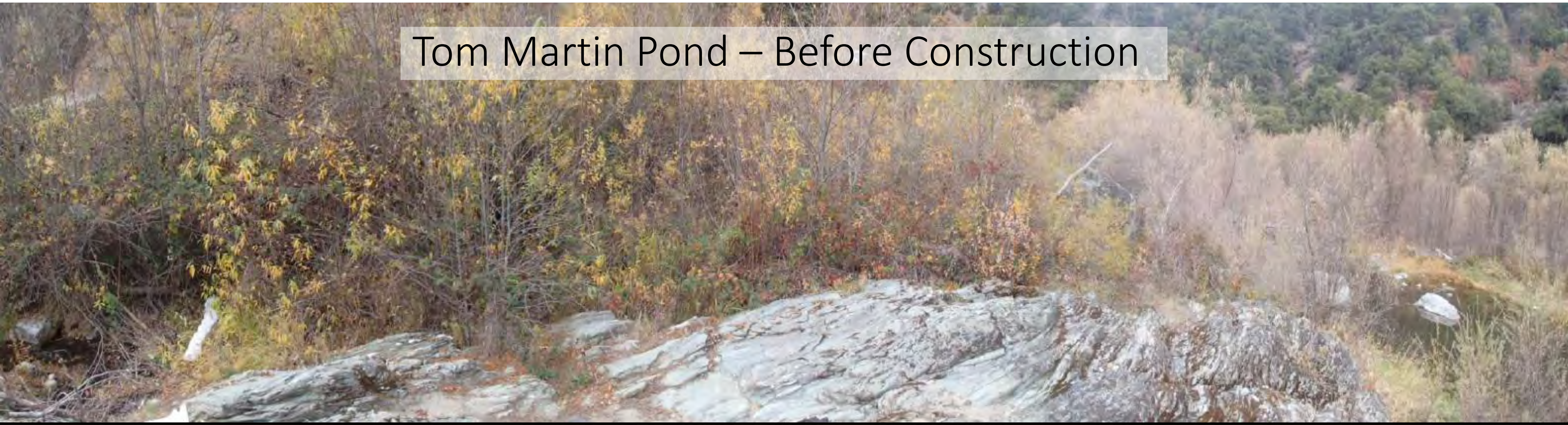

Growth Rate Comparison Between West Grider and May Ponds
0.0200
0.0180
0.0160
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
May to June
June to July
May to July
West Grider Pond
May Pond

Coho Spawning Surveys

Seiad Creek Winter 2013-2014 Spawning Escapement More Than 2x Any Previous 10 Years Monitoring

Tom Martin Creek

- First thermal refugia below Scott River
- 748 coho observed in 200' section below Hwy 96 culvert (Summer 2012).
- First project with specific focus to expand summer thermal refugia.
- Implemented November 2013



Tom Martin Pond – Before Construction

Tom Martin Pond – After Construction

Tom Martin Pond

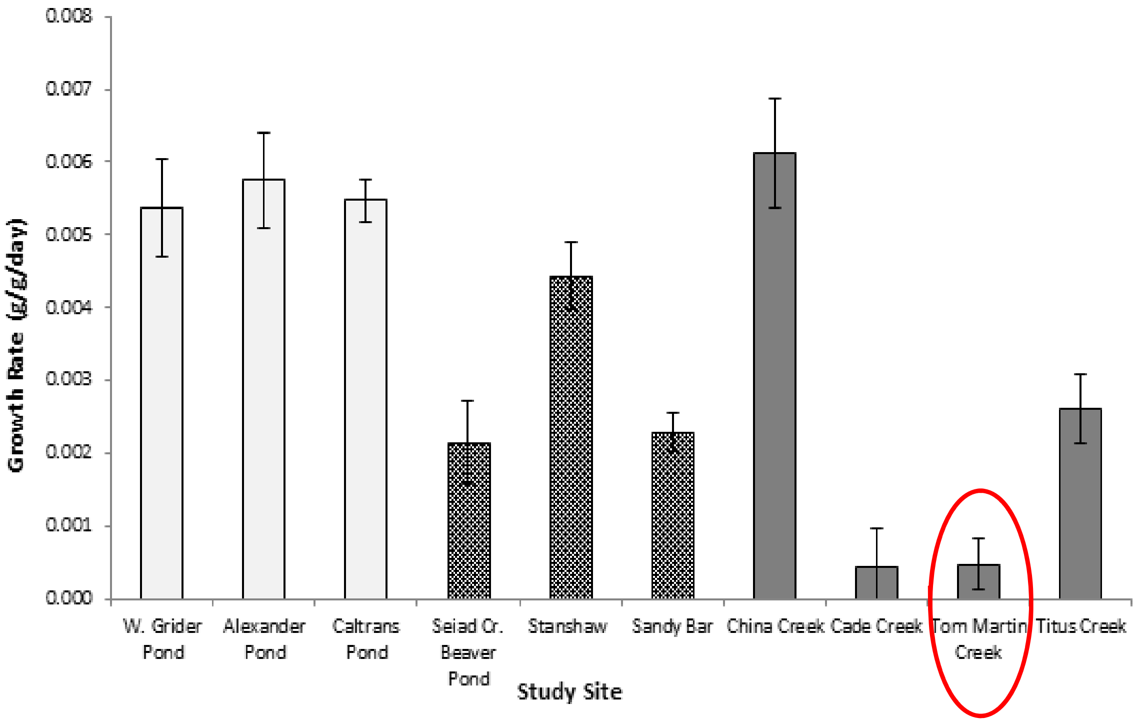
Tom Martin – After Brush Bundles


CALIFORNIA REPUBLIC

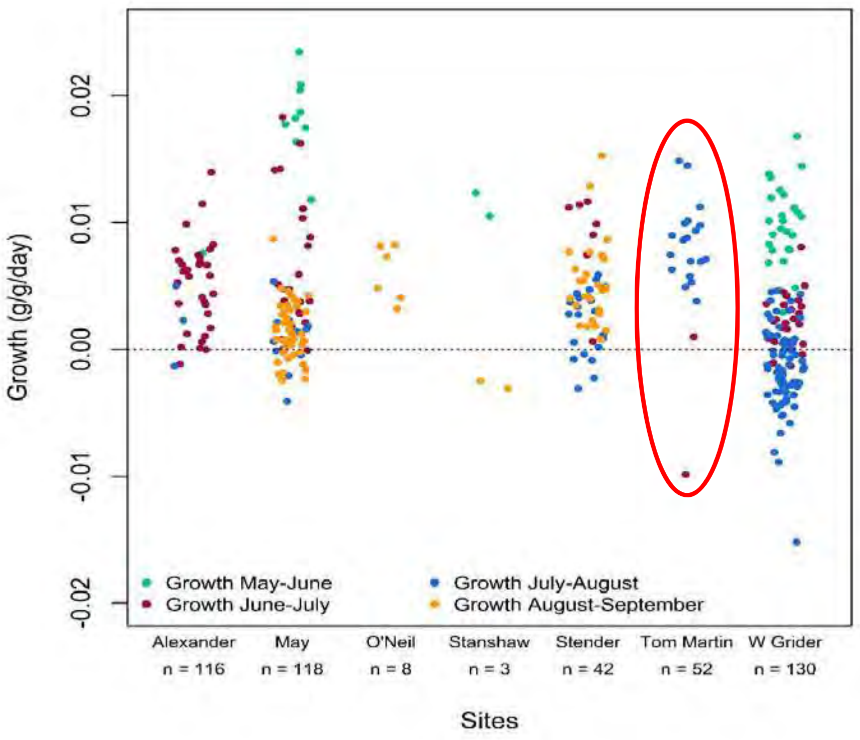
Tom Martin Pond After Feb 2015 High Flow Event

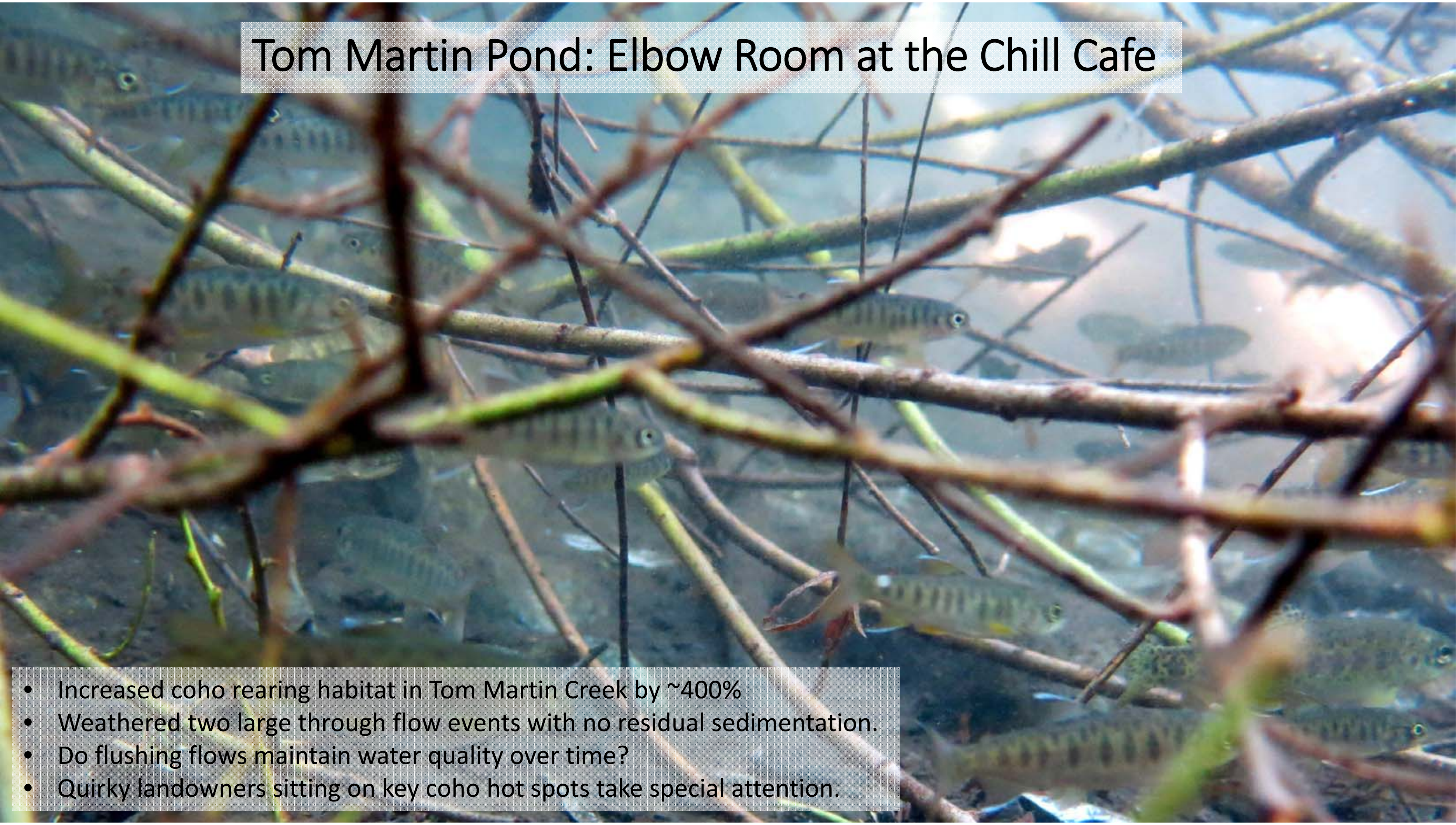
Summer Growth Rates in Tom Martin Creek Pre- and Post-Construction

Data from Shari Witmore MS Thesis (2014)



Data from Michelle Krall MS Thesis (preliminary)

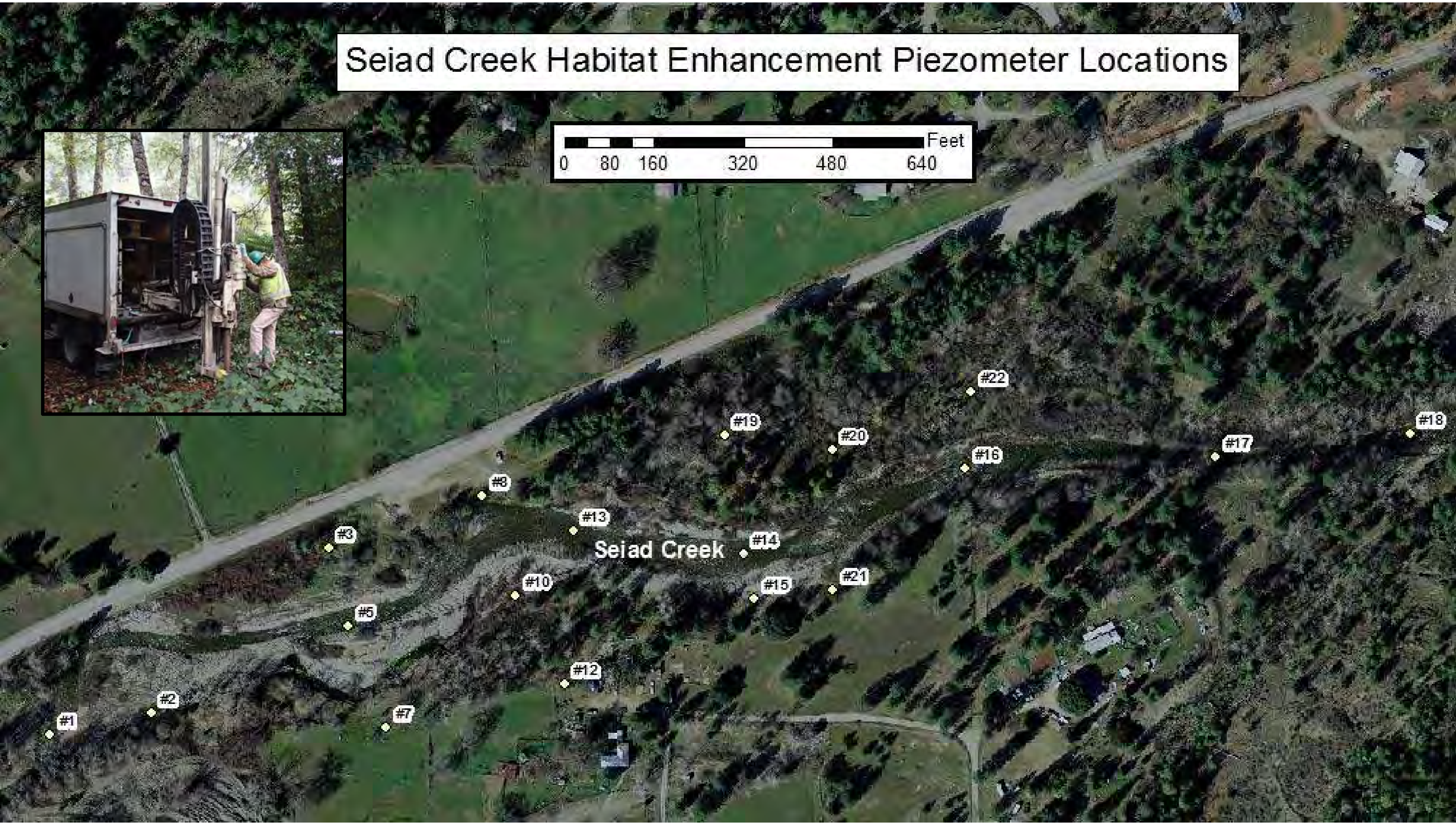




Tom Martin Pond: Elbow Room at the Chill Cafe

- Increased coho rearing habitat in Tom Martin Creek by ~400%
- Weathered two large through flow events with no residual sedimentation.
- Do flushing flows maintain water quality over time?
- Quirky landowners sitting on key coho hot spots take special attention.

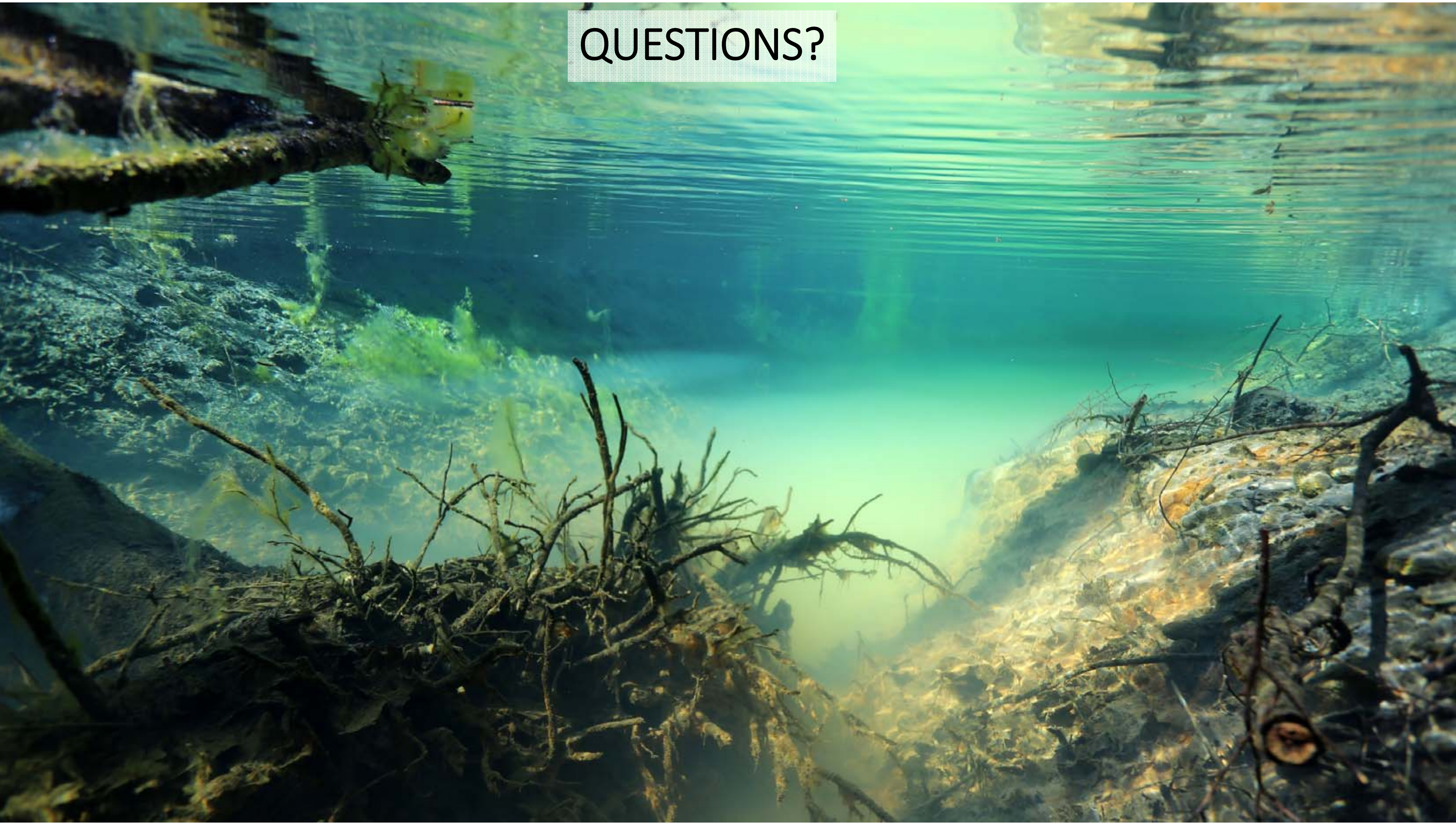
- **Don’t skimp on wood!**
- **Design Inlet/Outlets to be inviting during larger flow events.**
- **Avoid hard sill outlets if possible to maximize connectivity.**
- **In temperature stressed environments, maximize riparian cover.**
- **Know thy groundwater!**

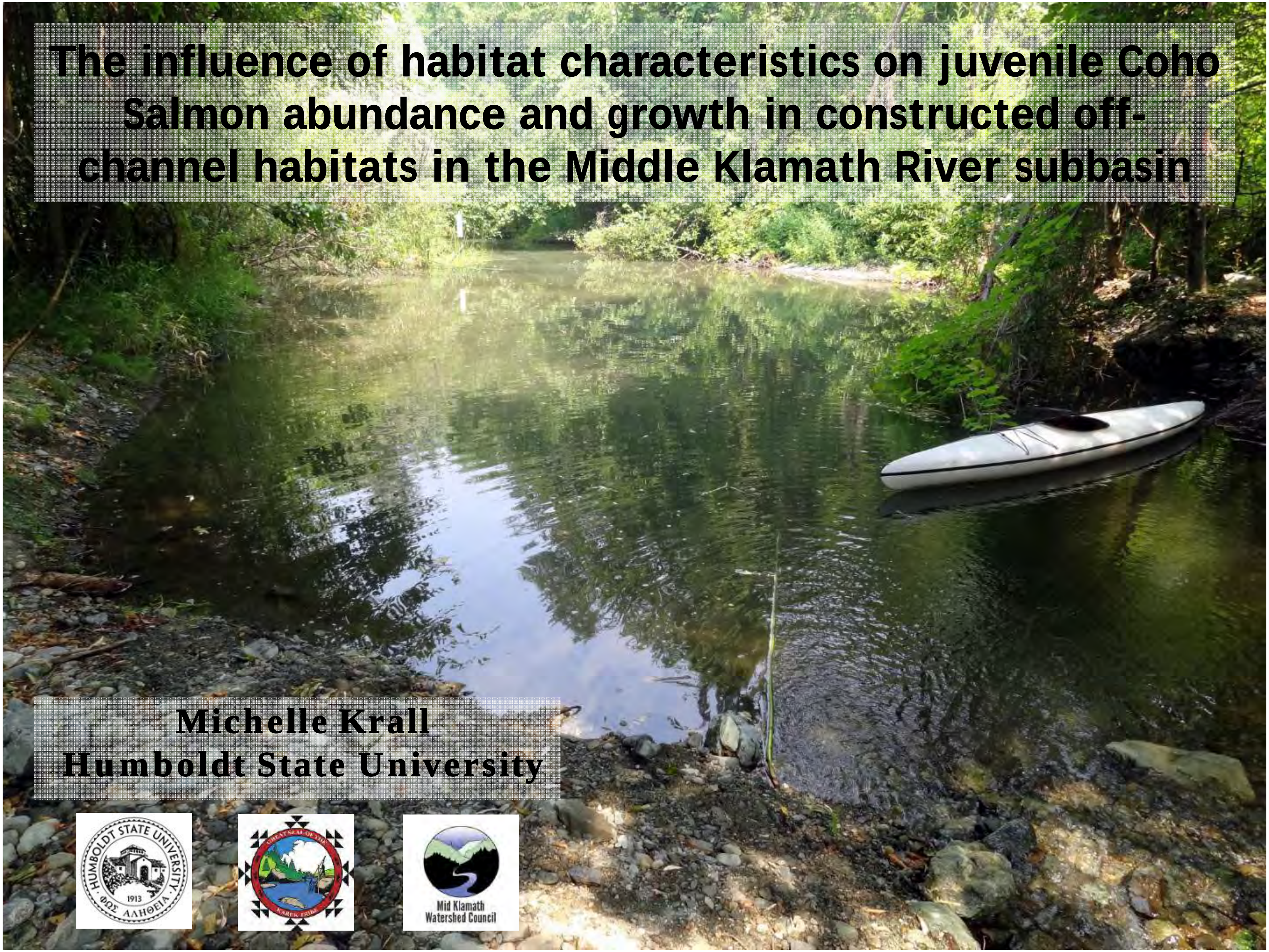


Seiad Creek Habitat Enhancement Piezometer Locations

- **Site projects based on coho life history observations (hot spots), groundwater observations and fluvial geomorphic processes. Work across property boundaries.**
- **Engage robust design team to increase likelihood of success.**
- **Monitor to determine potential direct benefits to the fish or necessary modifications.**
- **Share results so other restorationists can learn from our successes and failures (SRF! Klamath Fisheries Field Exchange).**

QUESTIONS?





The influence of habitat characteristics on juvenile Coho Salmon abundance and growth in constructed off-channel habitats in the Middle Klamath River subbasin

Michelle Krall
Humboldt State University

Mid Klamath
Watershed Council

Outline

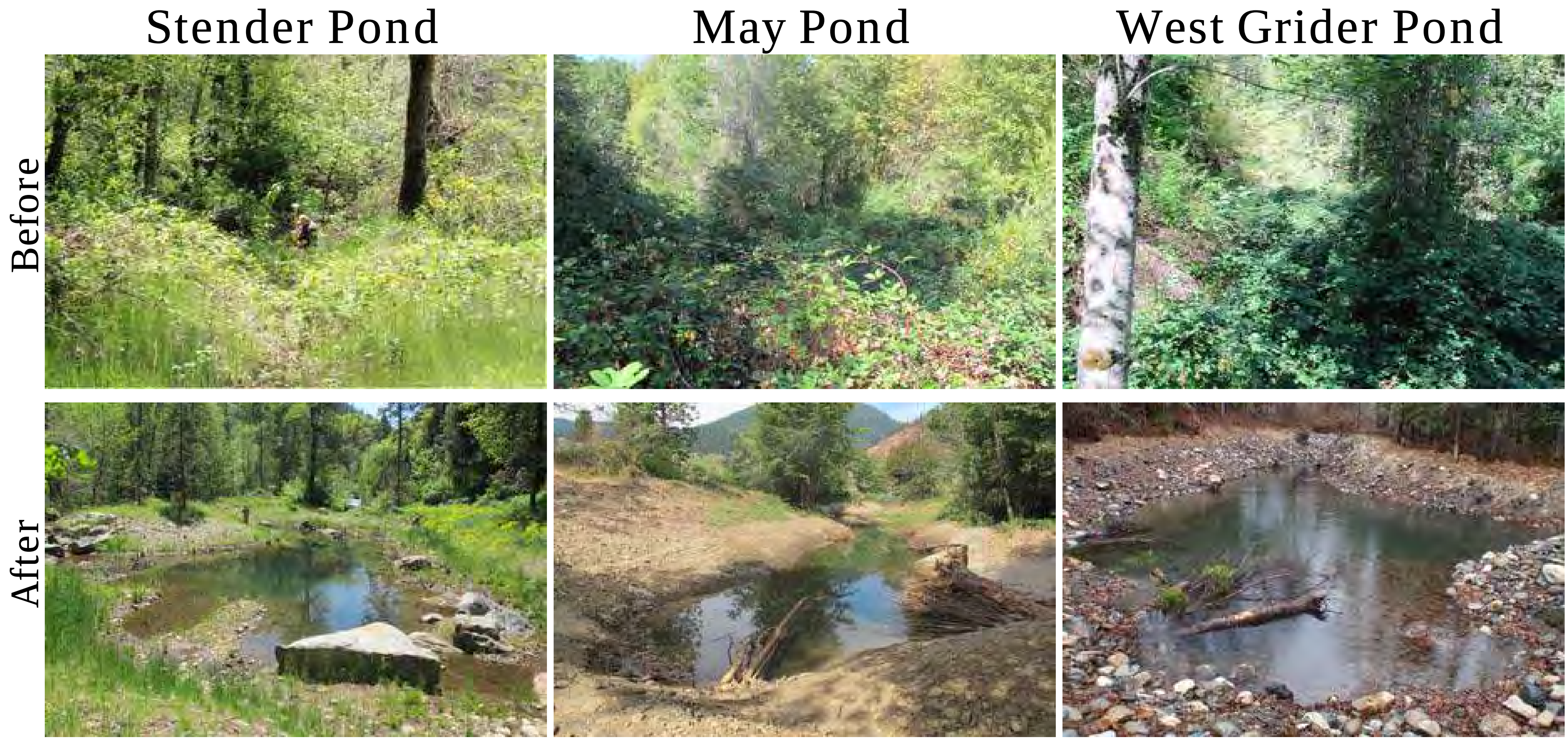
- Short Introduction
- Methods
- Results
    - Abundance
    - Diets and Growth
- Conclusions

Introduction

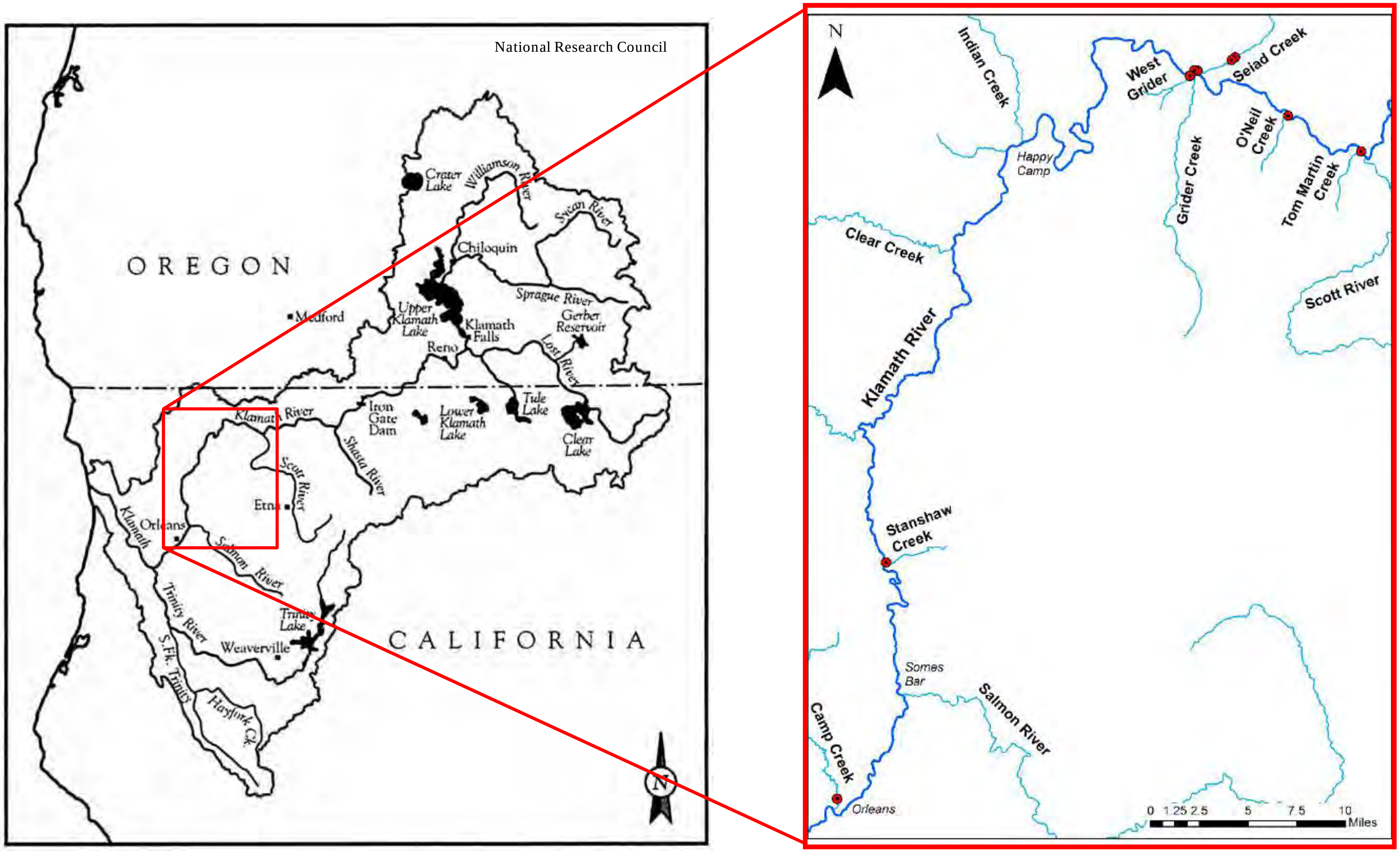
- Coho in the Klamath Basin in SONCC ESU
  - Listed as threatened in 1997
- Stresses & Threats in Klamath Basin
  - "Lack of quality summer and winter rearing habitat that is protected from warm temperatures and high winter flows, respectively…"
  - "[Summer] rearing is limited in terms of its quality, quantity, and connectivity…"

Will Harling

Introduction



Introduction



Research Questions

1. Is summer abundance of juvenile coho in constructed habitats better predicted by measures of **accessibility** of the habitat or **habitat conditions** within the site?

2. Is juvenile coho **growth** in constructed habitats greater in sites with abundant **food** and lower **densities** of coho?

Methods: Fish

- One time/month: May – September 2014
- Passive Integrated Transponder (PIT) tags

- Growth rate estimates (% body weight per day)

$$G = \left(\frac{ln(weight_{final}) - ln(weight_{initial})}{days\ passed}\right) \times 100$$

Methods: Fish

- Lincoln-Peterson Population estimates in June & September

$$\hat{N}_p = \frac{n_1 n_2}{m_2}$$

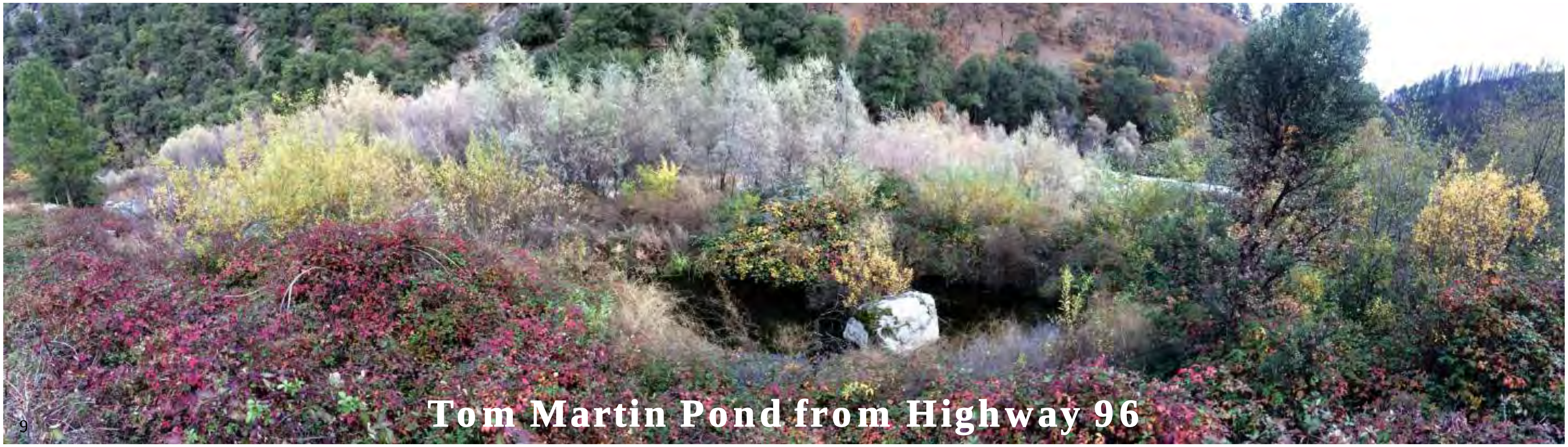
n_1 = total # captured day 1
n_2 = total # captured day 2
m_2 = total # recaptured on day 1 & 2

Methods: Accessibility

- Inlet depth
- MWMT of adjacent channel
- Habitat at inlet
  - Riffle or pool
- Distance & gradient from Klamath River

Methods: Within Off-Channel Pond

- MWMT
- Average diel variation
- Dissolved oxygen
- Suspended chlorophyll *a*
- Aquatic vegetation cover
- Turbidity
- Pond volume
- Average pond depth

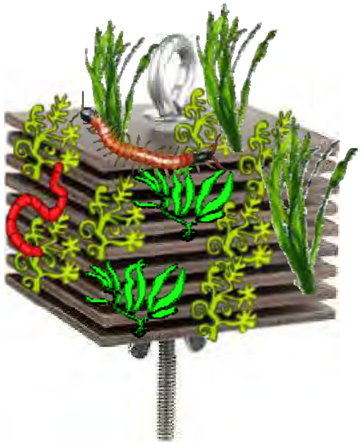


Tom Martin Pond from Highway 96

Methods: Food

- Available Food
  - Hester-Dendy samplers

- Diet composition
  - Gastric lavage



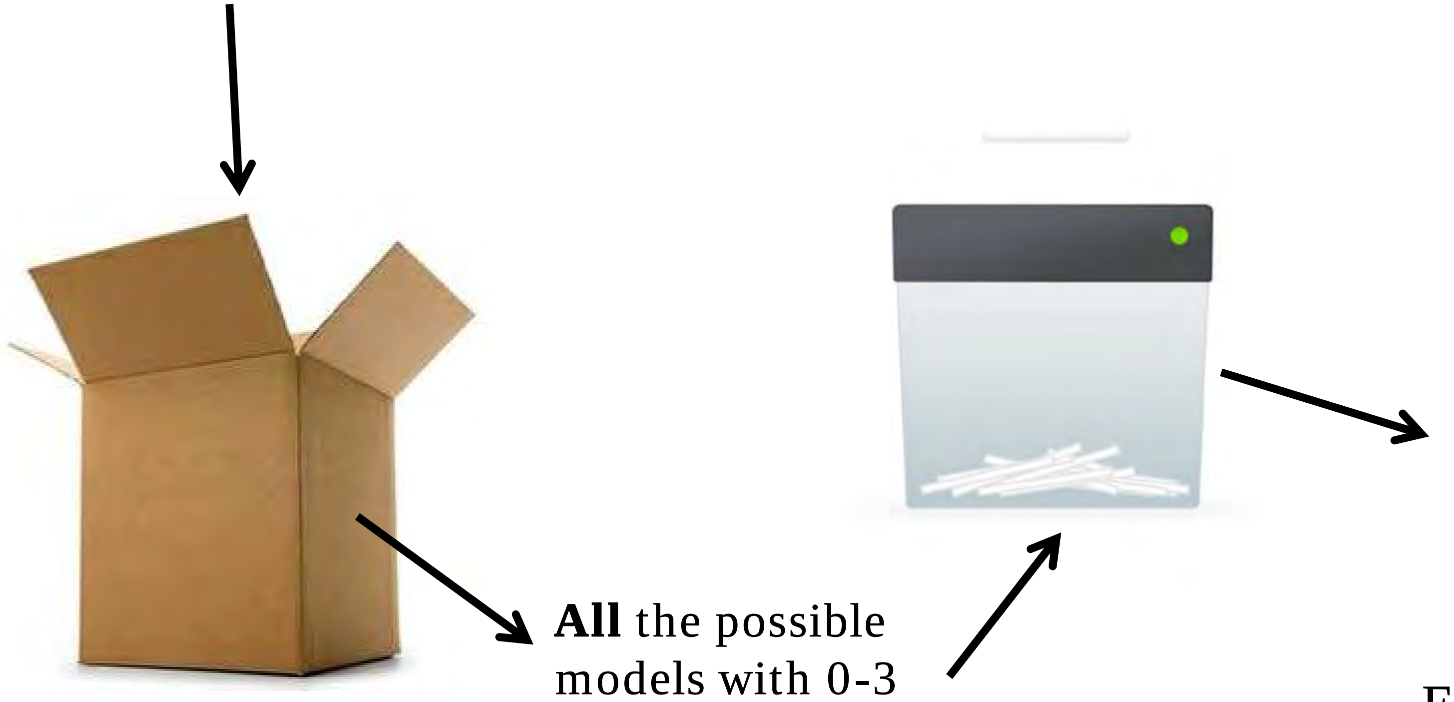
Methods: Statistical Analysis

1. Access vs. Habitat Conditions

- Lots of variables, few (nine) ponds = bad analysis
- Exploratory Analysis

Methods: Statistical Analysis

- Lots of predictor variables
- 1 response variable



All the possible models with 0-3 predictor variables

Best models
(based on BIC and excluding those much less likely than the best model)

END RESULT:
Averaged coefficient for each predictor variable

Methods: Statistical Analysis

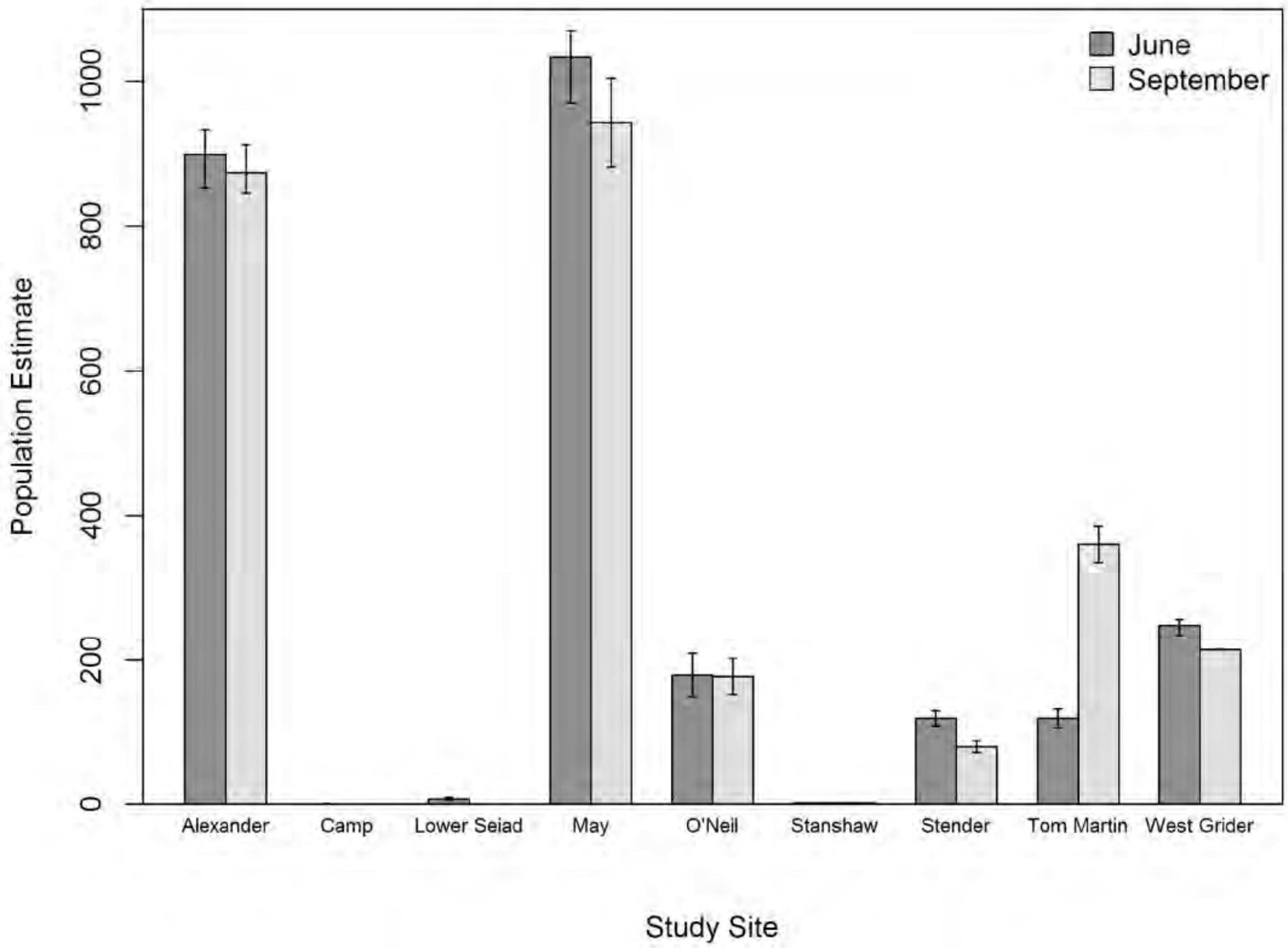
1. Access vs. Habitat Conditions

- Lots of variables, few (nine) ponds = bad analysis
- Exploratory Analysis
  - Throw in lots of predictor variables
  - Limit the # of variable in output
  - Candidate models selected based on minimum BIC
  - Averages the coefficients of candidate models
- Response variable: Abundance
- Predictor variables:
  1. All access variables (6)
  2. All habitat variables (8)

2. Growth

- Nonmetric multidimensional scaling (NMDS)

Results


Population Estimate
0
200
400
600
800
1000
June
September
Alexander
Camp
Lower Seiad
May
O'Neil
Stanshaw
Stender
Tom Martin
West Grider
Study Site

Results

Habitat conditions within the pond

predicted coho abundance better than

Accessibility to site

Habitat Predictor Variables	Coefficient (SE)
Relative Chlorophyll *a*	-0.45 (0.2)
Algae/Aquatic Vegetation Cover (%)	-0.05 (0.03)
Average Diel Variation (°C)	-0.35 (0.6)
Volume (m^3)	--
Average Pond Depth (m)	--
Turbidity (NTU)	--
MWMT (°C)	--
Dissolved Oxygen (mg/L)	--

Top model: $R^2 = 0.78$, BIC = -5.7

Accessibility Predictor Variables	Coefficient (SE)
Distance from Klamath River	0.0004 (0.0005)
Gradient (%) from Klamath River	-0.29 (0.6)
MWMT of Nearby Channel	1.14 (0.8)
Natal Stream	--
Habitat at Inlet	--
Inlet Depth (m)	--

Top model: $R^2 = 0.61$, BIC = -3.3

Results

Habitat conditions within the pond

predicted coho abundance better than

Accessibility to site

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Natal Stream	--
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Results

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Dissolved Oxygen (mg/L)	--

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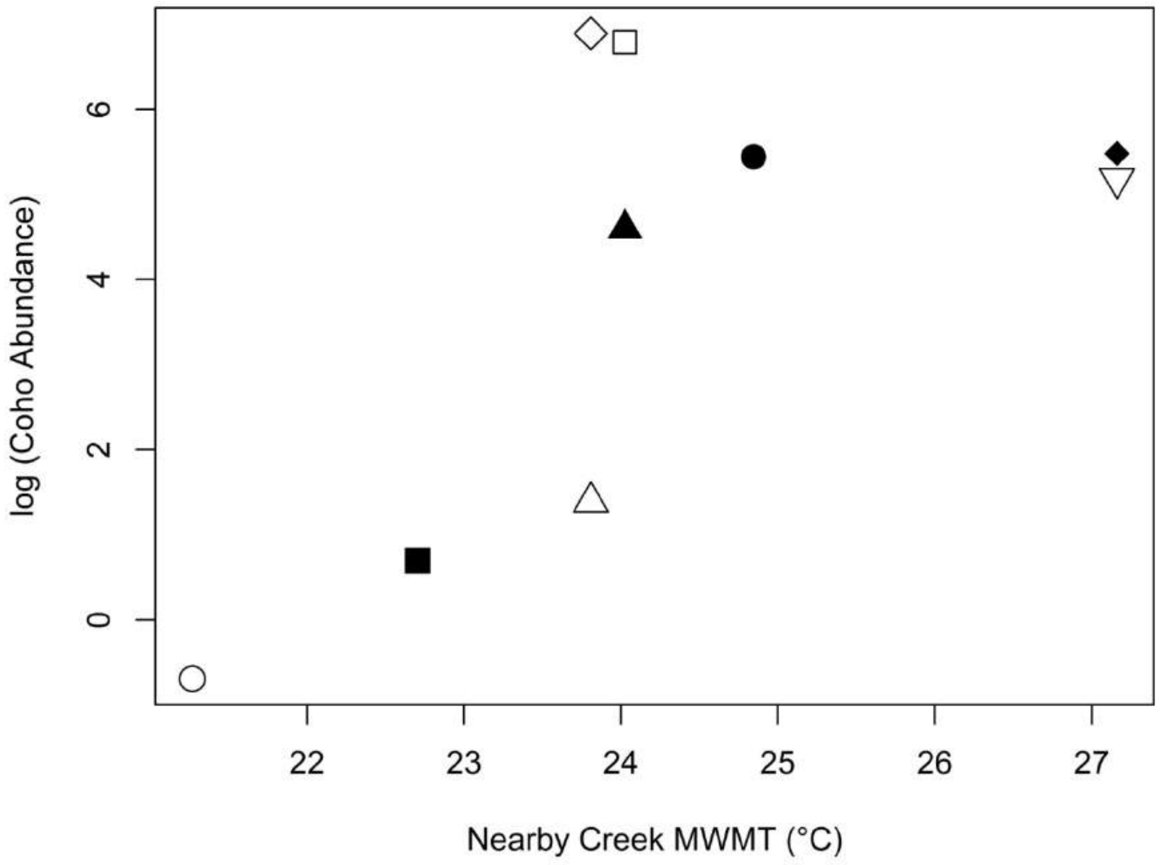
MWMT of Nearby Channel	1.14 (0.8)
Natal Stream	--
Habitat at Inlet	--
Inlet Depth (m)	--

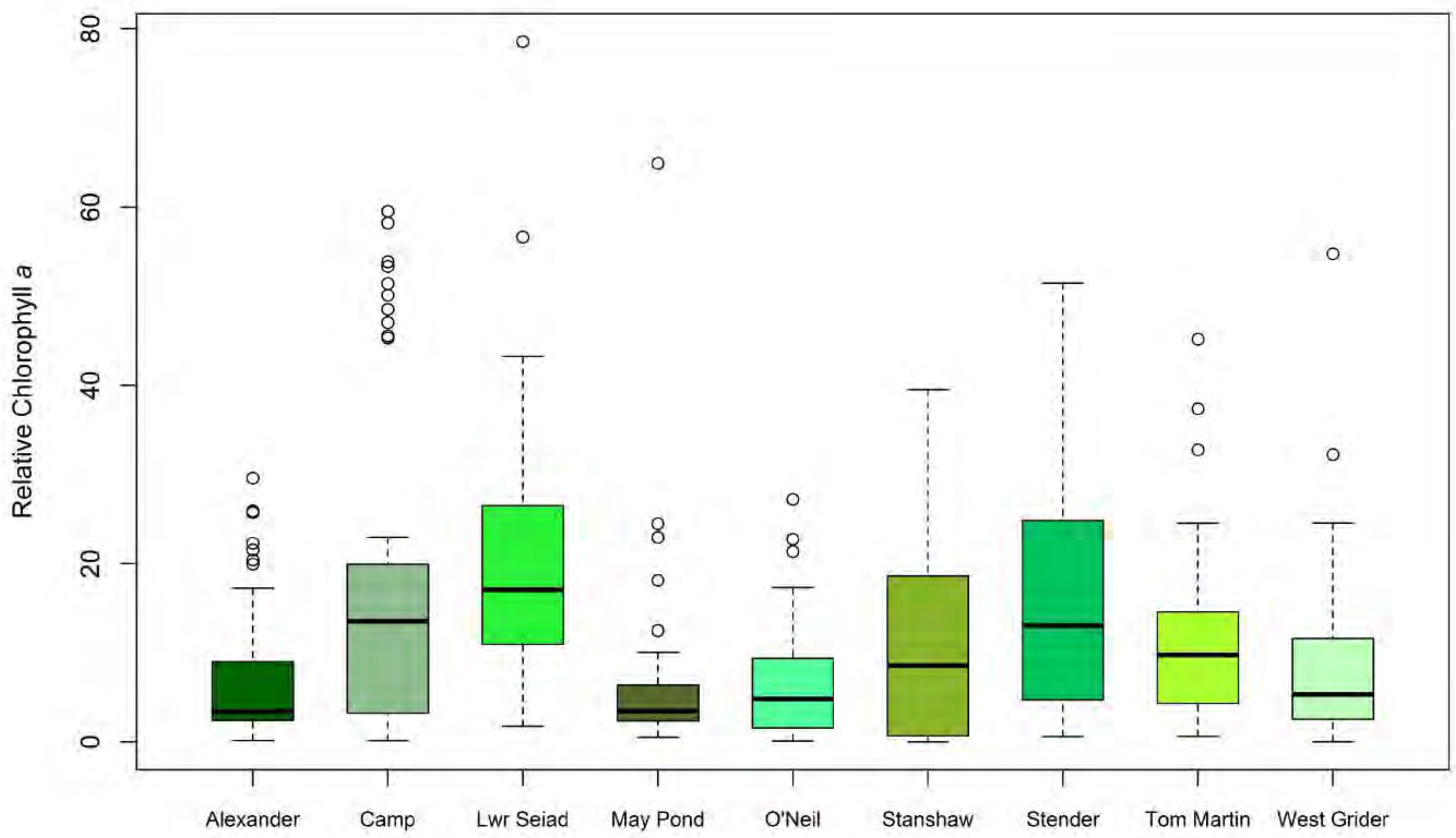
Top model: **R^2 = 0.61**, BIC = -3.3

Results

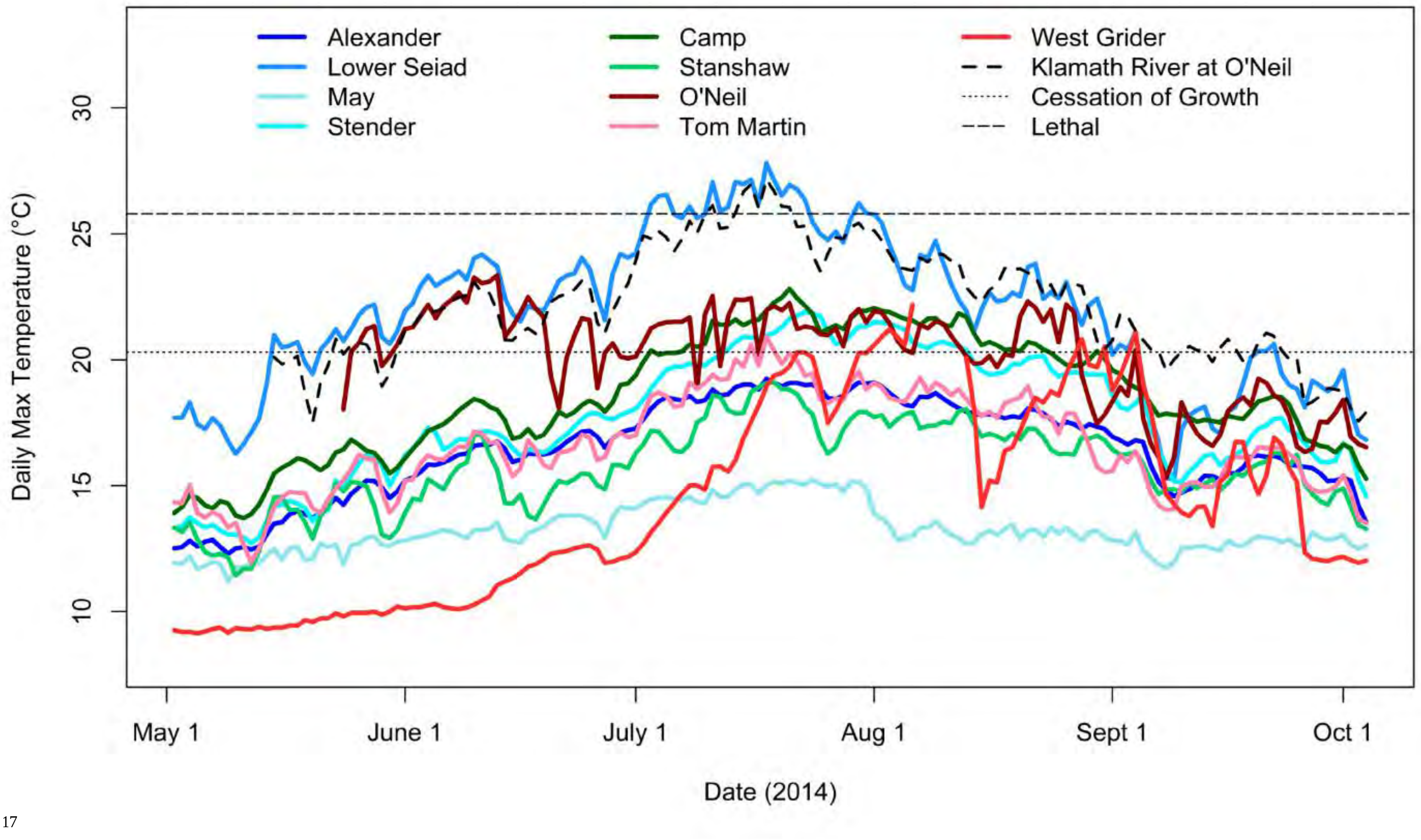


- Camp and Lower Seiad ponds
  - MWMT within habitat higher than nearby creek

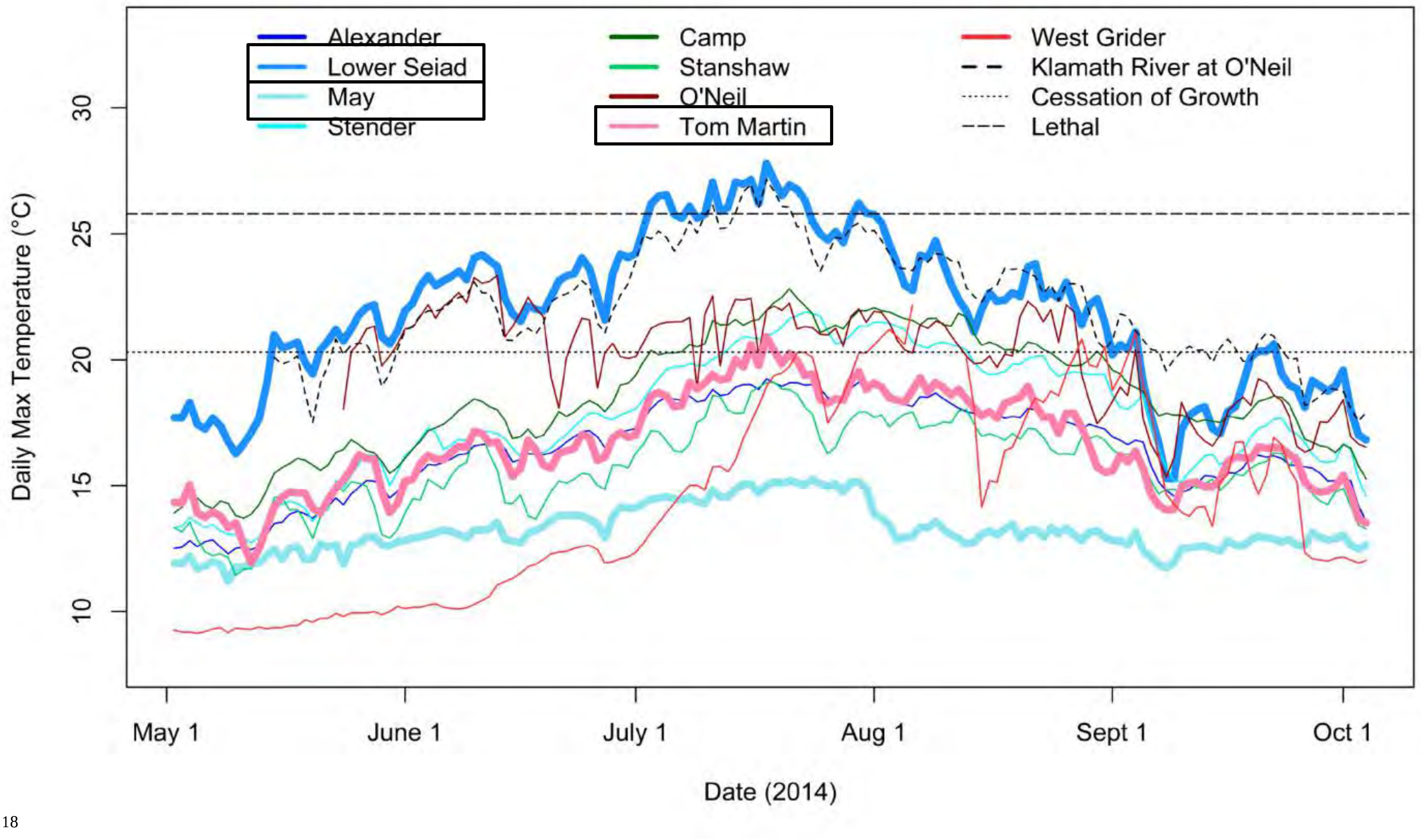
Results


Relative Chlorophyll *a*
0
20
40
60
80
Alexander
Camp
Lwr Seiad
May Pond
O'Neil
Stanshaw
Stender
Tom Martin
West Grider

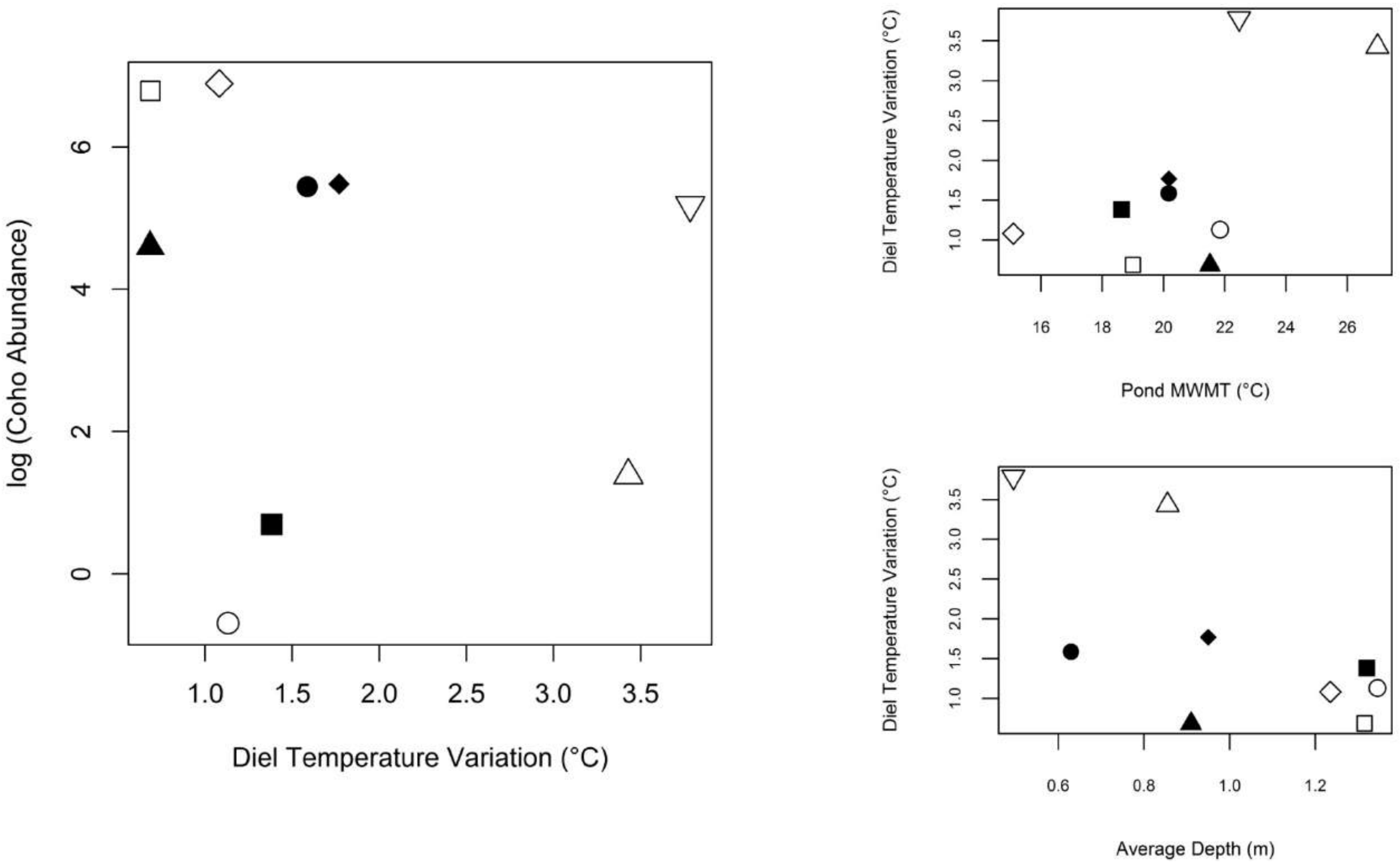
Results


Alexander
Lower Seiad
May
Stender
Camp
Stanshaw
O'Neil
Tom Martin
West Grider
Klamath River at O'Neil
Cessation of Growth
Lethal
Daily Max Temperature (°C)
10
15
20
25
30
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1
Date (2014)

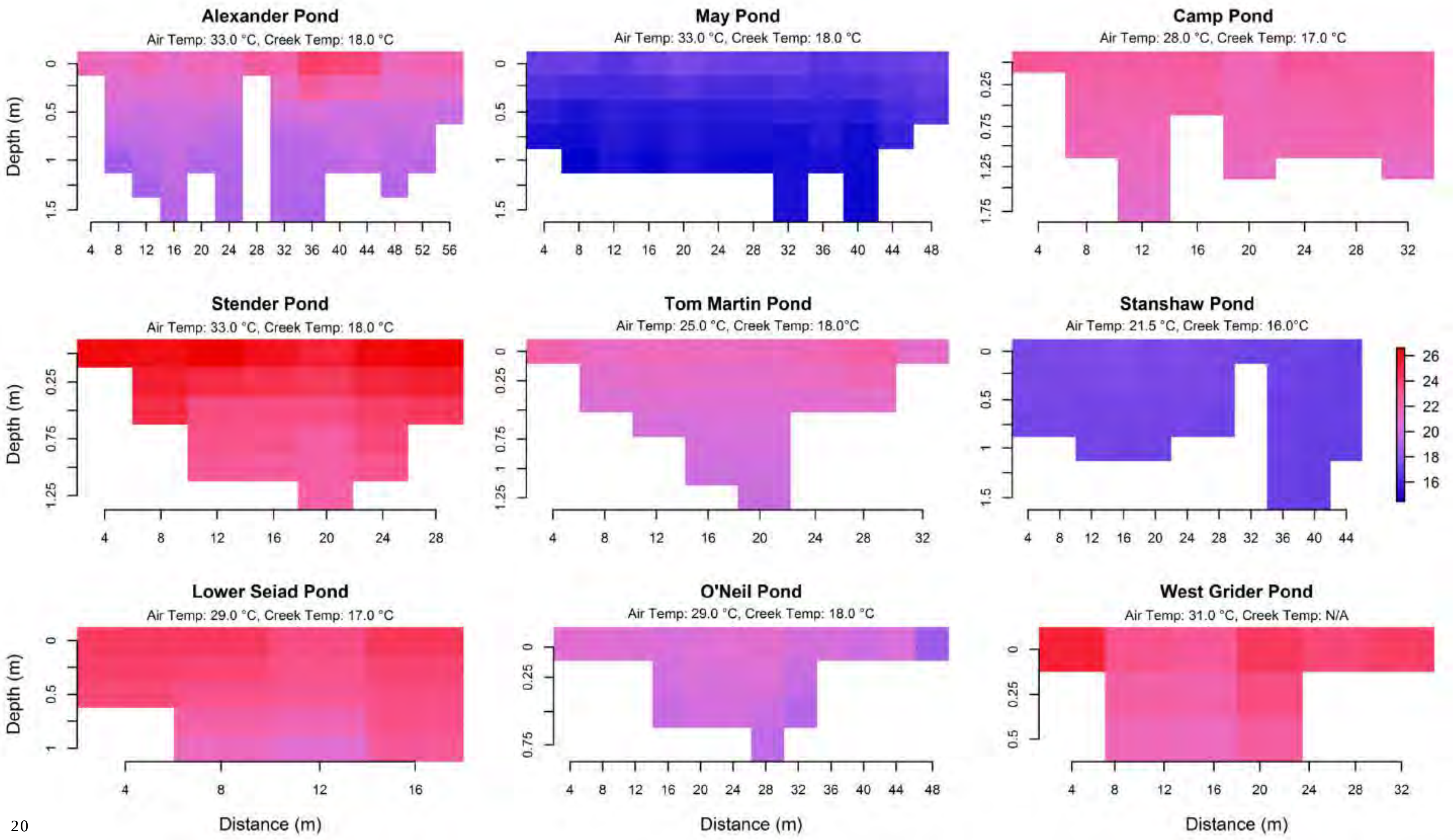
Results


Alexander
Lower Seiad
May
Stender
Camp
Stanshaw
O'Neil
Tom Martin
West Grider
Klamath River at O'Neil
Cessation of Growth
Lethal
Daily Max Temperature (°C)
10
15
20
25
30
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1
Date (2014)

Results


log (Coho Abundance)
0
2
4
6
1.0
1.5
2.0
2.5
3.0
3.5
Diel Temperature Variation (°C)
Diel Temperature Variation (°C)
1.0
1.5
2.0
2.5
3.0
3.5
16
18
20
22
24
26
Pond MWMT (°C)
Diel Temperature Variation (°C)
1.0
1.5
2.0
2.5
3.0
3.5
0.6
0.8
1.0
1.2
Average Depth (m)

Results


Alexander Pond
Air Temp: 33.0 °C, Creek Temp: 18.0 °C
May Pond
Air Temp: 33.0 °C, Creek Temp: 18.0 °C
Camp Pond
Air Temp: 28.0 °C, Creek Temp: 17.0 °C
Stender Pond
Air Temp: 33.0 °C, Creek Temp: 18.0 °C
Tom Martin Pond
Air Temp: 25.0 °C, Creek Temp: 18.0°C
Stanshaw Pond
Air Temp: 21.5 °C, Creek Temp: 16.0°C
Lower Seiad Pond
Air Temp: 29.0 °C, Creek Temp: 17.0 °C
O'Neil Pond
Air Temp: 29.0 °C, Creek Temp: 18.0 °C
West Grider Pond
Air Temp: 31.0 °C, Creek Temp: N/A
Depth (m)
Distance (m)
26
24
22
20
18
16

Question #2

Is juvenile coho growth in constructed habitats greater in sites with abundant food and lower densities of coho?

Results

- Dominant three taxa on Hester-Dendy samplers by biomass in all sites

Gastropoda

Worm-like

Odonata

Results

- Dominant taxa in the diets based on biomass

Alexander

1. **D. Chironomidae (P)**
2. Ephem/Trichop (A)

Lower Seiad

1. **Diptera (A)**
2. Ephem/Trichop (A)

May Pond

1. **D. Chironomidae (P)**
2. Gastropoda

O’Neil

1. **Diptera (A)**
2. Hemiptera

Stanshaw

1. **Megaloptera**
2. Diptera (A)

Stender

1. **Odonata (L)**
2. D. Chironomidae (P)

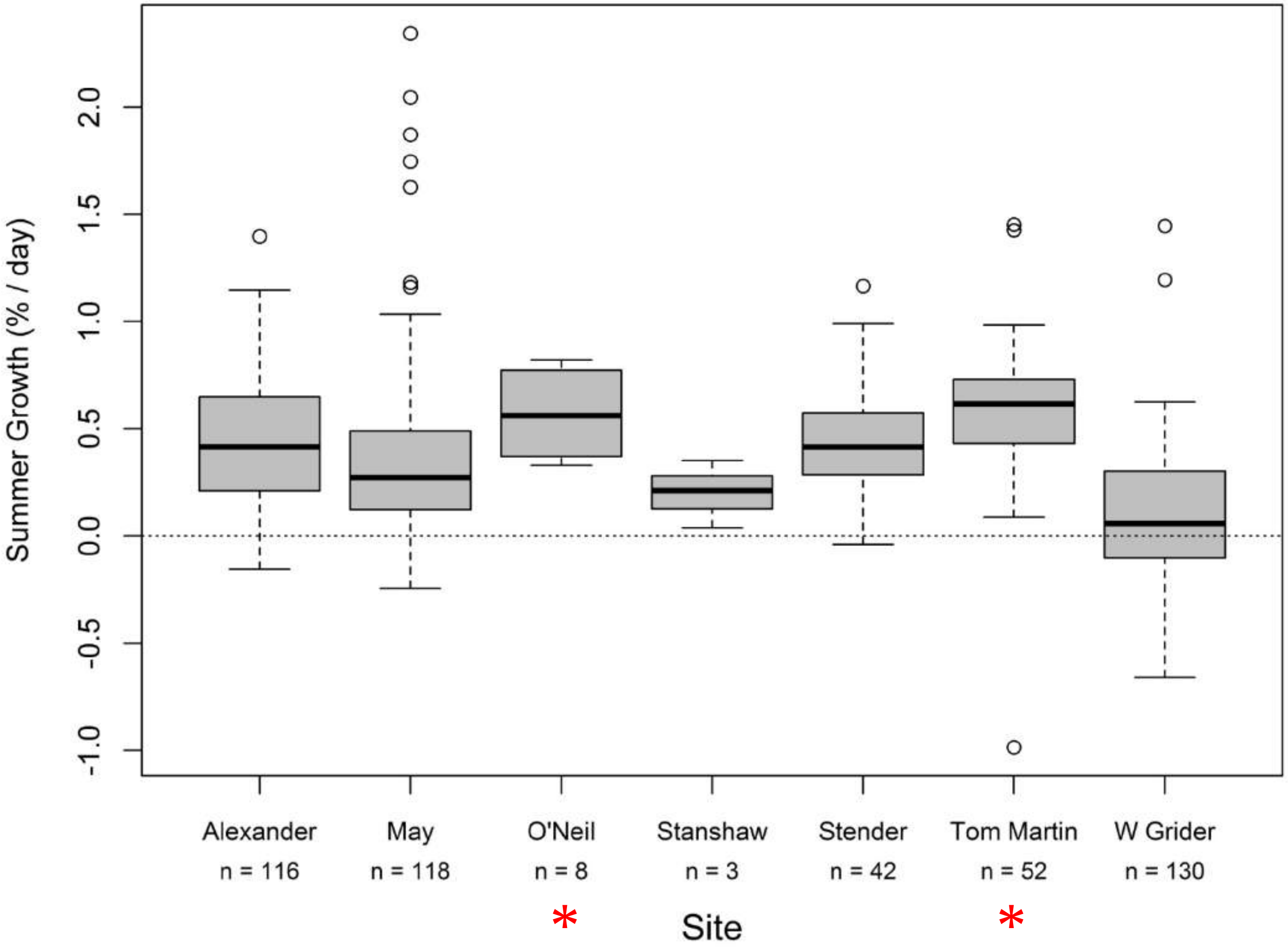
Tom Martin

1. **Diptera (A)**
2. Ephemeroptera (L)

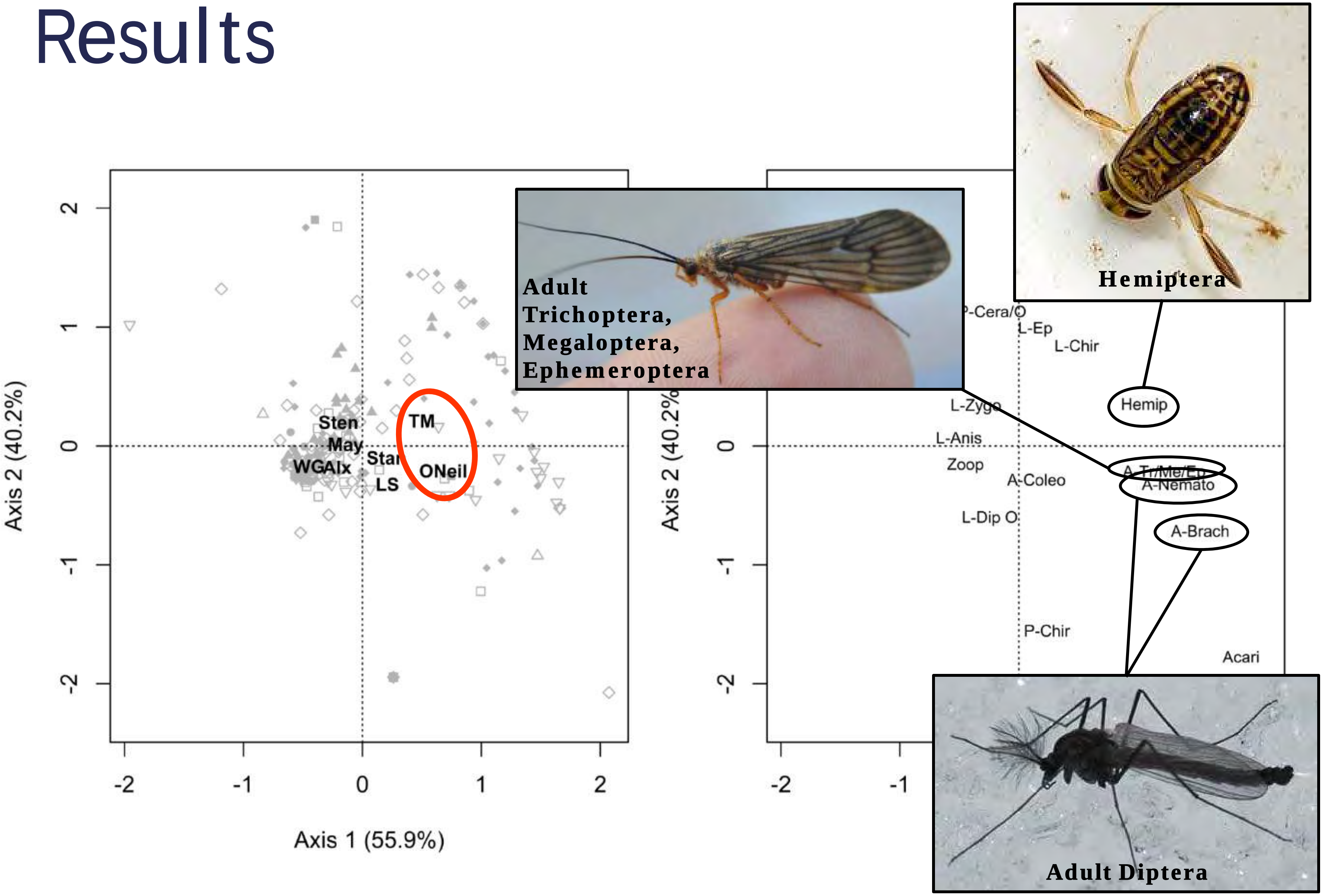
West Grider

1. **D. Ceratopogonidae (P)**
2. Diptera (A)

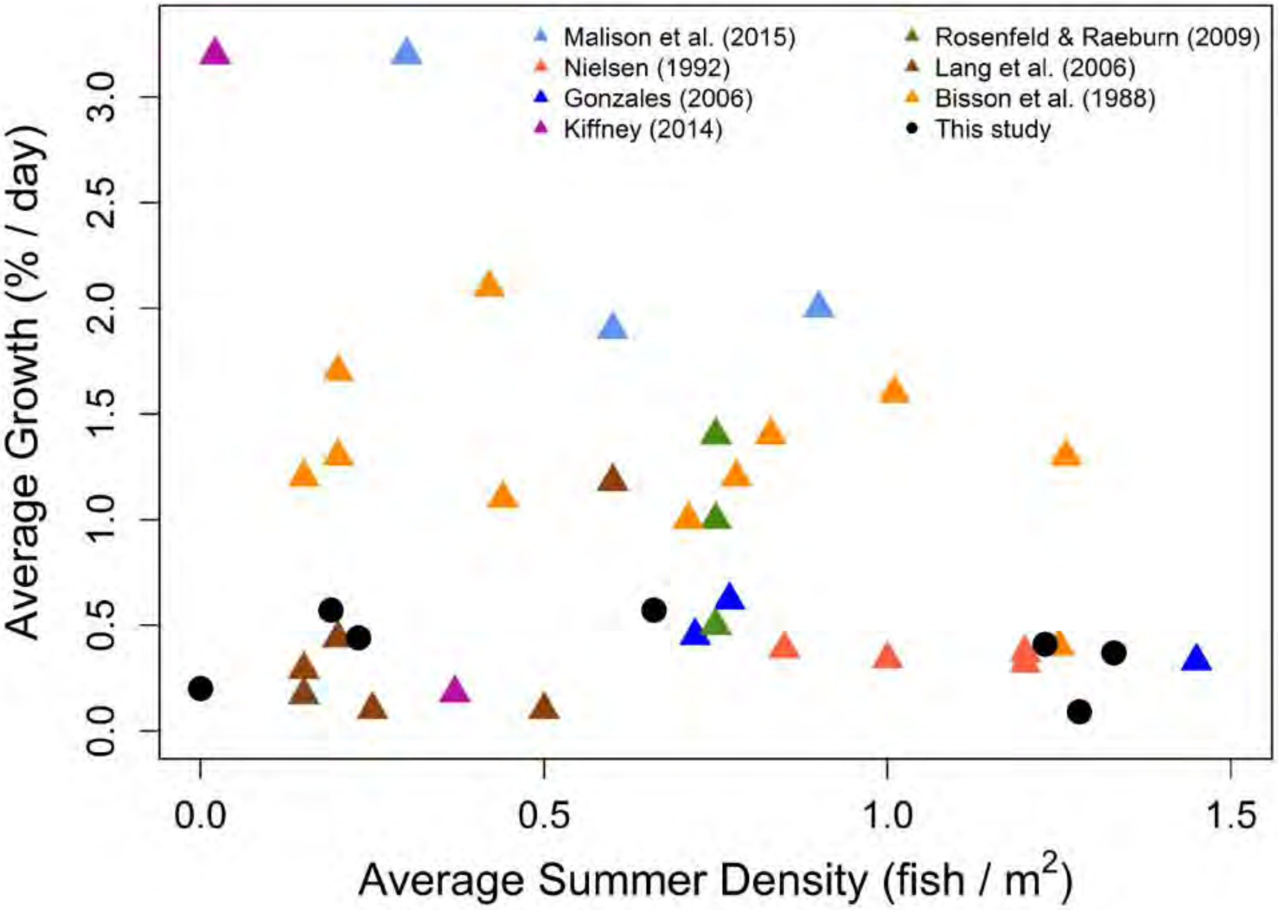
Results


Summer Growth (% / day)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Alexander
n = 116
May
n = 118
O'Neil
n = 8
Stanshaw
n = 3
Stender
n = 42
Tom Martin
n = 52
W Grider
n = 130
*
Site
*

Results


Axis 2 (40.2%)
Axis 1 (55.9%)
2
1
0
-1
-2
-2
-1
0
1
2
Sten
May
WGAlx
Star
LS
TM
ONeil
Adult Trichoptera, Megaloptera, Ephemeroptera
Hemiptera
Axis 2 (40.2%)
-Cera/O
L-Ep
L-Chir
Hemip
L-Zygo
L-Anis
Zoop
A-Tr/Me/Ep
A-Nemato
A-Coleo
L-Dip O
A-Brach
P-Chir
Acari
Adult Diptera

Results


Malison et al. (2015)
Nielsen (1992)
Gonzales (2006)
Kiffney (2014)
Rosenfeld & Raeburn (2009)
Lang et al. (2006)
Bisson et al. (1988)
This study
Average Growth (% / day)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Average Summer Density (fish / m²)
0.0
0.5
1.0
1.5

Conclusions

- Utilized in the summer
  - Temperature within habitat and in adjacent channel
- Depth of habitat

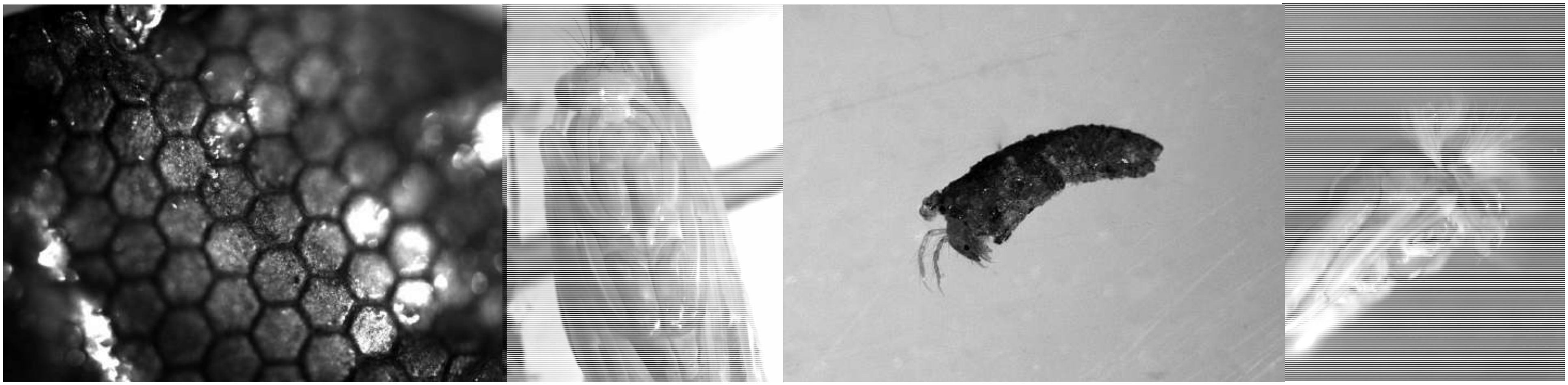
- Aerial and surface feeding
- Good connection may allow for drift feeding in adjacent channel
  - Witmore (2014), Rosenfeld & Raeburn (2009)
- Variability in available food and food consumed
  - Distance from Klamath, floodplain level, pond morphometry, substrate, and vegetation

Acknowledgements

- **Karuk Tribe**
  - **Research funding**
  - **Toz Soto, Fisheries Crew**
- **Mid Klamath Watershed Council**
  - **Research funding**
  - **Will Harling, Charles & Mitzi Wickman, Fisheries Technicians**
- **Committee Members: Darren Ward, Bret Harvey, Peggy Wilzbach**

Will Harling

Questions?



Physical and Biological Monitoring of Beaver Dam Analogues in the Scott River Watershed

Erich Yokel – Scott River Watershed Council
Michael M. Pollock, PhD - NOAA, Northwest Fisheries Science Center
Mark Cookson - US Fish and Wildlife Service-Habitat Restoration Branch
Chris Adams – CDFW – Michigan Technological University
Lindsay Magranet – Siskiyou Resource Conservation District

Scott River Watershed

- Historic legacy effects in the Scott River have reduced stream complexity, flood plain connectivity, riparian forest condition and groundwater surface water interactions.
- The effects create water quality impairments (temperature and sediment) and significant reductions in instream habitat volume and quality.

Ecological Benefits from BDAs

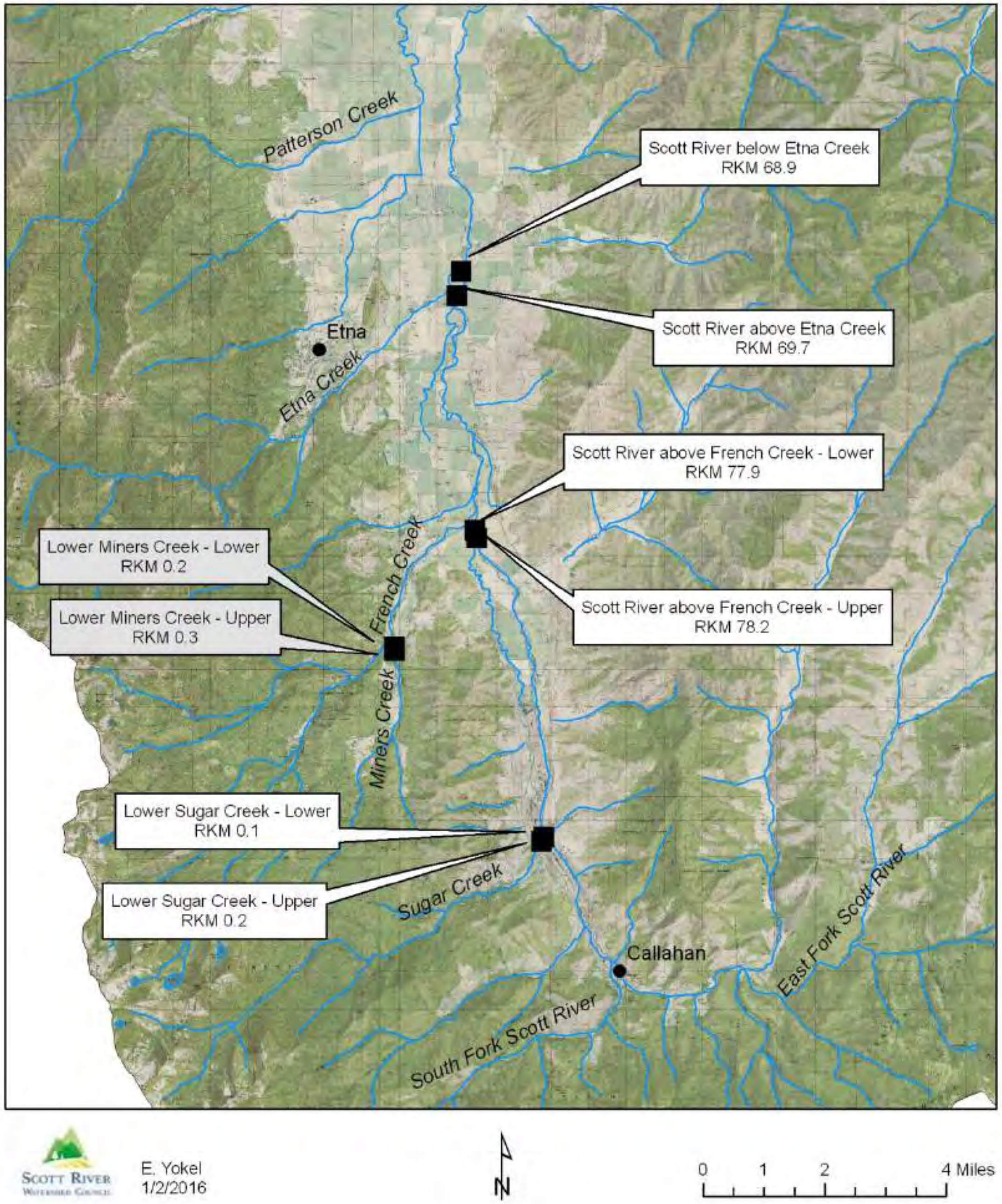
- Provide flow resistance to reduce water velocities, retain sediment and increase water surface elevation
- Create and enhance pools, ponds and wetlands
- Increase the water table of surface water and connected groundwater - increasing the instream habitat volume and riparian habitat condition.

Monitoring

- Surface and Ground Water Elevations
- Geomorphic Change
- Water Quality
- Fish Passage
- Habitat Characterization
- Fish Utilization
- Multi-species Benefit

NATIONAL FISH AND WILDLIFE FOUNDATION
NFWF

Installed BDA Structures - 2014 & 2015
Watershed View

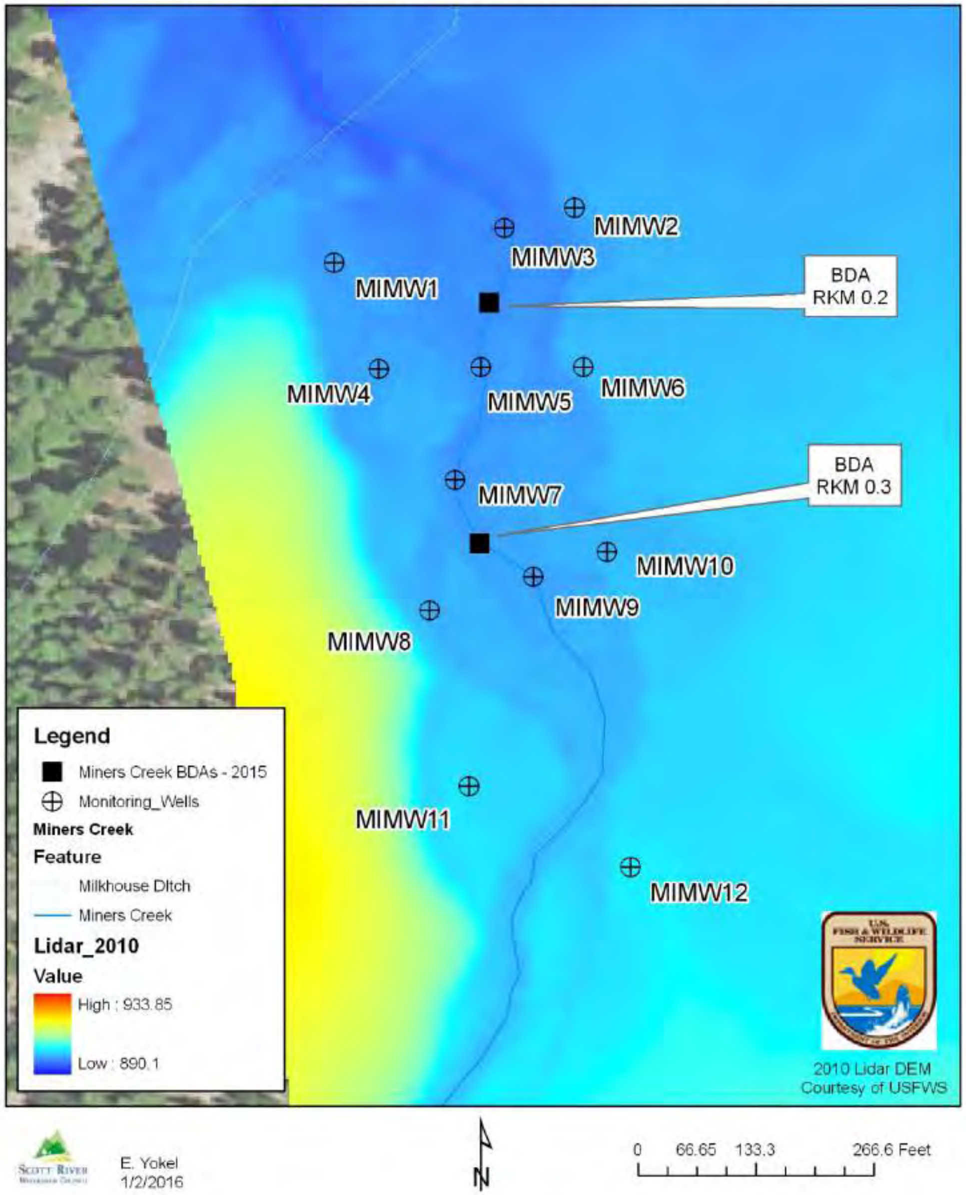


Scott River Watershed Council

E. Yokel
1/2/2016

Water Surface Elevation (WSE) Monitoring

Miners Creek BDAs - Monitoring Wells



2010 Lidar DEM
Courtesy of USFWS

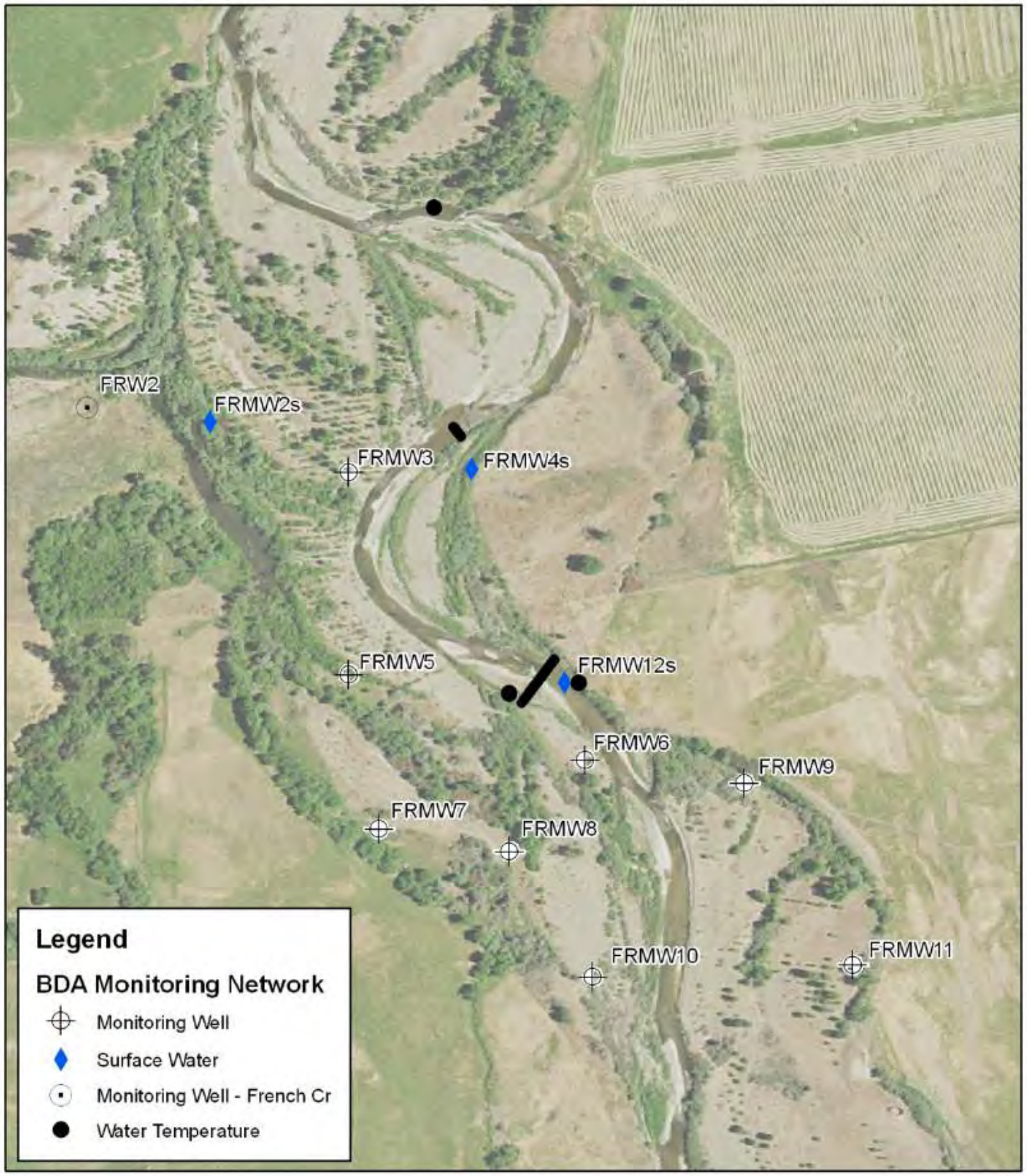
E. Yokel
1/2/2016

UCDAVIS
UNIVERSITY OF CALIFORNIA

Department of
LAND, AIR AND WATER RESOURCES
University of California, Davis
Climate Change • Sustainable Agriculture
Environmental Quality • Landscape Processes

United States Department of Agriculture
NRCS Natural Resources Conservation Service

Scott River above French Creek BDAs - Monitoring Network



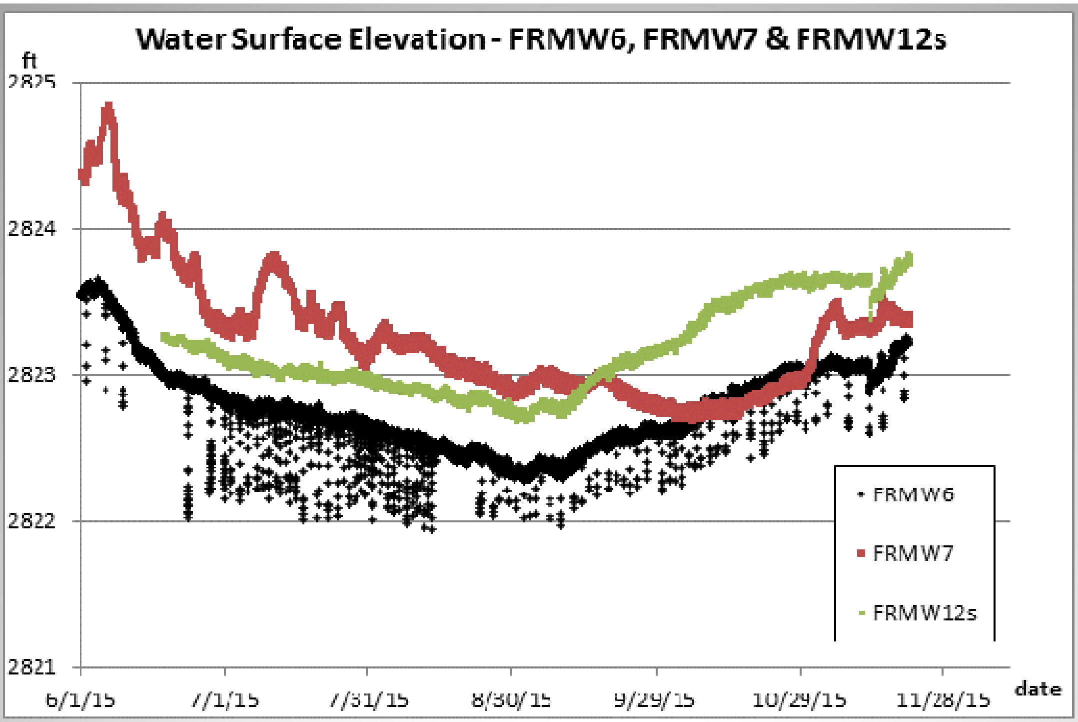
Scott River Watershed Council

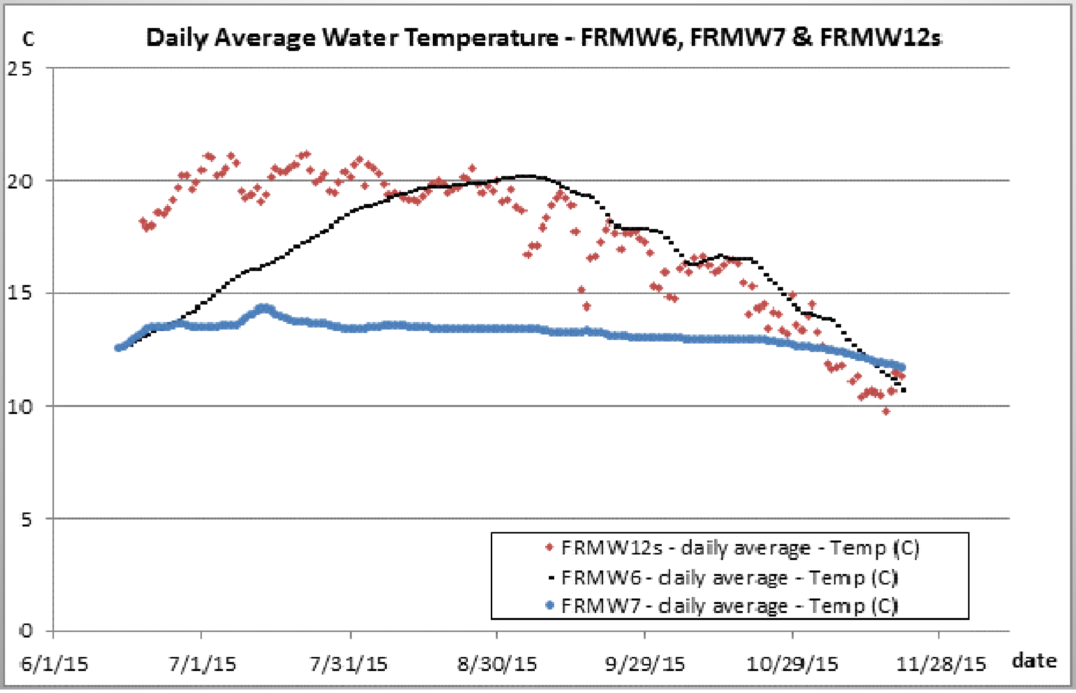
E. Yokel
12/31/2015

N

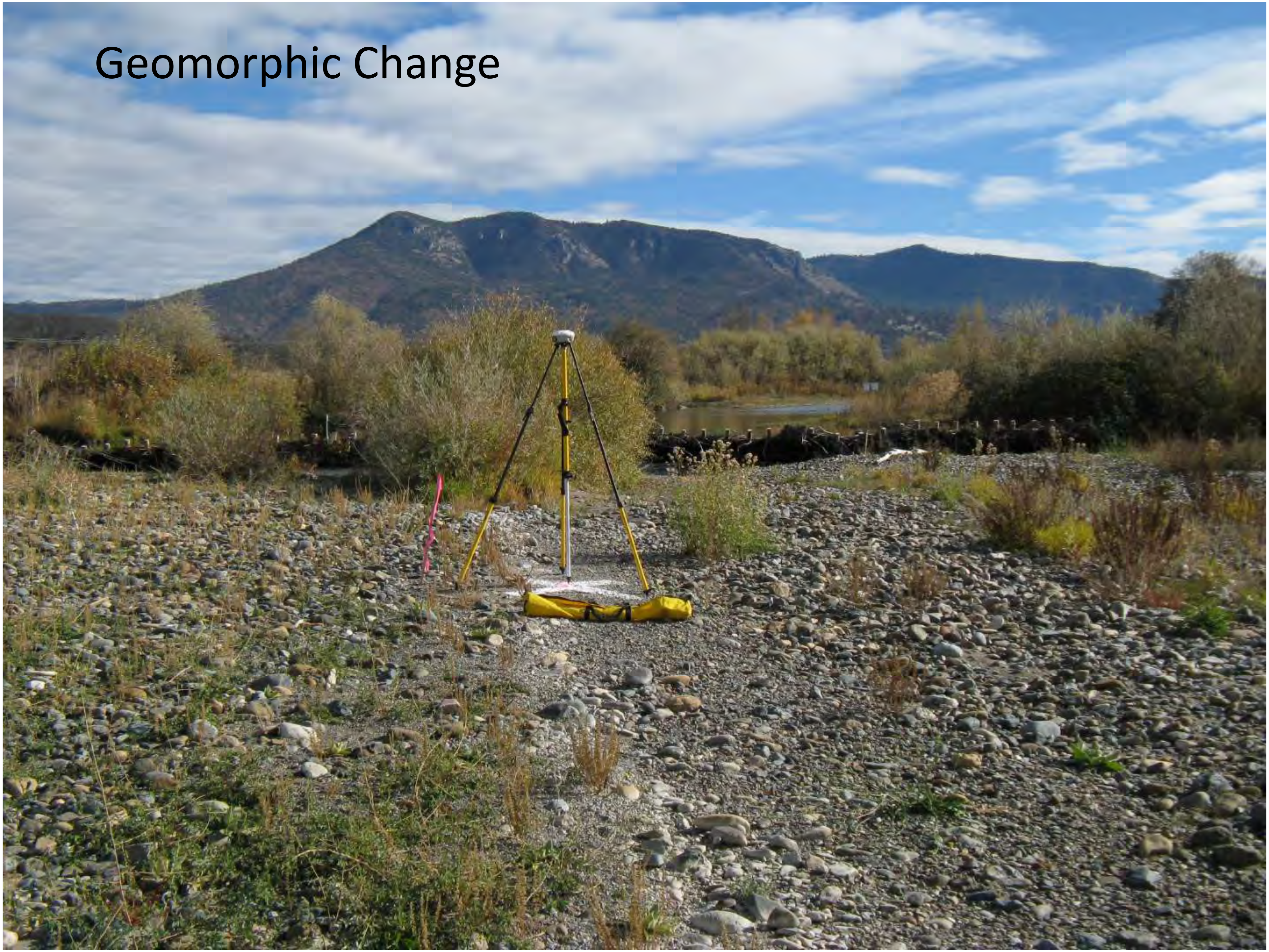
0 175 350 700 Feet

11/11/2015


Water Surface Elevation - FRMW6, FRMW7 & FRMW12s
ft
2825
2824
2823
2822
2821
6/1/15
7/1/15
7/31/15
8/30/15
9/29/15
10/29/15
11/28/15
date
FRMW6
FRMW7
FRMW12s


Daily Average Water Temperature - FRMW6, FRMW7 & FRMW12s
C
25
20
15
10
5
0
6/1/15
7/1/15
7/31/15
8/30/15
9/29/15
10/29/15
11/28/15
date
FRMW12s - daily average - Temp (C)
FRMW6 - daily average - Temp (C)
FRMW7 - daily average - Temp (C)

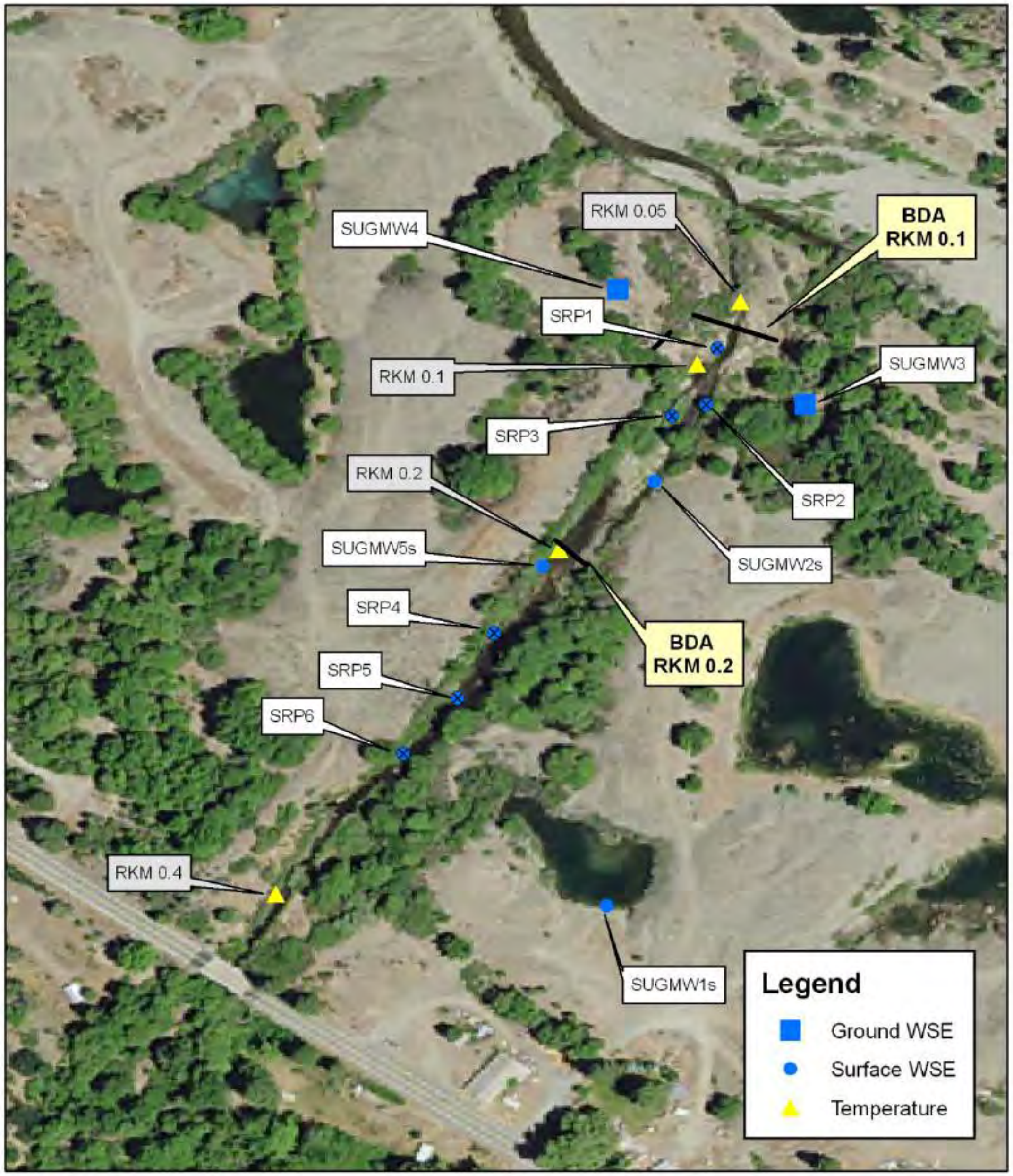
Geomorphic Change



7/25/2014

9/9/2015

Sugar Creek BDAs - Monitoring Network



Scott River Watershed Council

E. Yokel
12/31/2015

N

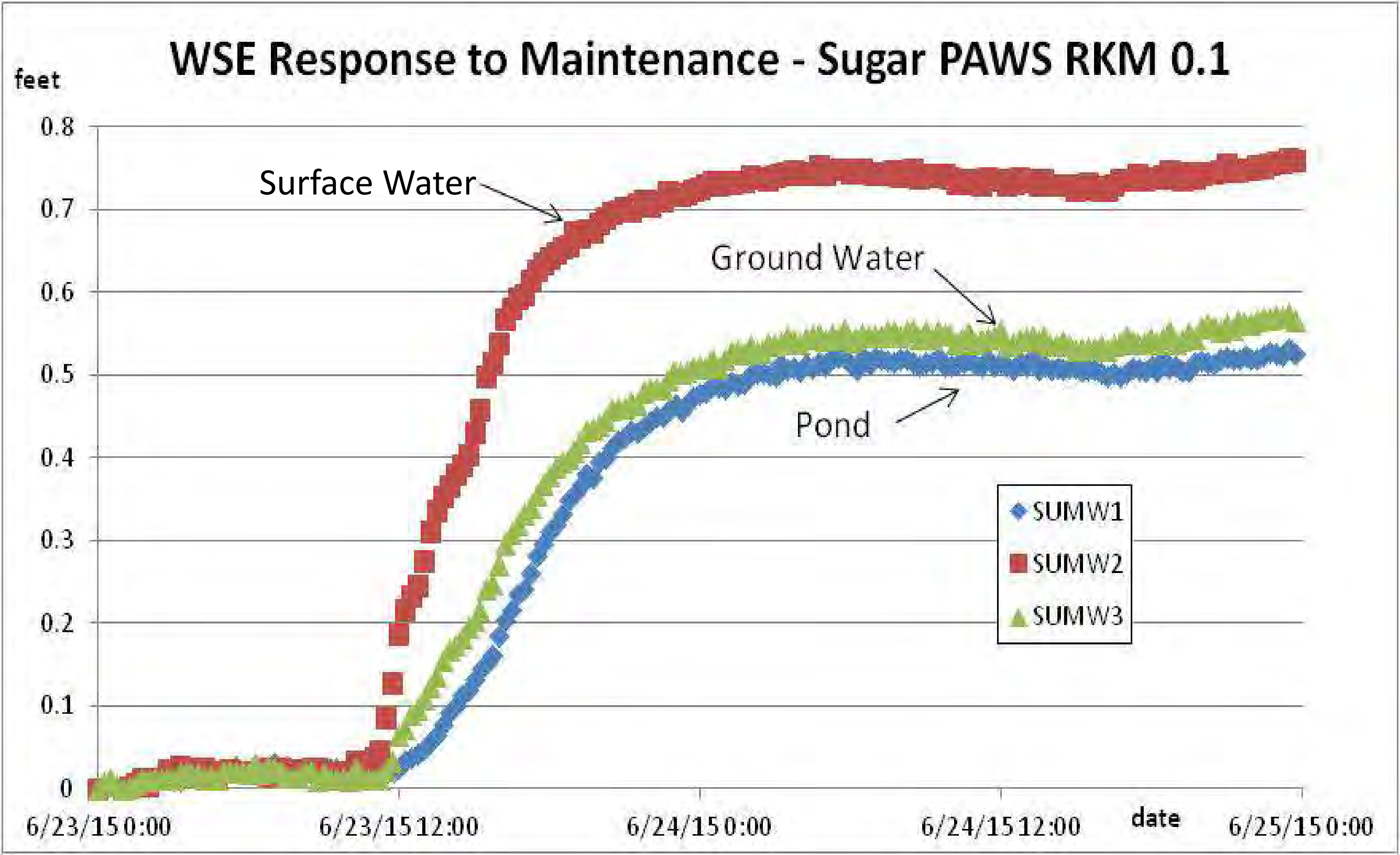
0 100 200 400 Feet

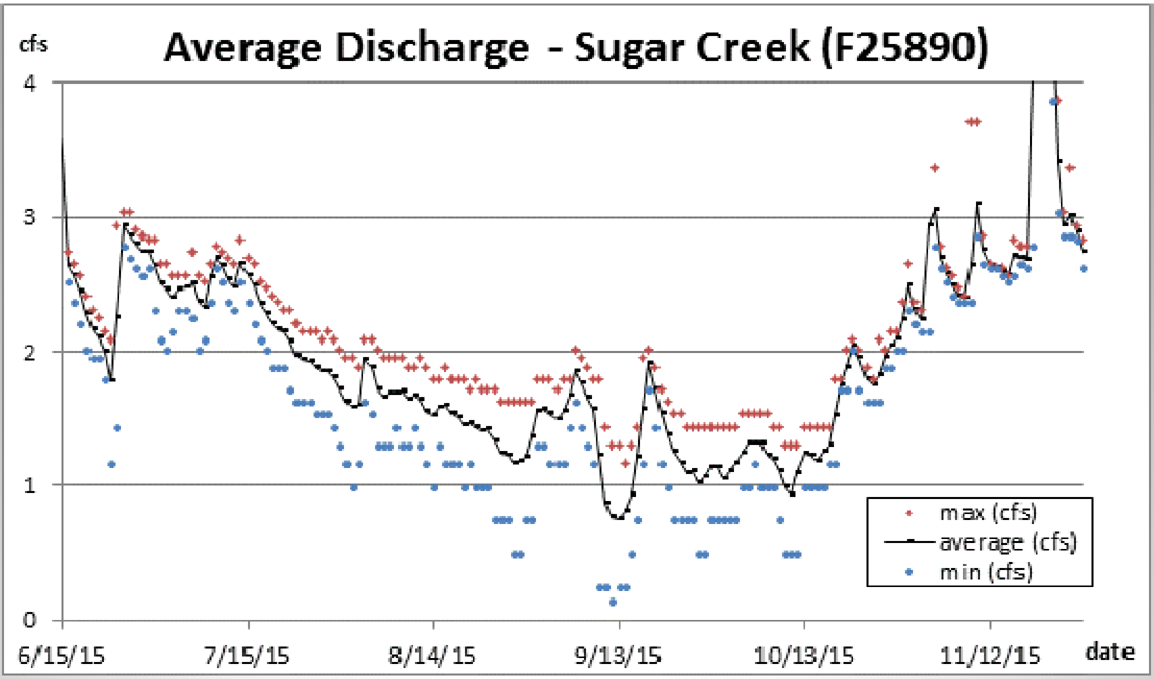
BDA maintenance in Lower Sugar Creek

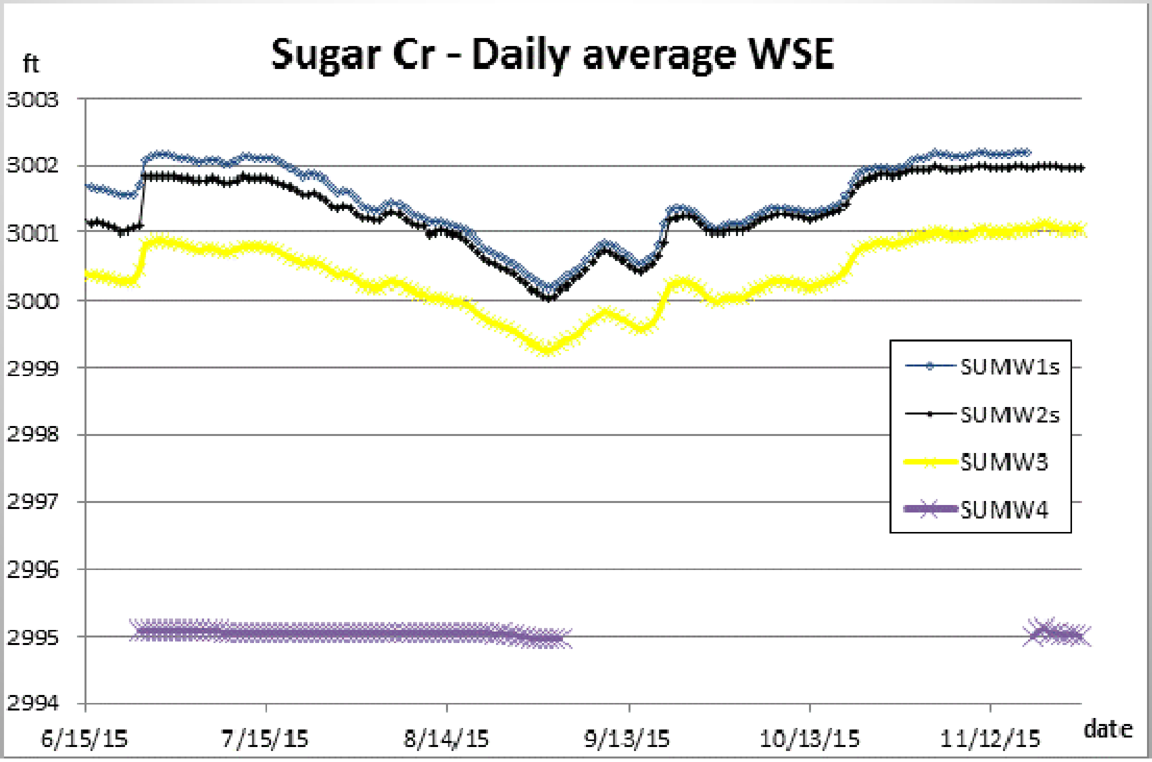
- SRWC performed maintenance on the BDAs of Lower Sugar Creek on 6/23 – 6/25/2015
- Documented 0.75 ft increase in WSE of BDA RKM 0.1 pond
- Documented significant increase in groundwater and off channel pond WSE associated with maintenance
- Estimate approximately 1,500 cubic meter habitat volume increase

6/23/2015

7/6/2015


WSE Response to Maintenance - Sugar PAWS RKM 0.1
feet
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Surface Water
Ground Water
Pond
◆ SUMW1
■ SUMW2
▲ SUMW3
6/23/15 0:00
6/23/15 12:00
6/24/15 0:00
6/24/15 12:00
date
6/25/15 0:00


Average Discharge - Sugar Creek (F25890)

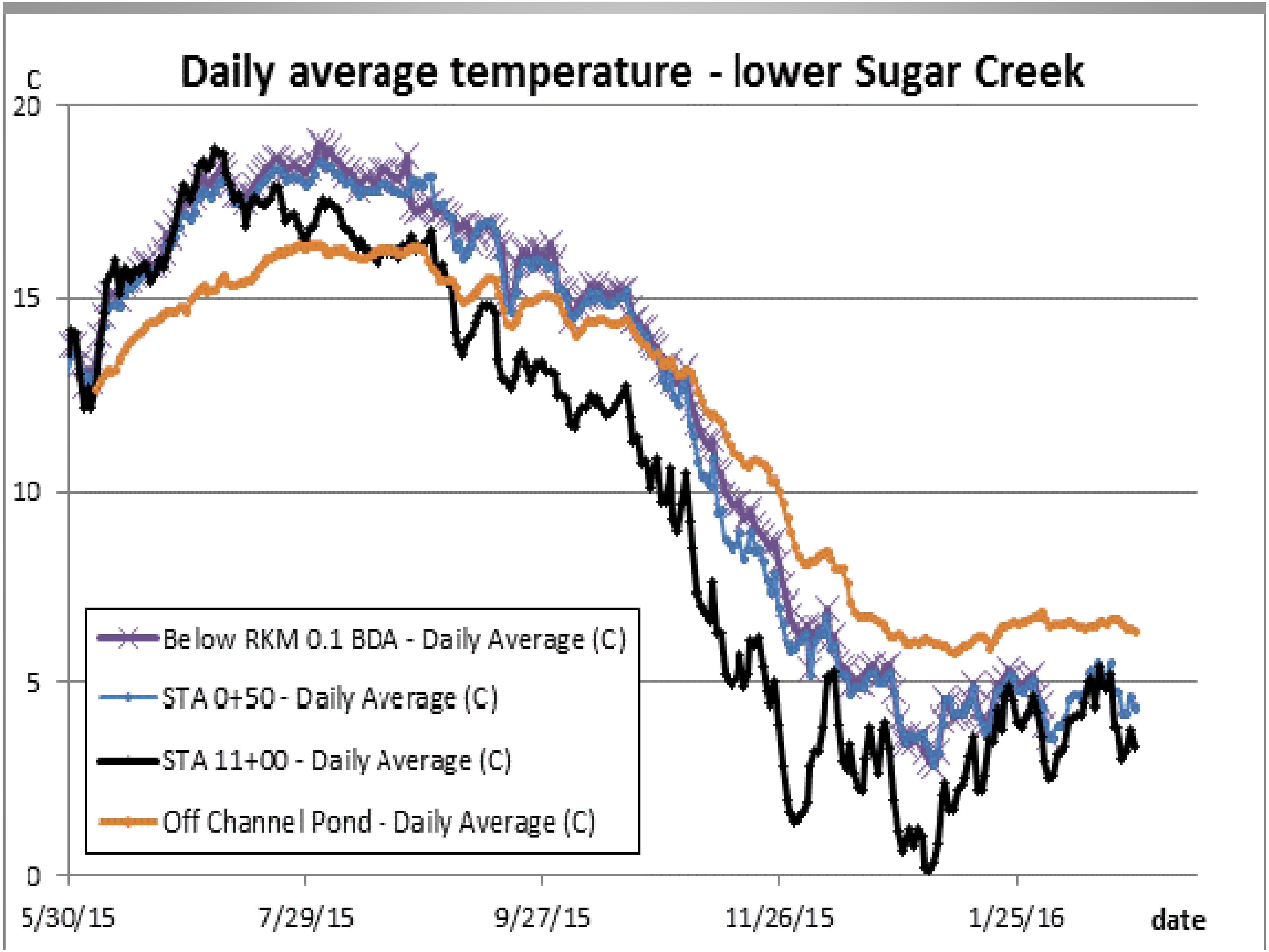

Sugar Cr - Daily average WSE

Habitat Characterization and Fish Utilization

Sugar Creek BDAs - Temperature Monitoring

SCOTT RIVER WATERSHED COUNCIL

E. Yokel
12/31/2015


Daily average temperature - lower Sugar Creek
C
20
15
10
5
0
5/30/15
7/29/15
9/27/15
11/26/15
1/25/16
date
Below RKM 0.1 BDA - Daily Average (C)
STA 0+50 - Daily Average (C)
STA 11+00 - Daily Average (C)
Off Channel Pond - Daily Average (C)

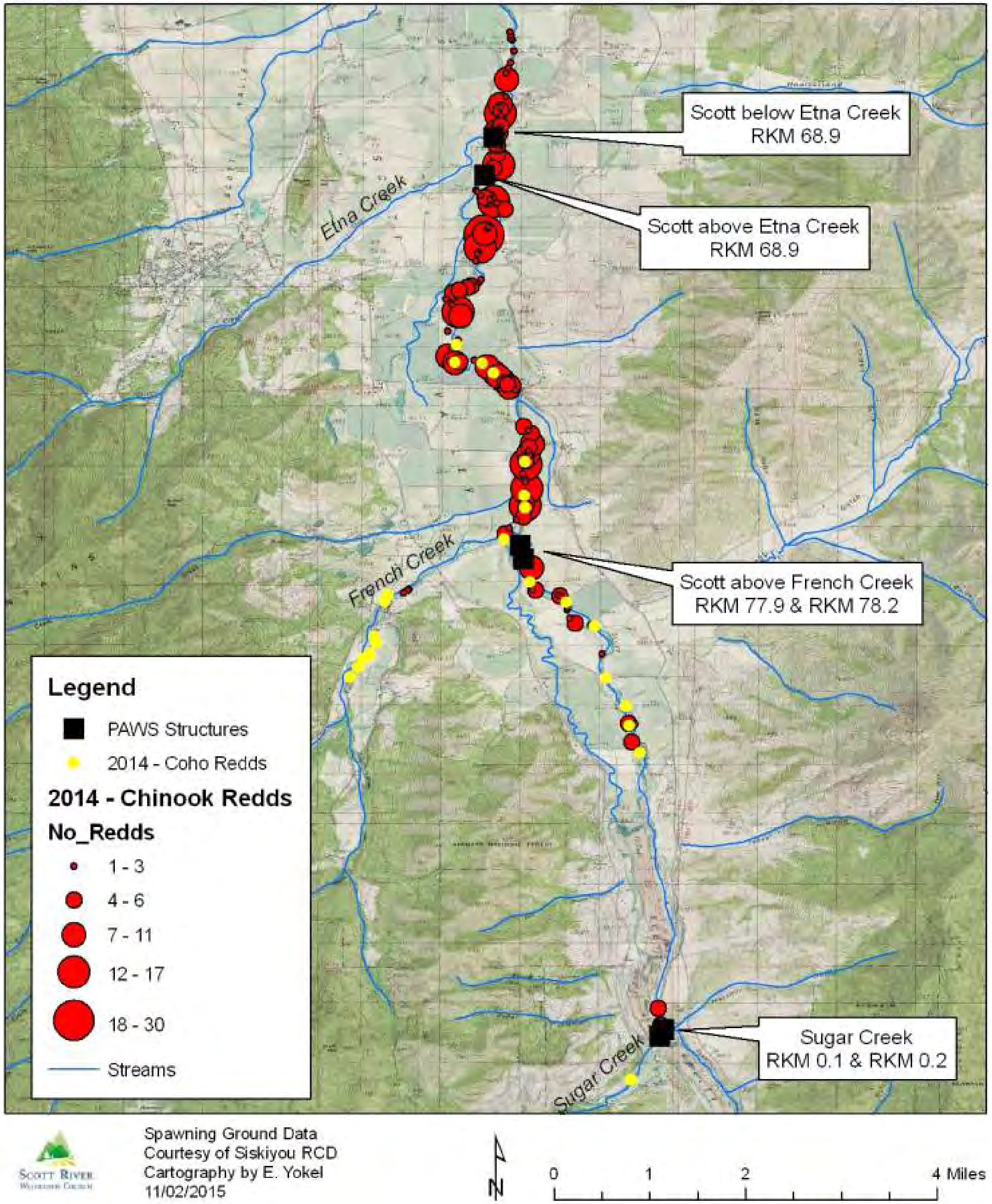
Scott River coho population

- The Scott River supports a Core, Functionally Independent Population of SONCC coho within the Interior Klamath River diversity stratum
- The Scott River population is at a Moderate Extinction Risk
- The Scott River population is likely above depensation threshold
- The Scott River population serves as a source of juvenile and adult strays for nearby populations in the Klamath Basin

National Marine Fisheries Service. 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, CA

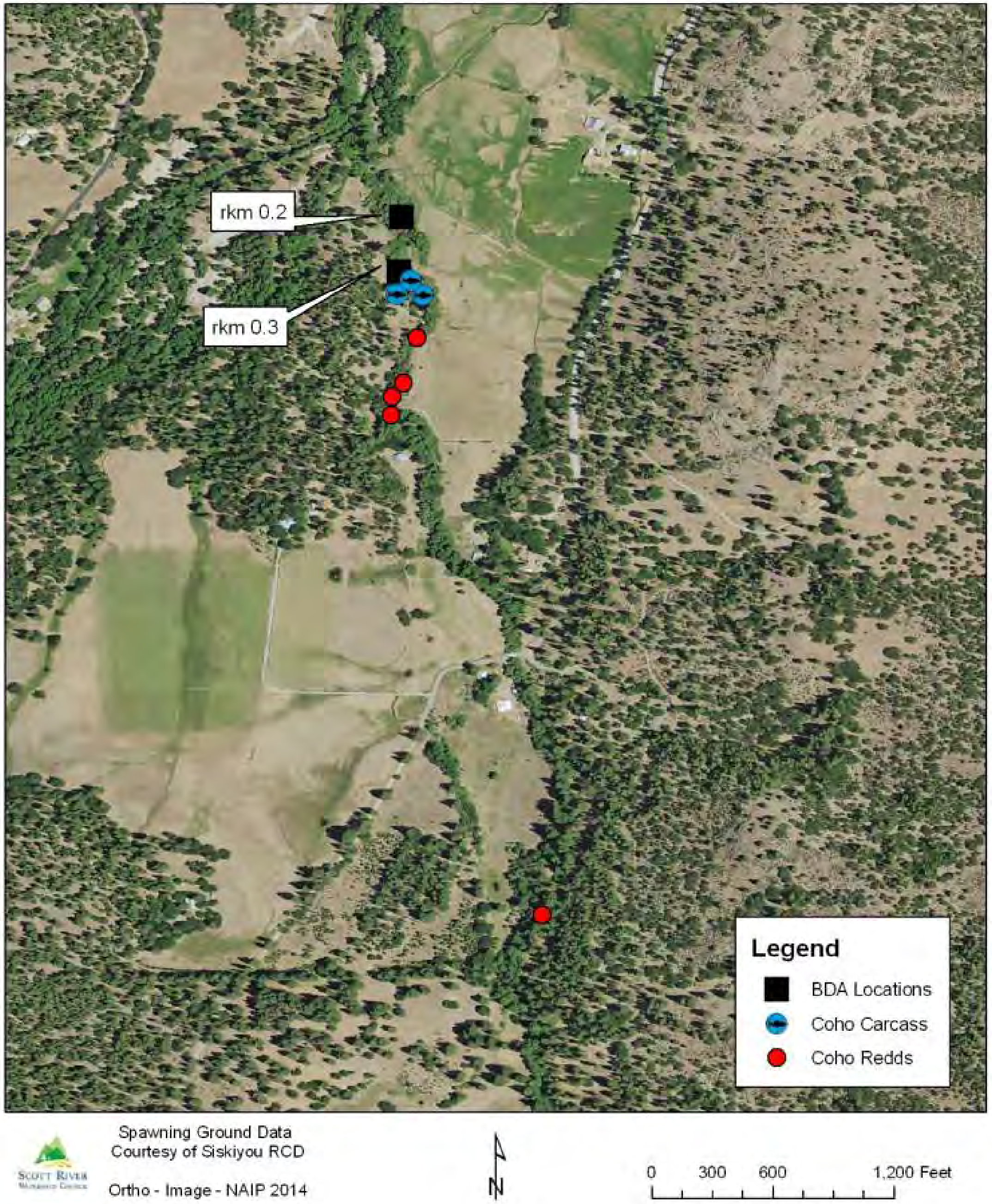
Adult Fish Passage

2014 Chinook and coho redds



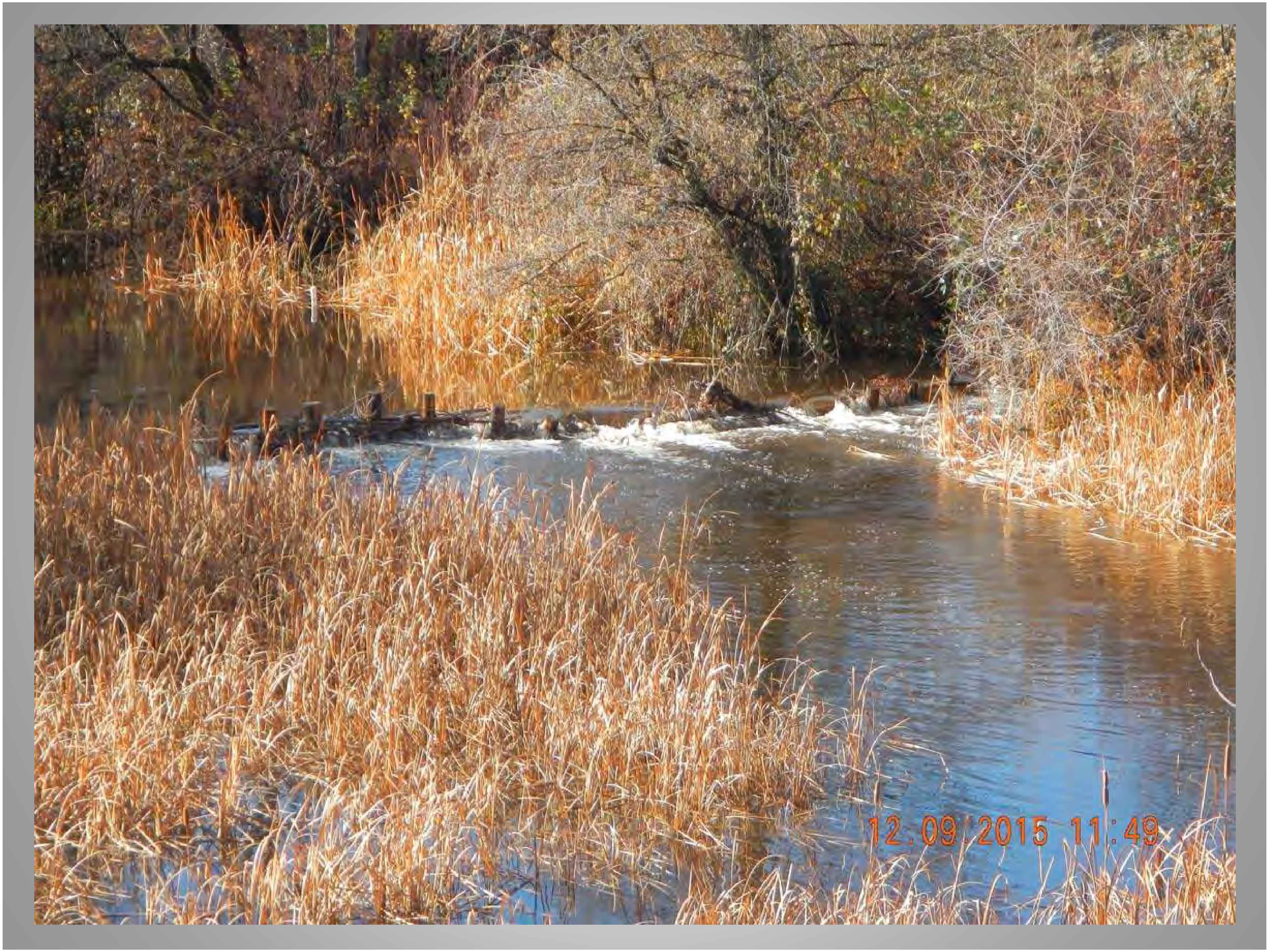
Spawning Ground Data
Courtesy of Siskiyou RCD
Cartography by E. Yokel
11/02/2015

Coho redds - Miners Creek
2015-16



Spawning Ground Data
Courtesy of Siskiyou RCD

Ortho - Image - NAIP 2014


12.09.2015 11:49

Slow Water Habitat Survey

Direct Observation Surveys

August 31st, 2015

Age Class and Species	0+ Coho	1+ Coho	0+ Chinook	1+ Chinook	0+ Trout	1-2+ Trout
Downstream of Project Site	1	0	32	0	38	2
Lower PAWS Impoundment	1	0	3	0	26	1
Upper PAWS Impoundment to Bridge	770	0	13	0	70	0
Total Fish Counted	772	0	48	0	134	3

May 28th, 2015

Age Class and Species	0+ Coho	1+ Coho	0+ Chinook	1+ Chinook	0+ Trout	1+ Trout
Downstream of Project Site	255	0	95	0	1,005	15
Lower PAWS Impoundment	350	0	20	0	500	5
Upper PAWS Impoundment	320	0	0	0	500	0
Total Fish Counted	925	0	115	0	2,005	20

June 19th, 2015

PIT Tag Program

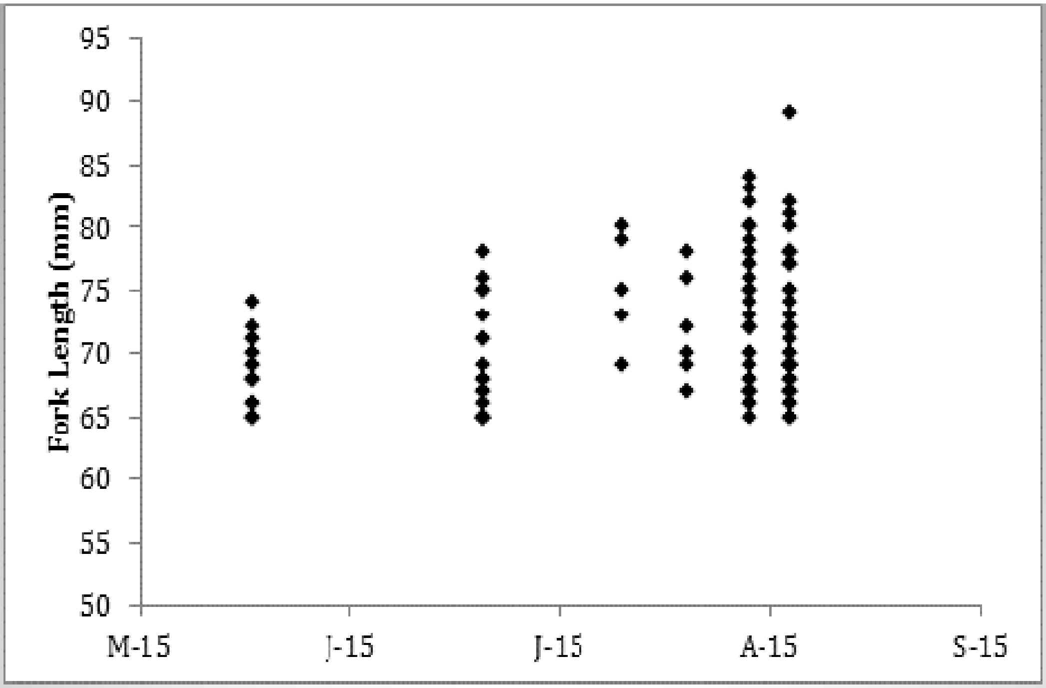
PIT# 989001003467450

Species coho Date 8-3-15

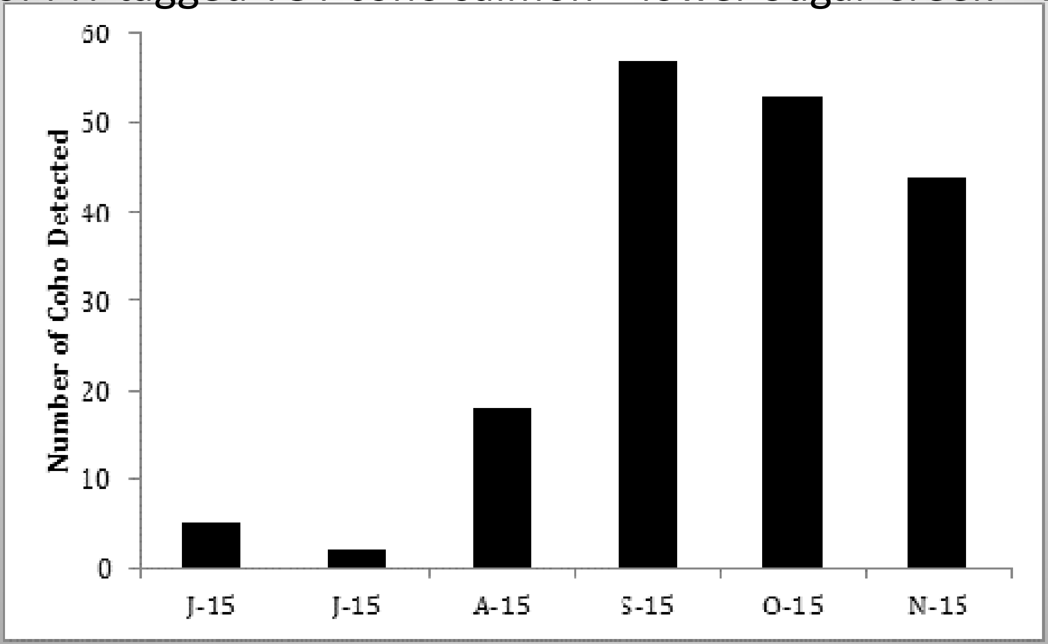
F.L 79 mm Wt. ______ g.

Location Sugaro Gear Min Traps

California Department of
Fish and Wildlife



Forklength of PIT tagged YOY coho salmon – lower Sugar Creek – BY14 (n = 124)



Monthly total number of BY2014 coho detected at the Sugar Creek Rkm 0 antenna station.

Documentation of Movement

- YOY Juvenile coho salmon PIT tagged in the Scott River in 2014 and released in the South Fork Scott and Scott River entered Sugar Creek during winter (Dec. 14 – Feb. 15) and out migrated in May 2015.
  (C. Adams, 2016)
- YOY Juvenile coho salmon PIT tagged in Sugar Creek in 2011 were observed rearing in Waukell Creek (Klamath RKM 53.0). Out-migrant coho salmon estimates for Waukell Creek in 2012 were 11,955 ± 869 and were all non-natal fish
  (M. Olswang, 2015)

Off Channel Pond Habitat in Lower Sugar Creek

Multi-species Benefits

Copyright of Jim Livaudais

Copyright of Jim Livaudais

Klamath Bird
Observatory

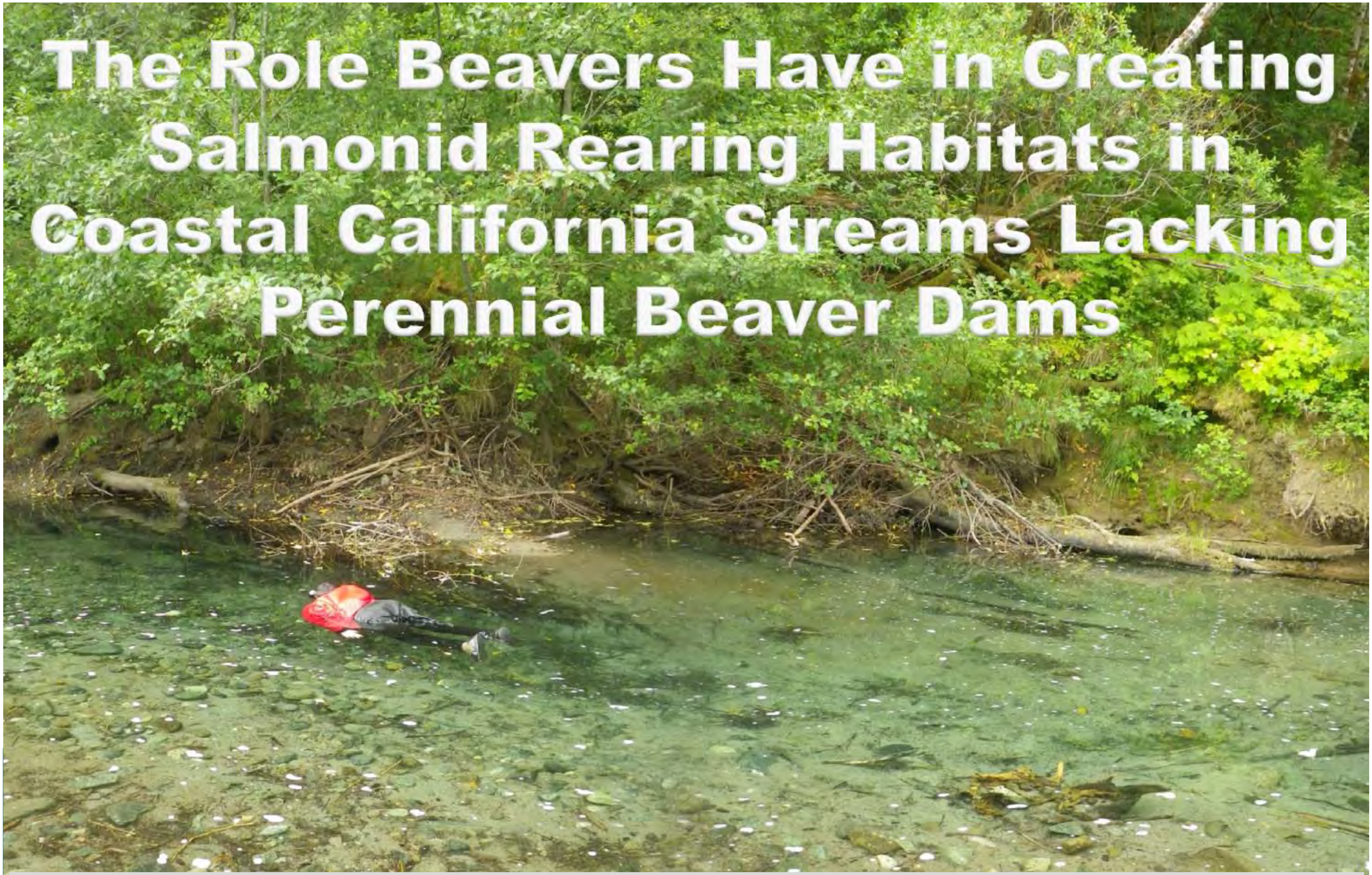
Copyright of Jim Livaudais

Copyright of Jim Livaudais

Thank you!

12/22/2015

The Role Beavers Have in Creating Salmonid Rearing Habitats in Coastal California Streams Lacking Perennial Beaver Dams

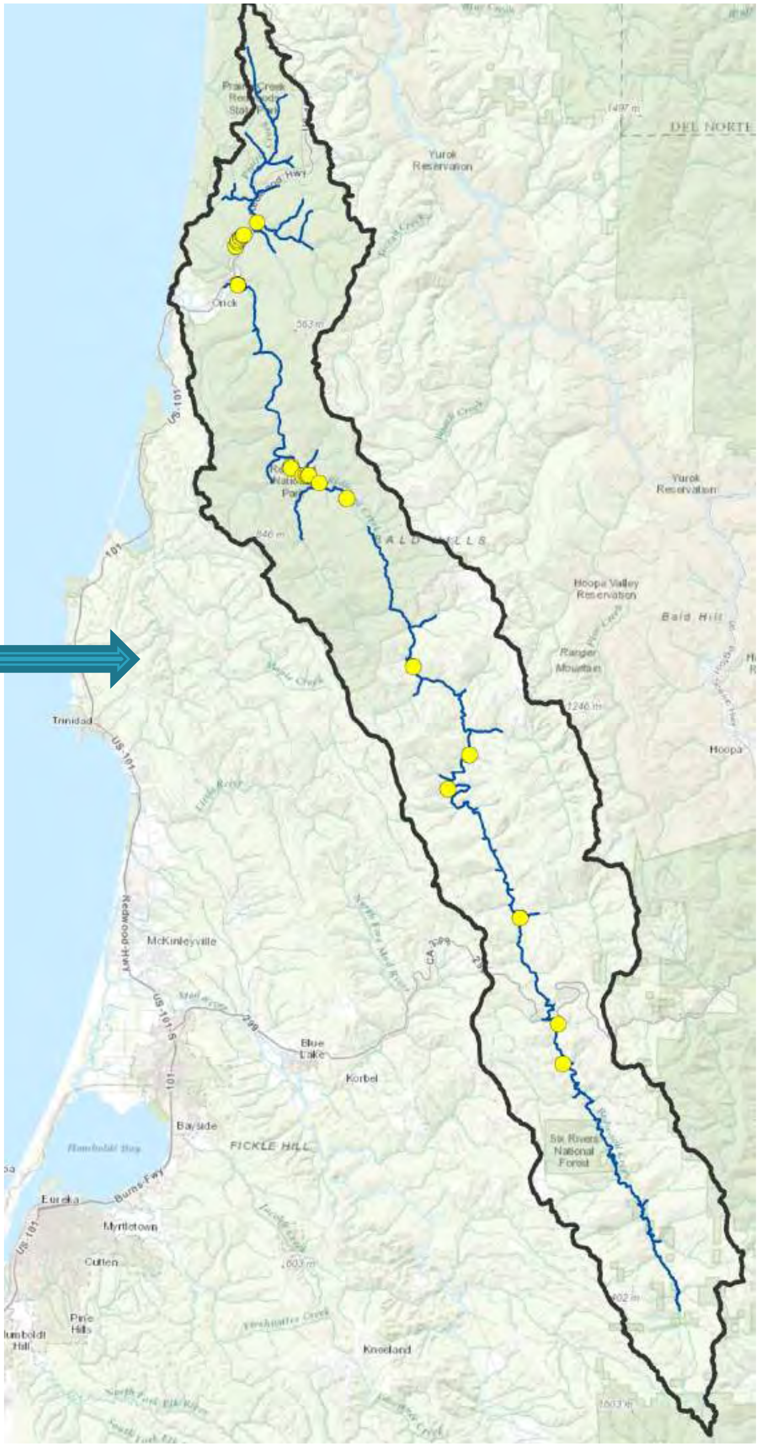


Justin Garwood
California Department of Fish & Wildlife

Marisa Parish
Humboldt State University, Wildlife Department

Coastal creeks and rivers have beavers

- Smith River
- Elk Creek
- Klamath River
- Redwood Creek
- Big Lagoon/Maple Creek
- Little River
- Strawberry Creek
- Mad River
- Eel River



Past Research:
Beaver dam influence on salmonids

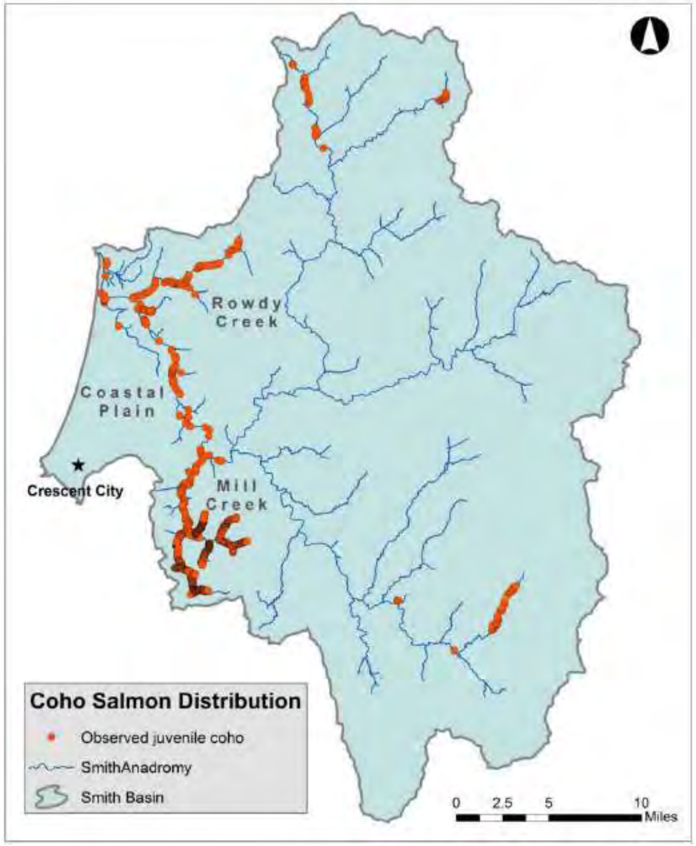
- Increased salmonid growth and productivity in streams with beaver dams when compared to streams without dams *(Bustard and Narver 1975)*.

- Significantly higher densities of juvenile Chinook salmon in tidal beaver ponds than other tidal channel habitats *(Hood 2012)*.

Smith River
SONCC Coho Salmon

Threatened Species

- 1997 – Federal ESA
- 2002 – California ESA



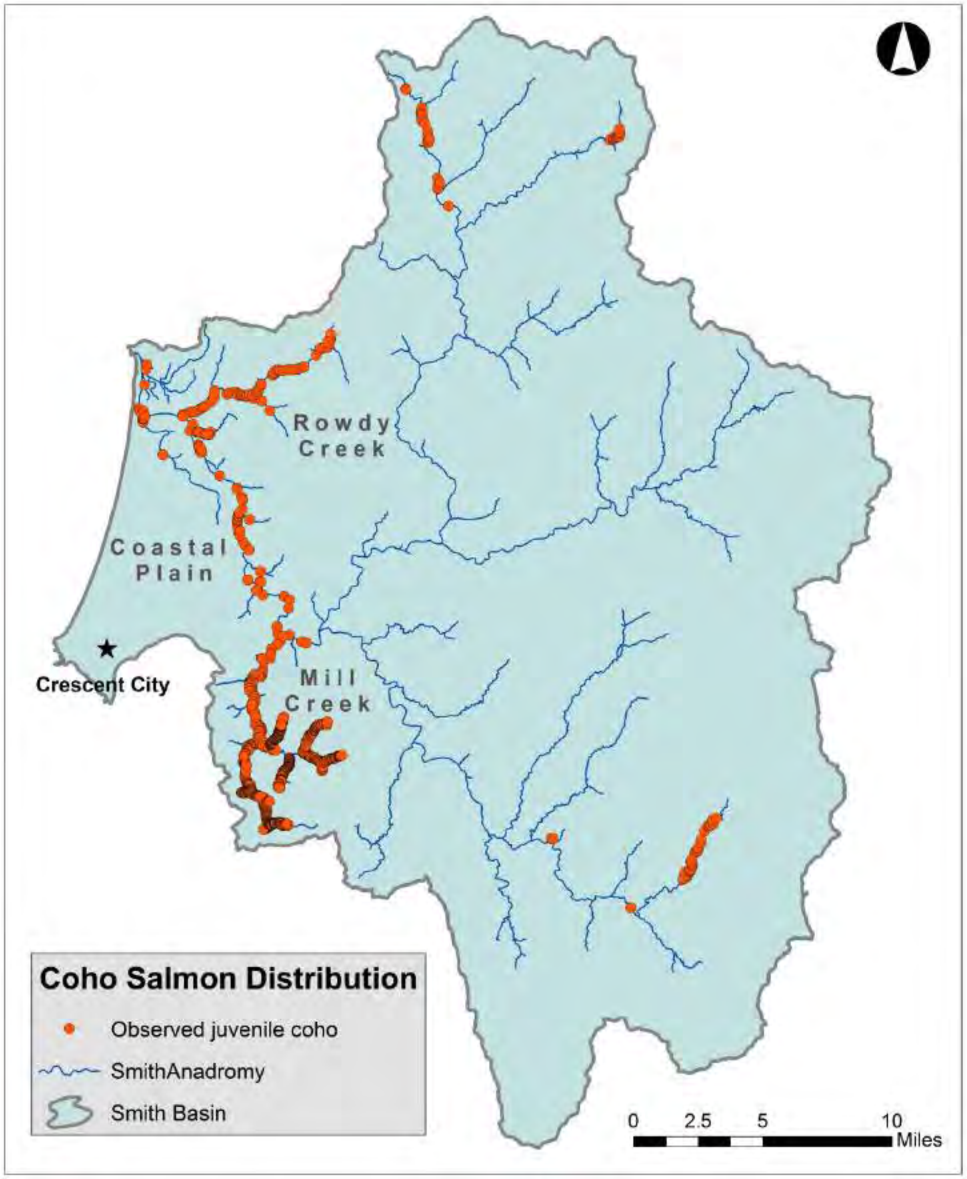
Mouth and estuary of the Smith River

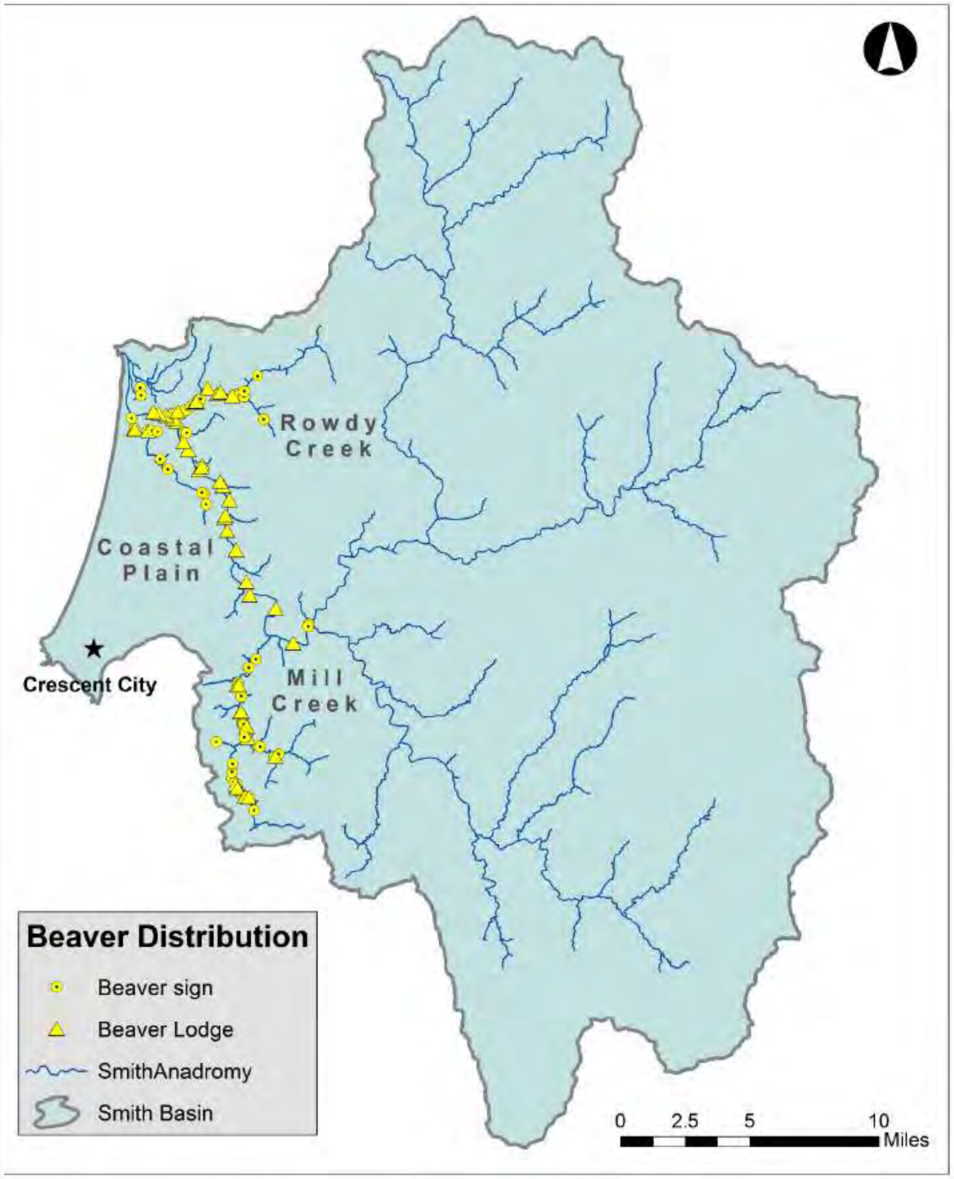
Dams are not the whole story

Marisa Parish-DFW

Bank Lodges= River Reefs

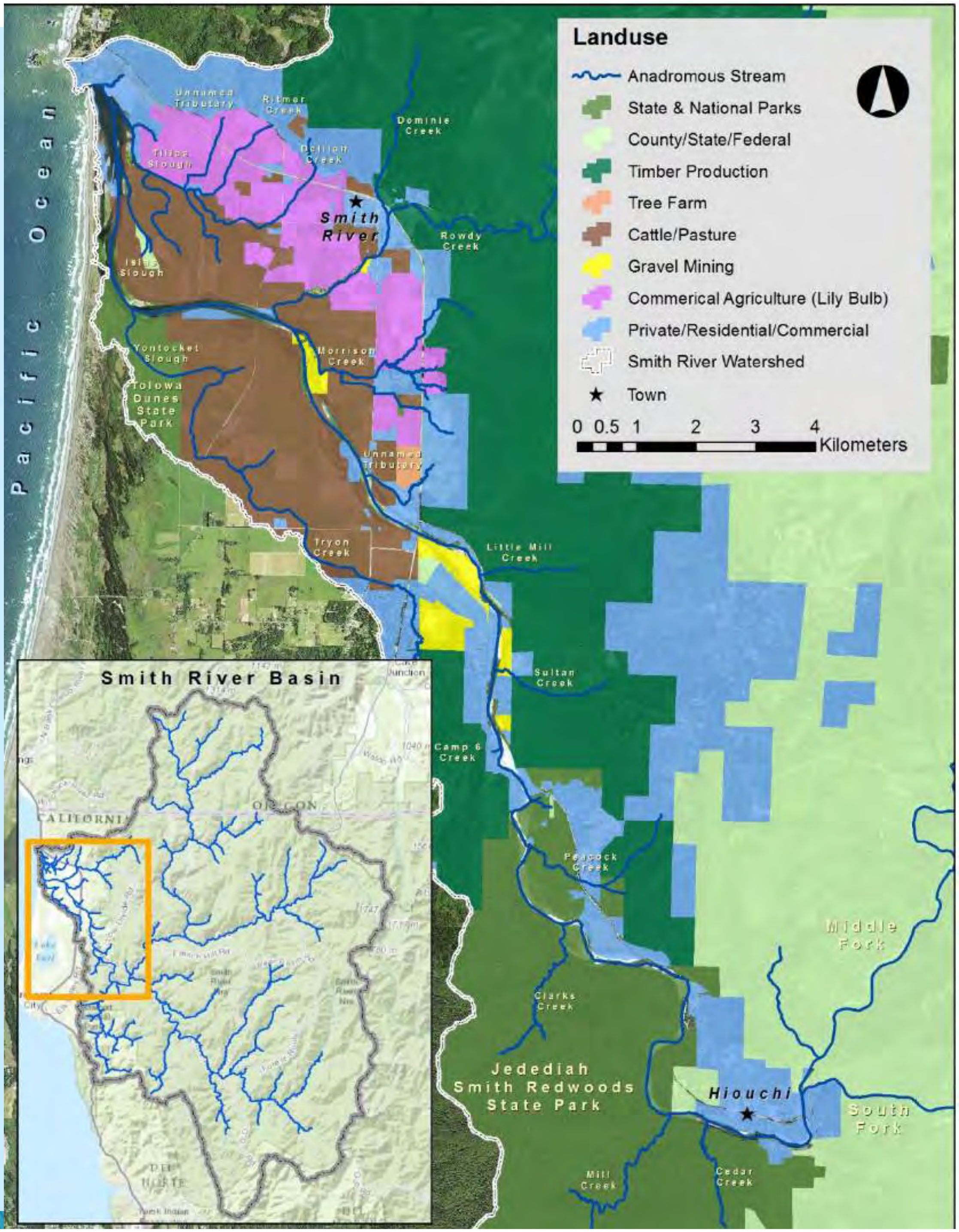
Beaver and Coho salmon overlap





Outline

- Study Area/Background
- Thesis (2)
    - Objectives
    - Methods
    - Results
  - Summary
    - Restoration and Management Considerations

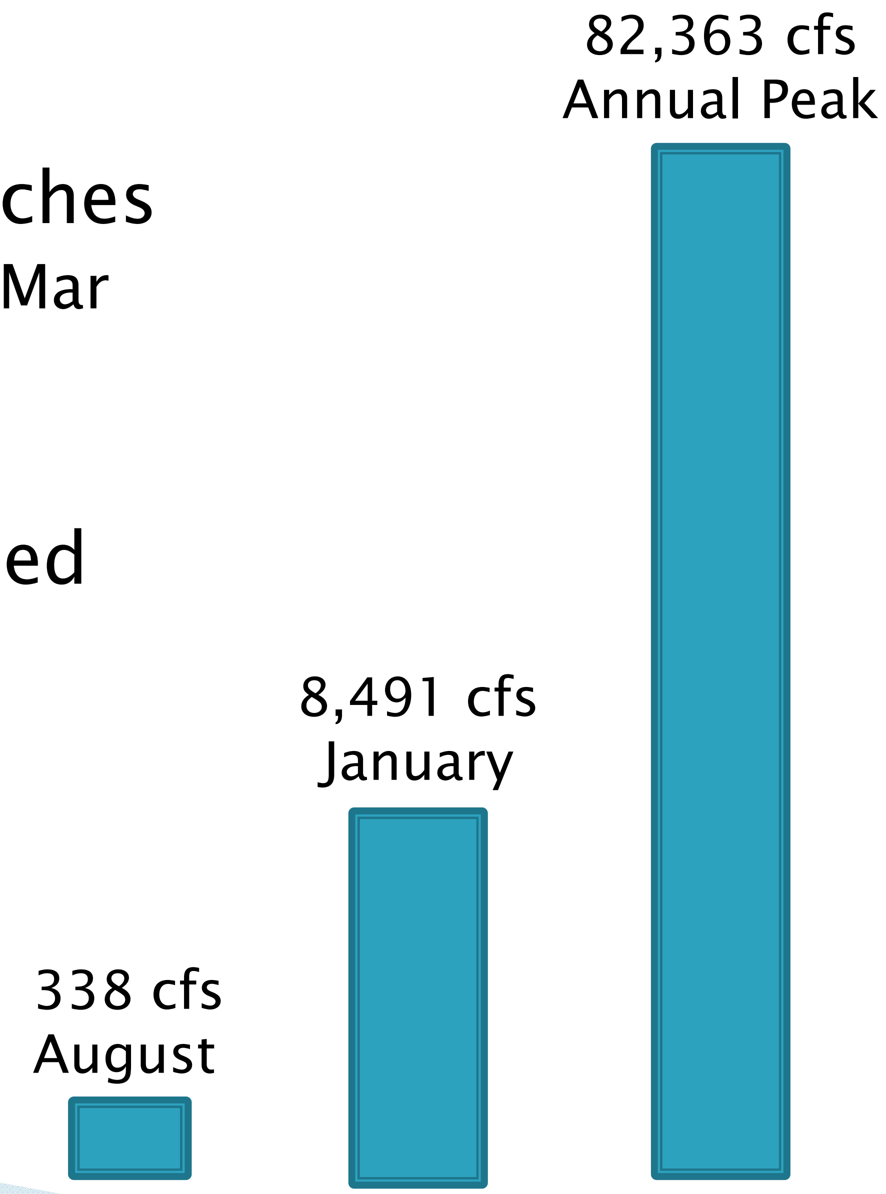

Landuse
Anadromous Stream
State & National Parks
County/State/Federal
Timber Production
Tree Farm
Cattle/Pasture
Gravel Mining
Commerical Agriculture (Lily Bulb)
Private/Residential/Commercial
Smith River Watershed
Town
0 0.5 1 2 3 4
Kilometers
Pacific Ocean
Unnamed Tributary
Ritmer Creek
Tillas Slough
Dominie Creek
Dillon Creek
Smith River
Rowdy Creek
Islas Slough
Yontocket Slough
Morrison Creek
Tolowa Dunes State Park
Unnamed Tributary
Tryon Creek
Little Mill Creek
Sultan Creek
Camp 6 Creek
Peacock Creek
Clarks Creek
Jedediah Smith Redwoods State Park
Hiouchi
Middle Fork
South Fork
Mill Creek
Cedar Creek
Smith River Basin
CALIFORNIA
OREGON

Past Research: Beaver Habitat Suitability

- Beavers prefer seasonably stable water levels
  - Large rivers and lakes where water depth cannot be controlled are partially or wholly unsuitable for beavers *(Allen 1983)*

Smith River

- Annual average precipitation = 92.3 inches
  - 84% received from Oct – Mar
- Thin serpentine soils support poorly vegetated steep slopes



Smith hydrograph

Can it withstand Winter storms

Past Research:

- Beavers prefer seasonably stable water levels
  - Large rivers and lakes where water depth cannot be controlled are partially or wholly unsuitable for beavers *(Allen 1983)*
- Beavers prefer deeper water that meets the demands of the colony without requiring alteration *(Beier and Barrett 1987, Dieter and McCabe 1989)*

Bank Lodges/Bank Burrows

Thesis Objectives – Beavers

1. Identify beaver distribution and gain understanding of lodge site selection and abundance throughout the Smith River coastal plain

Beaver Distribution – methods

- Summer 2014
    - Surveyed 88.5 km across the mainstem and coastal tributaries
        - Kayak
        - Bank
        - Snorkel
        - Game Cameras

Lodge Site Selection – methods

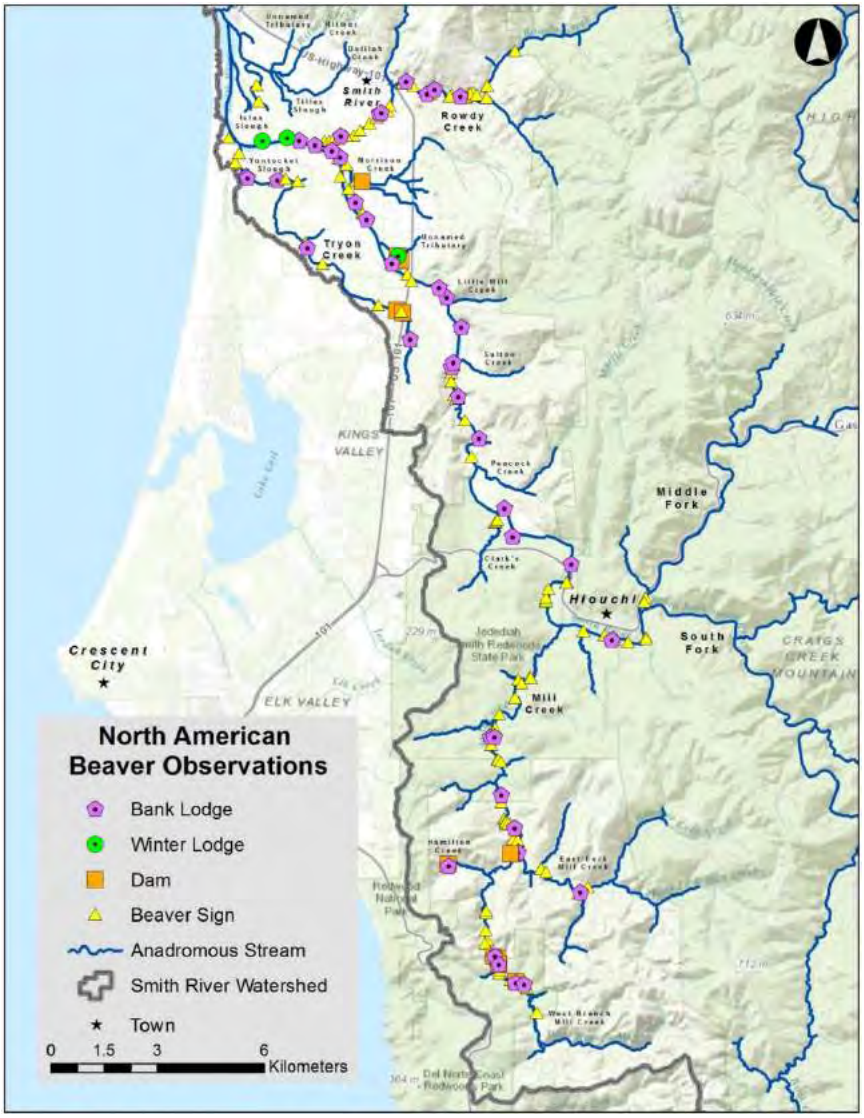
- Compared Lodges with paired random sites

Measured

- Canopy Cover
- Water depth
- Substrate
- Bank height
- Bank length
- Bank slope
- Presence of a hydraulic control

Beaver Distribution – results

- Distributed across 59.9km
  - 41 Lodges (0.82 lodges/km)
    - Across a diversity of land use
    - Winter: 3 additional lodges distribution – 71.1 km
  - 12 Dams
    - Only 1 active year round
- Seasonal variation



Lod lts

- Hyd nd ban
- Taller bank provides more area for denning chambers at a wider range of flows

Thesis Objectives – Coho

1. Identify beaver distribution and gain understanding of lodge site selection throughout the Smith River coastal plain
2. Utilize multi-season occupancy models to analyze beaver non-damming influence on juvenile salmonid non-natal rearing habitats for summer and winter

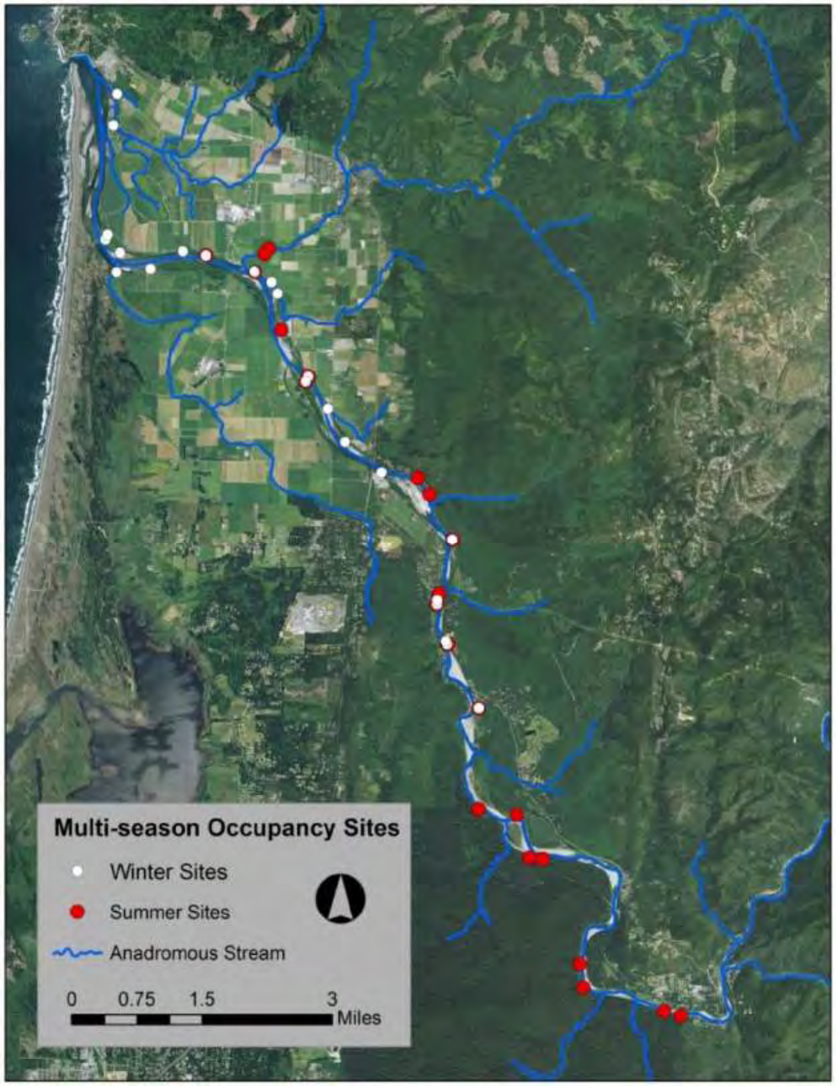
Multi-season Occupancy

24 Fish monitoring sites

½ bank lodges
½ non-lodges

Repeat surveys conducted
4 visits per season

- Summer 2014
  (June - September)
  across 22.5 km
- Winter 2014-15
  (January - March)
  across 15.8 km



Measurements

- Habitat measurements
  - Cover created by beaver
  - Total cover
  - LWD
  - Depth
  - Canopy cover

- Water quality measurements
  - Dissolved Oxygen
  - Salinity
  - Temperature

Methods – detection <1

Summer – Snorkel surveys

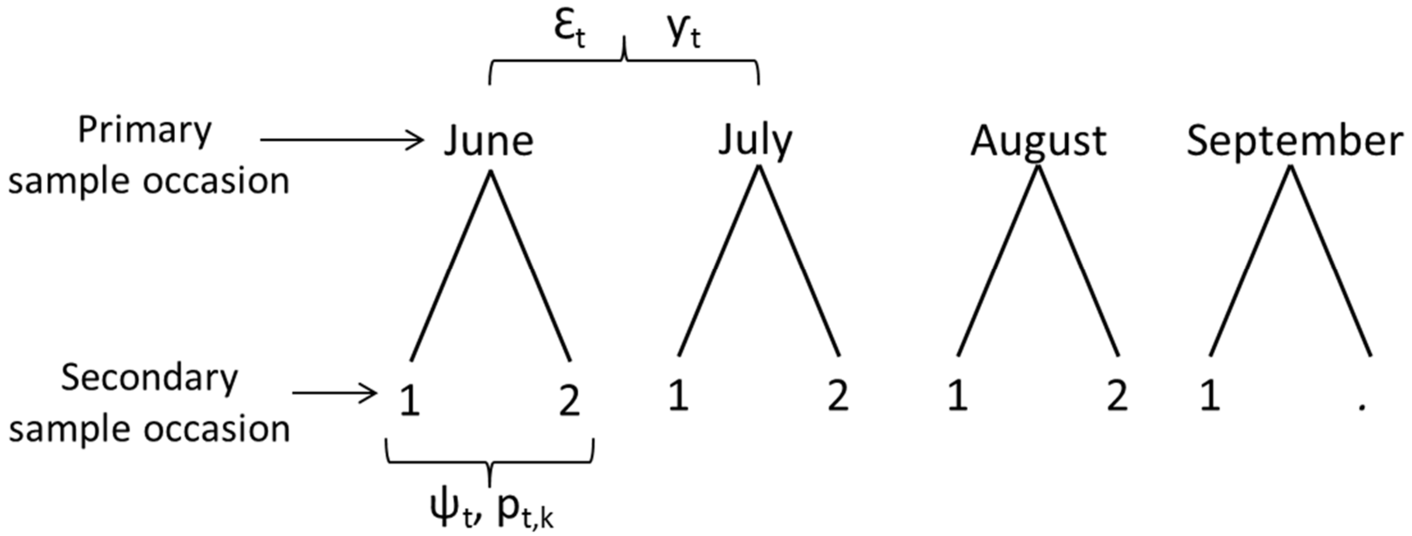
- 2 independent divers on the same day

Winter – Minnow trapping

- Back-to-back days (traps soaked for 80-120min/day)

Multi- season Occupancy

Pollock's Robust Design



ε_t γ_t

Primary sample occasion → June July August September

Secondary sample occasion → 1 2 1 2 1 2 1 .

ψ_t, $p_{t,k}$

ψ: Occupancy

Ɛ: Extinction (emigration)

γ: Colonization

p: Detection

Seasonal Occupancy

Summer

species	Occupancy (ψ)				Colonization (γ)			Extinction (ε)			Detection (*p*)		
	June	July	August	September	Estimate	SE	95% CI	Estimate	SE	95% CI	Estimate	SE	95% CI
coho salmon	0.80 ± 0.08 (0.59 - 0.92)	0.76 ± 0.08 (0.62 - 0.91)	0.74 ± 0.09 (0.57 - 0.91)	0.72 ± 0.10 (0.52 - 0.92)	0.14	0.1	0.03 - 0.44	0.08	0.04	0.02 - 0.21	0.93	0.03	0.86 - 0.96
Chinook salmon	0.88 ± 0.07 (0.68 - 0.96)	0.69 ± 0.08 (0.54 - 0.84)	0.55 ± 0.10 (0.36 - 0.74)	0.44 ± 0.11 (0.23 - 0.65)	0.03	0.06	<0.01 - 0.83	0.22	0.07	0.11 - 0.38	0.89	0.04	0.80 - 0.94

Winter

	Occupancy (ψ)				Colonization (γ)			Extinction (ε)			Detection (*p*)		
species	Early Jan	Late Jan	Mid-Feb	Mid-March	Estimate	SE	95% CI	Estimate	SE	95% CI	Estimate	SE	95% CI
coho salmon	0.19 ± 0.11 (0.05 - 0.50)	0.20 ± 0.08 (0.04 - 036)	0.20 ± 0.09 (0.03 - 0.38)	0.20 ± 0.10 (0.01 - 0.40)	0.11	0.06	0.04 - 0.28	0.42	0.25	0.09 - 0.84	0.44	0.15	0.19 - 0.72

ψ: Occupancy, Ɛ: Extinction (emigration), ɣ: Colonization, p: Detection

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ψ: Occupancy, Ɛ: Extinction (emigration), ɣ: Colonization, p: Detection

Results

Summer

Model	AICc	Δ AICc	AICc *w*	Accumulated Weight	k
{ψ(Beaver Cover), ε(.), γ(.), p(.)}	131.44	0	0.31	0.31	5
{ψ(.), ε(.), γ(.), p(.)}	132.21	0.77	0.21	0.52	4
{ψ(June MWMT), ε(.), γ(.), p(.)}	133.39	1.95	0.12	0.64	5
{ψ(CC), ε(.), γ (.), p(.)}	133.67	2.23	0.10	0.74	5
{ψ(Volume), ε(.), γ(.), p(.)}	133.67	2.23	0.10	0.84	5
{ψ(LWD), ε(.), γ(.), p(.)}	134.09	2.65	0.08	0.92	5
{ψ(Lodge), ε(.), γ(.), p(.)}	134.24	2.80	0.08	1	5

ψ: Occupancy, Ɛ: Extinction (emigration), ƴ: Colonization, p: Detection

Winter

- No significant difference in beaver created cover at sites with and without coho salmon
  - Depth only habitat variable that differed

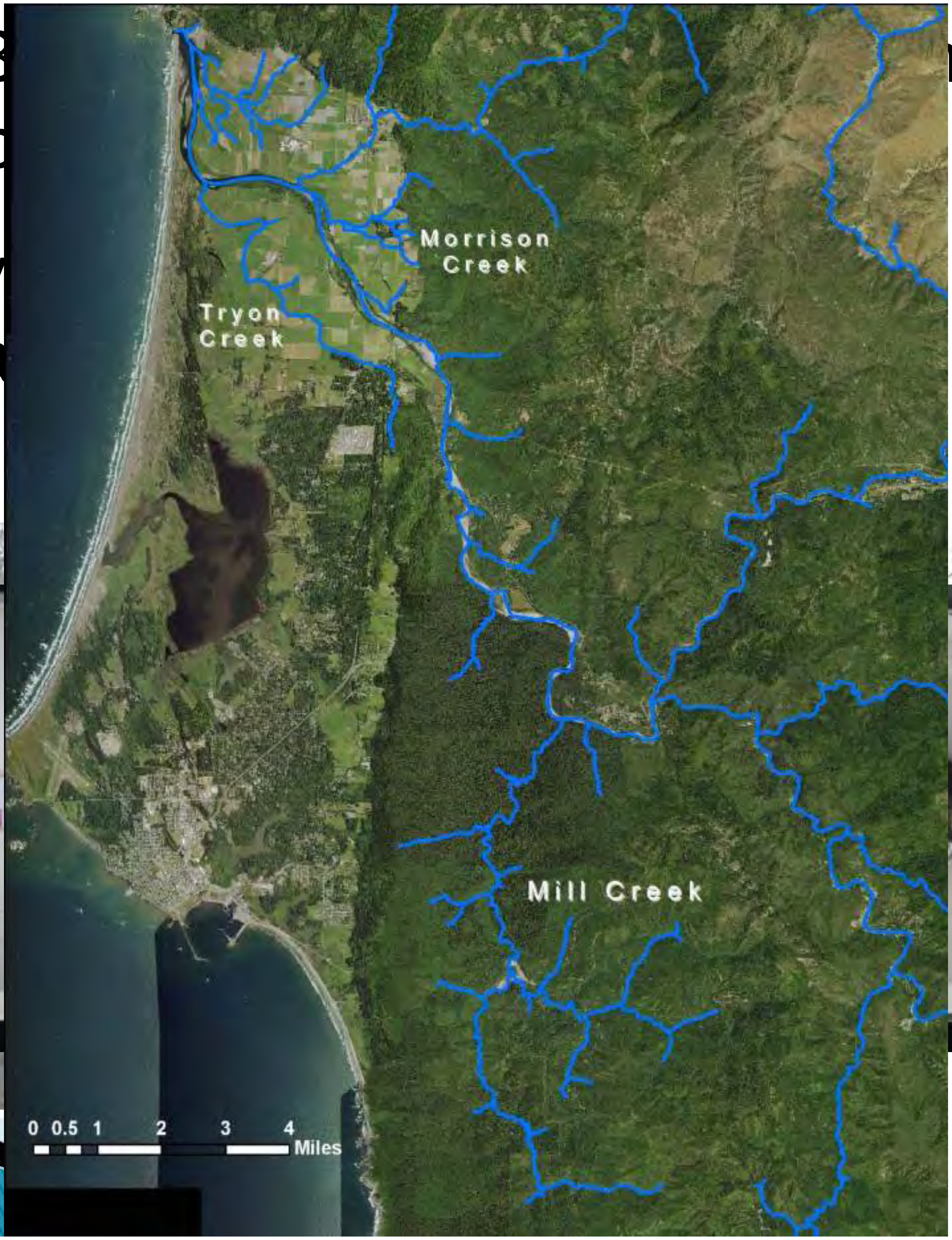
Beaver seasonal variation & movement

- Summer
  - Constantly modify lodge to maintain underwater entrance
- Winter
  - Utilize and build dams in intermittent streams, that were dry in the summer

~18 m wide and 25 cm tall

Fish seasonal movement

- Summer: B nked other habitat typ ration
- Seasonal v n mimics beaver sea



Restoration and Management Considerations

- Assess beaver distribution and abundance
  - Seasonal and annual variation
- Beaver protection and management
  - Maintaining habitat and increase underwater complexity
  - Natural revegetation
- Project designing: Consider beaver habitat needs (Bank stabilization and revegetation)

Thanks to Supporters

CALIFORNIA
DEPARTMENT OF
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Fisheries Restoration Grants Program

HUMBOLDT STATE UNIVERSITY

GOLDEN WEST WOMEN FLYFISHERS

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AAUW
Humboldt (CA) Branch

Stockton Sportsmen's Club

Questions?